Sticky Facts for Armenian Consumer Prices

CBA Working Paper 2023/07

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Abstract

We examine the price-setting behavior in Armenia by studying consumer price data from 2006 to 2021. Our findings indicate that price changes in Armenia occur more frequently compared to other countries examined in previous studies, with an average price spell duration of 2.4 months. The frequency of price changes varies dramatically across categories. We propose an approach to calculate sticky and flexible price inflation measures for Armenian consumer prices. Gaining insight into the dynamics of inflation caused by sticky prices is essential for effective monetary policy, as this measure of underlying inflation incorporates inflation expectations. Inflation variation is mostly influenced by the size of price changes rather than the frequency. Inflation is more volatile compared to the predictions of time-dependent pricing models. Both frequency and size of price adjustment change sizably after significant shocks consistent with state-dependent pricing models.

JEL: E31, E52, E58.
Keywords: sticky prices, price adjustment, inflation measurement, monetary policy.

Content

1. Introduction

Understanding the nature of the price adjustment mechanism is crucial for the formulation of effective monetary policy. For instance, the sensitivity of inflation to the output gap depends on several non-policy factors, including the degree of price stickiness. In particular, when prices are stickier, the New Keynesian Phillips curve becomes flatter, as prices adjust less in response to wage pressures. This paper aims to investigate the empirical properties of price stickiness in Armenia, compare our findings with the testable implications of theories behind price-setting behavior as well as to build sticky-price index for Armenian consumer prices.

The theoretical literature describes the mechanism of price adjustment using two primary approaches: time-dependent pricing models (TDP) and state-dependent pricing models (SDP). TDP models assume that the frequency of price changes is determined exogenously. For instance, firms may set their prices every n-th period in Taylor (1980) or receive random exogenous signals to change prices in Calvo (1983). Therefore, this family of models assumes that the variance of inflation is explained by the size of price changes and does not allow for any variation in the frequency of price changes.

According to SDP models, both the frequency and the size of price changes are endogenous. An example of this modeling approach is when firms' price-changing decisions are subject to "menu costs"; inflation variance then is a result of both margins of price adjustment. As such, the degree of price stickiness is endogenous and depends on the state of the economy. In SDP models, prices respond to monetary policy and exogenous shocks more rapidly than in TDP models.

The availability of microeconomic consumer price data enables investigating the consistency of observed price-setting behavior with both TDP and SDP models. The pioneering work by Bils and Klenow (2004) use the price data of goods and services in the US consumer basket for 1995-1997 to quantify the stickiness of prices. Their findings suggest a more frequent price adjustment, with a median duration of prices of 4.3 months, than what is usually assumed in calibrated macro models. Additionally, for nearly all consumer goods, these models predict inflation rates that are much more persistent and much less volatile than what is observed in the data.

Klenow and Kryvstov (2008) show that the variance in US inflation is largely due to the size of price changes. After considering several TDP and SDP models, the authors concluded that none of the models could explain these results.[1] Nakamura and Steinsson (2006) find that the frequency of price increases in US consumer price data co-varies strongly with inflation, whereas the frequency of price decreases and the size of price changes do not. The authors showed that these results are consistent with a benchmark menu-cost model. However, the seasonality of price-setting frequency and the upward-sloping hazard function of price changes for individual products are not in line with menu-cost models. Bryan and Meyer (2010) argue that prices changing at different rates may suggest differing signals about the state of the economy. More specifically, flexible-price items (those recording frequent changes) are more likely to reflect the current state of the economy, whereas

[1] Calvo (1983) and Taylor (1980) models predict bigger absolute price changes for older prices, when no such pattern exists in the data. Golosov and Lucas (2007) model does not generate many small price changes.

sticky-price items (those recording non-frequent changes) contain more information about future expectations.

Our study documents the basic aspects of price adjustment of consumer prices in Armenia over the period of January 2006 to December 2021.

We begin by estimating the frequency and the size of price changes. Our findings indicate a high frequency of price changes in Armenia compared to developed economies, with a frequency of 74%. This suggests that Armenian consumer prices change, on average, every 2.4 months.[2] We document essential heterogeneity in frequency of price changes across consumption categories. However, price changes are usually small in absolute terms, averaging around 3%, although a large subset is much smaller (almost 70 percent of price changes are 1% or less in absolute terms). We also observed that both the frequency and size of price changes adjust sizably after significant shocks, consistent with SDP models.

Our proposed approach involves calculating sticky and flexible price inflation measures for Armenian consumer prices. By doing so, we can better understand the dynamics of inflation; monthly inflation is largely driven by changes in flexible prices. On the other hand, sticky-price inflation is crucial for the formulation of effective monetary policy, as this measure of inflation reflects the inflation expectations of price setters.

Next, we decompose the inflation variation in Armenia into variation in the frequency and the size of price changes. Our findings suggest that the variance of aggregate monthly inflation is mostly due to the size of price changes (the intensive margin) rather than the frequency of price changes (the extensive margin).

We also explore the co-movement of the frequency and the size of price changes with inflation. When inflation increases, the fraction of price increases grows while the fraction of price decreases lowers. The average sizes of both price increases and price decreases highly correlate with inflation. In addition, we observe a sharply declining hazard rate after the first months of price changes.

Finally, we test time-dependent pricing models against our empirical findings. In particular, we examine the Calvo (1983) and Taylor (1980) models, which propose that price stickiness mitigates the initial response of an item's inflation rate to a shock. These models suggest that price stickiness reduces the volatility of an item's inflation rate and raises its persistence. However, we do not find the evidence of this in our data. Contrary to time-dependent pricing models, we find that the frequency of price changes and the persistence of an item's inflation are positively correlated though this correlation is moderate.

The remainder of this paper is organized as follows. Section 2 describes the frequency of price changes and constructs sticky and flexible price indices. Section 3 reports basic results on the size of

[2] Bils and Klenow (2004) report 4.3 months of median price spell duration for US consumer prices. According to Baudry (2004) median duration of price spell in France is 6.2 months. Baumgartner (2005) reports 11.1 months of price spell duration for Austria.

price changes. Section 4 provides inflation variation decomposition and Section 5 presents hazard rates for consumer prices. Section 6 compares actual inflation with inflation in time-dependent models, and Section 7 concludes.

2. How often do prices change?

In this section, we present statistics on the frequency of price changes in the Armenian economy. The analysis uses a data set containing item level price information[3], collected by Statistical Committee of the Republic of Armenia (Statistical Committee). The data covers period from January 2006 to December 2021 and includes the entire consumer basket. Between 2006 and 2016, the consumer basket contained 470 items and by 2021, the number of items has been reduced to 425. The Statistical Committee collects prices of representative items on a monthly basis. Prices are recorded at pre-selected shopping outlets in urban areas, mainly in capital Yerevan and in 10 cities of the republic representing all 10 regions of Armenia.

2.1. Duration of Price Spell

In the literature, the descriptive analysis of the degree of price rigidity is based on either frequency of price changes (frequency approach) or duration of price spells (duration approach).

The duration approach calculates the duration of price spells by simply counting the number of periods during which a price remains unchanged. The frequency of price changes is then calculated indirectly. However, the presence of large number of censored price spells can complicate this strategy[4].

On the other hand, the frequency approach computes the frequency of price changes directly from the data, and the duration of price spells is derived indirectly from that frequency. Lower frequency of price changes then indicates stickier prices. This approach is advantageous because it can be used for short time periods. This is particularly important since the structure of the Armenian CPI basket has been revised on a yearly basis since 2015, which means that some items might only be observed for one year. In addition, this approach does not require an explicit treatment of the censoring of price spells.

