Working Paper 2008 | 38

Regime Dependence, Common Shocks and the Inflation-Relative Price Variability Relation

Tomás Castagnino / Laura D´Amato
BCRA

September, 2008

ie | BCRA
INVESTIGACIONES ECONÓMICAS

Banco Central de la República Argentina
ie | Investigaciones Económicas

September, 2008
ISSN 1850-3977
Electronic Edition

Reconquista 266, C1003ABF
C.A. de Buenos Aires, Argentina
Phone: (5411) 4348-3719/21
Fax: (5411) 4000-1257
Email: investig@bcra.gov.ar
Web Page: www.bcra.gov.ar

Regime Dependence, Common Shocks and the Inflation-Relative Price Variability Relation*†

Tomás Castagnino   Laura D ´Amato
BCRA   BCRA

September 2008

Abstract

Using frequency domain techniques to separate short and long run dynamics and decomposing inflation into its common and idiosyncratic components, we study the regime dependence of the inflation-RPV relation in Argentina and the USA. Under High inflation, strong long-run comovement between RPV and Inflation is found for both economies, that extends to the short run adding extra noise to that usually present at high frequencies. High inflation also leads to ideosyncratic movements in prices that do not cancel out, adding persistence to the process. When inflation is low, no long-run interaction between variables is expected. This is the case of the US, even though supply shocks are comparable to those of the seventies when trend inflation was high. Surprisingly, the findings for Argentina do not support the a-priori as both variables show significant long term comovement. Studying disaggregate price responses to common shocks helps to understand sectoral pattens behind these dynamics. Our results suggest that long run variablity in inflation can be induced, not only by a high trend inflation, but also by policy stabilization efforts based on relative price adjustments.

JEL: C22, C43, E31, E52

Keywords: inflation; frequency domain analysis; regime; common shocks; monetary policy; relative prices

*The opinions expressed here are of the authors and do not necessarily represent those of the Banco Central de la República Argentina.

†We are indebted to Andrew Levin, for his encouragement and useful suggestions to our first approach to the problem, and to other participants of the "Inflation Persistence in Latin America: Learning from Research in the Euro Area" Seminar, held at BCRA in August 23 - 24, 2007. We are also greatful to Juan Sotes Paladino, for having insisted on the relevance of frequency domain analysis in assessing inflation dynamics, and to Daniel Heymann, Sebastián Katz and George McCandless, for their useful comments and suggestions to a first draft of this paper.

1 Introduction

The relation between inflation and relative price variability (RPV) deserved a lot of attention in both, the empirical and the theoretical literature during the eighties, highly motivated by the impact of the oil shocks on domestic inflation in industrialized countries, but the topic lost interest once inflation stabilized at much lower levels worldwide.[1] In 1981, in an empirical seminal paper, Fisher provided evidence that the relation between inflation and RPV during the seventies in the US was highly dominated by relative price shocks, more precisely by the oil shocks.

The interest on the inflation-RPV relationship reappeared recently in a new strand of theorethical literature that studies the effects of a positive and eventually high trend inflation in the context of the standard new-keynesian model.[2] These literature suggests that moderate to high trend inflation may amplify the effects of a relative price shock on inflation. The volatility of inflation induced by cost-push shocks is, all else equal, higher at higher rates of inflation.

Albeit in a different way, macroeconomic policy in developing countries has been an important source of relative price variability, either because of policy induced relative price adjustments of great magnitude (i.e. devaluations), monetary instability, or the inability of policies to smooth out the impact of exogenous shocks in the economy.[3]

Thus, under a broad perspective, policy can act not only counteracting or accommodating aggregate supply shocks to the economy and hence reducing or amplifying their effects on inflation. It can also be itself a source of innovations, by either producing nominal surprises, with the aim of taking advantage of the inflation output trade off or collecting inflation tax, or by producing large adjustments of key relative prices as the RER, eventually influencing the medium and long term dynamics of inflation.

But, at least during normal times, a high portion of the variability of inflation simply reflects noise, i.e. idiosyncratic or seasonal short-run movements in sectoral prices which generally wash out, adding no persistence to inflation. On the contrary, policy innovations or supply shocks which impact sectoral inflation rates in a more generalized way, can influence the common medium trend of inflation, having a more permanent effect on it. This common trend is what is essentially behind the notion of core inflation, defined by Bryan and Cecchetti as "the component of price changes that is expected to persist over medium-term horizon for several years" and is the one that matters from the point of view of monetary policy.[4]

It seems then, that to assess the importance of aggregate shocks in driving the RPV-inflation relation it is important to separate the short-run component

[1] See for example Fisher (1981), Blejer (1983), Ball and Cecchetti (1990), among others.

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

[3] See in this respect Montiel (2003).

[4] See also in this respect, Cogley (2002), Cristadoro, Forni, Reichlin and Veronese (2005) and Altissimo et al. (2007).

from the persistent long-run component of both, RPV and inflation. This has not been the way in which the RPV inflation relation has been addressed in the empirical literature, which has mainly focused on testing the validity of different theories using conventional time series analysis.[5,6]

Here, we depart from this literature an adopt a quite different approach to the RPV- inflation relation. We argue that this relation is regime specific. By regime specific, we mean that it depends on the type of common shocks that predominately hit the economy and the way these shocks are transmitted to it. This in turn, is related to the way economic policy reacts to shocks, i.e., the policy reaction function, and how private agents respond to both, policy and exogenous shocks, under different policy environments.

Our focus on the dependence of the inflation-RPV relation on regime, although in essence atheoretical, relates to Ball and Mankiw's (1995) approach to the issue. They argue that negative supply shocks can create an inflationary environment, i.e. regime in our view, by shifting the distribution of the desired responses of sectoral prices to innovations to the right, preventing price changes to compensate between them. In a context like this, increases in the variance of shocks can increase inflation.

The importance of regime in determining the features the RPV-inflation was noted by Fisher op.cit., who remarked that accommodative monetary policy could have perpetuated the effects of supply shocks in the case of the US in the seventies. The way in which the empirical literature has addressed this issue has been to simply periodize time series analysis.[7] The problem with this is that, as stressed by Cogley (2002), inflation contains a substantial amount of high frequency noise, that needs to be disentangled from the common long-run component of inflation in order to identify the role of aggregate shocks in driving the RPV-inflation relation.

Thus, it seems pretty clear that to identify the particular features of inflation-RPV covariation under different regimes it is necessary to (i) disentangle short and long run components of both series and (ii) construct a measure of impact of aggregate shocks on inflation variability. To address (i) we use frequency domain analysis, which seems a natural tool to determine the relative importance of low (long run) medium (short run) and high frequency (noise) components in explaining (univariate and bivariate) variability across monetary regimes. To deal with (ii) we assume that the features of a particular inflation regime can be summarized by the common average evolution of sectoral inflation rates. Our approach allows for policy to react but also to be itself a source of innovations.

[5] See in this respect Fisher op. cit., Blejer (1983), Ball and Cecchetti (1990), among others, and Dabús (1996), and Carballo Pou et.al. (2006) for the Argentine case.

[6] In fact, few pieces of work point out the differece between the short and the long run relation between inflation and RPV. Nath (2004) looks at the long run relationship between RPV and inflation using VAR. Another examples are Banerjee et al. (2002), who estimate a VEC and Parsley (1996), who calculates impulse response functions to examine the persistence of the inflation-RPV relation.

[7] Dabús (1996), Pou (1996) and Dabús et al (2006) look at the RPV-inflation relation under different "inflation regimes" in the Argentine case splitting their sample according to mean inflation.

As in Ascari and Ropele op. cit., we characterize regimes in terms of trend inflation, as a proxy of the commitment of monetary policy with a low and stable rate of inflation.

Different monetary regimes should show a different distribution of the variance of inflation and RPV across frequencies and strength of comovement between both variables. In a low inflation regime, both the variance of inflation and RPV should mainly reflect temporary movements in prices and thus concentrate at very high frequencies. This pattern is expected to get at least partially reversed under a higher inflation trend: The variability of inflation should be concentrated on both, very high and low frequencies, as it becomes a more persistent and noisy process, while the variability of RPV should probably be more spread across frequencies.

Using the methodology described above we look at the RPV-inflation relation in Argentina under different regimes: high inflation in the eighties, low inflation in the nineties and a transition period in the two thousands. We contrast Argentina with the US, particularly in terms of what could be expected the RPV inflation relation to be during normal times, i.e. under low and stable inflation. In the case of the US, we focus on two regimes: high inflation in the seventies and low inflation in the nineties and two thousands.

The two economies are very different in terms of size and economic development, fact that is reflected in a different composition of their consumption basket, but the comparison with the US is particularly interesting because of the very different nature of the shocks that seem to have dominated inflation dynamics in both countries: In the US supply shocks have been a main source of innovations to the inflation rate. As argued by Sargent (1999) and Cogley and Sargent (2001), among others, these aggregate shocks perpetuated in a high trend inflation during the seventies due to an inadequate monetary policy framework that excessively relayed on exploiting the inflation output trade-off. In Argentina, as in many other emerging economies, policy innovations have been a major source of inflation variability. In particular, high inflation in the eighties was mainly the result of monetary financing of fiscal imbalances through the inflation tax. Disinflation in both countries was also conducted using very different policy strategies: In the US it was achieved through an aggressive interest rate policy. In Argentina, inflation was lowered and stabilized by adopting a hard peg to the dollar as the nominal anchor, what implied the abandonment of monetary policy as a stabilization tool, and a persistent real appreciation of the currency, i.e., a relative price adjustment.

The paper is organized as follows: In section 2 we briefly describe our methodological approach to the analysis the RPV-inflation relation. Section 3 presents a brief description of our treatment of the data. In section 4 we conduct univariate analysis of both, inflation and RPV to analyze how the distribution of the variance of both time series across frequencies changed depending on regime. In section 5 we look at the interactions between RPV and inflation using frequency domain analysis tools and then go deeper in our analysis decomposing both inflation and RPV into their idiosyncratic and common components, to assess the importance of common shocks in explaining their comovement. In section 7 we use the decomposition in section 6 to get a deeper insight to the sectoral patterns behind the inflation-RPV dynamics and see how they change across regimes in both countries, Argentina and the US. Finally, in section 8, we conclude.

2 Our approach to the inflation-RPV relation: Frequency domain analysis and unobservable shocks to inflation

Depending on regime, inflation and RPV are supposed to have an specific way of interacting. These specificities may show on different time horizons. Frequency domain analysis is a useful tool to detect such features. In fact, it allows to decompose the evolution of time series in defined periodic contributions to their variance, providing a natural description of their structure in terms of cyclical behavior at different time scales.

Frequency domain analysis can be performed in both univariate and bivariate grounds. While the former allows the detection of movements inside each of the series, by means of the latter it is possible to detect frequency specific covariance between series. In other words, conventional time-domain correlation analysis can be shuttled to the frequency domain.

