Inflation and relative price variability in Brazil from 1989 to 2007

Julia P. Araujo[†]

ABSTRACT: I document new evidence on the relationship between inflation and relative price variability (RPV) using store-level data on prices in Brazil from 1989 to 2007. In brief, the linkage grows stronger during periods of lower inflation rates. I divide the sample into two subsamples: from 1989 to 1993 (hyperinflation); and from 1995 to 2007 (low inflation). I study the distribution of inflation at the most disaggregate level (brands), and I find strong support regarding the effect of *Plano Real* in decreasing inflation variability almost immediately after its implementation. The size and frequency of price changes also decreased right after the plan took place. The intramarket RPV significantly increased with the rate of inflation, but I find marked differences between the two inflationary scenarios. During hyperinflation, the relationship is roughly 70% of the magnitude during lower inflation, i.e., the linkage is looser during hyperinflation. The impact of deflation (in absolute terms) is weaker than the impact of positive inflation during hyperinflation, yet stronger during lower inflation. I also document similar patterns aggregating brands into sectors and groups of products. This paper highlights the importance of considering different inflation scenarios when assessing inflation-related effects.

Keywords: Inflation; Hyperinflation; Relative price variability; Panel data

RESUMO: Este artigo documenta novas evidências sobre a relação entre inflação e variabilidade de preços relativos (RPV) usando dados de preços no nível da loja no Brasil entre 1989 e 2007. Em resumo, a ligação se fortalece durante períodos de taxas de inflação mais baixas. Eu divido a amostra em duas subamostras: de 1989 a 1993 (hiperinflação) e de 1995 a 2007 (baixa inflação). Eu estudo a distribuição da inflação no nível mais desagregado (marcas), e encontro evidências sobre o efeito do Plano Real na redução da variabilidade da inflação quase imediatamente após a sua implementação. O tamanho e a frequência das mudanças de preço também diminuíram logo após o plano. A RPV intra-mercado aumentou significativamente com a taxa de inflação, mas eu encontro diferenças marcantes entre os dois cenários inflacionários. Durante a hiperinflação, a relação é de aproximadamente 70% da magnitude encontrada durante o período de inflação mais baixa, isto é, a ligação é mais fraca durante a hiperinflação. O impacto de uma deflação (em termos absolutos) é menor do que o impacto de uma inflação positiva durante a hiperinflação, porém mais forte durante o período de inflação mais baixa. Eu também documento padrões semelhantes agregando marcas em setores e grupos de produtos. Este artigo destaca a importância de se considerar diferentes cenários de inflação ao avaliar impactos relacionados à inflação.

Palavras-chave: Inflação; Hiperinflação; Variabilidade relativa de preço; Dados em painel

JEL: C23; E31; E50
Área 4 - Macroeconomia, Economia Monetária e Finanças

[†] PhD, Department of Economics, University of São Paulo, Brazil. E-mail: juliapassabomaraujo@gmail.com

1 Introduction

Homogeneous goods are often sold at different prices across various stores. Firms also adjust their prices in different amounts over time. When prices do not rise in tandem, demand shocks and monetary policy have real economic effects. Understanding the sources of price rigidities and unsynchronized price adjustments is central to assessing welfare losses and designing effective public policies.

Despite widespread evidence of a positive relationship between inflation and relative price variability (RPV), there is still room for studies regarding developing economies, especially studies that address hyperinflationary episodes. This article addresses the issue through an examination of microdata from Brazil using almost 19 years of data including 5 years of hyperinflation.

The main question of this paper is as follows: Do inflation and intramarket inflation variability have the same relationship during periods of hyperinflation and periods of low inflation? Using store-level price quotes collected by the *Fundação Instituto de Pesquisas Econômicas* (FIPE) in the city of São Paulo, I find compelling evidence of marked differences between these two scenarios.

The dataset comprises more than 6 million price quotes for 1,272 brands sold in 10,490 different stores from January 1989 to June 2007. I divide the sample into two very different inflationary regimes: (i) 1989–1993, when monthly inflation averaged 25.3% (hyperinflation), and (ii) 1995–2007, when monthly inflation averaged 0.6% (low inflation[1]).

I document the shape and structure of brand-level intramarket inflation for these two time periods. The distribution of price changes is far from uniform or even symmetric. I find evidence of persistent inflation dispersion among firms selling the same brand of good or service. The kernel estimation function drastically collapses after the hyperinflation ended.

I find strong support that *Plano Real* decreased inflation dispersion immediately after its implementation. The size and frequency of price changes also decrease right after the plan was put into practice. There is no evidence of a transition path. The lower the level of aggregate inflation, the lower the dispersion of price changes at the store level.

In both sample periods, inflation (in absolute terms) has a positive impact on intramarket inflation variability. I perform fixed effects panel estimations considering two measures of RPV: the standard deviation (SDP) of price changes across stores and the coefficient of variation (CV) of price levels across stores.

The magnitude of the impact of inflation on RPV is stronger when measured by the SDP than when measured by the CV. Both measures indicate the presence of a positive and significant linkage, although the magnitude is roughly 70% weaker during hyperinflation. Higher levels of inflation are normally associated with higher degrees of inflation variability, yet the link is somewhat looser during the hyperinflation period.

[1] I refer to the period between 1995–2007 as the low-inflation period. Keep in mind that Brazil exhibits higher and more volatile inflation levels than do developed economies. I use the term "low-inflation period" only to emphasize the difference between this period and the hyperinflation years.

During hyperinflation, the weaker impact of inflation on its variability results from the frequency of price increases. When inflation is very high, most price changes are increases, thus narrowing the observed inflation dispersion among all items. On the other hand, when inflation is low and more stable, price decreases and price increases are almost equally likely, thus widening inflation dispersion. This translates into a relatively higher impact of inflation on its dispersion in my low-inflation sample.

Note that inflation dispersion is, in fact, higher during hyperinflation. My results indicate only that the correlation between inflation and inflation dispersion is weaker during hyperinflation. When inflation is extremely high, inflation dispersion is also high, but not as high as predicted by their relationship during low inflation.

I also investigate the presence of asymmetric effects from negative and positive price movements on RPV. The impact of deflation (in absolute terms) is weaker than the impact of positive inflation during hyperinflation. In contrast, from 1995 to 2007, price decreases have a more significant impact on RPV than price increases. I also document the same pattern when analyzing different sectors and groups of brands.

A higher frequency of price decreases also helps to explain the greater impact of negative price movements on inflation dispersion during the 1995–2007 period for each sector/group of product. I find robust evidence of a structural change in the relationship between inflation and RPV, depending on the inflationary regime. Although the effect is significant, I do not assume any causal mechanism.

This paper contributes to a vast literature on tracking the relationship between inflation and inflation variability. The novelty of this study's empirical contribution is its rich and unprecedented dataset on store-level prices in Brazil, encompassing years of hyperinflation as well as years of low inflation. I analyze more than 6 million price quotes taken from a period spanning almost 19 years. The data included here is also extensive in terms of products (1,272 brands of goods and services). I analyze a much larger dataset than Angelis (2012).

This paper closely relates to studies by Lach and Tsiddon (1992), Caglayan and Filiztekin (2003), and Konieczny and Skrzypacz (2005). Lach and Tsiddon (1992) is one of the first empirical works based on microdata to investigate the relationship between inflation and RPV.[2] The authors use data on 26 food items in Israel, at a time when inflation peaked at roughly 60% a year.

Lach and Tsiddon (1992) find a positive association, mainly driven by the expected component of inflation. The authors also find evidence of unsynchronized price setting among firms, and therefore advocate for some staggering in the way prices are set. They document that whenever inflation is high, the distribution of real prices is not uniform or symmetric. My study strongly supports their findings. I also document a positive relationship between RPV and inflation, as well as an asymmetric inflation distribution during the years of hyperinflation in Brazil.

Caglayan and Filiztekin (2003) employ a similar approach, using price data on 22 food products

[2] Hoomissen (1988) also investigates the impact of inflation on price dispersion. She highlights the role of inflation in reducing the information content of prices, which translates into greater price dispersion.

in Turkey. They emphasize the importance of considering structural changes in inflation.[3] Their main conclusion is that the association between inflation and RPV is significantly weaker during higher levels of inflation. I reach the same conclusion here.

The impact of inflation on its variability is stronger in the sample taken from 1995 to 2007 (low inflation) in Brazil than in the sample taken from 1989 to 1993 (hyperinflation). When inflation is low, price decreases are more likely, which widens the inflation distribution and translates into a greater correlation between the level of inflation and its dispersion.

Konieczny and Skrzypacz (2005) investigate price-setting behavior in Poland after the dissolution of the Soviet Union. This was a period of high inflation in the country (from 250% in 1990 to 18% in 1996). The authors highlight a positive relationship between RPV and the frequency, size, and dispersion of price changes. They document a stronger effect of inflation on RPV when the latter is measured by the SDP than when it is measured by the CV. I reach the same conclusion using Brazilian data.