Following Bils and Klenow (2004) we employ the frequency approach to calculate frequency of price changes and price spell duration. For each item i, frequency of price changes (fr_i) is computed as the ratio of observed price changes to total number of periods available. If we assume that frequency of price changes follows the exponential distribution of $fr_i = 1 - e^{-\lambda}$ and prices can change at any moment, not just at monthly intervals, then the instantaneous probability of a price change is

[3] Item level price is the average price of product or service observed in different outlets. Similar to other studies we use item level data. See Saita, Takagawa, Nishizaki and Higo (2006), Sonoda (2006).

[4] Censoring is a major issue when analyzing durations in general. In our context, it occurs when incomplete information is available about the price spell of some items.

$-ln(1-fr_i)$. According to Baudry et al. (2004), implied mean duration of price spells can be estimated as:

$$d_i^{mean} = \frac{-1}{ln(1-fr_i)},$$

and implied median duration as:

$$d_i^{median} = \frac{ln(0.5)}{ln(1-fr_i)}.$$

Price stickiness measured by implied median duration varies considerably across CPI basket.[5] Table 1 illustrates the heterogeneity in implied median duration measures for Armenian consumer prices. In Table 1, the duration indicators are separated for food, non-food products and services as well as for main consumption categories by Classification of Individual Consumption by Purpose (COICOP). Not all items are equally important; their weights in 2021 CPI basket range from 0.005 percent (postal services) to 6.29 percent (natural gas). Thus, median duration numbers are weighted by CPI expenditure weights. Column 2 provides weights of each consumption category in the whole CPI basket in 2021.

Armenian CPI prices change every 2.4 months on average. According to this numbers, consumer prices are more flexible in Armenia, than in other countries.[6] Food products display a rather high frequency of price changes and thus a short implied duration (0.2 months)[7]. In contrast, service prices display a high degree of stickiness implying price spell duration of 6.3 months on average. Moreover, some service items change their price very infrequently; postal services, metro, fixed phone services are examples of sticky-price services having price spell duration of 100 months or longer.

The next twelve rows of Table 1 provide price change indicators for each of twelve main consumption categories. "Clothing and footwear" category is the flexible extreme. Such a high flexibility in clothing and footwear (also in food products) is because of many seasonal and imported items included in these categories. The opposite extreme with the stickiest items in CPI basket, are communications (postal service, fixed and mobile phone services, internet) displaying more than 23 months of average median duration.

Table 2 presents a different breakdown of items, emphasizing their characteristics. Almost 35 percent of Armenian CPI basket are imported items. As expected, imported items are more flexible with price spell duration of 0.3 months on average.

[5] The implied median duration of the price spell is preferred over the implied mean duration as a measure of average duration because the distribution of price changes is asymmetric around the mean.

[6] See Appendix I.

[7] Although price observations are conducted monthly, for some consumption categories, the implied duration is smaller than one month due to the continuous time assumption used to derive the formulas for duration.

Table 1: Median Duration of Price Spell, 2006-2021

	CPI expenditure weight in 2021 (%)	Implied Median Duration (months)
All goods and services	100	2.4
Food	41.7	0.2
Non-food	22.2	0.3
Services	36.1	6.3
By 12 main consumption categories		
Food and Non-Alcoholic beverages	37.2	0.2
Alcohol and Tobacco	4.5	0.3
Clothing and Footwear	4.0	0.1
Housing, Water, Gas, Electricity etc.	16.0	1.6
Furnishings, Household, Maintenance	3.5	0.3
Health	9.6	1.6
Transport	8.7	2.7
Communications	4.3	23.5
Recreation and Culture	1.9	0.3
Education	3.2	1.9
Restaurants and Hotels	1.4	0.4
Miscellaneous Goods and Services	5.7	10.5

Note: Sample runs from January 2006 through December 2021 and includes data from capital Yerevan and all 10 regions. The source of data is the Statistical Committee and authors' calculations. Implied median durations are reported in months. "Implied median duration" is equal to $\ln(0.5)/\ln(1-\mathrm{fr}_i)$, where fr_i is the mean frequency of price change. Durations are weighted by CPI expenditure weights.

Table 2: Median Duration of Price Spell,
Imported vs Domestic, Tradables vs Non- tradables, 2006-2021

	CPI expenditure weight in 2021 (%)	Implied median duration (months)
Imported items	34.8	0.3
Domestic items	65.2	3.6
Tradables	57.8	0.6
Non-tradables	42.2	4.9

Note: See Table 1.

Domestic products have median price spell duration of 3.6 months. Longer price spell duration of domestic products is mainly driven by services. Table 2 draws also the distinction between tradables and non-tradables.[8] As expected, tradables display more frequent price changes than non-tradables.

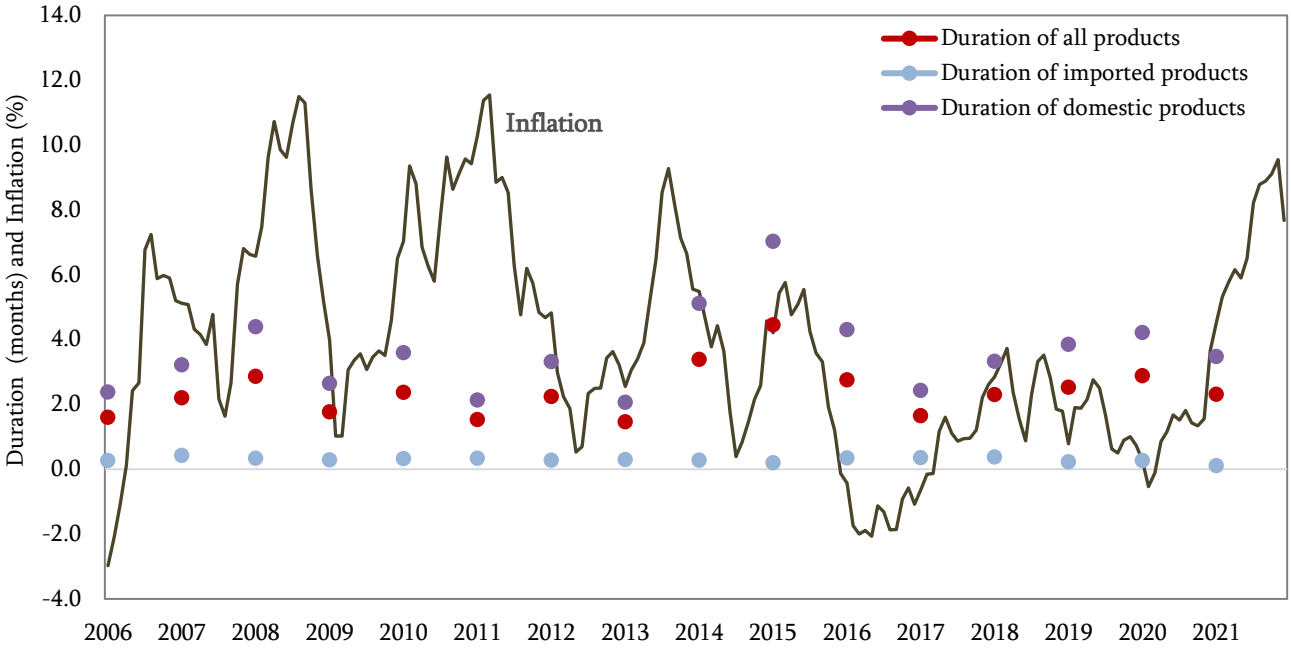
[8] Categories with mostly tradable components are: Food and non-alcoholic beverages; Alcoholic beverages and tobacco; Clothing and footwear; Furnishing and household equipment; and Transport. Categories with higher non-tradable

Figure 1 depicts the dynamics of 12-month rate of inflation and the median duration for imported and domestic items in 2006-2021. The median duration displays cyclical features driven mainly by domestic items. In contrast, imported prices have very low and stable duration of price spells during the whole period indicating that importers directly pass on the changes in the international markets.