This approach appears to be specially insightful in what regards the association between relative price variability and inflation for at least three reasons (not mutually exclusive, though): (i) It allows to avoid trivial correlation between series due to data construction, a methodological issue some kind absent in previous discussions on the subject. It seems natural that high frequency RPV should reflect in a more volatile aggregate index of inflation also in that frequency, mainly because this latter aggregates movements of individual disaggregated series; (ii) The way these variables interact might be frequency specific, in the sense that their relation may vary – get reinforced or diminished – depending on the time horizon considered; finally, (iii) The approach allows to focus on relevant time horizon. That is, an important part of the variability of inflation comes from short run seasonal or transitory idiosyncratic changes in prices. These movements in prices are of no interest for macroeconomic policy, which is supposed to react to changes which are quite generalized and persist over time. Frequency domain analysis is a very suitable tool for this purpose: It allows to detect and discard this noise and concentrate on medium and long term movements of RPV and inflation. In particular, as discussed by Phillips (1991) and stressed by Andrews and Chen (1994), the spectrum at the zero frequency, which is a measure of the low-frequency autocovariance of a time series, can be considered as a measure of persistence.

But separating high frequency noise from persistent sources of variability is not enough if we want to identify specific regime features driving the inflation-RPV relation. Prices are affected by shocks that can either be common or idiosyncratic. When working with monthly inflation rates, these latter explain an important portion of inflation variability and thus of RPV. While common shocks are in general related to policy and macroeconomic developments, idiosyncratic shocks mainly reflect innovations to the demand in specific markets, seasonal movements, missperceptions, etc. The majority of times, common shocks have a persistent or low frequency effect on inflation, while idiosyncratic innovations are generally transitory or high frequency.There might appear, however, situations in which those duets may not apply. Thus, we need to find some way of capturing the effects of unobservable common shocks on inflation, disentangling them from idiosyncratic sources of variability and verifying at what frequencies these two unobservable components of inflation interact with RPV. We address this using the methodology in Stock and Watson (2002) and Clark (2003) to construct measures of both, the common and the idiosyncratic components of CPI inflation.

3 Data

The data consists on CPI month over month inflation rates for the two countries, Argentina and the US. In the case of Argentina, inflation indexes are taken from the Instituto Nacional de Estadística y Censos (INDEC) and correspond to the three digits CPI indexes.Taking note of the findings in D'Amato et al. (2007), we define three different regimes: (i) high inflation, from 1980:01 to 1987:12; (ii) low inflation, from 1993:01 to 2001:12; and (iii) a moderate-low inflation post-devaluation transition period under a managed float, from 2003:01 to 2006:12. When considering (iii), we deliberately excluded the observations corresponding to 2002, the year after the devaluation of January 2002, mainly because the impact effect of this shock on the inflation rate can have a great influence on the results for this sub-period. Another reason for the exclusion of this period is the heterogenous timing of breaks at the disaggregated level after the 2002 devaluation. We evaluated the presence of structural breaks in individual time series using the Bai Perron (2003) test for multiple unknown breaks. We find that most of the breaks (78%) occur in the neighborhood of the regime shift date (but not precisely on that date) and that some services break later. We also exclude from the CPI calculation regulated goods and services. This left 51 sub-indexes for (i) period and 56 sub-indexes for (ii) and (iii) period, because the consumption basket changed form one period to another. Aggregate inflation rate was recalculated as the weighted sum of the remaining adjusted sectoral inflation rates. Finally, we seasonally adjusted the data by the X-12 ARIMA method when required.

In the case of the US, data on seasonally adjusted price indexes for all components of consumption as measured in the NIPA accounts are taken from the BEA's web site. Based in the Bai Perron op. cit. test for multiple unknown breaks, we consider two regimes: (i) high inflation between 1974 and 1981 and (ii) low inflation between 1991 and 2007. When considering (ii), we deliberately excluded the observations corresponding to 1973, the year when the petroleum shock impacted the stronger, mainly because the impact effect of it on the inflation rate and RPV can have a great influence on the results for this regime. We do not consider, also, the interim disinflation period, that has no interest to our purpose of studying "purely" low and high inflation regimes. The data used allows for breakdowns at various levels of aggregation up to more than 150 series. The results below focus on the so called third level of aggregation (124 subindexes 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 is performed, fixed rather time-varying weights are used because we are interested only in price variation but not in quantity variation. Shares used are based on average expenditures in each period considered. Anyway, although not reported, estimates based on time-varying weights were performed showing no significant changes in conclusions.

We use the relative price variability (RPV) measure adopted in Theil (1967) and Fisher op cit., that is defined as follows:

$$RPV_t = \sum_{i}^{n} \theta_i \ (\pi_{it} - \pi_t)^2$$

where π_{it} is the inflation rate of sector i in period t, π_t is the aggregate inflation rate in period t and θ_i is the weight of sector i in the consumption basket.

Resulting time series are plotted in Figures 1 to 5.

Figure 1
USA: Inflation and RPV (1974:01-1981:12)

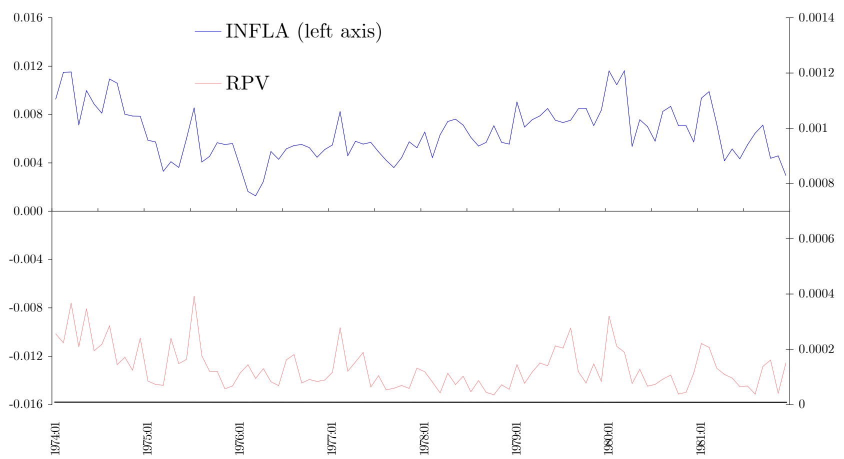


Figure 2
USA: Inflation and RPV (1991:01-2007:12)

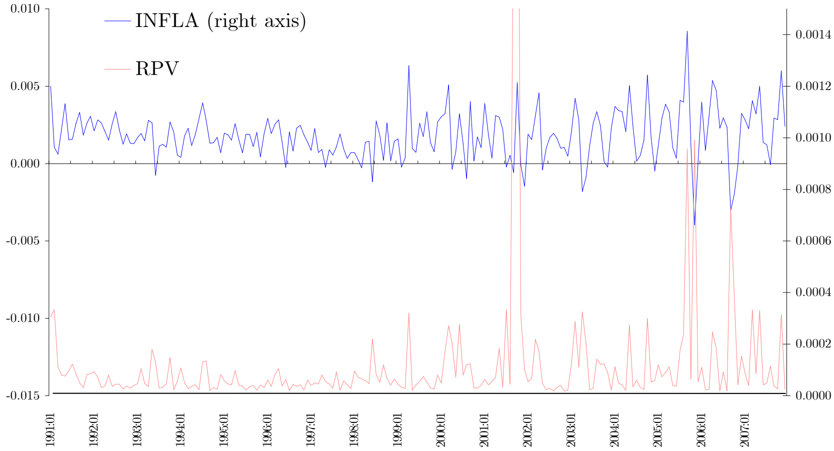


Figure 3
Argentina: Inflation and RPV (1980:01-1987:12)

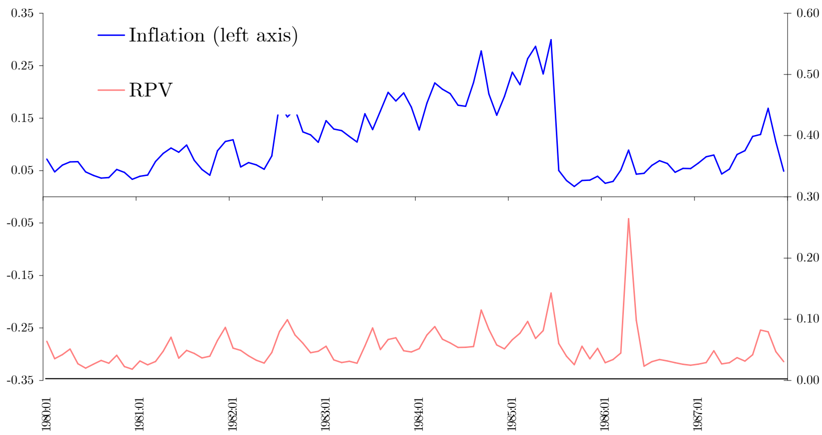


Figure 4
Argentina: Inflation and RPV (1991:01-2001:12)

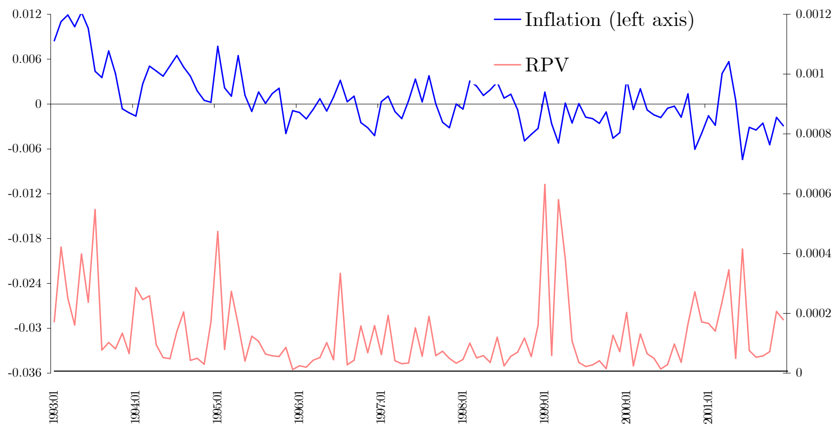
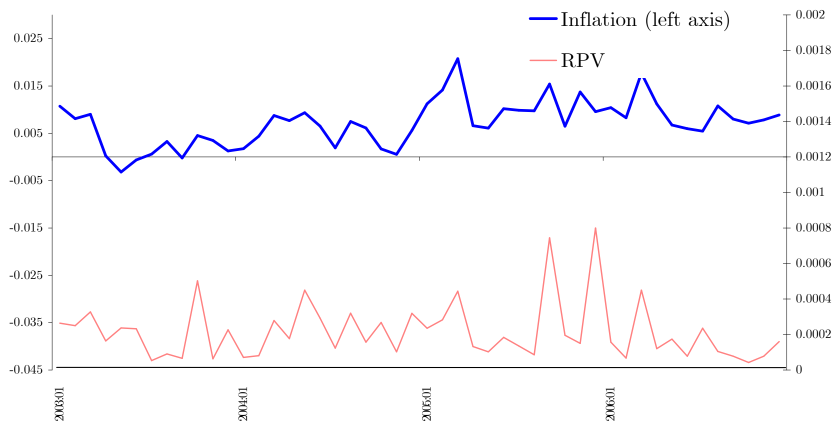


Figure 5
Argentina: Inflation and RPV (2003:01-2006:12)



4 Spectrum and regimes: Typical shapes behind inflation dynamics?

The variance of a time series can be thought as the integral of the spectrum, $g(\omega)$, across all frequencies $-\pi \leqslant \omega \leqslant \pi$. While the portion of the variance at very high frequencies relates to temporary movements in time series, that can be loosely referred as *noise*, the portion at low frequencies relates to the permanent, *trend* component of their variability. 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 conclussions might be in general true, we argue that there might still be valuable information in the spectral decomposition of inflation. In particular, we expect that different monetary regimes reflect in a different level and distribution of the variance of inflation and RPV across frequencies. In fact, under a loose monetary policy regime, i.e. a high inflation regime, one would expect the variability of inflation, apart from being higher, to be concentrated in both, very high and low frequencies, simply because it becomes a more persistent and noisy process. On the contrary, the implementation of policies aimed at reducing inflation are expected to reduce variance and persistence. Thus, the decrease in variance would occur in combination with a decline of the spectrum at lower frequencies.