Price dispersion is a salient feature in both theoretical and empirical macroeconomic models. The phenomenon is often associated with three nonexclusive sources: (i) differences in costs and quality-related characteristics of products, (ii) menu costs, and (iii) imperfectly informed consumers. The first relates to inherent differences in the location where a product is sold. Stores may differ in terms of location, facilities, and other dimensions, a situation that results in different prices for the same commodity – see Stigler (1961) and Gorodnichenko et al. (2018).

Moreover, when price readjustments are costly, unsynchronized price setting may arise across firms – see Sheshinski and Weiss (1977) and Benabou (1988). Finally, search costs associated with discovering the lowest-priced firm may also lead to price dispersion in equilibrium – see Burdett and Judd (1983), Benabou (1992), and Rauh (2007).

As inflation increases, the range of prices for the same homogeneous good spreads, and the informational content of nominal prices decreases. Higher inflation is thus often associated with higher degrees of price-change variability, which is one of the social costs of inflation. There is a relatively broad consensus regarding the presence of a positive link between inflation and inflation variability. Nevertheless, some studies document an effect in the opposite direction, leaving room for further investigation on the direction of the final impact.

Reinsdorf (1994) uses data from the US Bureau of Labor Statistics from 1980 to 1982 (Volcker disinflation period) and finds that inflation and price dispersion may be negatively correlated. Sheremirov (2015) also finds a negative relationship between price dispersion and inflation, but the effect is driven entirely by the presence of temporary sales. The author finds a positive relation for regular prices. Silver and Ioannidis (2001) find a similar negative relationship based on intermarket data for 9 European countries.

The literature that investigates links between prices and their dispersion during high-inflation scenarios includes Hoomissen (1988) and Lach and Tsiddon (1992) for Israel; Tommasi (1992) for Argentina; Caglayan and Filiztekin (2003), Caglayan et al. (2008), and Baglan et al. (2016) for Turkey; and Konieczny and Skrzypacz (2005) for Poland. Among these countries, only

[3] Caraballo et al. (2006) analyze data on Spain and Argentina and document significant changes in the relationship between inflation and RPV depending on the inflationary regime.

Argentina experienced hyperinflation similar to that experienced by Brazil from the 80s until mid-90s. My dataset reflects considerably higher inflation variation than other studies.

The paper is organized as follows. Section 2 discusses the inflation environment in Brazil from 1989 to 2007. Section 3 presents the dataset and summarizes information on the frequency and size of price adjustments during the covered period. Section 4 documents patterns of inflation behavior at the brand level in different inflationary scenarios. Section 5 presents the econometric estimation of the relationship between inflation and intramarket inflation variability. Finally, Section 6 offers a conclusion.

2 Inflation environment

The data comprises two very different inflation scenarios in the Brazilian economy. From January 1989 to June 1994, the Consumer Price Index (CPI) measured by FIPE rose 472,894,862%. Annual inflation reached three digits, peaking at 2,490% in 1993. Monthly inflation peaked at 79.1% in March 1990. At a certain point, prices in Brazil rose close to 2% a day. A series of economics plans attempted halt the chronic hyperinflation process.

An extensive set of unorthodox policies were tested, such as freezing prices and wages adjustments by law and confiscating personal savings to prevent demand pressures on prices. From 1989 to 1993 all the plans failed. Brazil also changed currency four times during those years. See Giambiagi et al. (2010) for an extensive description of the Brazilian economy.

It was only under the successful implementation of *Plano Real* in July 1994 that hyperinflation was finally tamed in Brazil. The plan significantly altered inflation dynamics in the country, finally controlling the explosive CPI path. The impact of *Plano Real* was immediate. Monthly inflation went from 50.8% in June 1994 to 6.9% in July and 1.9% in August of the same year.

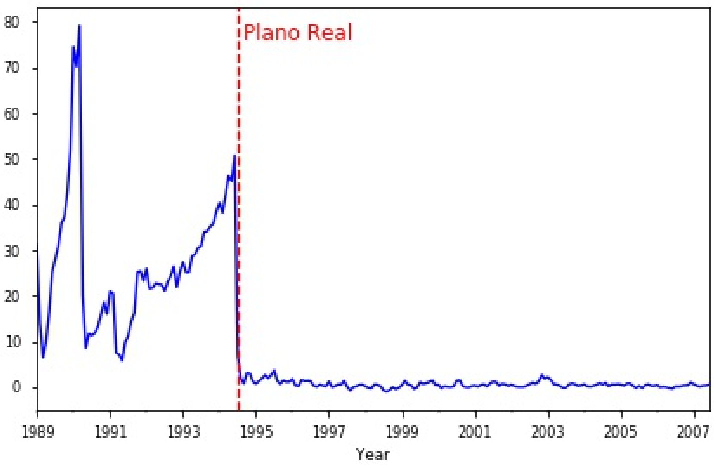
Figure 1 illustrates the behavior of the monthly CPI-FIPE during the sample years, as well as the subsamples in Figure 1b (hyperinflation) and Figure 1c (low inflation rates). The vertical line in Figure 1a marks the implementation of *Plano Real* in July 1994. My subsample division excludes 1994.

Brazil underwent two very distinct inflation regimes during the sample period. From 1989 to 1993 annual inflation averaged 1,470%, whereas from 1995 to 2007 it averaged 7.1%.[4] Monthly inflation averages 25.3% from 1989 to 1993 and 0.6% from 1995 to 2007. In this paper, I explore the differences inherent in each scenario.

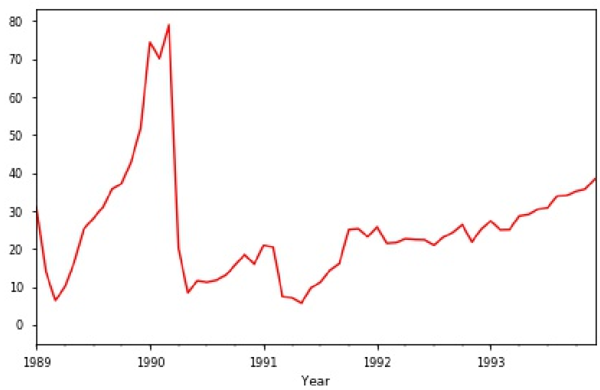
I split the sample into two subsamples: hyperinflation (1989–1993) and low inflation (1995–2007). This pragmatic division is possible only because Brazil has undergone two distinct inflationary regimes. There is a clear structural break in the data. Because the range of data is significantly large, the Brazilian case is especially suitable for analyzing inflation and inflation variability.

Brazil underwent one of the most prolonged periods of hyperinflation ever witnessed by a

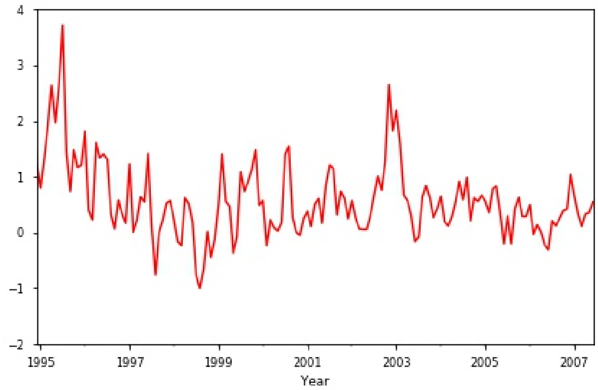
[4]Note that, although significantly lower, inflation in Brazil runs at higher levels than that in developed economies.



(a) 1989–2007



(b) 1989–1993



(c) 1995–2007

Figure 1: Monthly CPI-FIPE

country, and to a certain extent this was due to the fact that the economy was severely indexed. Indexation was probably the central component of Brazilian inflation. Almost all contracts were automatically adjusted according to past inflation.

Through a spiral of adjustments, high past inflation contributed to even higher future inflation. The key to taming escalating price increases was then to stop this cycle. *Plano Real* succeeded by introducing a temporary index into the economy, the units of real value (*Unidade Real de Valor* - URV).