It is interesting to note that the behavior of the frequency of price changes is endogenous, and it varies in response to economic shocks and changes in inflation and inflation expectations. The increase in median duration in 2014, for example, may suggest that firms were responding to a more stabilizing inflation environment by changing their prices less frequently.

Conversely, the subsequent shock of the oil price in December 2014 and the resulting exchange rate depreciation in Armenia led to more frequent price adjustments by firms after 2015. The next gradual increase in duration of price spells is from 2017 to 2020. This is consistent with the hypothesis that under more anchored inflation expectations firms change their prices less frequently.

Figure 1: Median Duration of Prices and 12-month percent change of Inflation



Note: Implied median durations are calculated according to methodology described in Section 2.1 and reported in months. The source of data is Statistical Committee and authors' calculations.

However, the uncertainty due to the Covid-19 pandemic in 2020-2021 caused a decrease in median duration of price changes. Therefore, the frequency of price changes displays endogenous variation and it is influenced both by external shocks and internal changes in the economy.

components are: Housing, water, electricity, gas, and other fuels; Health; Communications; Recreation and culture; Educational services; Hotels, cafés, and restaurants; Miscellaneous goods and services.

2.2. Sticky and Flexible Price Indices

In central banks that adopt an inflation targeting strategy, the primary objective of monetary policy is to maintain medium-term inflation at a pre-announced level. This means, that policymakers should not respond to short-term shocks to inflation, which die out in the medium term. However, temporary cost shocks, such as rising food and oil prices, have been increasingly common recently. Therefore, it is crucial for central banks to distinguish between the temporary effects of supply-side factors as well as high frequency movements and the more stable price changes driven by aggregate demand.

To achieve this, many central banks use a measure of core inflation that excludes certain volatile or transitory components from the CPI basket.[9] In Armenia, for example, seasonal food products and regulated services are excluded. However, even with this approach, some items with a relatively high frequency of price changes, such as imported products and processed food (which price changes might strongly co-move with volatile unprocessed food prices), may still be included in the core inflation measure, which can lead to some unnecessary noise in the indicator.

As an alternative, some central banks calculate pure statistical measures to filter high frequency movements from consumer price changes. Allocation of these high frequency movements is also useful in that prices of sticky and flexible-price items provide insight on different aspects of the inflation process.[10] Indeed, because flexible prices are quick to change, they are more responsive to changes in the current economic environment or the level of economic slack.

Sticky prices, on the other hand, contain a component of inflation expectations. Price setters take into account the costliness of changing prices, and therefore, they aim to incorporate their inflation expectations into their pricing decisions to cover the periods between infrequent price adjustments.

To study the evidence for Armenian consumer prices and calculate sticky and flexible price indices, we divide CPI basket into "sticky-price" and "flexible-price" items. Items with relatively small frequencies of price changes belong to the sticky-price basket. The latter contains the stickiest items summing up to 74 percent of CPI basket.[11] The remaining 26 percent (the most flexible items) are considered as "flexible-price" items. We use expenditure weights from the CPI in constructing both of these indices.

The structure of the two subgroups differs substantially. About half of the "sticky-price" items consist of service-based categories, while almost 80 percent of the flexible-price items are food and fuel products, which are subject to larger external shocks for obvious reasons.

Prices in "flexible" series have median price spell duration of 0.1 month, whereas prices in "sticky" series change every 3.9 months on average. Thus, the sticky-price index can be considered a "super"

[9] Various methodologies (statistical, structural, etc.) have been developed over time to calculate core inflation, and there is no one universally accepted approach.

[10] See Bryan and Meyer (2010), Millard and O'Grady (2012).

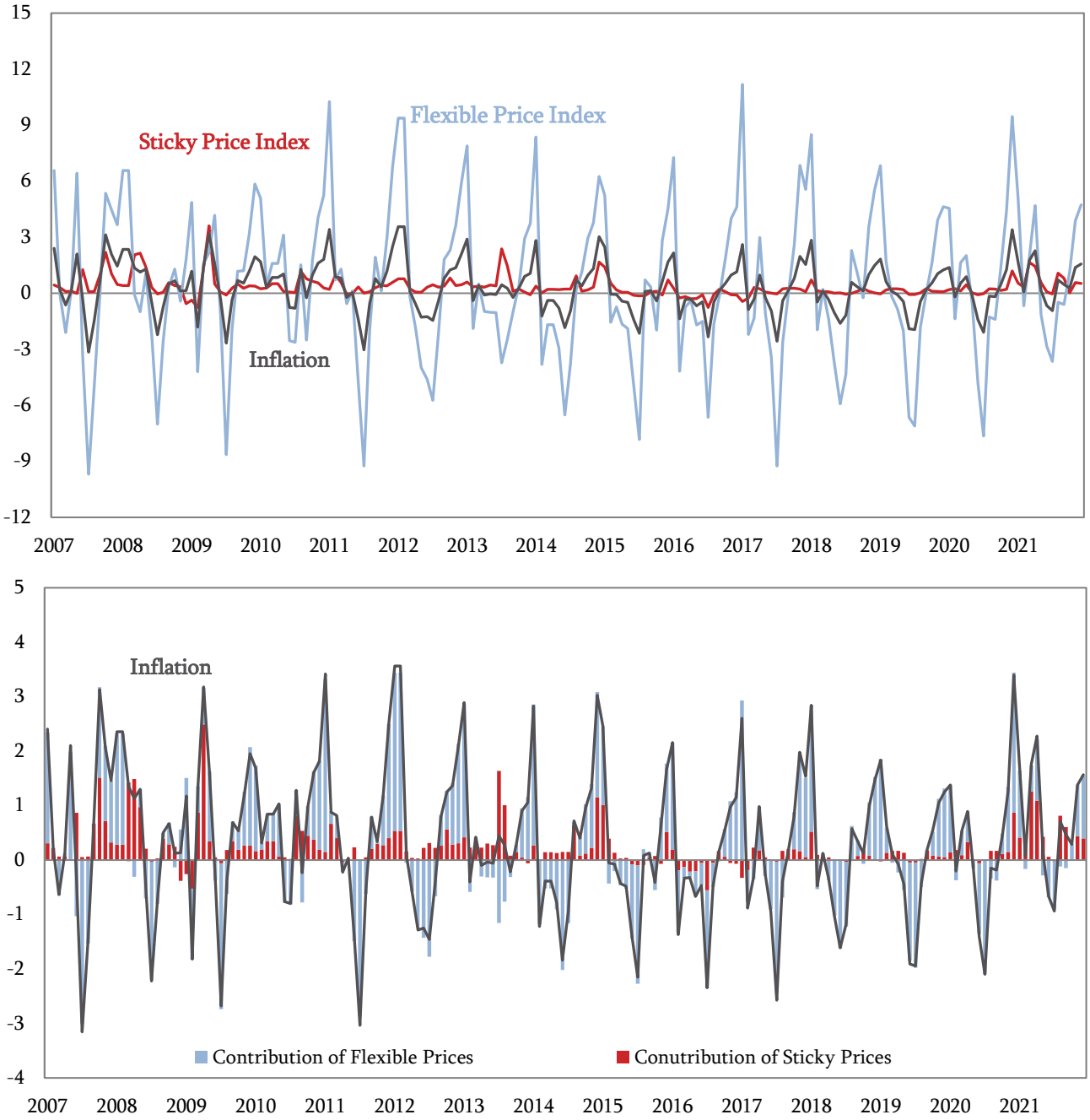
[11] The division of the CPI basket into sticky and flexible sub-groups follows a similar structure to that of the core inflation basket. The Armenian core inflation basket constitutes 74% of the total CPI basket.

measure of underlying inflation, as it comprises the sticky components of the official core inflation measure.