In turn, the variance of RPV in a low inflation regime, i.e, one in which monetary policy aims at maintaining inflation at low levels, should tend also to be smaller but to concentrate at very high frequencies, reflecting mainly temporary and minor corrections in prices. Under high inflation, this pattern is expected to change into one with higher variance and that appears to be more evenly spread across frequencies, thus showing certain long term dynamics driving the process. It is certainly possible that in a regime with higher trend inflation higher instability and uncertainty could lead to less synchronization and higher magnitude of price adjustments. This patterns in RPV can be motivated on the grounds of informational problems of the Lucas (1973) type: in an inflationary environment unexpected inflation (policy innovations) can reduce the informational content of prices, leading to missperceptions that could create increased relative price variability. Menu costs in price adjustment, as in Caplin and Spulber (1987), Blanchard and Kiyotaki (1987), among others, can also motivate a policy induced comovement between inflation and RPV.

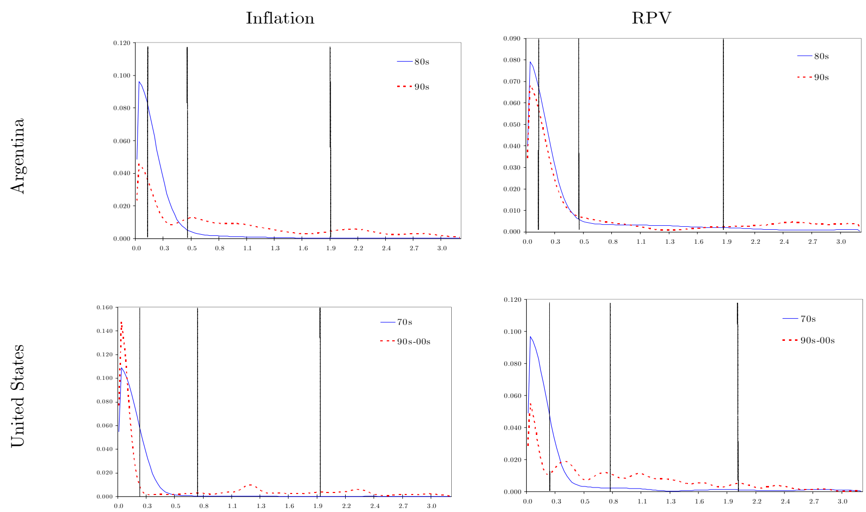
To have a better insight of the different distribution of the variance across frequencies and between regimes we need to isolate it from the change in its level. This can be attained by normalizing $g(\omega)$, that is, constructing $h(\omega) = g(\omega)/\sigma^2$. This measure is known as "normalized spectrum" and indicates the fraction of total variance that occurs at each frequency.

Our frequency domain approach is ilustrated in Figure 6. For each of the regimes and for each country, the left panel depicts an illustrative estimate of the normalized espectrum of inflation, and the right panel depicts the one for RPV. The horizontal axis expresses the frequency ω. The horizontal lines delineate three different frequency ranges. From right to left: Short Run, Medium Run and Long Run (defined as the relevant horizon for economic policy, many times identified with bussines cycle variation). A fourth region, the one at very low frequencies is not examined, as the estimated spectrum for those frequencies is subject to greater sampling variation (specially when the sample period is short) and hence the estimation precision is expected to fall significantly.

Figure 6 provides some preliminary evidence on expected patterns. While for the US the fall in inflation has brought a reduction in the variance explained by low frequency components for both inflation and RPV, in the Argentine case the evidence is mixed: whereas inflation shows a desproportionate decline in its spectrum giving in balance less weight to long run components (that is, it becomes a less persistent process), there seems to be no significant differences between high and low inflation regimes for RPV.

Figure 6

Normalized Spectrum of Inflation and RPV



4.1 Testing strategy

Following close the strategy in Ahmed et al.(2003), the hypothesis described above can be tested by the estimation of the "integrated spectrum" (see Priestley, 1982). The variance corresponding to a determinate frequency band $\omega_1 \leqslant |\omega| \leqslant \omega_2$ is given by $G(\omega_1,\omega_2) = 2\int_{\omega_1}^{\omega_2} g(\omega)\ d\omega$. Trivially, integrating the spectrum over all frequencies, that is, between $\omega_1 = 0$ and $\omega_2 = \pi$, yields the overall variance of the series.

Integrating the spectrum is quite a difficult task but fortunately there exists an estimator that is consistent and has asymptotic normal distribution on which perform conventional *t-statistics* tests. The integrated spectrum can be, thus, estimated in the following way:

$$\hat{G}(\omega_1,\omega_2) = \frac{\omega_2 - \omega_1}{\pi}\widehat{\Gamma}(0) + \frac{2}{\pi}\sum_{j=1}^{T-1}\widehat{\Gamma}(j)\frac{\sin\ \omega_2\ j\ -\ \sin\ \omega_1\ j}{j}\ , \qquad (1)$$

where $\widehat{\Gamma}(j)$ are the sample j order autocovariances of the process and $\widehat{\Gamma}(0) = \widehat{\sigma}^2$.

The estimation of the normalized integrated spectrum over a frequency range, $\hat{H}(\omega_1,\omega_2)$, is straight forward. The only thing needed to be done is to divide $\hat{G}(\omega_1,\omega_2)$ by $\widehat{\sigma}^2$. $\hat{H}(\omega_1,\omega_2)$ measures the portion of variance corresponding to the frequency band $\omega_1 \leqslant |\omega| \leqslant \omega_2$ and thus integrating over all frequencies results in a value of 1. Asymptotic properties of this estimator are similar to those of the integrated spectrum.

Fairly expected in the case of Argentina, according to the estimates of the integrated spectrum for inflation and RPV (not shown here but anyway available upon request), the variance of inflation has fallen appreciably between the eighties and the low and moderate inflation regimes whatever frequency is considered. In turn, between these latter, although it seems that the change in regime has resulted in a rise in variance in all frequencies, only the change for higher frequencies is significant. The RPV variance has also decreased appreciably in the low and moderate periods. Nevertheless, the evolution between these latter periods has been somewhat different, as the variance of RPV has tended to concentrate in higher frequencies in the last period.

The findings for the US are probably less obvious: The variance of inflation is rather the same across the two regimes, but it is distributed very differently across frequencies. Nowadays, it concentrates mostly in higher frequencies, in contrast with the seventies, when long run variability was as important as high frequency noise in explaining the total variance of inflation. Thus the lowering of mean inflation did not necessarily imply a reduction in the volatility of inflation, as suggested in the literature.[8] Rather, what it brought is a reduction in inflation uncertainty, i.e. less long run variability.

More interesting features come up when the frequency distribution of variance according to the estimates of the Integrated Normalized Spectrum is analyzed. Estimates for the US in Table 1 seem to match our *a-priori* in what regards RPV and inflation series properties in the frequency domain under different inflation regimes. Both inflation and RPV acquire shorter run characteristics as variation tends to concentrate in higher frequencies. For example, focusing on a relevant policy horizon for the US economy, the business cycle defined as in Baxter and King (1999) - cycles between eighteen months (one year and a half) and ninety months (eight years)-, variance has significantly fallen for the low inflation period.

[8] See in this respect Ball and Cecchetti, 1990.

Table 1
USA: Estimates of Integrated Normalized Spectrum

Variable and Frequency Band		Integrated Normalized Spectrum		Test (H$_0$: Regime i=Regime j)	
		1974-81	*1991-2007*	*70s vs. 90s/00s*	
Inflation:					
0-3 months	*area*	0.492	0.380	*stat.*	3.660 ***
	variance	0.085	0.011	*p-value*	0.000
1 year - 2 years	*area*	0.003	0.072	*stat.*	n.a.
	variance	n.a.	0.023	*p-value*	n.a.
more than 2 years	*area*	0.468	0.081	*stat.*	n.a.
	variance	0.110	n.a.	*p-value*	n.a.
Business Cycle	*area*	0.386	0.066	*stat.*	9.119 ***
	variance	0.113	0.012	*p-value*	0.000
RPV:					
0-3 months	*area*	0.431	0.445	*stat.*	-0.630
	variance	0.037	0.015	*p-value*	0.736
1 year - 2 years	*area*	0.098	0.153	*stat.*	n.a.
	variance	n.a.	0.007	*p-value*	n.a.
more than two years	*area*	0.275	0.158	*stat.*	4.878 ***
	variance	0.051	0.009	*p-value*	0.000
Business Cycle	*area*	0.210	0.174	*stat.*	4.027 ***
	variance	0.007	0.002	*p-value*	0.000

n.a.: excess kurtosis was so high as to make estimated variance negative.

The results for Argentina in Table 2 are some kind different. Remarkably, long run variance in the eighties shows significantly more weight than in the nineties or the two-thousands. Noise components of variance seem to be higher in the eighties, although they are not statistically different between regimes. In what regards RPV variance, evidence comes up to be quite puzzling. Despite of the fact that RPV variance is quite spread across frequencies in the eighties, the low frequency component explains a higher proportion of variance in the nineties. These feature arises even though inflation remained at very low levels during the period.

Table 2

Argentina: Estimates of Integrated Normalized Spectrum

Variable and Frequency Band		Integrated Normalized Spectrum			Test (H$_0$: Regime i=Regime j)			
		80s	*90s*	*00s*		*80s vs. 90s*	*80s vs. 00s*	*90s vs. 00s*
Inflation:								
0 - 3 months	*area*	0.521	0.483	0.459	*stat.*	0.869	1.099	0.488
	variance	0.129	0.062	0.088	*p-value*	0.192	0.136	0.312
1 year - 2 years	*area*	n.a.	0.134	0.063	*stat.*	n.a.	n.a.	n.a.
	variance	n.a.	n.a.	n.a.	*p-value*	n.a.	n.a.	n.a.
more than 2 years	*area*	0.597	0.391	0.344	*stat.*	4.536 ***	4.837 ***	1.093
	variance	0.144	0.063	0.060	*p-value*	0.000	0.000	0.138
RPV:								
0 - 3 months	*area*	0.441	0.363	0.208	*stat.*	4.405 ***	10.848 ***	8.415 ***
	variance	0.021	0.010	0.012	*p-value*	0.000	0.000	0.000
1 year - 2 years	*area*	0.099	0.123	0.084	*stat.*	-3.944 ***	n.a.	n.a.
	variance	0.000	0.003	na	*p-value*	0.000	n.a.	n.a.
more than 2 years	*area*	0.158	0.182	0.065	*stat.*	-1.488 *	4.846 ***	7.729 ***
	variance	0.019	0.005	0.009	*p-value*	0.068	0.000	0.000

n.a.: autocovariances for some time lags were so negative as to make estimated area and variance negative.