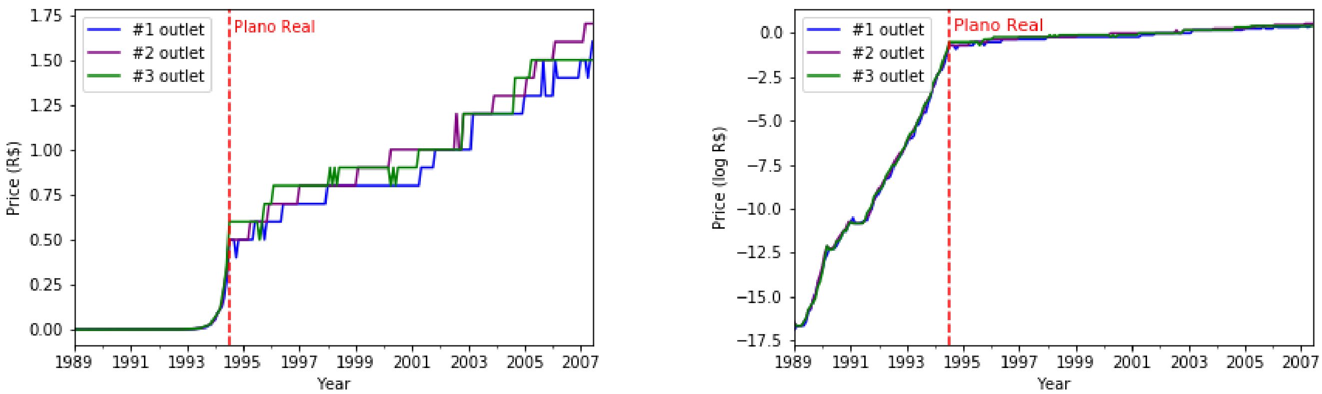
The most crucial aspect of the plan was the creation of the URV. Prices were quoted in *Cruzeiros Reais* (CR$) at that time, and by March 1994 the new index was introduced. The index had daily fluctuations pegged to the US dollar. The URV acted as a unit of account for transactions. All agents were encouraged to quote prices in CR$ and URV's. Prices would rise in CR$, but prices in URV's would be much better behaved, because they were connected to a stable currency.

Consumers and sellers had three months to adapt to the new indexing and pricing processes. Once prices in URV's were stable, the new currency (*Real* - R$) was introduced. On July 1, 1994, all prices in *Cruzeiros Reais* were converted to *Reais* at the rate of R$ 1 to CR$ 2,750. This mechanism made it possible to break once and for all the hyperinflation in Brazil. The *Real* is still the official currency in the country until today.

3 Data

This paper uses the dataset for the CPI collected by FIPE. The data consists of monthly price quotes at the store level for a variety of goods and services (100% in CPI weight). The original dataset comprises 12,921,795 price quotations from January 1989 to June 2007. The dataset covers the geographical area of the city of São Paulo, which corresponds to roughly 11% of the total national GDP.[5] Tracking the same good/service in the same store through time yields a price trajectory. The cross-section dimension tracks the dispersion among different brands and outlets.

The unit of interest is defined as a particular brand. Brands are set in the sample as a summary of the product's main characteristics, such as size, packing, material, etc. An aggregation of one or more brands comprises the product definition in the CPI. For example, many brands of soda, such as Coca-Cola, Guaraná, Fanta Uva, aggregate into the product level *Soda*, a part of the group *Foods and Beverages*, with a weight of 1.2% in the total CPI. The CPI-FIPE is published at the product level, which is the equivalent of the entry level items (ELIs) in the United States. There is no brand substitution or sales flag in the sample.



(a) Frequency (b) Size

Figure 2: Example of price trajectory: 3 outlets selling one 290-ml bottle of Guaraná

Figure 2 illustrates the price trajectory of three different outlets selling the same brands of soda, a one 290-ml bottle of Guaraná Antártica, a common soda in Brazil. The vertical line

[5] 2015 data, according to the national official statistic office, the *Instituto Brasileiro de Geografia e Estatística* (IBGE).

indicates the implementation of *Plano Real*. Figure 2a illustrates the evolution of prices in R$ and Figure 2b presents the evolution of prices in log scale. These two figures show how *Plano Real* affected individual price setting and inflation. They also illustrate how price dispersion is a common feature in the data. Although the brand is completely homogeneous, its price differs across stores in a given period of time.

The original dataset was treated to eliminate prices not in accordance with this paper's purpose. First, I drop all prices regulated by the government, because they obey particular rules of readjustment. Products in this sector include water and sewer utilities, electricity, gasoline, and prescription drugs, for instance. Regulated goods and services account for 502,463 price quotes in the dataset, which correspond to 27.3% in CPI weight on average. This paper focuses only on nonregulated prices.

I also exclude prices of *rent*, *condo fee*, and *housekeeping services*, because their methodology of price quoting changed many times during the sample period. I also drop brands with fewer than 10 price quotes per month, that is, fewer less than 10 stores selling the brand each month. Because the focus is on price variability, I ensure a minimal threshold of quotations per brand. The treated dataset corresponds to 51.9% of the original number of price quotes and 45.6% in CPI weight. Table 1 presents the comparison between the original and treated dataset.

Table 1: Sample treatment

	Original data	Treated data
Price quotes	12,921,795	6,708,165
Items	559,161	216,944
Brands	9,532	1,272
Products	578	386
Outlets	22,705	10,490

The treated sample encompasses 6,708,165 individual price quotes. A combination of brand and outlet defines an item. Brands are sold in 10,490 different stores, which results in 216,944 different items. Each item has its own price trajectory. The treated dataset comprises information about 1,272 brands. Most of the literature on inflation variability analyzes only a subset of products, mostly food. For instance, Hoomissen (1988) considers only 13 goods, Lach and Tsiddon (1992) analyze 26 food products, Reinsdorf (1994) addresses 65 food items, Konieczny and Skrzypacz (2005) examine 52 goods, and Baglan et al. (2016) investigate 128 goods.

The dataset is also representative in terms of groups of products considered. The FIPE-CPI basket is divided into 7 groups of products: (i) *Housing*, (ii) *Food*, (iii) *Transportation*, (iv) *Personal expenses*, (v) *Healthcare*, (vi) *Apparel*, (vii) *Education*. All 7 groups are represented in my dataset, which is a somewhat unique feature of this study. Figure 3 presents the comparison between the CPI weight (year 2000)[6] and the sample weight. The groups *Food* and *Personal*

[6]Weights in the CPI-FIPE are determined by Household Budget Surveys (*Pesquisa de Orçamento Familiar* [POF]). FIPE conducts the survey regularly to analyze the average consumption basket of a typical family in São Paulo earning up to 20 minimum wages of income. I use the weights calculated by the POF 98/99 in this study.

expenses gained importance, whereas *Housing* and *Transportation* lost a certain share. Regulated prices and *rent* explain most of the effect. Regulated prices in *Transportation* were also dropped.

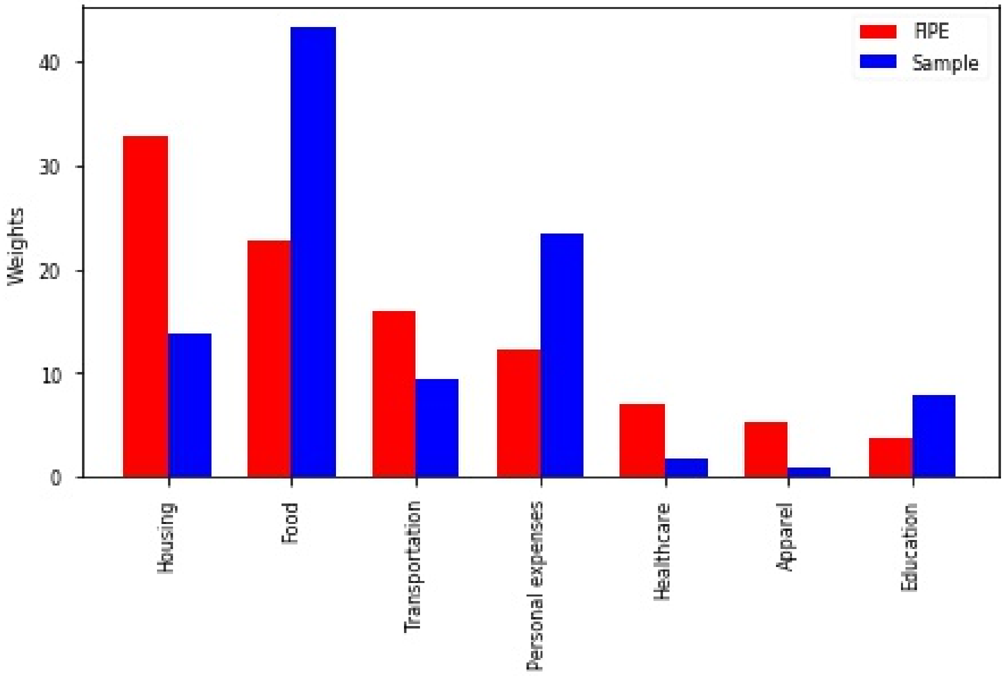


Figure 3: Sample and FIPE-CPI weights

3.1 Summary statistics

In this subsection, I summarize the information on the probability and size of price changes for the 1,272 brands in the sample. Let P_{ijt} be the price of a brand i sold in outlet j at time t. I first compute the average monthly frequency of price changes for each brand as the fraction of the total number of $p_{ijt} \neq p_{ijt-1}$ to all nonmissing price observations between two periods t and $t-1$ (including zero price changes).

I combine data from items to products by a simple average. I then use the product-specific FIPE-CPI weights to construct a measure of aggregate frequency f_t. It is also possible to decompose f_t into the frequency of price increases (f_t^+) and decreases (f_t^-). It follows that: $f_t = f_t^+ + f_t^-$.