Figure 2 depicts series of sticky and flexible-price indices over the previous month, as defined above, and the contributions of sticky and flexible prices to headline inflation between January 2006 and December 2021.

Figure 2: Sticky and Flexible Indices and Their Contributions to Inflation

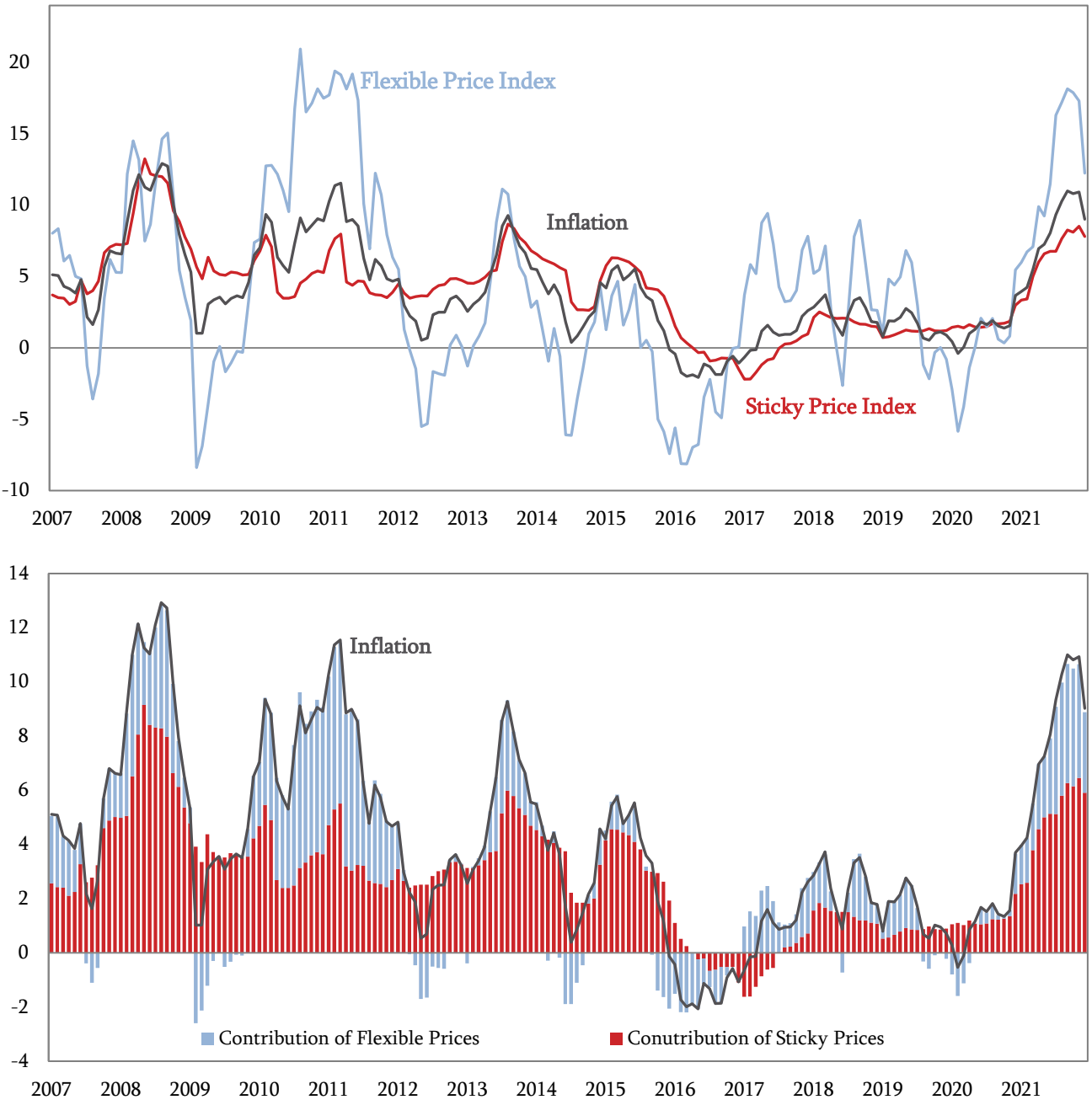
percent change over previous month



Source: Statistical Committee and authors' calculations.

As expected, the sticky-price index exhibits a relatively smooth trend, with only 2 percent of the variance of the flexible-price index. In the figure, the contributions of the sticky and flexible-price indices are calculated so that they sum up to overall inflation and show the relative importance of the sticky and flexible price indices in inflation over the previous month. In this regard, more than 80 percent of the monthly inflation variance is explained by the flexible-price index.

Figure 3: Sticky and Flexible Indices and Their Contributions to Inflation
12-month percent change



Source: Statistical Committee and authors' calculations.

On the other hand, Figure 3 presents the sticky and flexible price indices and their contributions to the twelve-month rate of inflation. For 12-month percent change series, relative importance of

flexible-price items is significantly lower compared to monthly series. "Sticky-price" items explain as much as 70% of inflation variance. Thus, yearly inflation turns out to have a heavy "sticky" component. This is important consideration from monetary policy viewpoint as policymakers target 12-month percent change of inflation. Indeed, theoretically it is optimal to target sticky prices. Additionally, sticky prices are important to gain context about longer-term trends and potentially policy-relevant features of the inflation process.[12]

3. How much do prices change?

In this section, we present summary statistics on the size of price changes, including price increases and decreases. We find that the magnitude of both overall price changes and price increases and decreases is not significant. The average size of expenditure-weighted price changes is 2.4 percent. The average size of price increases and decreases are 3.5% and -2.9%, respectively. Armenian data features relatively smaller price changes in size.[13]

Table 3: Size of Price Changes (%), 2006-2021

	CPI expenditure weight in 2021 (%)	Average absolute change	Average increase	Average decrease
All goods and services	100	2.4	3.5	-2.9
Food	41.7	4.3	4.8	-4.2
Non-food	22.2	1.2	1.7	-1.1
Services	36.1	0.6	1.8	-1.2
By 12 main consumption categories				
Food and Non-Alcoholic beverages	37.2	4.7	5.3	-4.5
Alcohol and Tobacco	4.5	0.5	0.6	-0.3
Clothing and Footwear	4.0	2.1	2.6	-2.0
Housing, Water, Gas, Electricity etc.	16.0	0.6	1.8	-0.7
Furnishings, Household, Maintenance	3.5	0.8	0.9	-0.7
Health	9.6	0.5	1.0	-0.5
Transport	8.7	1.0	2.3	-1.1
Communications	4.3	0.2	2.3	-2.3
Recreation and Culture	1.9	2.1	2.6	-2.2
Education	3.2	0.7	2.0	-5.3
Restaurants and Hotels	1.4	1.0	1.1	-1.3
Miscellaneous Goods and Services	5.7	0.8	1.2	-1.1

Note: Sample runs from January 2006 through December 2021 and includes data from capital Yerevan and all 10 regions. The source of data is Statistical Committee and authors' calculations. All average measures are reported in percent and are weighted by CPI expenditure weights.

[12] Reiff and Varhegyi (2013) suggest that sticky prices are useful indication for inflation targeting central banks.

[13] Studies for other countries report magnitude of price changes typically more than 10%, for both price increases and decreases. Klenow and Kryvtsov (2008) report 14 percent absolute size of price changes for US data. According to Dhyne *et al.*, (2004) average size of price changes is Euro area is 10 percent. Gabriel and Reiff (2009) reports 12.3 percent average size of price changes for Hungary.

The average size of price changes varies across products, as presented in Table 3. Typically, food products display the greatest magnitude of price changes, reaching more than 4.3% in absolute terms. Out of the 12 main consumption categories, the largest magnitudes are for food and non-alcoholic beverages, while the smallest are for communications. In most categories, the absolute value of price increases is larger than that of price decreases. This could be attributed to the inflationary environment over time, which is characterized by a relatively small number of price reductions that are also of small magnitude.