As hypothesized, changes in the monetary regime towards one with a lower trend inflation reflect in a disproportionate fall in the spectrum of inflation at different frequencies, giving on balance more weight to higher frequencies. This finding is in line with a vast literature on inflation persistence, where a lower trend inflation, associated to regimes where the awareness of inflation is higher, is related to lower long run components. Nevertheless, surprisingly in the case of Argentina, our findings do not support the hypothesis of the negative relation between the level of inflation and the concentration of the variance of RPV at more short run frequencies. This fact rises the question if there are other driving forces behind RPV long term dynamics.

5 Regime dependence and inflation-RPV interactions

Interactions of RPV and inflation have been largely documented by previous empirical work on the subject.[9] These pieces of research coincide in the finding of an empirically relevant relation between inflation and RPV. As suggested by Fisher op cit. and more recently by Kiley op cit., the way inflation and RPV interact can be regime specific. According to the empirical evidence in the previous section, the frequency distribution of variance of both time series differs across regimes. Thus, these distinct features of regimes in terms of RPV and inflation comovement should reflect mainly in the frequency domain.

[9] See for example Fisher *op.cit.*; Reisendorf, (1984); Parsley (1996) and Dabús *op.cit.*, Pou, *op.cit.* and Dabús et al *op.cit.*, for the Argentine case.

One may think that, at least in normal times, RPV is short run in nature, except for some secular movements in relative prices related to technological innovation. Thus, interaction between inflation and RPV in a low and stable inflationary environment should be restricted to high frequencies. However, loose monetary policy can contribute to magnify and, in the extreme, perpetuate the initial effect of an one and for all relative price shock. That is, a high trend inflation could induce a long run correlation between both variables. Thus, correlation coefficients calculated in the time domain may not be informative about the strength of the comovement between variables at different frequencies. We formally test these features in data through the calculation of a frequency band specific correlation coefficient:

$$\rho(\omega_1, \omega_2) = \frac{Cov(\widetilde{\pi}(\omega_1, \omega_2); \widetilde{\nu}(\omega_1, \omega_2))}{\sqrt{Var(\widetilde{\pi}(\omega_1, \omega_2))}\sqrt{Var(\widetilde{\nu}(\omega_1, \omega_2))}} \tag{2}$$

where $\widetilde{\pi}(\omega_1, \omega_2)$ and $\widetilde{\nu}(\omega_1, \omega_2)$ are frequency band specific time series extracted from data vectors x and y (see the Methodological Appendix for details), and $Cov(\circ)$ and $Var(\circ)$ are the covariance and variance, respectively. Inference on the obtained coefficients can be performed in the conventional way adequately considering the loss in degrees of freedom due to the filtering procedure (see Engle, 1974). The reason of choosing a correlation coefficient approach rather than a regression approach lies in the fact that there is little agreement over the functional form of the relationship and even over which is the appropriate right hand side variable (see Fisher, op.cit. and Ball and Mankiw, op.cit.). Arguably, at the same time, the correct model specification may change with the regime (see Fisher, op.cit.).

Tables 3 and 4 present the results of the estimation for US and Argentina, respectively. As in the previous section, we define short run as fluctuations with periodicity less than 3 months, and the long run as fluctuations of more than 2 years, but we also show results for other frequency bands. Each column in the table corresponds to a different period of analysis and the rows include the frequency band specific estimated correlation coefficient. Also, in the case of Argentina, that experienced a deflationary period by the end of the nineties, we calculate the correlation between RPV and the absolute value of inflation for the nineties (column three of Table 4), since it can be thought that either inflation and deflation create resource misallocations and generate transaction costs (see Fisher, op.cit.). The last row shows the correlation coefficient calculated in the conventional time-domain way.

Results for the US in Table 3 seem again to confirm our a-priori. As expected, during the seventies inflation exhibits a long run correlation with RPV, fact that strictly restricts to the short run in the current low inflation regime.

Table 3
USA: Correlation Coefficients - Relative Price Variability vs. Inflation

		1974-81	*1991-07*
0 - 3 months	*corr. coef.*	0.5432 ***	0.2649 **
	p-value	0.0005	0.0123
1 year - 2 years	*corr. coef.*	0.5936 ***	0.0838
	p-value	0.0000	0.1856
1 year and a half - 8 years (Business cycle)	*corr. coef.*	0.8990 ***	-0.0726
	p-value	0.0012	0.6127
more than 2 years	*corr. coef.*	0.5922 *	0.0502
	p-value	0.0806	0.4294
Overall	*corr. coef.*	0.5351	0.1005
	p-value	0.0000	0.1528

Table 4
Argentina: Correlation Coefficients - Relative Price Variability vs. Inflation

Frequency Band		*80s*	*90s* *(abs. inflation)*	*00s*
0 - 3 months	*corr. coef.*	0.3667 **	0.4715 ***	0.4786 **
	p-value	0.0165	0.0014	0.0223
1 year - 2 years	*corr. coef.*	0.5603 ***	0.4314 ***	0.4549 ***
	p-value	0.0000	0.0002	0.0098
more than 2 years	*corr. coef.*	0.7588 **	0.8953 ***	0.6868
	p-value	0.0240	0.0006	0.1001
Overall	*corr. coef.*	0.5099 ***	0.4870 ***	0.4043 ***
	p-value	0.0000	0.0000	0.0044

Table 4 shows results for Argentina. In this case, the lower the frequency, the stronger the correlation between inflation and RPV. This result is consistently found across regimes, even in the nineties, contradicting our a-priori in what regarded the frequency specific association between inflation and RPV in a low inflation regime.

This puzzle is further explored in the light of the presence of common shocks and the heterogeneous response of individual series to this signal. In the next section we look in more detail into disaggregate inflation time series, their relation with the common and idiosyncratic components of inflation, and its implications to the comovement of inflation and RPV.

5.1 Principal components and common shocks

As suggested previously, individual sectors can react differently to common shocks. As we will show later, this dynamic feature can vary with time, depending on the inflation regime.

Price setting by sector can be rationalized as being composed by a response to a macroeconomic common shock - the first principal component-, that is supposed to be driven by specific underlying, unobserved forces (in e.g. aggregate demand or supply shocks to which that all sectors are exposed to), and an idiosyncratic factor that could reflect sector heterogeneity in terms of demand, technology, climatic factors as well as missperceptions and idiosyncratic timing of price adjustment in a determinate economic environment. Thus, inflation dynamics in a particular sector is the result of the common shock and the idiosyncratic component.

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

$$\pi_{it} = \lambda_i(L)U_t + \varepsilon_{it} \tag{3}$$

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, ε_{it} is the idiosyncratic component and $U_t \perp \varepsilon_{it}$.

According to this setting, RPV will grow with the magnitude of the common shock that in turn will induce higher RPV the higher the heterogeneity in the propagation mechanism (that is, the higher the dispersion in the $\lambda_i(L)$ polynomial). Note, also, that this setting does not rule out the idiosyncratic component as a source of RPV.

Aggregate inflation rate is:

$$\pi_t = \sum_{i=1}^{n} \theta_i \ \pi_{it} = \sum_{i=1}^{n} \theta_i \lambda_i(L)U_t + \sum_{i=1}^{n} \theta_i \varepsilon_{it} = C_t + I_t \tag{4}$$

where C_t and I_t are the common component and the aggregate idiosyncratic component of inflation, respectively, and θ_i is sector i´s weight in the consumption basket. We estimate sector responses to common shocks according to 3 and calculate C_t and I_t based on 4.

C represents the aggregate response of sectoral rates of inflation to common macroeconomic shocks hitting the economy. Thus, it can be thought as a resume measure of the regime specific driving forces behind inflation dynamics. Again, in a low inflation regime, nothing suggests that this component should comove with RPV at any frequency and I is expected to be the only component showing comovement with RVP but restricted to the higher frequencies. However, when there is a trend in inflation, it seems natural to think that C will emerge as a driver of the lower frequencies comovement between RPV and inflation.

As in previous sections, we first look at the estimation results for the US in Table 5. Again, as expected, the lower mean inflation in the current regime cannot be associated to C-RPV developments at any frequency and I-RPV is strictly restricted to the very short run. The seventies, on the other hand, show significant long run correlation for RPV and both I and C, that extends much further for this latter.

In the Argentinean case, the existence of a trend inflation shows up in the significant correlation of C and RPV at low frequencies whatever regime is considered. This is what we show in C columns in Table 6. In both regimes, the eighties and the nineties, RPV and C correlation coefficient increases as frequency decreases, indicating that the regime underlying driving forces have a role in explaining RPV long-run dynamics.

Table 5
USA:
Correlation Coefficients - RPV vs. Common (C) and Idiosyncratic (I) components of inflation

		1974-81		*1991-07*	
		C	I	C	I
0 - 3 months	*corr. coef.*	0.4829 ***	0.2346 *	0.0412	0.2637 **
	p-value	0.0019	0.0908	0.3657	0.0126
1 year - 2 years	*corr. coef.*	0.3519 ***	0.5014 ***	0.0627	0.0813
	p-value	0.0045	0.0001	0.2519	0.1927
1 year and a half - 8 years	*corr. coef.*	0.8728 ***	0.7554 **	-0.1308	-0.0568
(Business cycle)	*p-value*	0.0023	0.0151	0.6975	0.5886
more than 2 years	*corr. coef.*	0.7128 **	0.3355	-0.4289	0.1327
	p-value	0.0361	0.2309	0.9447	0.3187
Overall	*corr. coef.*	0.4401 ***	0.3831 ***	-0.1783 **	0.1097
	p-value	0.0000	0.0001	0.0107	0.1184

Note, however, that the correlation coefficient for the very short run frequencies in the nineties is statistically not significant (and negative). This fact is indicating that nothing of short run RPV is associated to the regime underlying dynamics. This is not the case in the eighties, where the common component of inflation shortens its frequency of incidence on RVP. Naturally, the higher the trend inflation the earlier common shocks to the economy impact on individual price dynamics. This, in turn, induces a more short run association between C and sectoral inflation dispersion. This significant comovement between RPV and C at high frequencies in the eighties suggests that higher trend inflation makes the inflation process more noisy, in terms of creating more short run RPV, a finding in line with the positive link between trend inflation and price dispersion suggested by the recent literature on trend inflation (see Kiley, op cit.).