I also investigate the size of price nonzero price changes Δp_t. I compute the absolute size of price changes at the store level level by $\Delta p_{ijt} = \frac{|p_{it} - p_{it-1}|}{p_{it-1}}$, whenever $p_{ijt} \neq p_{ijt-1}$. Items are again aggregated into brands and products by a simple average and then weighted using product-specific FIPE-CPI weights. Finally, I compute the size of price increases (Δp_t^+) and price decreases (Δp_t^-). Note that: $\Delta p_t = \frac{f_t^+}{f_t}\Delta p_t^+ + \frac{f_t^-}{f_t}\Delta p_t^-$.

Table 2: Frequency and size of price changes (%)

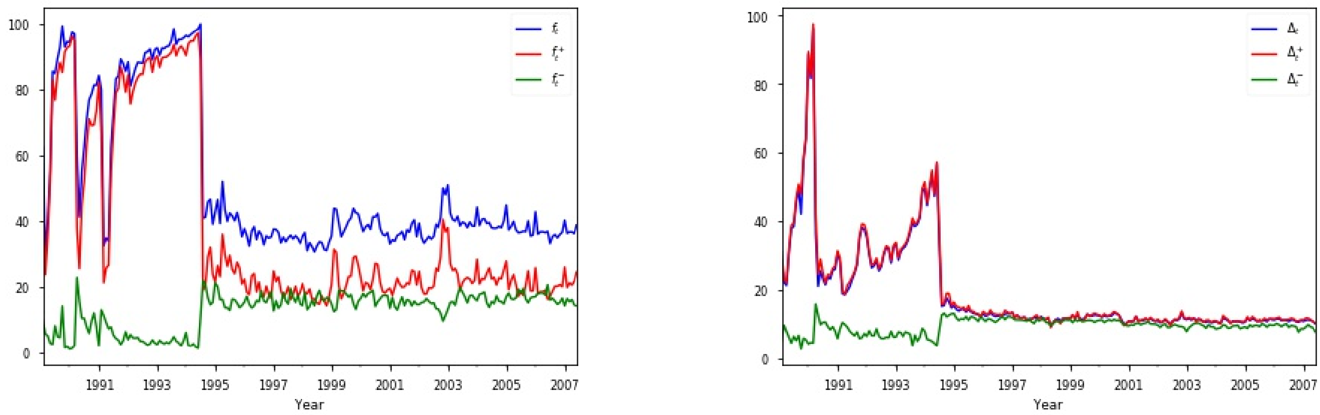
Year	$\pi_t MoM$	f_t	f_t^+	f_t^-	Δ_t	Δ_t^+	Δ_t^-
1989	27.2	75.1	69.6	5.5	39.7	41.2	5.9
1990	29.2	74.7	65.8	8.9	41.0	42.7	8.9
1991	15.6	69.2	62.9	6.3	26.8	27.7	7.6
1992	23.3	88.3	84.6	3.7	29.4	30.1	6.7
1993	31.2	93.9	90.7	3.2	36.2	36.9	6.6
1994	23.3	74.6	65.0	9.6	34.4	35.6	8.6
1995	1.8	42.0	26.3	15.8	13.7	14.2	11.7
1996	0.8	35.4	19.5	16.0	12.6	13.1	11.4
1997	0.4	35.1	19.4	15.8	11.9	11.9	11.1
1998	-0.1	32.8	16.9	15.9	11.2	11.1	10.7
1999	0.7	40.1	24.0	16.1	12.1	12.2	10.9
2000	0.4	38.4	21.3	17.0	12.0	12.1	10.7
2001	0.6	36.0	21.0	15.0	11.1	11.2	10.0
2002	0.8	38.5	24.6	13.9	11.1	11.2	9.4
2003	0.7	40.5	24.1	16.4	11.0	11.2	9.4
2004	0.5	39.3	23.3	16.0	10.7	10.9	9.1
2005	0.4	37.9	20.8	17.1	11.1	11.3	9.4
2006	0.2	36.4	19.4	17.0	11.0	11.3	9.3
2007	0.4	37.4	22.2	15.1	10.8	11.1	8.9
Mean 1989–1993	25.3	80.3	74.6	5.7	27.8	28.2	8.2
Mean 1995–2007	0.6	37.5	21.6	15.9	10.6	9.9	10.2

The two inflationary scenarios in my sample display marked differences regarding the frequency and size of price adjustments. Table 2 summarizes the information on the frequency and size of price changes. The average inflation rate from 1989 to 1993 is 25.3%. During hyperinflation (1989 to 1993), an average of 80.3% of all prices changes every month. The frequency peaks at 93.9% in 1993; that is, prices are almost entirely flexible. Prices also may change more than once per month, but my monthly dataset prevents me from observing such movements. It may be the case that some stores changed prices more than once per month.

From 1989 to 1993, the majority of price movements are increases. The frequency of increases is 74.6%, whereas the frequency of decreases is only 5.7%. Price decreases are no more than 7% of all price changes during hyperinflation. Although it is less frequent, some prices drop each month during hyperinflation.

I do not find evidence of the frequency of price decreases converging to zero. Even during hyperinflation, some prices are dropping every month in Brazil. Nevertheless, this behavior is mainly observed in prices of food items, whereas prices of services present more rigidity (see Araujo (2018) for a detailed discussion).

The monthly frequency of price changes drops drastically after *Plano Real*. During the lower-inflation period (1995–2007), the average frequency of price changes is 37.5%. Not only do prices change less often, but price decreases become more likely. From 1995 to 2007, price decreases correspond to a share of roughly 43% of all price movements. The shift in the frequency of price change occurs immediately after *Plano Real*. Figure 4a plots the monthly series of f_t, f_t^+, and f_t^-. I find no evidence of a transition period after the plan. *Plano Real* significantly changed price setting in Brazil.



(a) Frequency

(b) Size

Figure 4: Frequency and size of price changes

Figure 4b plots the time series for the absolute size of nonzero price changes. From 1989 to 1993, the average size is 27.8%, above the average inflation of 25.3%. The size of price increases is 28.2% on average, whereas the size of price decreases is 8.2%. During hyperinflation, prices often undergo changes – and changes of large magnitude. On the other hand, from 1995 to 2007, the average size of price changes is 10.6%. The magnitude is larger than the average monthly inflation in this period (0.6%). This gap results from the higher frequency of price decreases, because the size of price increases and decreases are somewhat similar (8.2% *vs.* 10.2%).

4 The morphology of inflation

In this section, I focus on the shape and structure of the distribution of price changes (inflation dispersion). This approach, rather than directly examining price level dispersion, has the advantage of differencing out store-level effects, controlling for possible nonstationarities in price levels, and facilitating aggregation of different products. See Lach and Tsiddon (1992). I focus on heterogeneities in the rate of inflation across sellers of the same brand.

Define p_{ijt} as the price of a brand i in store j at time t. The rate of change in prices between t and $t-1$ is set as: $\pi_{ijt} \equiv \ln p_{ijt} - \ln p_{ijt-1}$. The in-sample rate of inflation of a brand i among all sellers is set by a simple average: $\pi_{it} = \frac{1}{S_{it}} \sum_j \pi_{ijt}$. Where S_{it} is the number of stores in which prices are observed (the number of two consecutive nonmissing observations).

In order to address the comprehensiveness of the sample, Figure 5 plots the comparison between the official FIPE-CPI and a measure of aggregate inflation constructed using the sample brands ($\widehat{\pi}_t$). Brands are aggregated into n products using a simple average. A measure of aggregate inflation is then obtained by weighting products by their correspondent FIPE weight

$$\widehat{\pi}_t = \sum_{n=1}^{N} \omega_{nt} \frac{1}{S_{nt}} \sum_{i} \pi_{it}$$

Where S_{nt} is the set of brands defining a product n in a month t (number of nonmissing observations). Weights (ω_{nt}) are calculated by the Household Budget Survey (POF) conducted by FIPE. I choose weights relative to the year 2000 POF and recalibrate them to always sum 1 every month. The counterfactual ($\widehat{\pi}_t$) presented in Figures 5b and 5c correctly replicates CPI patterns in both sample periods.

Although using different methodologies[7] and different products, $\widehat{\pi}_t$ properly reproduces the behavior of the official CPI. The correlation coefficient is 0.99 from 1989 to 2007. In the low-inflation sample, $\widehat{\pi}_t$ is more volatile due to a larger contribution of food items. The counterfactual inflation also replicates the drastic decrease in inflation immediately after *Plano Real*.

I now focus on the morphology of inflation variability. Firms adjust prices in different amounts each period, and this pattern is consistently present. Figure 6 displays the kernel estimates of the inflation rate distribution pooled over brands (π_{it}). I split the sample into years and inflation scenarios. The data clearly shows that the hypothesis of synchronized price adjustments does not hold. Each market for a specific brand adjusts prices by a certain amount.