Table 4: Size of Price Changes, Imported vs Domestic, Tradables vs Nontradables, 2006-2021

	CPI expenditure weight in 2021 (%)	Average absolute change	Average increase	Average decrease
Imported items	34.8	1.2	1.6	-1.2
Domestic items	65.2	3.1	4.8	-4.3
Tradables	57.8	3.4	4.1	-3.4
Non-tradables	42.2	0.7	1.6	-1.1

Note: See Table 3.

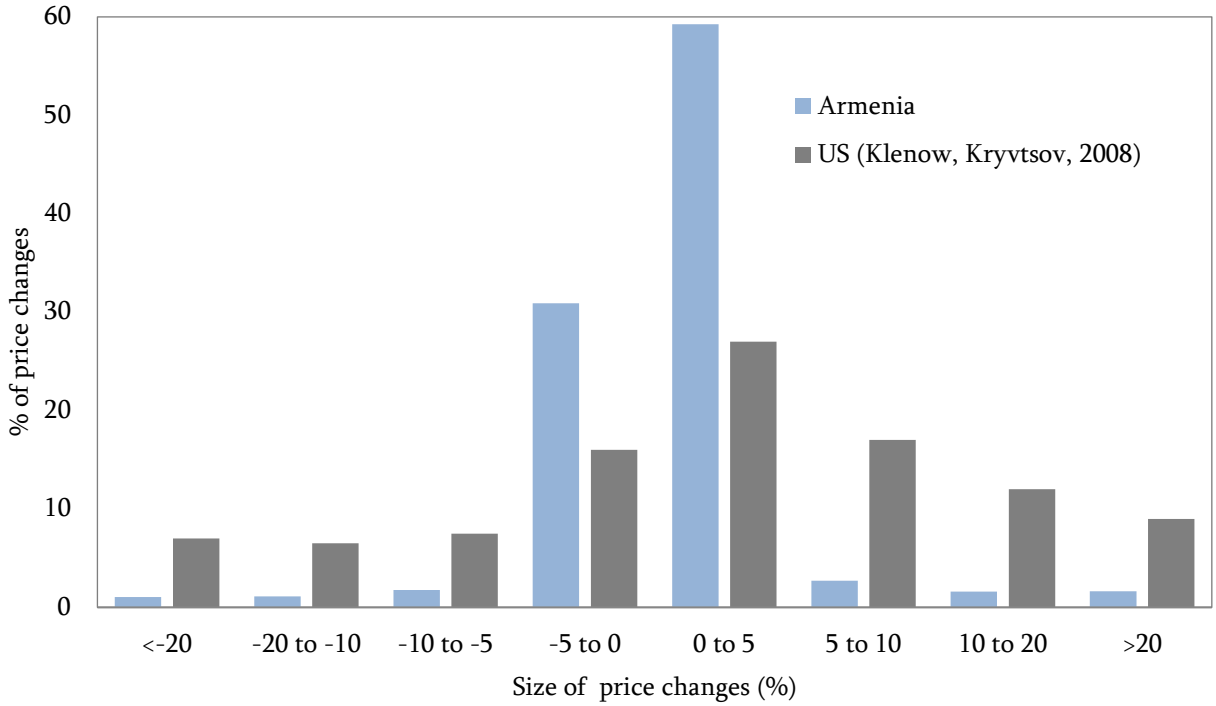
Table 4 illustrates the size of price changes with respect to product characteristics. Domestic items, which are mainly driven by seasonal items, change their prices to a larger extent than imported items, with an average absolute value of price changes of 3.1 percent. The size of price changes is significantly higher for tradables compared to non-tradables.

As noted, there is a significant gap between the size of price changes in Armenia and those in other countries. Figure 4 provides a histogram of price changes for Armenian CPI data and for US consumer prices by Klenow and Kryvstov (2008). The bins of price changes are shown on the horizontal axis, and the percentage of price changes in each bin is shown on the vertical axis. It is clear that small changes predominate in Armenian consumer price changes. In addition, the tails of the histogram are thicker for US prices compared to Armenian prices, indicating that US consumer prices record large price changes more frequently.

Table 5 provides details on small price changes. Around 90% of price changes are smaller than 5% in absolute value, 83% are smaller than 2.5%, and 69% are smaller than 1%. These percentages are much higher than what Klenow and Kryvstov (2008) find for the US.[14] Note also that there is no significant difference between weighted and unweighted measures of price changes, suggesting that small price changes do dominate quantitatively.

[14] Klenow and Kryvstov (2008) report that about 44 percent of price changes are below 5% in absolute value, 25 percent are smaller than 2.5% and 12 percent are smaller than 1%.

Figure 4: Distribution of Consumer Price Changes



Source: Authors' calculations.

Table 5: Fraction of Price Changes below Size Thresholds

	$\|p_{it}\|$< 1%	$\|p_{it}\|$< 2.5%	$\|p_{it}\|$< 5%
Weighted	0.69	0.83	0.90
Unweighted	0.72	0.84	0.90

Note: Samples run from January 2006 through December 2021 and include data from capital Yerevan and all 10 regions. The source of data is the Statistical Committee and authors' calculations. Entries are both weighted and unweighted mean fractions of price changes that are smaller than 5%, 2.5%, or 1% in absolute value; $|p_{it}|$ is the absolute size of price changes. Indicators are weighted by the CPI expenditure weights.

The prevalence of "small" price changes in the data is often brought up as an evidence against state-dependent pricing models. Such models do not generate many small price changes, since small adjustments are not reconcilable with the large menu costs needed to justify price changes.[15]

Another aspect to consider in relation to small price changes is their impact on inflation dynamics, i.e., how they affect inflation. Despite small price changes being relatively large in quantitative terms and representing a substantial portion of the CPI basket, their contribution to monthly inflation is not significant. Furthermore, when we examine the price changes that are large in absolute value (e.g., 1% in absolute terms), it can be observed that these price changes are primarily attributed to

[15] For instance, menu-cost model in (Golosov and Lucas, 2007).

flexible-price items. It turns out that the subgroups of flexible-price items and items with large price changes mostly coincide, indicating that a small group of products with frequent and substantial price changes is the main driver of monthly inflation. [16]

4. Inflation Variation: Decomposition into Frequency and Size Effects

We follow Klenow and Kryvtsov (2008) to decompose inflation, given that monthly inflation (π_t) is the product of the fraction (fr_t) of items with price changes and the average size (dp_t) of those changes, $\pi_t = fr_t * dp_t$. This decomposition helps to determine whether the frequency or the size of price changes is driving inflation variation.

We decompose the variance of inflation over time into "extensive margin" (frequency of price change, EM) and "intensive margin" (average size of price change, IM). To perform the variance decomposition we take the variance of a first-order Taylor series expansion of $\pi_t = fr_t * dp_t$ around the sample means fr_t and dp_t:

$$var(\pi_t) = \underbrace{var(dp_t) * \overline{fr}^2}_{IM\ term} + \underbrace{var(fr_t) * \overline{dp}^2 + 2 * \overline{fr} * \overline{dp} * cov(fr_t, dp_t) + O_t}_{EM\ terms}$$

The fraction $var(dp_t) * \overline{fr}^2 / var(\pi_t)$ ("time-dependent part" of inflation variation) shows how closely TDP models match the empirically observed inflation variation. The intensive margin accounts for 72.5 percent of the variance of consumer price inflation($IM = 1.27, var(\pi_t) = 1.76$). This result suggests that the size of price changes has a greater impact on inflation than the frequency of price changes. Our result for the IM term is lower than the US figure (94 percent) reported by Klenow and Kryvtsov (2008).