Table 6

Argentina:

Correlation Coefficients - RPV vs. Common (C) and Idiosyncratic (I) components of inflation

Frequency Band		*80s*		*90s* *(abs. inflation)*		*00s*	
		C	I	C	I	C	I
0 - 3 months	*corr. coef.*	0.3017 **	0.3555 **	-0.1124	0.6179 ***	0.4238 **	0.5923 ***
	p-value	0.0414	0.0195	0.7493	0.0000	0.0398	0.0048
1 year - 2 years	*corr. coef.*	0.4328 ***	0.3846 **	0.4457 ***	0.4437 ***	0.2976 *	0.3461 **
	p-value	0.0005	0.0020	0.0001	0.0002	0.0699	0.0416
more than 2 years	*corr. coef.*	0.7327 **	0.7493 **	0.7570 ***	0.2525	0.6005	0.8436 **
	p-value	0.0305	0.0263	0.0091	0.2561	0.1421	0.0363
Overall	*corr. coef.*	0.4296 ***	0.4104 ***	0.3643 ***	0.4732 ***	0.2270	0.4356 ***
	p-value	0.0000	0.0000	0.0001	0.0000	0.1208	0.0020

These differences across regimes are confirmed if we look at the correlation coefficients between RPV and I in Table 6. In the nineties the comovement between this two variables is restricted to shorter run frequencies, and looses significance as frequency decreases. That is, short run RPV is only related to idiosyncratic movements in prices and not influenced by the regime underlying factor. This is not the case in the eighties, where the correlation between RPV and I is significant at low frequencies and increases as frequency decreases. Apparently, in the high inflation regime, the idiosyncratic components of individual inflation rates, which are supposed to be in general restricted to short run movements in prices, when aggregated in I, add persistence to the inflation process.

During the post-devaluation period, the two thousands regime, there is less comovement between C and RPV and the correlations become statistically insignificant in the long run, except for those frequencies between 1 and 2 years, which still show, albeit little, significant correlation between these two variables. This seems reasonable for a transition period after a strong change in relative prices. On the contrary, even though its incidence is pretty low and statistically not significant for the very long run frequencies, I shows a strong low frequency relation with RPV. So, in the transition post-devaluation period, RPV appears to be more related to sustained idiosyncratic corrections than to a generalized comovement among individual time series. These features turn out to be quite clear if we focus on columns corresponding to the *00s* in Table 6.

The finding of an aggregate idiosyncratic component of inflation that exhibits a trend in the eighties and significantly comoves with RPV is consistent with the time series properties we find in the individual idiosyncratic components of sectoral inflation rates: While in the eighties we cannot reject the null of a white noise for 43.1% of the series, this portion increases to 58.8% and reaches 84.5% in the two-thousands. Of course, these features have an impact on the aggregate idiosyncratic component: Although for all three regimes the null of white noise for I cannot be rejected, the *p-values* of the test are smaller as the portion of white noise individual series increases. For the eighties the *p-value* is of 0.14, for the nineties is of 0.39 and for the two-thousands is of 0.85. This helps to explain long run RVP$-I$ dynamics as the white noise test on I shows that the idiosyncratic components tend to wash out in the nineties and two-thousands but not that much in the eighties. Thus, for the eighties the observed trend in inflation is partially explained by idiosyncratic movements in individual prices that do not compensate and hence add persistence to the inflation process.

Recaping, inflation-RPV relation seems to be regime dependent. In general, under high inflation, common shocks become a significant source of RPV in both the short run and, even more intensively, the long run. Also, under such circunstances, idiosyncratic movements in prices seem to covariate at both time scales, adding persistence (or long-run variability) to aggregate inflation. When inflation is low, although no long-run interaction between the variables is expected, as it is in fact the case for the US, the findings for Argentina do not support this *a-priori* as they show a strong long-run comovement that is basically explained by the common component of inflation. In the next section, we study disaggregate price responces to common shocks and try to explain these dynamics by means of looking at sectoral patterns behind price movements.

6 Common shocks and heterogeneity: sectoral patterns behind inflation-RPV dynamics

Results in previous sections are consistent with the fact that policy, associated to the common component of inflation, may induce or perpetuate RPV. Higher inflation regimes were found to be characterized by a stronger relation between the common component of inflation and RPV, with this strength increasing as the frequency decreases. The converse was expected to be true for low inflation regimes, but these features were only verified for the most recent US inflation regime. The inflation-RPV dynamics during the Argentine Convertibility period, thus, was argued to be quite peculiar for a low inflation regime.

In this section, by going one step down in the level of aggregation, we try to get a deeper insight into individual inflation dynamics. By analysing sectoral responses to common shocks, we study in a more comprehensive way inflation-RPV interactions.

6.1 Common shocks across regimes

Broadly speaking, it can be argued that there are at least two features that characterize regimes: (i) aggregate shocks and (ii) transmission mechanisms of those aggregate shocks. Shocks might be qualitatively distinct across regimes. For example, in some regimes nominal shocks dominate supply shocks. Also, the latter might be of different nature, as is the case of Oil and Food shocks *vis à vis* movements in the RER. Transmission mechanisms may also vary from one regime to another, showing that sectoral prices can respond differently conditional on the environment were they operate. This would reflect in different dynamic structures in the processing of common shocks.

We start first by inspecting joint responses to common shocks. In Figures 6 to 10 we plot the evolution of the inflation rate in the different regimes along with that of the variance explained by the first principal component estimated in subsection 5.1. We construct three different measures of this last indicator: (i) a recursive estimation, that is, starting a year before the initial observation of our sample periods and adding observations and recalculating as time proceeds (dotted green line), (ii) a two year window rolling (red line) and (iii) a single year rolling (blue line).

The first feature to remark is that the first principal component of inflation tends to explain a higher proportion of overall individual series variability for higher inflation regimes, what reflects higher comovement among sectoral inflation time series. Essentially, common macroeconomic shocks will be predominant relative to idiosyncratic shocks, thus driving to a great extent the variability of individual prices. On the contrary, when inflation is relatively low, idiosyncratic innovations to individual prices would probably dominate prices dynamics. This is what we find if we compare, for example, the eighties and the nineties Argentine regimes: in the case of the former the first principal component explains 70% of overall variability, whereas in the latter restricts to nearly 25%. In turn, in the US case the first principal component explains considerably less of total comovement, although it seems to be higher for the seventies regime (approximately, 15% vs. 8%).

The second is that higher magnitude of shocks is associated to higher coordination in price setting among sectors. In coincidence with Sheshinski and Weiss (1977) and Dotsey et al.(1999) arguments, coordination in price corrections appear to be fostered by strong and sudden changes in market conditions. Appreciably, the figures show that shocks of large magnitude reflect in high peaks of the variance explained by the first component, thus reflecting a generalized comovement of series in response to those shocks.

However, as argued, the nature of these shocks has shown many times to be different depending on the regime. For the US, as shown in Figures 7 and 8, the sources of relative price shocks were basically associated to strong (and quantitatively similar) changes in food and energy prices under both regimes considered, mainly in 1973, 1979, 1991, 1999 and 2004 (see in this respect De Gregorio et al., 2007). Probably, as analyzed in the next subsection, a difference between regimes will be found in the way sectors process these shocks. A first difference emerges just looking at the recursive estimate of the first principal component in Figures 7 and 8: Whereas from 1973 on the variance explained jumps to a level that hardly tends to decline, for 1999 and subsequent relative price shocks the explained variance does not change. In other words, as opposed to the 70s regime, at present times these shocks have induced a comovement that seems not to generalize. We can look at this phenomenon from a different perspective. In Figure 9 we plot rolling variation coefficients of inflation and ex-energy & food inflation. Clearly, whereas in the seventies regime both series do not differ much at any point of time, in the latest regime overall inflation variability is greater than ex-energy and food inflation variability when relative price shocks take place. This finding may reflect the fact that variability induced by these shocks does not spill over other sectors of the economy.

Figure 7
USA: Inflation rate and % of variance explained by the principal component of inflation
1969-1981

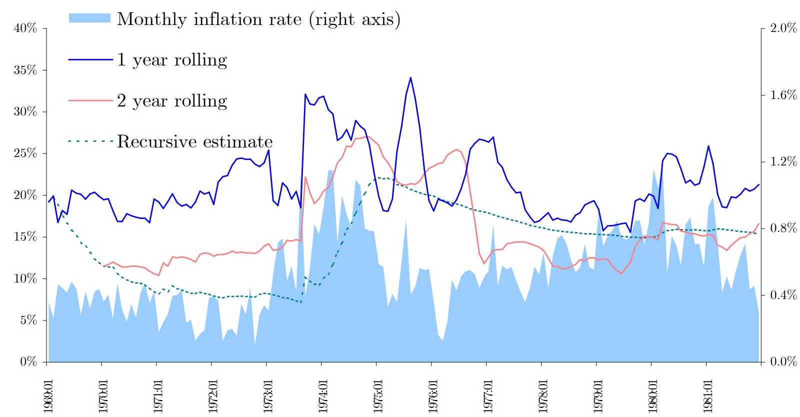
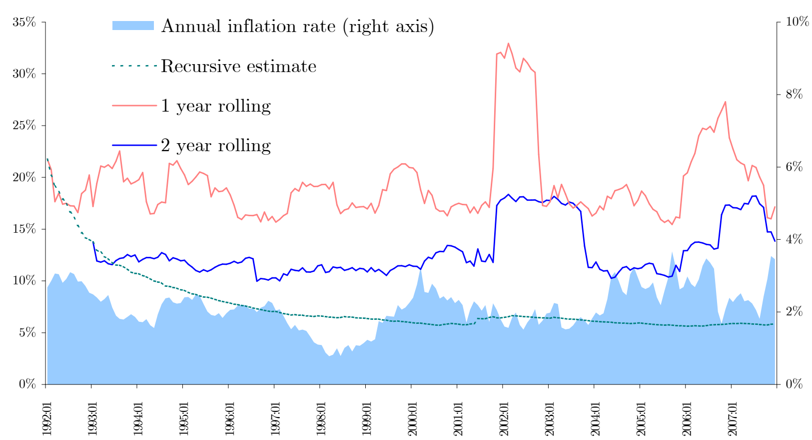


Figure 8
USA: Inflation rate and % of variance explained by the principal component of inflation
1991-2007



Argentina has experimented a greater variety of sources of shocks on relative prices. During the eighties, as shown in Figure 10, aggregate nominal shocks -basically rooted in an inflationary financing of fiscal imbalances- prevailed compared to relative price shocks, resulting on average in a higher and more steady comovement among sectoral inflation rates. Two features are worth to be highlighted. Firstly, rolling estimations show a declining trend of variance explained by first principal component. This feature is in line with the strong and significant comovement of RPV and I found in the previous section. Arguably, as inflation increases, price movements become more uncoordinated giving in result idiosyncratic but persistent inflation dynamics (a similar phenomena, albeit much more weak, can be found for the seventies US regime). Secondly, perhaps less striking, is the finding that stabilization efforts, as the Plan Austral of June 1985, produced a sensible reduction of inflation as a by-product of coordinated generalized downward movements in sectoral prices.