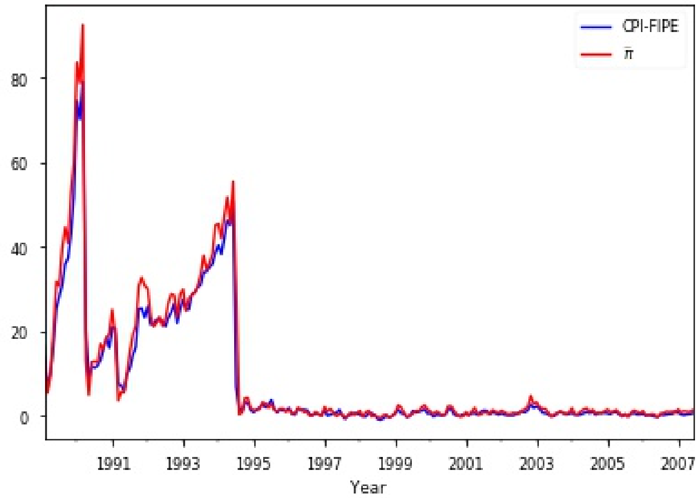
The link between inflation and the inflationary environment is also interesting. Figure 6a presents the kernel estimates for the hyperinflation years, and Figure 6b presents the estimation for the low rates of inflation years. During the 1989–1993 period, the kernel estimate exhibits a higher degree of dispersion. The distribution is also leptokurtic and asymmetric. The size of price adjustments is approximately 30% of monthly price increases. I find no evidence of unified price adjustments during hyperinflation.

In contrast, during the 1995–2007 sample period, the kernel estimation is consistently more symmetric around zero and exhibits noticeably less dispersion. The kernel distributions for all years from 1995 to 2007 are surprisingly similar.

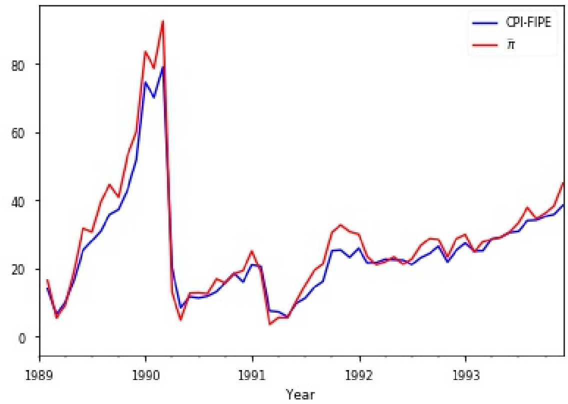
In order to illustrate the remarkable impact of *Plano Real* on the distribution of price adjustments, Figure 7 illustrates the density function for the years 1993 and 1994. Note the concentration around 30% of price changes during 1993 in Figure 7a. The distribution of inflation is mildly asymmetric to higher adjustment values.

Interestingly, the 1994 distribution is bimodal. This pattern results from the implementation of *Plano Real* in the middle of the year, in July 1994. Figure 7b illustrates the monthly kernel estimates of intramarket inflation for the year 1994. Note the bimodal pattern in the data, with a transition month (July 1994), precisely when the plan was implemented.

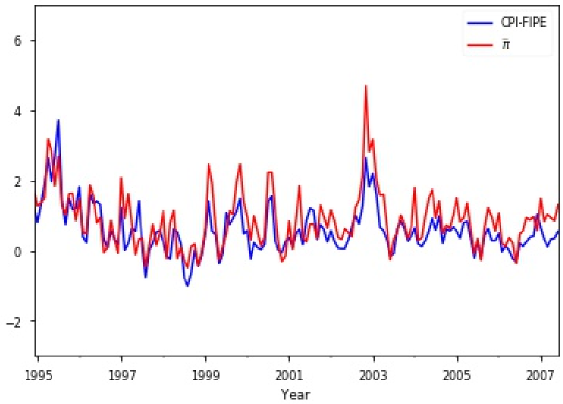
[7] FIPE-CPI is calculated as a geometric mean based on a Cobb-Douglas utility.



(a) 1989–2007



(b) 1989–1993



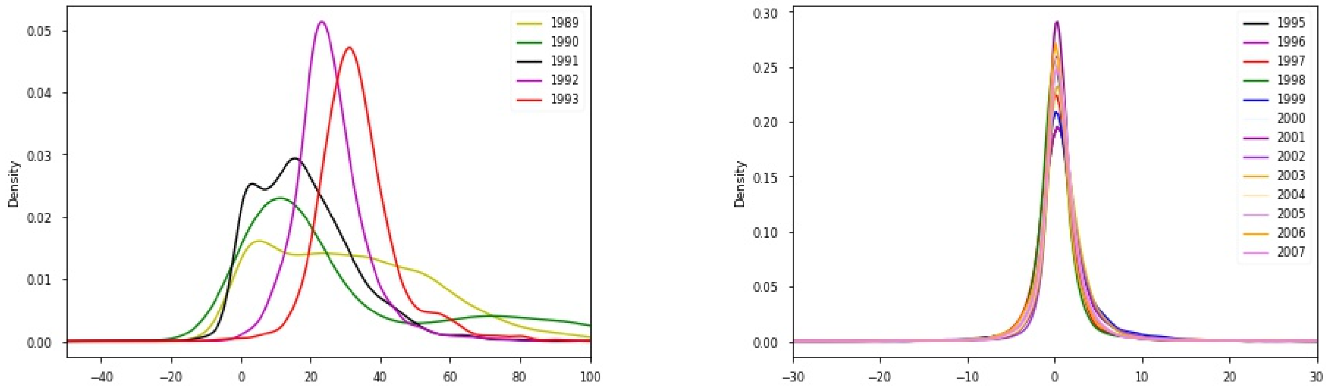
(c) 1995–2007

Figure 5: FIPE-CPI and aggregate in-sample inflation ($\widehat{\pi}$)

Figures 6 and 7 illustrate the importance of *Plano Real* in controlling inflation and its dispersion among the most individual-level price observations in the sample (brands). The plan not only ended hyperinflation but significantly altered price-setting behavior as well. Once inflation is lower, producers adjust prices less often and less dispersed in time. There is less dispersion in inflation both between sellers of the same good and between sellers of different goods.

5 Inflation and relative price variability

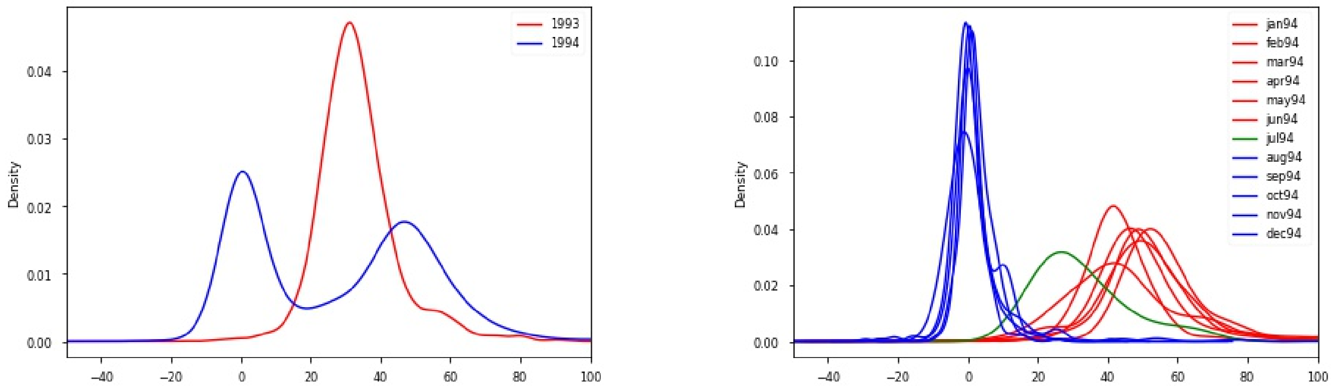
This section investigates the impact of inflation on the dispersion of price adjustments among all firms selling the same brand of good/service (intramarket RPV). The interest lies in how the



(a) 1989–1993

(b) 1995–2007

Figure 6: Inflation density: 1989–2007



(a) 1993–1994

(b) 1994 (monthly)

Figure 7: Inflation density: 1993–1994

first moment of inflation affects the second moment of its distribution, that is, how inflation is linked to inflation variability. Following Konieczny and Skrzypacz (2005), I focus on two measures of inflation variability: the standard deviation of price changes and the coefficient of variation of price levels. Define the standard deviation (SDP_{it}) of price changes across stores as

$$SDP_{it} = \left[\frac{1}{S_{it}} \sum_j (\pi_{ijt} - \pi_{it})^2 \right]^{1/2}$$