We carry out a more extensive decomposition of the inflation rate by breaking down monthly inflation into components attributed to price increases and decreases.

$$\pi_t = fr_t * dp_t = \underbrace{fr_t^+ * dp_t^+}_{pos_t} + \underbrace{fr_t^- * dp_t^-}_{neg_t}$$

where fr_t^+ and fr_t^- (dp_t^+ and dp_t^-) denote the frequency (the average size) of price increases and decreases, respectively. pos_t and neg_t are contributions of price increases and decreases to overall inflation rate, respectively (Gagnon, 2009).

[16] The selection of the dividing line between sticky and flexible-price items is somewhat arbitrary, and in the current approach, the flexible-price items constitute 24% of the CPI basket. Interestingly, even when the share of flexible-price items is reduced to just 10 percent of the CPI basket, the flexible-price index is still able to capture the main movements in monthly inflation.

Table 6 displays the correlation coefficients between inflation rate and frequency and size measures. The size of price changes shows a strong correlation with inflation, which is in line with the results of the inflation variation decomposition analysis.

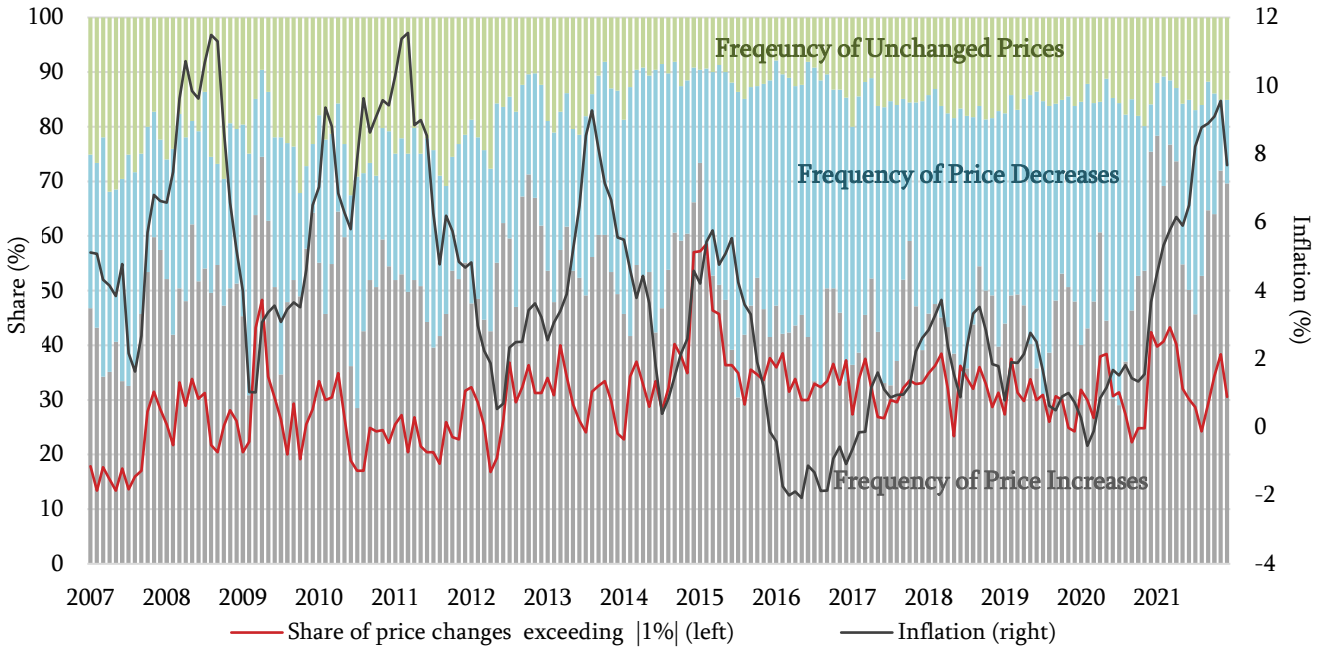
Rows 4-5 of Table 6 state that the fraction of items with rising prices is positively correlated with inflation rate (0.6), and correlation between inflation and fraction of items with falling prices is negative (-0.6). These two effects offset each other that is why overall fraction of items with changing prices shows low correlation with inflation-similarly to Gagnon's (2009) findings.

Table 6: Correlation of Frequencies and Sizes with the Inflation Rate

Variable	Correlation with π
The fraction of items with changing prices ($\boldsymbol{fr_t}$)	0.1
The size of price changes ($\boldsymbol{dp_t}$)	0.9
The fraction of items with rising prices ($\boldsymbol{fr_t^+}$)	0.6
The fraction of items with falling prices ($\boldsymbol{fr_t^-}$)	-0.6
The size of price increases($\boldsymbol{dp_t^+}$)	0.7
The absolute size of price decreases ($\boldsymbol{dp_t^-}$)	-0.6
Contribution of price increases to inflation ($\boldsymbol{fr_t^+ * dp_t^+}$)	0.8
Contribution of price decreases to inflation ($\boldsymbol{fr_t^- * dp_t^-}$)	-0.8

Note: Samples run from January 2006 through December 2021 and include data from capital Yerevan and all 10 regions. The source of data is Statistical Committee and authors' calculations.

Figure 5. Frequency of Price Changes and 12-month percent change of Inflation



Note: Sample runs from January 2007 through December 2021. The source of the data is Statistical Committee and authors' calculations.

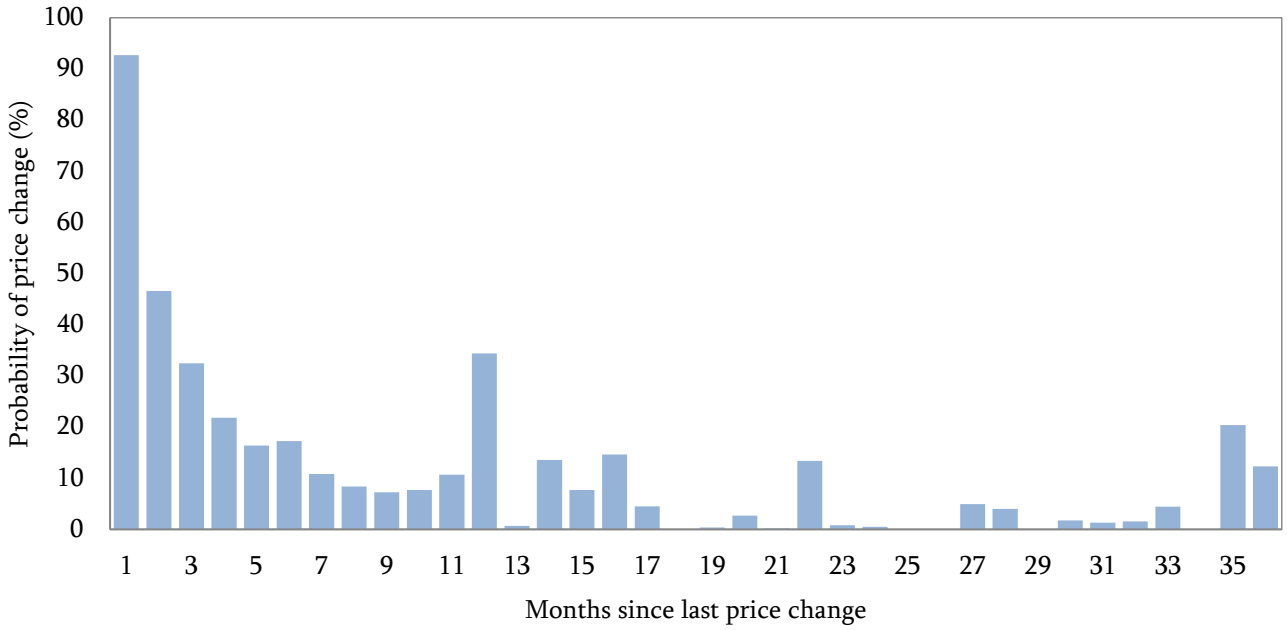
The average sizes of both price increases and decreases show anticipated signs of correlation with inflation. Finally, last two rows of Table 6 document relative importance of price increases and decreases in the inflation variation: both price increases and decreases are equally important.