Figure 9

USA: Rolling estimate of variation coefficient of inflation overall vs. ex-energy and food

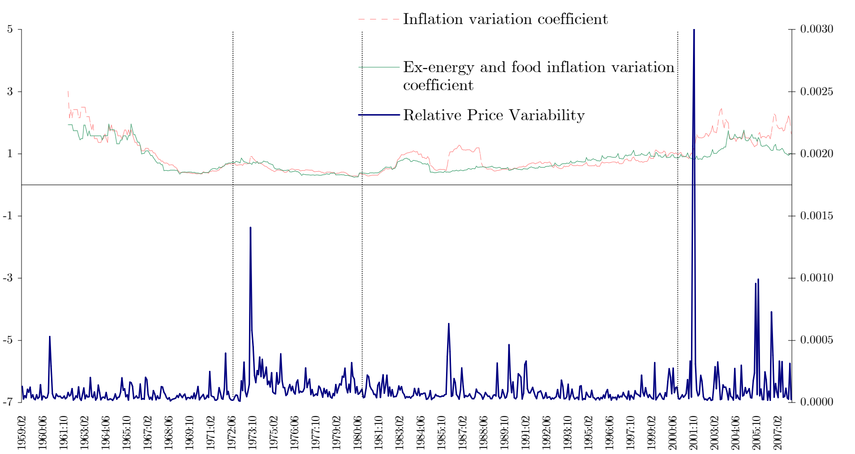


Figure 10

Argentina: Inflation rate and % of variance explained by the principal component of inflation

1980-1987

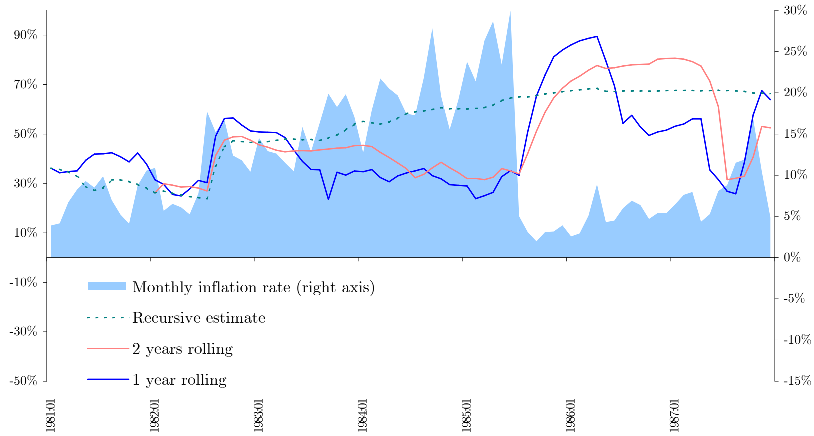
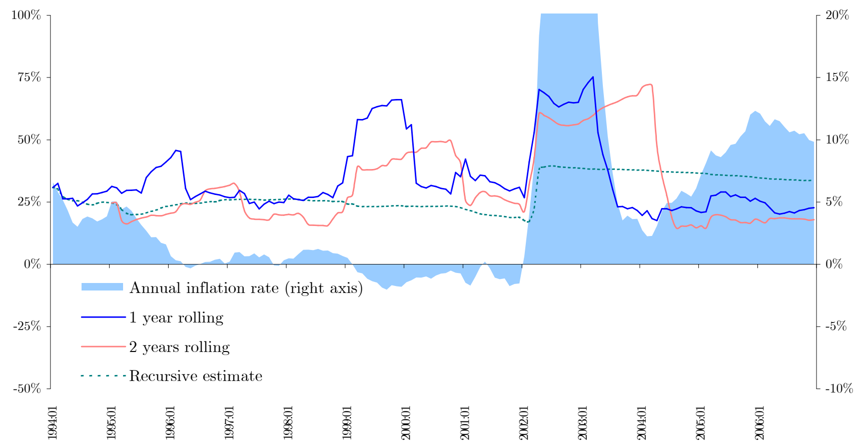


Figure 11

1993-2006



The nineties and the two-thousands, on the other hand, are characterized by relative price shocks, typically on the RER. The attempt to anchor inflation expectations by a strong peg to the dollar left no room for monetary policy to counteract the impact of shocks of different nature. The dollar appreciation and the Brazilian devaluation in 1999, thus, impacted fully and deepened the disequilibrium of an already misaligned RER. This had an almost instantaneous and widespread impact on individual inflation rates, as reflected in the strong comovement among sectoral prices shown in Figure 11. Trivially, the end of the regime, the subsequent 2002 peso devaluation and immediate pass-through on tradable goods' prices constitute another relative price shock. This, in turn, stamped tradable-non-tradables price adjustment dynamics on the two-thousands transition period. All these events, are again captured by the hikes in the rolling estimate of the variance explained by the first principal component in Figure 11.

6.2 Common shocks and heterogeneity in transmission mechanisms

Adapting the Ball and Mankiw *op. cit.* setting to our problem, it can be hypothesized that desired price setting responses to aggregate shocks will be influenced by the economic environment were sectors evolve. Thus, loose monetary regimes are expected to be associated to a skewed distribution of the response of sectors to the common shock, showing the predominance of certain incentives to adjust prices positively. On the contrary, under a low inflation regime, except for the presence of shocks to relative prices of important magnitude and/or persistence, one would expect responses to be rather heterogeneously distributed across sectors but even though reflecting no salient pattern. In the presence of shocks to relative prices, however, conventional relative price adjustments mechanisms may also be at work, giving in result differential responses to the common shock across groups of sectors. It is also natural to think that this features will manifest with more strength in the long run, where the macroeconomic setting impacts full in price behaviors.

With this conceptual framework in mind, again resorting to correlation analysis, we approximate sectoral responses to the common shock by estimating the correlation coefficient of the first principal component of inflation and each of the individual series of inflation at different frequencies. Figures 12 and 13 plot the cross section frequency distribution of those correlation coefficients in each of the regimes at two frequency bands, referred as High Frequency, that of cycles of less than three months, and Low Frequency, that of cycles of more than two years. Also, in each of them we have overlapped the frequency distribution of tradable vs. non-tradables -whose relative price can be considered as a proxy of the RER- and food & energy vs. non-food & energy components of inflation. While the first disaggregation seems to be the relevant for Argentina, given the importance of shocks to the RER in driving inflation, the second fits better for the US, where shocks to food and energy were main drivers of inflation, at least in the seventies. For the sake of brevity, thus, we will limit our exposition to underline only, when present, distinct patterns among those different sets of sectors for each country (anyway, results regarding the alternative classifications in each case are available upon request). In the tables A.1 and A.2 in the Appendix we present basic descriptive information on these frequency distributions for each regime and country.

Figure 12

Argentina

Frequency Distribution of correlation coefficients of the first principal component of infaltion and individual inflation rates

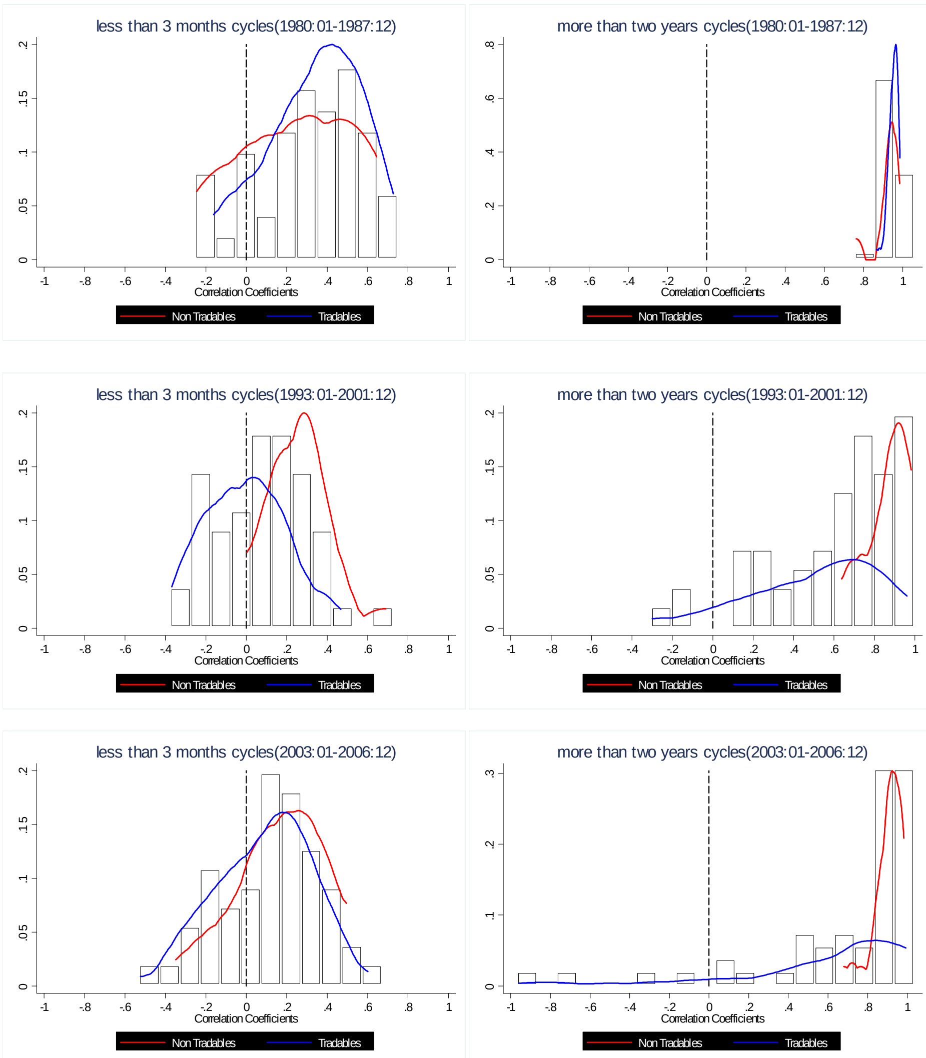
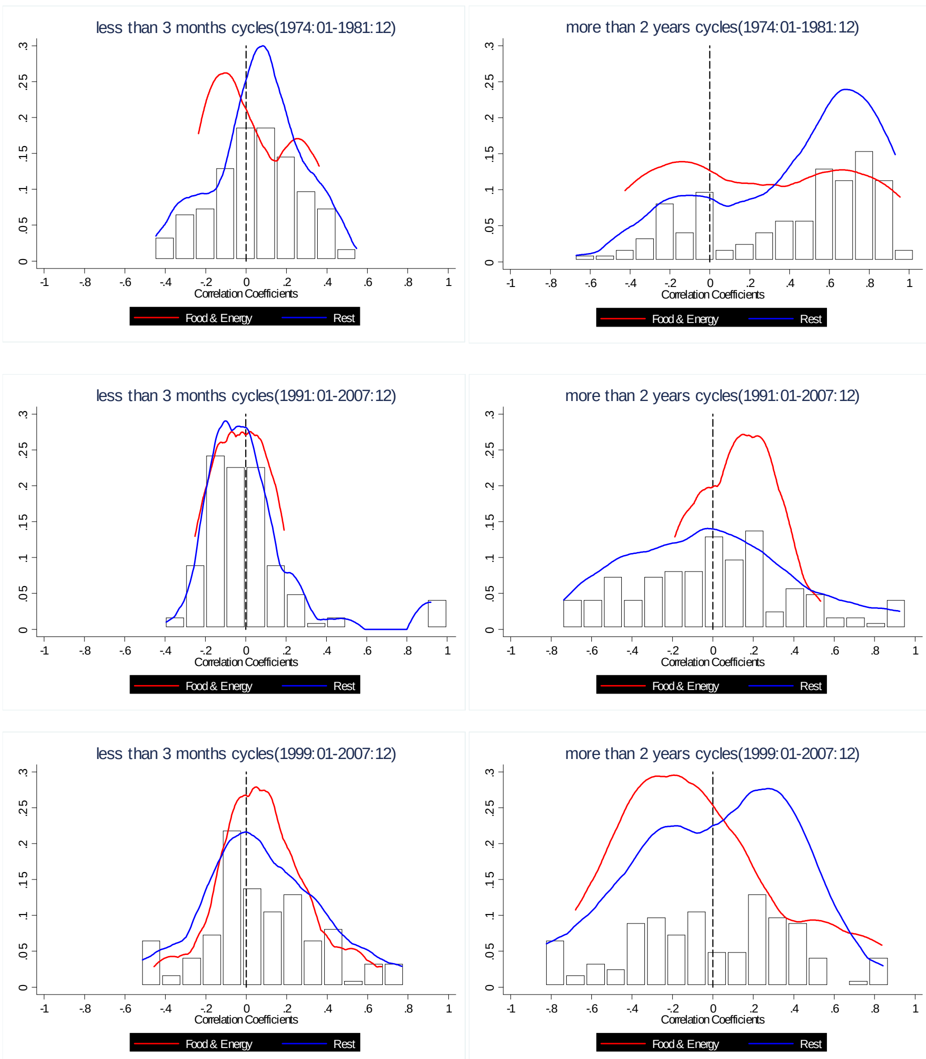