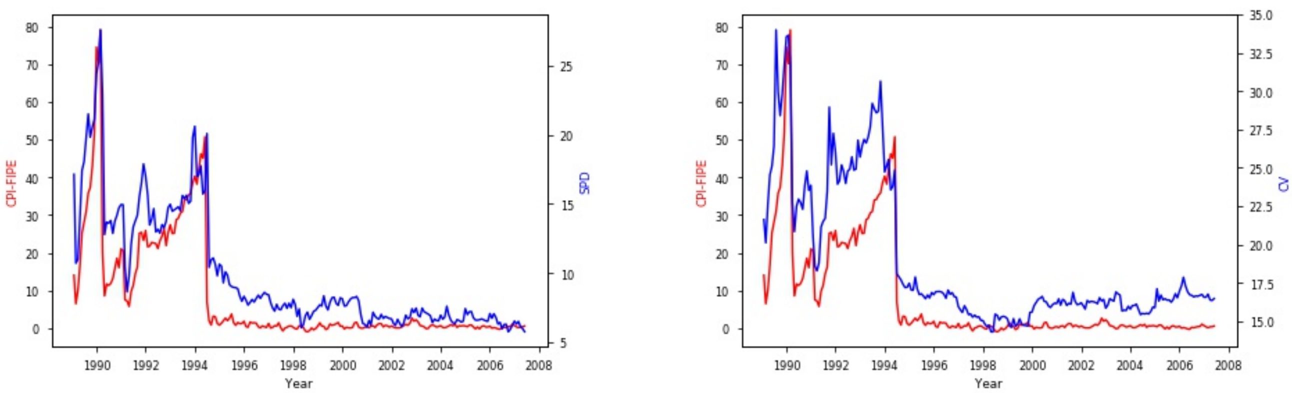
Where S_{it} is the number of two consecutive nonmissing price-change observations and π_{ijt} and π_{it} are in-sample inflation at the store and brand level, respectively. SDP_{it} yields the evolution of the rates of price change around the average inflation rate across all sellers of a particular brand, the cross-sectional variance of inflation.

In addition, define the coefficient of variation (CV_{it}) of price levels across stores as

$$CV_{it} = \left[\frac{1}{S_{it}} \sum_{j} \left(\frac{p_{ijt} - P_{it}}{p_{it}} \right)^2 \right]^{1/2}$$

Where p_{it} is the average price level of a brand i across stores at time t. The coefficient (CV_{it}) accounts for contemporaneous discrepancies between the price of the same brand across all of its sellers. Following Konieczny and Skrzypacz (2005), I work with both measures of price variability.

One imperfect aggregate measure of price-change dispersion is set by combining brands into products by a simple average and then using CPI weights to compute an aggregate index for both measures of variability (SPD and CV). Following Alvarez et al. (2011), Figure 8 plots the aggregate measures alongside monthly CPI-FIPE. The correlation coefficient is 0.94 for SPD and 0.87 for CV. Note that during the hyperinflation period in Brazil, RPV was significantly higher. Higher levels of inflation widen the inflation variability range under both measures.

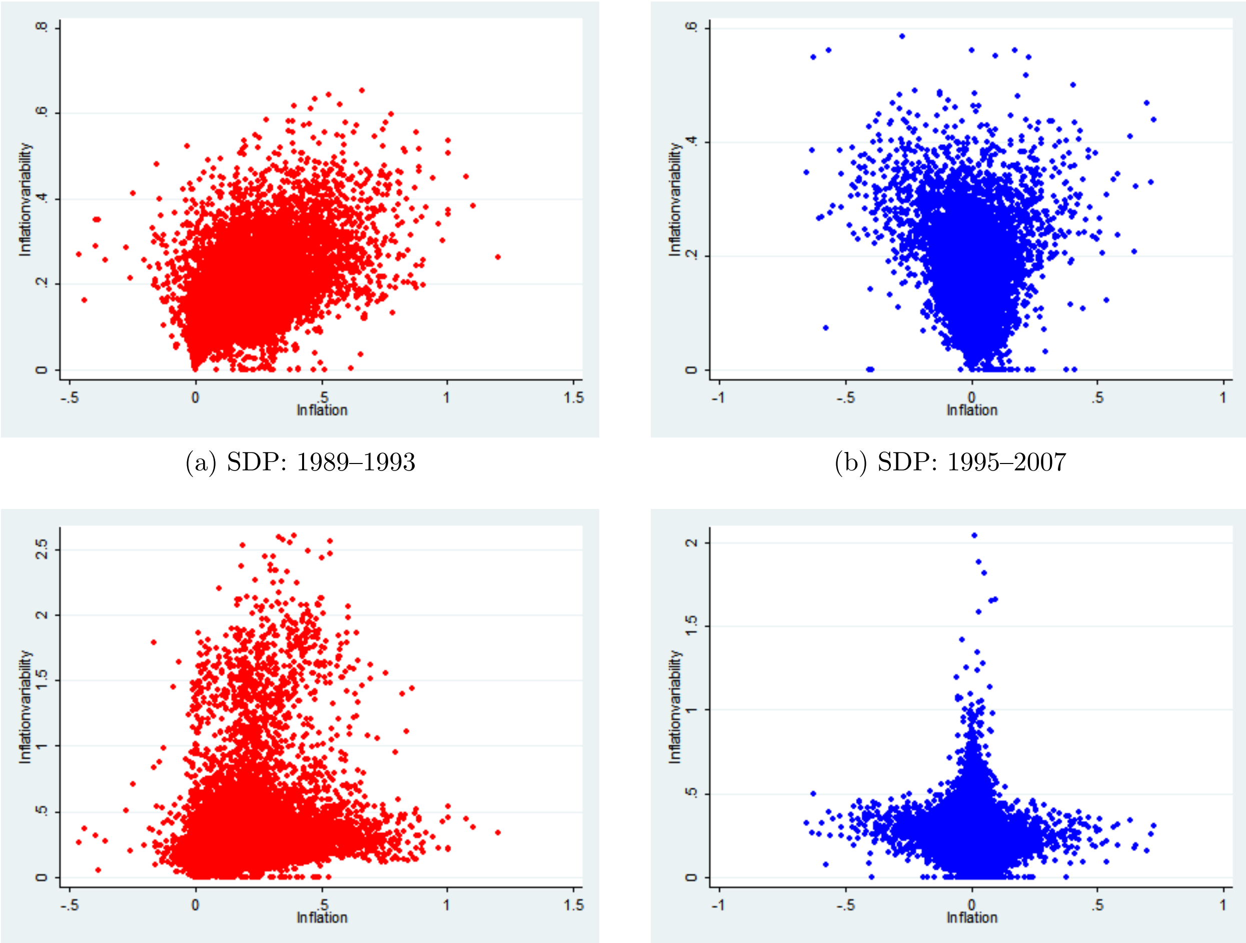


(a) Standard deviation of price changes (SPD)

(b) Coefficient of variation of price levels (CV)

Figure 8: Inflation and relative price variability

As an initial guideline, Figure 9 present a visual inspection of the relationship between inflation and inflation variability during both sample periods. Figures 9a and 9b present scatter plots of the standard deviation of price changes, and Figures 9c and 9d for the coefficient of variation of price levels. The distribution of inflation variability is quite different between the two inflationary scenarios. For both measures, the relationship does not appear to be symmetric around zero.



(a) SDP: 1989–1993

(b) SDP: 1995–2007

(c) CV: 1989–1993

(d) CV: 1995–2007

Figure 9: Scatter plots of inflation and inflation variability

5.1 Fixed effects panel

To estimate the effect of inflation on inflation variability, I run fixed effects panels regressions with both measures of dispersion (SPD and CV) as dependent variables. I use two different approaches: I estimate the impact of the absolute value of inflation and I also split inflation into the absolute value of positive and negative movements to highlight the importance of asymmetric impacts. The estimation procedure is defined as

$$\mathrm{SDP}_{it} = \lambda_i + \sum_{t'}^{T'} \tau_t + \sum_{s}^{S} D_s + \beta \left|\pi_{it}\right| + \epsilon_{it} \tag{1}$$

$$\mathrm{SDP}_{it} = \lambda_i + \sum_{t'}^{T'} \tau_t + \sum_{s}^{S} D_s + \beta_1 \pi_{it}^{+} + \beta_2 \left|\pi_{it}^{-}\right| + \epsilon_{it} \tag{2}$$

$$CV_{it} = \lambda_i + \sum_{t'}^{T'} \tau_t + \sum_{s}^{S} D_s + \beta \left|\pi_{it}\right| + \epsilon_{it} \tag{3}$$

$$CV_{it} = \lambda_i + \sum_{t'}^{T'} \tau_t + \sum_s^S D_s + \beta_1 \pi_{it}^+ + \beta_2 \left|\pi_{it}^-\right| + \epsilon_{it} \quad (4)$$