Figure 5 provides additional insights into price-setting patterns in Armenia by displaying the frequency of prices that have risen or fallen and the share of price changes that exceed 1 percent in absolute terms, alongside the twelve-month inflation rate. The frequency of price increases in Armenia shows some noticeable peaks, which mainly follow external shocks and inflationary pressures as discussed in Section 2. During these peak periods, there is also an increase in the size of price changes, particularly those exceeding 1 percent in absolute value.

5. Hazard Rates for Consumer Prices

Estimating hazard rates for each age of prices allows us to examine how the probability of changing price varies over time. This provides further insights into the price-setting behavior of firms and can help identify which models of price adjustment are most consistent with the data. Price-adjustment models often have stark predictions for the shape of hazard function. For instance, Calvo (1983) assumes a flat hazard function. On the other hand, the deterministic timing of price adjustment in Taylor (1980) model predicts a zero hazard except at a single age, where the hazard is one. Menu-cost models, on the other hand, can generate a variety of shapes.

Figure 6. Weighted Hazard Rates



Instead of assuming a flat profile of price change hazards, we follow Klenow and Kryvstov (2008) to estimate hazard rates for each age of prices. The weighted average frequency of price changes is calculated conditional on reaching each age.

We normalize CPI expenditure weights to sum up to one across all items and all months and use them for weighting procedure ($\widetilde{\omega}_{it}$). This pooled sample is used to calculate the weighted average of the price change indicator for each age of prices τ, using the indicator $I\{\tau_{it} = \tau\}$, which is one, when $\tau_{it} = \tau$ and zero otherwise:

$$\{\overline{I_{it}}|\tau_{it} = \tau\} = \frac{\Sigma_i \Sigma_t \widetilde{\omega}_{it} I_{it} I\{\tau_{it} = \tau\}}{\Sigma_i \Sigma_t \widetilde{\omega}_{it} I\{\tau_{it} = \tau\}}$$

Figure 6 displays monthly hazard rates for each age of prices up to 3 years. The probability of price change in the first month is very high (about 0.9). The hazard is sharply declining in the first months. The spike at 12th month supports the concept that some prices are changed on a fixed schedule as suggested in Taylor (1980). Such a pattern of hazard function is consistent with a mix of Calvo (1983) and Taylor (1980) time-dependent pricing models but can be also generated under state-dependent pricing.

6. Actual Inflation and Inflation in TDP models

Popular TDP models imply that in sectors with high price stickiness, inflation rate should display a relatively low volatility and a relatively high persistence, relative to underlying marginal cost of producing. Bils and Klenow (2004) argue that Calvo (1983) model predicts more persistent and less volatile inflation than they observe in US data. We follow the authors to explore inflation behavior across consumer goods.

According to Calvo (1983) model, process for inflation (π_{it}) for item i can be captured by the following expression:[17]

$$\pi_{it} = (1 - fr_i)\pi_{it-1} + fr_i \epsilon_{it},$$

where fr_i is the probability of price change for item i and ϵ_{it} is the independently and identically distributed (i.i.d.) growth rate of item i's marginal cost. Thus, TDP models argue that if price changes are infrequent (fr_i is well below one), there is an evidence of high persistence and low volatility in inflation.

We examine persistence and volatility of Armenian inflation estimating an AR(1) process for monthly inflation series.

$$dp_t = \rho dp_t + \epsilon_{it},$$

where dp_t is the first difference of p_t (log of price index), ϵ_{it} is i.i.d. with standard deviation σ_i.

[17] Assuming that the log of nominal marginal cost (ϵ_{it},) follows a random walk.

The estimation uses seasonally adjusted data that run from January 2006 to December 2021. Importantly, this implies that regular seasonal cycles in pricing do not generate transience and volatility we see in items' inflation rates.

Table 7 presents the results. Panel A shows estimates for aggregate headline inflation, where aggregate monthly inflation rate is fitted to an AR(1) process; aggregation is over 425 items. Panel B illustrates the variation in the persistence and volatility of inflation across different items. We fit an AR(1) process for the monthly inflation rates for each of the 425 items. The degree of persistence is measured by the AR(1) coefficient, denoted as ρ_i. As a measure of volatility, we concentrate on the standard deviation of innovations, denoted as σ_i, in an item's AR(1) process for inflation.

Table 7 reports that inflation shows negative serial correlation over 2006-2021. Its serial correlation is -0.16 (standard error 0.07). However, the magnitude of this persistence, averaging -0.34 (standard error 0.15) across items, is modest.

Across 425 items, correlation between frequency of price changes and persistence (the degree of serial correlation) is 0.29. This finding goes against the predictions of the Calvo (1983) and Taylor (1980) models, as we observe that items with higher frequency of price changes tend to have inflation rates with stronger serial correlation.

Table 7: Persistence and Volatility of Monthly Inflation Rates

Variable	Monthly Time Series (2006-2021)
	A. Aggregate of all items (inflation)
$\boldsymbol{\rho}$ (measure of persistence)	-0.16 (0.07)
$\boldsymbol{\sigma}_{\in}$ (measure of volatility)	0.01 (0.00)
	B. Across all items (i=1, 2, …, 425 items)
Mean ($\boldsymbol{\rho_i}$)	-0.34 (0.15)
Mean ($\boldsymbol{\sigma}_{\in,\boldsymbol{i}}$)	0.05 (0.09)
Correlation between $\boldsymbol{\rho_i}$ and $\boldsymbol{fr_i}$	0.29
Correlation between $\boldsymbol{\sigma}_{\in,\boldsymbol{i}}$ and $\boldsymbol{fr_i}$	0.18

Note: dp_t is the first difference of p_t, where p_t is the log of the price deflator. $dp_t = \rho dp_t + \epsilon_{it}$, where ϵ_{it} i.i.d. with standard deviation σ_i, fr_i is the probability of price change for item i. Standard errors are in parentheses. Seasonally adjusted series for 2006-2021 are used. Mean measures of persistence and volatility are weighed by CPI expenditure weights.

On the other hand, we do observe a positive correlation (0.18) between the frequency of price changes and the standard deviation of inflation innovations, indicating that items with more frequent price changes tend to have greater volatility. This positive correlation is in line with the predictions of the Calvo (1983) and Taylor (1980) sticky-price models.

The discussion on the persistence of inflation assumes that the growth rate of marginal cost is serially uncorrelated. This assumption may be the reason for the failure of the Calvo (1983) model in the

figures presented above. To test this assumption a measure of marginal cost, or at least its persistence is needed. In general, marginal cost is expressed as payments to labor, i.e., unit labor cost. For Armenia, there is no directly published labor cost indicator. However, Statistical Committee publishes quarterly series on both the number of employed and wages. The product of these two measures is the overall wage. [18] By taking the ratio of the overall wage to GDP, we can calculate a unit labor cost indicator. We use seasonally adjusted series of the natural log of the unit labor cost to test marginal cost persistence. We find that the growth rate of the unit labor cost is actually negatively serially correlated, with an AR(1) parameter of -0.36 and standard error of 0.28. This estimate suggests a low persistence in marginal cost.[19] Therefore, it can be concluded that the lack of persistence in the inflation series is a problem in sticky-price models; they over-predict persistence.

7. Concluding Remarks

Using CPI data from the Statistical Committee, we document several facts about Armenian consumer prices from January 2006 through December 2021.