Figure 13

USA:

Frequency Distribution of correlation coefficients of the first principal component of inflation and individual inflation rates



The differences in the mode and shape of histograms is an indication of heterogeneity in the transmission mechanism of the common shock. Moreover, as expected, the specific characteristics of each regime manifest in the skewness of the correlations distribution. For instance, higher inflation regimes tend to show a greater proportion of sectors commoving positively with the common shock in the long run. The extreme example of this proposition is the Argentine experience during the eighties, where distribution almost collapses in extreme values of correlation. In the short run, responses to the common shock tend to be nearer to cero, showing a weaker response to the aggregate shock in this frequency. However, although in the case of the US the distribution seems to be roughly centered in cero, in the case of Argentina it is displaced to the right. In this last case, as also pointed out in the previous section, common aggregate shocks are imposing (on average) a positive trend in sectoral price updating even in the short run.

Things appear to be remarkably different under low inflation. In the short run, distributions seem to be even closer to cero (even more in the case of the US), showing no apparent incidence of common shocks on short term evolution of individual prices. When looking at low frequency responses striking results pointed out in previous sections emerge. Specifically, while for the US sectoral responses show a cero-centered and widely heterogeneous distribution, perfectly in line with what is expected for a low inflation period, Argentina departs strongly from that *a-priori*, showing in the long run a quite generalized positive comovement with the aggregate shock.

Sectoral patterns can help to further explain these features. Tables 7 and 8 show the average response of tradable and non-tradable sectors, in the case of Argentina, and food and energy and the rest of the sectors, in the case of the US, and test for differences between them in both, different regimes and time horizons (rank sum test of Mann and Whitney for differences in mean). The distribution of correlation coefficients during low inflation in Argentina, although quite heterogenous, reflects a certain pattern. In particular, as shown in Table 7, non-tradable goods respond considerably and significantly more than tradable goods to the aggregate shock. These results confirm the importance of relative price movements in driving the trend inflation in the nineties, induced, as mentioned, by shocks that promoted further and further real appreciations of the peso. Clearly, this feature helps to explain the striking result of a strong long-run comovement between inflation and RPV we find for the nineties.

Another feature that is worth noting is the distinct way an economy could respond to similar supply shocks under low and high inflation. Taking into account the developments during seventies and the more recent regime in the US, certain sectoral patterns can be distinguished in the response to the common shock. As shown in Table 8, whereas during the former the positive price adjustment in response to the common shock seems to be a characteristic that both groups of sectors (food & energy and non-food & energy) on average share with no significant difference even in the long run, during the latter regime it turns not to be so. In fact, each group of sectors appears to respond significantly different and with the opposite sign. We can speculate, then, that (i) supply shocks have become more idiosyncratic, restricting their range of incidence to a more reduced set of sectors (that is to say, it has become less common), and (ii) that the low inflation macroeconomic setting allows more for conventional relative price adjustment mechanisms to act. Of course, it can be argued that (i) and (ii) reinforce each other. Anyway, this finding leads us to think that the fact that large supply shocks have a persistent impact on price level crucially depends on the macroeconomic setting.

Table 7
Argentina: Mann and Whitney rank sum test for differences in mean

		Argentina			
		Mean		*statistic*	*p-value*
		non-tradables	*tradables*		
80s	*Short-Run*	0.2576	0.3355	0.688	0.491
	Long-Run	0.9260	0.9511	1.329	0.184
90s	*Short-Run*	0.2545	-0.0018	-4.093 ***	0.000
	Long-Run	0.8621	0.4961	-4.673 ***	0.000
00s	*Short-Run*	0.1702	0.0866	-1.246	0.213
	Long-Run	0.9022	0.5899	-3.08 ***	0.002

Table 8
United States: Mann and Whitney rank sum test for differences in mean

		USA			
		Mean		*statistic*	*p-value*
		food & energy	*rest*		
70s	*Short-Run*	0.0345	0.0597	0.788	0.431
	Long-Run	0.2430	0.4343	1.737 *	0.083
90s-00s	*Short-Run*	-0.0299	0.0248	0.343	0.731
	Long-Run	0.1208	-0.0104	-2.018 **	0.044

7 Conclusions

We study the dependence on regime of the inflation-RPV relation. Regimes are identified here in terms of trend inflation and characterized by the nature of aggregate shocks that predominate in the economy and the way these shocks transmit to the dynamics of inflation. To analyze these features we use frequency domain analysis, which allows us to separate the short and long run components of inflation and RPV variability and look at their interactions at different frequencies. Also, by disentangling sectoral responses to common shocks from idiosyncratic sources of variability in inflation, we are able to identify the role of common shocks in either creating long-run dispersion in prices, or exacerbating short-run noise.

We conduct this exercise for the US and Argentina. While both countries share having passed through periods of high and low inflation, trend inflation was considerably higher in Argentina in the eighties than it was in the US during the seventies. Also, the nature of the shocks that have predominated in the two economies differs considerabily.

In the US relative price shocks have been an important source of inflation variability of inflation in both regimes. While in terms of the total variance of inflation and RPV, the magnitude of these shocks is quite similar across the two regimes, frequency domain analysis reveals that this variability is very differently distributed across frequencies. As a result, the comovement between both variables across frequencies differs dramatically between the two regimes: High and low inflation. In the seventies, high trend inflation reflects in long run comovement between inflation and RPV. Under low inflation this comovement restricts to the high frequency, adding no trend to inflation. That is, exogenous shocks of same magnitude in terms of the total variance of inflation, generate completely different dynamics. In the recent low inflation period, the effects of common shocks to the economy, as the hikes of oil and food prices of 1999, 2001 and 2006, did not induce any long-run relative price variability in inflation, in spite of their magnitude. In any case, they showed up in additional short-run idiosyncratic variability in inflation. This results suggest that commodity price shocks to the US economy have acquired a more idiosyncratic nature, either because of substitution in consumption or a stronger commitment of monetary policy with low and stable inflation.

In Argentina, inflation dynamics have been mainly dominated by policy induced macroeconomic shocks. Their nature is, however, quite different across the two regimes. In the eighties, when trend inflation was very high as a consequence of monetary financing of fiscal imbalances through the inflation tax, nominal shocks were a main source of variability for inflation. The variance of both, inflation and RPV is high and quite homogeneously distributed across frequencies. This leads to a strong comovement between both variables, that strengthens as frequency decreases. Common shocks not only made inflation more noisy in the short-run, they also induced long-run idiosyncratic movements in prices that did not compensate, adding persistence to inflation. Disinflation was achieved through the adoption of a strong peg to the dollar, what implied giving up the use of monetary policy as a tool to smooth out the effects of exogenous shocks to the economy. Trend inflation dropped dramatically and so did the variance of inflation and that of RPV. Contrary to the US and perhaps strikingly, our analysis reveals that low inflation in Argentina did not come along with the prevalence of idiosyncratic short lived movements in prices driving the dynamics of inflation as it should hypothetically be the case in a low inflation environment. Rather, long-run relative price adjustments, i.e. RER adjustment, significantly contribute to explain inflation variability and are the underlying driving forces explaining the presence of low frequency RPV over those years.

To get a deeper insight on the potential dependence of price setting behavior on regime, we go one step further, looking at the distribution of correlations between sectoral inflation rates and the common shock at different frequencies. We identify distinct patterns in sectoral responses to common shocks depending on regime and on the nature of shocks: Under high inflation most of sectoral inflation rates exhibit a strong positive correlation with the common shocks in the long run, confirming a bias towards positive price adjustments. This is particularly true for Argentina in the eighties, with correlations collapsing at very high positive levels. Short run correlations with the common shocks are heterogenous and centered in zero in the US, suggesting that heterogeneous idiosyncratic movements in prices prevail at high frequencies. In Argentina, common shocks induce positively correlated sectoral price movements even in the short run.

Things differ considerably under low inflation in the case of the US. The prevalence of idiosyncratic shocks in driving price adjustment relative to common shocks is clear from both, the short and long run distribution of correlations with the common shocks, which are in both cases quite heterogeneously distributed around a zero mean. Again, in Argentina, the importance of policy induced relative price shocks is evident from the positive long run correlation of sectoral inflation rates with the common shocks and becomes more clear once we look separately at the distribution of correlations of tradable vs. non-tradable goods with the common shock, with non-tradable inflation rates responding strongly positively to the successive shocks promoting further real appreciation of the peso.

To sum up, we find evidence that a higher trend inflation induces long-run relative price variability, thus creating inflation uncertainty. In an environment of very high inflation, as it was the case of Argentina in the eighties, when innovations to money growth drive inflation dynamics, shocks not only amplify the high frequency noise always present in inflation, they also induce idiosyncratic long-run movements in prices that do not cancel out, adding persistence to inflation. A low trend inflation reduces inflation uncertainty, not necessarily because the overall volatility of inflation lowers, but rather because this volatility does not translate to the long-run through a common trend in sectoral inflation rates, but rather restricts to idiosyncratic adjustments in prices that cancel out. The US case in recent years is a clear example in this respect: While overall variability of inflation is not far from that of the seventies, it has added no trend to inflation and neither led to long-run relative price variability.The results for Argentina in the nineties and two thousands are illustrative in what regards the particular dynamics that relative price adjustment policies can induce in inflation in terms of creating long run relative price variability , even when trend inflation is very low, as it was the case of Argentina over those years.