Where λ_i is the brand specific effect, τ_t are year dummies, and D_s are month dummies controlling for seasonal effects. The idiosyncratic error term is ϵ_{it}. I follow the procedure presented in Konieczny and Skrzypacz (2005). The coefficient β refers to the impact of absolute inflation on inflation variability. The coefficient β_1 refers to the impact of positive price movements and the coefficient β_2 to the impact of the absolute value of negative price movements. Table 4 presents the estimation results for the hyperinflation period (1989–1993), the low-inflation period (1995–2007), and the entire sample period

Table 3: Fixed effects panel results

	SDP as dependent variable			*CV as dependent variable*		
	$\lvert\pi\rvert$	π^+	$\lvert\pi^-\rvert$	$\lvert\pi\rvert$	π^+	$\lvert\pi^-\rvert$
1989–1993	0.314**	0.355***	0.301***	0.221***	0.327***	0.204***
1995–2007	0.448**	0.389***	0.518***	0.304***	0.345***	0.462***
1989–2007	0.345***	0.294***	0.489***	0.306***	0.313***	0.363**

a Note: $***p < 0.01, **p < 0.05, *p < 0.1$

The hypothesis of a positive relationship between inflation and inflation variability finds strong support in the Brazilian data. I find evidence of a significant and positive correlation between inflation and inflation variability captured by the linear coefficient. Considering all 19 years of the sample, the linear coefficient on the absolute value of inflation indicates an effect of 0.345 in magnitude for SPD and 0.306 in magnitude for CV. The magnitude of the impact of inflation on RPV is stronger when measured by SDP than when measured by CV. Konieczny and Skrzypacz (2005) reach the same conclusion.

The overall degree of association between inflation and RPV is weaker during the hyperinflation years. The interstore inflation variability significantly increases with the rate of inflation, but the relationship is somewhat looser during hyperinflation. Considering Equation (1), the coefficient β is 0.314 from 1989 to 1993 and 0.448 from 1995 to 2007. The strength of the linear relationship is roughly 70% weaker during the years hyperinflation in Brazil (or, equivalently, 40% stronger during the low-inflation sample).

A similar conclusion is reached in Equation (3), where the coefficient β is also roughly 70% weaker comparing hyperinflation to low inflation (0.221 *vs.* 0.304). Both results are statistically significant at the 5% confidence level. The inflationary regime thus impacts the strength of the relationship. This result is in line with Caglayan and Filiztekin (2003), who also report evidence on a significantly lower association between inflation and inflation variability during high-inflation years in Turkey.

The looser link between inflation and RPV during hyperinflation is explained by the higher frequency of price increases during that period. When inflation is high, most price changes are price increases, which narrows inflation dispersion at the brand level. Thus, the relationship between inflation and its dispersion is weaker during these years.

Nevertheless, after *Plano Real*, price decreases are almost as likely as price increases, which widens price-change dispersion in the data and increases the impact of inflation on it. Note that price changes dispersion is higher during hyperinflation than during low inflation. The point is that the impact of inflation on RPV is relatively higher during low inflation because for low inflation levels, there is higher inflation dispersion due to the presence of price decreases.

I also find evidence of asymmetric effects. Deflation, in absolute terms, has a higher impact on RPV considering both RPV measures during the 1995–2007 sample. During lower levels of inflation in Brazil, price decreases contribute marginally more to price dispersion than do price increases. From Equation (2) 1995–2007 sample period, the impact of $\left|\pi_{it}^{-}\right|$ is 0.518 against 0.389 of π_{it}^{+}. From Equation (4), during the same low-inflation sample period, the impacts are, respectively, 0.462 and 0.345.

In contrast, during hyperinflation, because price decreases are less frequent, the effect of $\left|\pi_{it}^{-}\right|$ is weaker than the effect of π_{it}^{+}, yet positive and significant. Even during hyperinflation, some prices (mostly for food items) drop every month and this impacts overall inflation variability. Tommasi (1992) reaches the same conclusion.

To gain further insight into the importance of inflation in price adjustment variability, I perform a simple least squared estimation on intramarket data individually for each of the 221 months in the sample. Table 4 presents evidence on a structural change in the relationship between inflation and RPV. During hyperinflationary episodes, the relationship is significantly lower. The additional exercise enables for time-varying effects without imposing any timing for breakpoints in the sample, thus allowing for an investigation of the structural change. The estimation procedure is set as

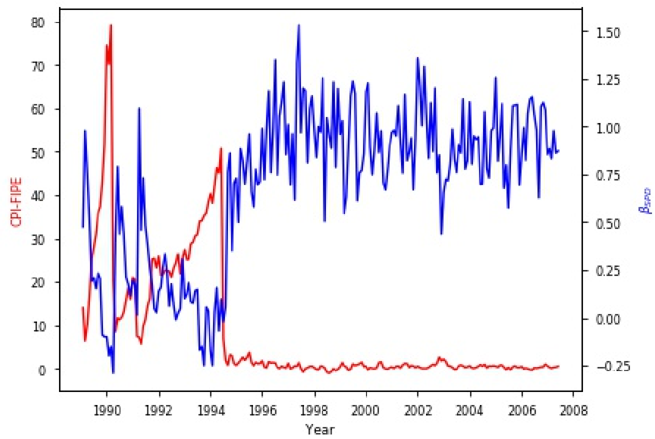
$$\text{SPD}_{it} = \lambda_{it} + \beta_t \left|\pi_{it}\right| + \epsilon_{it}, \qquad \textit{for each } t = 2, 3, ..., 222 \tag{5}$$

$$\text{CV}_{it} = \lambda_{it} + \beta_t \left|\pi_{it}\right| + \epsilon_{it}, \qquad \textit{for each } t = 2, 3, ..., 222 \tag{6}$$

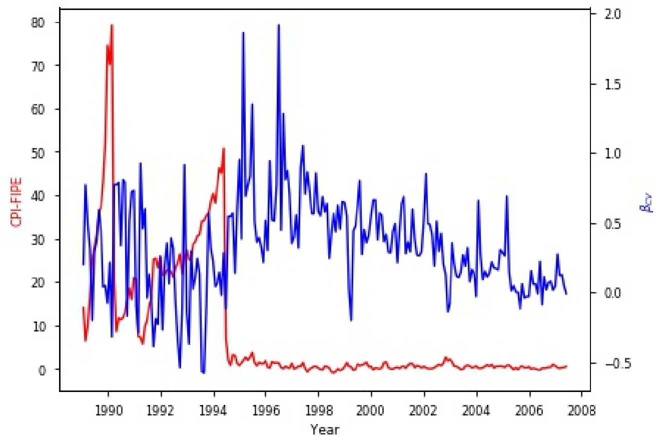
Where λ_{it} is the intercept of the regression for each month. I focus on the time evolution of β_t. Figure 10 plots the OLS results for all months in the sample. A major structural change is clearly evident in July 1994, precisely when *Plano Real* was implemented. The shift is clear, and both coefficients – considering SDP and CV as the dependent variable – display a similar timing of breakpoints.

Once the hyperinflation spiral was tamed, the structure of the relationship between inflation and inflation variability changed. I confirm a higher impact of inflation on RPV for both SDP and CV during low inflation. The link between inflation and inflation variability was looser during the hyperinflation years. Once again, I find no evidence of a transition period.

I also document the estimation results of β, β_1, and β_2 based on sectors and groups of brands. The estimation results are displayed in Table **??**. I aggregate products into three sectors: *Services*, *Industrial goods*, and *Food at home*. I follow the methodology of the Brazilian Central Bank (BCB) to aggregate products. This aggregation is common in the literature as well. I



(a) β_{SPD}



(b) β_{CV}

Figure 10: Rolling regression results for β_{SPD} and β_{CV}

also present the estimation for products in each of the 7 groups of products in the CPI-FIPE, namely *Housing*, *Food*, *Transportation*, *Personal expenses*, *Healthcare*, *Apparel*, and *Education*.

All sectors and groups associated with the 1,272 brands confirm the same aggregate empirical result: inflation and inflation variability present a significant positive relationship, and this link is stronger during low inflation than during hyperinflation. I also document asymmetries for upward and downward price movements.

It may not be the case that all goods and services will be affected to the same degree by variations in inflation. It is possible that, due to the purchase frequency or relative expensiveness of brands, price adjustments dispersion will vary across brands. Although different categories of brands are similar in terms of the impact's significance and direction, some differences appear across these categories. The magnitude of the impact of inflation is stronger for *Services*.

Food at home items, on the other hand, present a weaker relationship, which is probably due to a higher incidence of supply shocks (price decreases). Regarding the division of products in groups, the RPV of *Healthcare* and *Education* brands are strongly correlated to inflation. Prices are stickier in both groups, so unsynchronized timing of adjustments also affects the link. The coefficient is also high in *Apparel*.

In short, the empirical evidence suggests a looser link between inflation and inflation variability during the Brazilian hyperinflation years. Inflation drives a wedge into the informational content of nominal prices, causing persistent distorting impacts on relative price adjustments. Nonetheless, when inflation is at skyrocketing levels, as in the Brazilian economy in the mid-80s and mid-90s, firms will change prices according to sources of information other than price movements among their competitors. High inflation distorts the channel through which inflation affects relative price variability.