First, we find that price changes are quite frequent. There is a great deal of heterogeneity in the frequency of price changes across the categories of goods and services. There are both flexible and sticky prices in the economy. For that, we calculate sticky and flexible price indexes to explore behavior of these prices.

In addition, we find that price changes are typically small in absolute value. The variance of inflation stems mostly from the intensive margin (size of price changes) rather than the extensive margin (fraction of prices changing). Inflation varies with both size and frequency of price increases and decreases and prices respond to major shocks by changing both the size and the frequency of price changes.

Finally, we examine whether time series for inflation are consistent with time-dependent pricing models, given the frequency of price changes we observe. Although a positive correlation between volatility and frequency of price changes is observed in the data, it is over-predicted in the models. Furthermore, the prediction of a negative correlation between the frequency of price changes and the persistence of an item's inflation is not supported by the data.

[18] Bils (1987) constructs a metric for the fluctuations in marginal cost, assuming that output (Y_{it}) can be linked to at least one of its inputs (N_{it}) through a power function: $Y_{it} = N_{it}^{\propto} f_{it}\ (all\ other\ inputs)$. The Cobb-Douglas form is a specific example where any input can take the role of input N. Bils considers the case where labor is the relevant input and expresses marginal cost as the price of labor (W) relative to its marginal product. In this case, the natural logarithm of marginal cost can be written as $z_{it} = \ln(\propto) + w_{it} + n_{it} - y_{it}$, where w, n, and y are the natural logarithms of their uppercase counterparts. Bils and Klenow (2004) suggest measuring WN as payments to labor.

[19] We consider output gap as another proxy for marginal cost to check the robustness of the results. Output gap is positively serially correlated, but not significantly. The AR(1) parameter is 0.28, with standard error 0.14.

References

- Bryan, M F and Meyer, B, 2010. “Are some prices in the CPI more forward looking than others? We think so”, Federal Reserve Bank of Cleveland Economic Commentary No. 2010/2.
- Emi Nakamura & Jón Steinsson, 2008. "Five Facts about Prices: A Reevaluation of Menu Cost Models," The Quarterly Journal of Economics, Oxford University Press, vol. 123(4), pages 1415-1464.
- Jean Boivin & Marc Giannoni & Ilian Mihov, 2007. "Sticky Prices and Monetary Policy: Evidence from Disaggregated U.S. Data," NBER Working Papers 12824, National Bureau of Economic Research, Inc.
- Josef Baumgartner & Ernst Glatzer & Fabio Rumler & Alfred Stiglbauer, 2005. "How Frequently Do Consumer Prices Change in Austria? Evidence from Micro CPI Data," Working Papers 101, Oesterreichische Nationalbank (Austrian Central Bank).
- Katsurako Sonoda, 2006. "An Empirical Analysis of Price Stickiness and Price Revision Behavior in Japan Using Micro CPI Data," Bank of Japan Working Paper Series 06-E-8, Bank of Japan.
- Klenow, Peter J. & Malin, Benjamin A., 2010. "Microeconomic Evidence on Price-Setting," Handbook of Monetary Economics, in: Benjamin M. Friedman & Michael Woodford (ed.),Handbook of Monetary Economics, edition 1, volume 3, chapter 6, pages 231-284, Elsevier.
- Luis J. Álvarez & Pablo Burriel & Ignacio Hernando, 2005. "Price setting behavior in Spain: evidence from micro PPI data," Working Papers 0527, Banco de España; Working Papers Homepage.
- Mankiw, N G and Reis, R, 2002, “Sticky information versus sticky prices: a proposal to replace the New Keynesian Phillips Curve”, Quarterly Journal of Economics, Vol. 117, pages 1,295-328.
- Mark Bils & Peter J. Klenow & Oleksiy Kryvtsov, 2003. "Sticky prices and monetary policy shocks," Quarterly Review, Federal Reserve Bank of Minneapolis, vol. 27(Win), pages 2-9.
- Mark Bils & Peter J. Klenow, 2004. "Some Evidence on the Importance of Sticky Prices," Journal of Political Economy, University of Chicago Press, vol. 112(5), pages 947-985, October.
- Martin Eichenbaum & Nir Jaimovich & Sergio Rebelo & Josephine Smith, 2014. "How Frequent Are Small Price Changes?" American Economic Journal: Macroeconomics, American Economic Association, vol. 6(2), pages 137-155, April.
- Özmen, M. Utku & Sevinç, Orhun, 2015. "Price rigidity in Turkey: evidence from micro data," LSE Research Online Documents on Economics 66507, London School of Economics and Political Science, LSE Library.
- Peter J. Klenow & Oleksiy Kryvtsov, 2005. "State-Dependent or Time-Dependent Pricing: Does It Matter for Recent U.S. Inflation?" Staff Working Papers 05-4, Bank of Canada.
- Richard De Abreu Lourenco & David Gruen, 1995. "Price Stickiness and Inflation," RBA Research Discussion Papers rdp9502, Reserve Bank of Australia.
- Sandor Valkovszky & Janos Vincze, 2001. "Estimates of and Problems with Core Inflation in Hungary," Central Bank Review, Research and Monetary Policy Department, Central Bank of the Republic of Turkey, vol. 1(1), pages 69-99.
- Sevestre, Patrick & Baudry, Laurent & Le Bihan, Hervé & Tarrieu, Sylvie, 2004. "Price rigidity. Evidence from the French CPI micro-data," Working Paper Series 384, European Central Bank.

Appendices

Appendix I. Price Spell Duration in Selected Countries

Authors	Country	Mean Duration (months)	Median Duration (months)
Bils and Klenow (2004)	US	7	4.3
Nakamura and Seinsson (2008)	US	7.5	4.7
Klenow and Kryvtsov (2008)	US	6.8	3.7
Ozmen and Sevnc (2011)	Turkey	1.6	-
Reiff and Varhegyi (2013)	Hungary	less than 5	-
Baumgartner (2005)	Austria	14.1	11.1
Baudry (2004)	France	8.4	6.2
Aucremanne and Druant (2005)	Belgium	-	13
Buckle and Carkson (2000)	New Zealand	6.7	-
Dias and Neves (2004)	Portugal	-	8.5

Note: Source of the duration numbers is corresponding studies.

Appendix II. Median Duration of Price Spell, 2006-2021 with thresholds for price changes

	Without threshold	$\|p_{it}\|$>0.1%	$\|p_{it}\|$>0.5%	$\|p_{it}\|$>1%
All goods and services	2.4	4.8	6.3	8.3
Food	0.2	0.5	1.5	3.1
Non-food	0.3	0.8	2.3	4
Services	6.1	13.6	15.9	18.7
By 12 main consumption categories				
Food And Non-Alc.	0.2	0.5	1	2.7
Alcohol And Tobacco	0.3	0.9	2.9	6.8
Clothing And Footwear	0.1	0.4	0.8	1.2
Housing, Water, Gas, Electricity etc.	1.5	4.6	6.7	8.3
Furnishings, Household, Maintenance	0.3	0.7	1.7	3
Health	1.5	1.5	4	7.5
Transport	2.6	3	4.7	8.8
Communications	23	54.1	55.2	56.1
Recreation And Culture	0.3	1	1.9	3.1
Education	1.9	2.5	3.3	4.4
Restaurants And Hotels	0.4	1.2	3.8	14.3
Miscellaneous Goods And Services	10.1	4.8	9.3	11.2

Notes: Sample runs from January 2006 through December 2021 and includes data from capital Yerevan and all 10 regions. The source of data is Statistical Committee. Implied median durations are reported in months. "Implied median duration" is equal to $ln(0.5)/ln(1-fr_i)$*, where* f_i *is the mean frequency of price change. Durations are weighted by CPI expenditure weights. Thresholds are defined so that price changes only larger than the specific value in absolute term are considered price change.*