References

[1] Altissimo, F., B. Mojon, and P. Zaffaroni (2007), "Fast Micro and Slow Macro: Can Aggregation Explain the Persistence of Inflation", *Federal Reserve Bank of Chicago,* WP 2007-2.

[2] Ahmed, S., A. Levin, and B. A. Wilson, "Recent U.S. Macroeconomic Stability: Good Policies, Good Practices, or Good Luck?", *The Review of Economics and Statistics*, August 2004, 86(3), pp 824-832.

[3] Andrews, D. and H. Chen (1994), "Approximately Median-Unbiased Estimation of Autorregresive Mdel", J*ournal of Business & Economic Statistics*, Apirl 1994, Vol. 12 No. 2, pp 187-204.

[4] Ascari, G. and T. Ropele (2007), "Trend Inflation, Taylor Principle and Indeterminency", *Kiel Working Paper* N°1332, Kiel Institute for World Economics.

[5] Bai, J. and P. Perron (2003), "Computation and Analysis of Multiple Structural Change Models", *Journal of Applied Econometrics*, 18: 1-22.

[6] Ball, L. and S. Cecchetti (1990), "Inflation Uncertainty at Short and Long Horizons", *Brookings Papers of Economic Activity*, Vol 1990, No.1., pp 215-254.

[7] Ball, L. and G. Mankiw (1995), "Relative-Price Changes as Aggregate Supply Shocks", *The Quarterly Journal of Economics*, Vol. 110, No. 1, pp 161-193.

[8] Banerjee, A., P. Mizen and B. Russell (2002), "The Long-Run Relationship among Relative Price Variability, Inflation and the Markup", *EUI Working Paper* ECO No. 2002/1, European University Institute.

[9] Baxter M. and R. King (1999), "Measuring Business Cycles: Approximate Band-Pass Filters for Economic Time Series", *The Review of Economic and Statistics*, Vol. 81, No. 4, pp. 575-593.

[10] Benabou, R. and R. Gertner (1993), "Search with Learning from Prices: Does Increased Inflationary Uncertainty Lead to Higher Markups?", *Review of Economic Studies*, Vol. 60, pp. 69-94.

[11] Blake A. y E. Fernández-Corugedo (2006), "Optimal monetary policy with non-zero steady-state inflation", *Mimeo.*

[12] Blanchard, O. and N. Kiyotaki (1987), Monopolistic Competition and the Effects of Aggregate Demand", *The American Economic Review*, LXXVII, pp. 647-666.

[13] Blejer, M.(1983), "On the Anatomy of Inflation: the variability of Relative Commodity Prices in Argentina", *Journal of Money Credit and Banking*, XV, pp. 469-482.

[14] Caplin, A. and D. Spubler (1987), " Menu-costs and the neutrality of money", *Quarterly Journal of Economics*, 102, pp 703-726.

[15] Carballo Pou, M.A., C. Dabús and D. Caramuta, "A Non-linear Inflation Relative Prices Variability Relationship: Evidence from Latin America", *Documento de Trabajo E2006/09*, Centro de Estudios Andaluces.

[16] Clark, T. (2003), "Disaggregated Evidence on the Persistence of Consumer Price Inflation", *Federal Reserve Bank of Kansas City, RWP* 03-11.

[17] Cogley, T. and T. Sargent (2001), "Evolving post-World War II inflation dynamics", *NBER Macroeconomics Annual*, 16, MIT Press, Cambridge.

[18] Cogley, T. (2002) "A Simple Adaptative Measure of Core Inflation", *Journal of Money Credit and Banking, Vol. 34, No. 1., pp 94-113.*

[19] Cristadoro, R., M. Froni, L. Reichlin and G. Veronese (2005), "A Core Inflation Indicator for the Euro Area", *Journal of Money Credit and Banking,* Vol. 37, No. 3, pp 539-560.

[20] Dabús, C. (1996), "Causalidad Inflación-Precios Relativos: algunas implicaciones del caso argentino", *Desarrollo Económico*, vol. 36, No. 142 (julio-setiembre), pp621-633.

[21] D'Amato, L., L. Garegnani and J. Sotes (2007), "Inflation Persistence and Changes in the Monetary Regime: The Argentine Case", *Working Paper 2007/23*, Banco Central de la República Argentina.

[22] De Gregorio, J., O. Landerretche and C. Nielsen (2007), "Another Pass-Through Bites the Dust? Oil Price and inflation", *Economía*, V 7 (2), 155-208.

[23] Dotsey, M., R. King and A. Wolman (1999), "State-Dependent Pricing and The General Equilibrium Dynamics of Money and Output", *Quarterly Journal of Economics*, Vol. 114, No. 2, pp. 655-690.

[24] Engle, R. (1974), "Band Spectrum Regression", *International Economic Review*, Vol. 15, No. 1, pp. 1-11.

[25] Fisher, S. (1981), "Relative Price Shocks, Relative Price Variability and Inflation", *Brooking Papers on Economic Activity*, 22, 381-440.

[26] Granger, C., "The Typical Spectral Shape of an Economic Variable", *Econometrica*, Vol. 34, No. 1, pp. 150–161.

[27] Kiley, M. (2007), "Is Moderate-to-High Inflation Inherently Unstable?", International Journal of Central Banking, Vol. 3, No. 2, pp. 173-198.

[28] Lucas, R. (1973) "Some International Evidence on Output Inflation Tradeoffs", *American Economic Review*, June 1973, 63(3), pp. 326-34.

[29] Montiel, P. (2003), "Macroeconomics in Emerging Markets", Cambridge University Press.

[30] Nath, H. (2004), "Inflation and relative price variability: short run vs. long run", *Economic Letters*, 82, pp 363-369.

[31] Parsley, D. (1996), "Inflation and Relative Price Variability in the Short and Long Run: New Evidence from the United States", *Journal of Money Credit and Banking,* Vol. 28, No. 3, pp 323–341.

[32] Priestley, M. B. (1982) "Spectral Analysis and Time Series", *London Academic Press.*

[33] Phillips, P. (1991), "Bayesian Routes and Unit Roots": The Rebus Prioribus Semper et Disputandum", *Journal of Applied Econometrics*, 6, pp. 436-473.

[34] Reisendorf, M. (1984), "New Evidence on the Relation Between Inflation and Price Dispersion", *The American Economic Review,* Vol 84, No. 3, pp.720-731.

[35] Sargent, T. (1999), "The Conquest of American Inflation", Princeton University Press, Princeton.

[36] Sheshinski, E. and Y. Weiss (1977), "Inflation and Costs of Price Adjustment", *Review of Economic Studies*, LIV, pp. 287-303.

[37] Stigler, G. and J. Kindhal, J. (1970), "The behavior of industrial prices", *National Bureau of Economic Research General Series No. 90*, New York, Columbia University Press.

[38] Stock, J. and M. Stock (2002), "Macroeconomic Forecasting Using Diffusion Indexes", *Journal of Business and Statistics*, 20 (Apr.), pp. 147-162.

[39] Van Hoomissen, T. (1988a), "Search, Information and Price Dispersionin Inflationary Circumstances: Theory and Evidence", unpublished manuscript, State University of New York, Stony Brook.

[40] Van Hoomissen, T. (1988b), "Price Dispersion and Inflation: Evidence from Israel"„ Journal of Political Economy, December 1988b, 96(6), pp. 1303-14.

Appendix

Table A.1
Argentina:
Frequency Distribution of correlation coefficients of the first principal component of inflation and individual inflation rates: Basic Descriptive Stats

	80s		90s		00s	
	Non Tradables	Tradables	Non Tradables	Tradables	Non Tradables	Tradables
			Short-Run (less than three months cycles)			
Mean	0.2576	0.3355	0.2545	-0.0018	0.1702	0.0866
Std. Dev.	0.2958	0.2336	0.1645	0.1979	0.2254	0.2383
Variance	0.0875	0.0546	0.0271	0.0392	0.0508	0.0568
Skewness	-0.2569	-0.5193	0.6422	0.2290	-0.5471	-0.3384
Kurtosis	1.8264	2.5094	3.8315	2.5329	2.7858	2.8265
			Long-Run (more than two years cycles)			
Mean	0.9260	0.9511	0.8621	0.4961	0.9022	0.5899
Std. Dev.	0.0625	0.0251	0.1112	0.3223	0.0757	0.4719
Variance	0.0039	0.0006	0.0124	0.1039	0.0057	0.2227
Skewness	-1.9388	-1.1519	-0.8677	-0.7873	-1.5964	-1.7417
Kurtosis	5.9309	4.7197	2.4619	2.8149	5.2738	5.5895
N ° obs.	10	41	19	37	19	37

Table A.1
USA:
Frequency Distribution of correlation coefficients of the first principal component of inflation and individual inflation rates: Basic Descriptive Stats

	70s		90-00s		00s	
	food & energy	rest	food & energy	rest	food & energy	rest
			Short-Run (less than three months cycles)			
Mean	0.0345	0.0597	-0.0299	0.0248	0.0831	0.0822
Std. Dev.	0.2017	0.2167	0.1334	0.2544	0.2481	0.2930
Variance	0.0407	0.0470	0.0178	0.0647	0.0616	0.0859
Skewness	0.3644	-0.2463	-0.0656	2.0991	0.2418	0.2478
Kurtosis	1.6227	2.7016	1.8820	8.0566	3.4524	2.7858
			Long-Run (more than two years cycles)			
Mean	0.2430	0.4343	0.1208	-0.0104	-0.0638	0.0059
Std. Dev.	0.4642	0.4033	0.1938	0.4172	0.4134	0.4014
Variance	0.2155	0.1627	0.0375	0.1740	0.1709	0.1611
Skewness	0.0709	-0.7754	0.0282	0.3997	0.7597	-0.2490
Kurtosis	1.4878	2.4143	2.3424	2.5947	2.9103	2.3539
N ° obs.	22	102	22	102	22	102

Methodological Appendix

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, lets consider a vector $x = [x_1, x_2, x_3, ..., x_T]'$. For $s = 1, 2, 3, ..., T$ frequencies are defined as $\omega_s = 2\pi s/T$. The finite Fourier transform of x at frequency ω_s is then

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

where

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

Letting $W = [\omega_0 \; \omega_1 \; \omega_2 \; ... \; \omega_{T-1}]'$ it can be shown that W columns are orthonormal such that $W^*W = WW^* = I$ and W is a unitary matrix, where * indicates the Hermitian conjugate, that is, the traspose 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. In the specific case of inflation and RPV, $\widehat{\pi} = W\pi$ and $\widehat{\nu} = W\nu$ are the vectors of the discrete Fourier transforms of time series π and ν at all fundamental frequencies ω_s, for $s = 0, 1, 2, ..., T-1$.

We can define A as a $T \times T$ 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

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

Finally, the complex data vector $A(\omega_s, \omega_r)\widehat{x}$ 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

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

Computational issues

Frequency domain analysis applied to finite samples is frequently subject to the wrap-around effect. That is, because of the assumption that series are periodic, it treats 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 in necessary for the filter to work accurately, we selected a number of frequency ordinates equal to 576.