Table 4: Fixed effects panel results by sector and group

	SDP as dependent variable			CV as dependent variable		
	$\|\pi\|$	π^+	$\|\pi^-\|$	$\|\pi\|$	π^+	$\|\pi^-\|$
Categories						
Food at home						
1989–1993	0.260***	0.260***	0.205***	0.212***	0.232***	0.167***
1995–2007	0.352***	0.287***	0.421***	0.269**	0.245**	0.265***
1989–2007	0.270***	0.257***	0.383***	0.257***	0.243***	0.234***
Industrial goods						
1989–1993	0.364***	0.365***	0.591***	0.199***	0.153***	0.281**
1995–2007	0.749***	0.646***	0.931***	0.377***	0.379***	0.676*
1989–2007	0.370***	0.362***	0.804***	0.353***	0.352***	0.411***
Services						
1989–1993	0.356***	0.358***	0.083	0.185***	0.154**	-0.062
1995–2007	1.344***	1.269***	1.070**	0.405***	0.404***	0.194**
1989–2007	0.327***	0.325***	1.367**	0.300***	0.300***	0.491**
Groups						
Housing						
1989–1993	0.420***	0.422***	0.421***	0.179***	0.120***	0.227
1995–2007	0.713***	0.614***	0.843***	0.430***	0.429***	0.255***
1989–2007	0.408***	0.394***	0.780***	0.386***	0.389***	0.300**
Food						
1989–1993	0.254***	0.254***	0.206***	0.218***	0.217***	0.211***
1995–2007	0.350***	0.285***	0.417***	0.436***	0.345**	0.482**
1989–2007	0.266***	0.251***	0.406***	0.292***	0.286***	0.454***
Transportation						
1989–1993	0.285***	0.291***	0.141	0.211*	0.126**	-0.026
1995–2007	0.497***	0.460***	0.633***	0.392**	0.394***	0.827
1989–2007	0.279***	0.272***	0.577***	0.324***	0.318***	0.540***
Personal expenses						
1989–1993	0.351***	0.353***	0.258***	0.285***	0.272***	0.311**
1995–2007	0.767***	0.678***	0.953***	0.387***	0.390***	0.866*
1989–2007	0.341***	0.337***	0.789***	0.385***	0.385**	0.462***
Healthcare						
1989–1993	0.351***	0.351***	–	0.0415	0.0415	–
1995–2007	1.204***	1.616***	0.964*	0.165***	0.387**	0.0895
1989–2007	0.361***	0.354***	1.085*	0.0537*	0.0522	0.299
Apparel						
1989–1993	0.318***	0.318***	0.286**	0.106*	0.143*	0.245**
1995–2007	1.104***	1.049***	1.757***	0.246***	0.250***	0.681**
1989–2007	0.318***	0.320***	0.499***	0.238***	0.243**	0.747***
Education						
1989–1993	0.339***	0.340***	0.694	0.341***	0.338***	0.357
1995–2007	0.996***	0.873***	1.535***	0.401***	0.403***	0.394*
1989–2007	0.353***	0.345***	1.285***	0.372***	0.372***	0.456***

a Note: $***p < 0.01, **p < 0.05, *p < 0.1$

a Note2: - not enough observations for estimation

6 Concluding remarks

This paper investigates patterns of price-change variability across firms selling the same homogeneous brand using Brazilian microdata from 1989 to 2007. I find evidence of a different relationship between relative price variability and inflation during hyperinflation and lower levels of inflation at the microeconomic level. The link (in magnitude) during hyperinflation is roughly 70% of the magnitude during low inflation. I also find asymmetric impacts from deflation and positive inflation.

I document the morphology of inflation variability at the brand level across time. I find evidence of an asymmetric and leptokurtic kernel density function during the years of hyperinflation. The distribution is more symmetric and concentrated around lower values of inflation during the 1995–2007 period. I find no evidence of a transitional period. The density function on inflation instantaneously adjusted to a new pattern once *Plano Real* was implemented in July 1994. I also provide a set of summary statistics regarding the frequency and size of price adjustments, which also highlight the substantial impact of the plan on price-setting behavior in Brazil.

The empirical results obtained in this paper indicate a positive relationship between inflation and intramarket inflation variability. Through a fixed effects panel estimation, I find compelling evidence of a significantly weaker association between inflation and RPV during hyperinflation. Higher levels of inflation are associated with higher inflation variability, but the relationship is somewhat looser during hyperinflation, which relates to the higher frequency of price increases during this period.

The impact of deflation (in absolute terms) is weaker than the impact of positive inflation during hyperinflation, yet stronger during low inflation. The magnitude of the impact of inflation on RPV is stronger when measured by SDP than when measured by CV. The empirical evidence indicates different inflation-RPV links depending on the inflationary environment.

Despite the extensive empirical evidence on the relationship between inflation and inflation variability, there is still room for research on developing countries, especially during hyperinflation. This paper contributes to the literature by analyzing a unique dataset on more than 6 million store-level prices encompassing 5 years of hyperinflation in Brazil. The data is also extensive in terms of products. I analyze data on 1,272 brands of goods and services from 1989 to 2007 (almost 19 years). The paper provides further evidence highlighting the importance of considering different inflation scenarios when assessing inflation-related effects.

References

Alvarez, Fernando, Martin Gonzalez-rozada, Andy Neumeyer, and Martin Beraja, "From hyperinflation to stable prices: Argentina's evidence on menu cost models," *Manuscript, University of Chicago*, 2011.

Angelis, Thiago, "Inflation, price dispersion and the informational content of prices: Evidence from a hyperinflation episode," *Universidade de São Paulo, mimeo*, 2012.

Araujo, Julia P., "Price setting in Brazil from 1989 to 2007: Evidence on hyperinflation and stable prices," *Working Paper*, 2018.

Baglan, Deniz, M. Ege Yazgan, and Hakan Yilmazkuday, "Relative price variability and inflation: New evidence," *Journal of Macroeconomics*, 2016, *48*, 263–282.

Benabou, Roland, "Search, price setting and inflation," *The Review of Economic Studies*, 1988, *55* (3), 353–376.

_ , "Inflation and efficiency in search markets," *The Review of Economic Studies*, 1992, *59* (2), 299–329.

Burdett, Kenneth and Kenneth L. Judd, "Equilibrium price dispersion," *Econometrica*, 1983, *51* (4), 955–969.

Caglayan, Mustafa, Alpay Filiztekin, and Michael T Rauh, "Inflation, price dispersion, and market structure," *European Economic Review*, 2008, *52* (7), 1187–1208.

_ **and** _ , "Nonlinear impact of inflation on relative price variability," *Economic Letters*, 2003, *79*, 213–218.

Caraballo, M. Angeles, Carlos Dabús, and Carlos Usabiaga, "Relative prices and inflation: New evidence from different inflationary contexts," *Applied Economics*, 2006, *38* (16), 1931–1944.

Giambiagi, Fabio, André Villela, Lavinia Barros de Castro, and Jennifer Hermann, *Economia brasileira contemporânea* 2010.

Gorodnichenko, Yuriy, Viacheslav Sheremirov, and Oleksandr Talavera, "Price setting in online markets: Does IT click?," *Journal of the European Economic Association*, 2018, pp. 1–48.

Hoomissen, Theresa Van, "Price dispersion and inflation: Evidence from Israel," *Journal of Political Economy*, 1988, *96* (6), 1303–1314.

Konieczny, Jerzy D. and Andrzej Skrzypacz, "Inflation and price setting in a natural experiment," *Journal of Monetary Economics*, 2005, *52* (3), 621–632.

Lach, Saul and Daniel Tsiddon, "The behavior of prices and inflation: An empirical analysis of disaggregated price data," *Journal of Political Economy*, 1992, *100* (2), 349–389.

Rauh, Michael T., "Nonstandard foundations of equilibrium search models," *Journal of Economic Theory*, 2007, *132* (1), 518–529.

Reinsdorf, Marshall, "New evidence on the relation between inflation and price dispersion," *The American Economic Review*, 1994, *84* (3), 720–731.

Sheremirov, Viacheslav, "Price dispersion and inflation: New facts and theoretical implications," *Working Paper, Federal Reserve Bank of Boston*, 2015.

Sheshinski, Eytan and Yoram Weiss, "Inflation and costs of price adjustment," *The Review of Economic Studies*, 1977, *44* (2), 287–303.

Silver, Mick and Christos Ioannidis, "Intercountry differences in the relationship between relative price variability and average prices," *Journal of Political Economy,*, 2001, *109* (2), 355–374.

Stigler, George J., "The economics of information," *Journal of Political Economy*, 1961, *69* (3), 213–225.

Tommasi, Mariano, "Inflation and relative prices: Evidence from Argentina," *Los Angeles: Department of Economics, University of California*, 1992.