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Evidence for the Explosive Behavior of Food and Energy Prices: Implications in Terms of Inflation Expectations

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Evidence for the Explosive Behavior of Food and Energy Prices: Implications in terms of Inflation Expectations*

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In this paper, using the recent recursive unit root tests proposed by Phillips et al. (2015), we identify and date-stamp the periods where processed food and energy prices deviate explosively from core inflation and analyze its implications in terms of anchoring inflation expectations. During the period of January 2003-March 2017, we identify existence of three such episodes. Identifying these explosive periods is particularly important, since the evidence reveals that consumers change, i.e., revise their inflation expectations during periods when processed food and energy prices deviate explosively from core inflation. Results indicate that when forming inflation expectations, consumers rely on macroeconomic variables as well as past inflation both in normal and explosive periods. A particularly important policy implication of these findings is that periods of explosive deviations of processed food and energy prices from core inflation should be monitored while designing policies to anchor inflation expectations.

Keywords: Explosive behavior, food prices, inflation expectations, Generalized sup ADF test, inflation, core inflation

JEL Classification: C5, E31

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Non-technical summary

Increasing trend of Turkish food prices which display quite divergent behavior in recent years from world food prices becomes a major concern and needs to be examined in the face of potential adverse effects on consumer welfare as well as on the headline inflation. In this study, our focus is on rising food prices as well as energy prices not in terms of being an important driver of inflation due to their high share within CPI, but creating a divergence between headline and core inflation, subsequently posing a difficulty in anchoring consumer inflation expectations. Concern about their impact on inflation expectations arise from the fact that consumers may read large increases in food and energy prices as signals of upcoming inflation and thereby revise their inflation expectations. Henceforth, when headline inflation diverges from core inflation repeatedly, not in a transitory manner, then this may pose difficulty in anchoring inflation expectations for central bankers.

Motivated with these ideas and the recent debate about the rising food prices in Turkey, in this study, we initially identified the periods where processed food and energy prices have explosively deviated from core inflation. On the basis of the findings, three such episodes are detected. Thereafter, an inflation expectations framework that integrates these explosive periods is specified to get a notion about the impacts of explosive behavior of food and energy prices on inflation expectations.

To the best of our knowledge, this study has been the first attempt that searches for the explosive behavior in processed food and energy prices relative to core inflation and its implications on consumers' inflation expectations for the Turkish economy. Our findings reveal that consumers change their expectations when they observe explosive deviations of food and energy prices from core inflation. Furthermore, when forming inflation expectations, consumers rely both on past inflation and information coming from macroeconomic variables during normal and explosive periods. An important policy implication of these outcomes is that behavioral change in inflation expectations during explosive periods requires close monitoring of the food and energy prices, while designing policies to anchor inflation expectations.

1. Introduction

Food prices in Turkey have displayed an upward trend with an increasing pace in recent years, dominating the discussions about rising Consumer Price Index (CPI) inflation. This surge in food prices becomes a major concern as unprocessed food group being one of the main drivers of inflation on the account of giving the highest contribution to inflation together with exchanges rate during the episode of 2006-2016[1]. Furthermore, volatility inherent in unprocessed food prices lead to dramatic swings in the contribution of food prices to inflation, while being one of the major drivers of inflation volatility.

Subsequently, in order to shed some light to these ongoing debates on rising inflation from a different perspective, we decided to focus on rising food and energy prices not in terms of being an important driver of inflation, but creating a divergence between headline and core inflation, therefore posing a difficulty in anchoring consumer inflation expectations. Inflation expectations play an essential role in the analysis of monetary policy. Since consumers may read large increases in food and energy prices as signals of upcoming inflation and thereby revise their inflation expectations, when headline inflation diverges from core inflation repeatedly, not in a transitory manner, then this may pose difficulty in anchoring inflation expectations for central bankers. Furthermore, this persistent divergence also activates the debate about whether monetary policy should focus on core versus headline inflation, as widely discussed by Thornton (2007, 2011) and Bullard (2011).

Along with these debates, the findings put forward by Arora et al. (2013) have motivated our study. Arora et al. (2013) identified episodes where headline inflation deviates from core inflation[2] in an explosive manner in the US economy, again with the worries about sharply increasing food prices. They find out that consumers set their inflation expectations differently under normal and explosive periods, building up their inflation expectations relying more on past inflation in explosive periods as compared to non-explosive periods.

Volatility and increases in food prices have serious impacts on consumer welfare as well. Consumers allocate an important share of their budget to food consumption in Turkey[3]. Over and above, food consumption constitutes an important part of household spending[4] especially for the poorest households, i.e., for the lowest 20 percent quintile of income, amounting to 30.2 percent of household expenditures. Therefore, severe and sustained divergence of food prices from other prices in the economy should be monitored when trying to anchor inflation expectations.

[1] Contribution of unprocessed food prices and exchanges rates to inflation have been 1.3 percentage points on average during the 2006-2016 period (Kara et al., 2017).
[2] Prices excluding food and energy.
[3] On the basis of latest Household Budget Survey 2015, carried out by Turkish Statistical Institute, consumers raised their allocation for food and non-alcoholic beverages within total household consumption expenditure from 19.7 percent in 2014 to 20.2 percent in 2015.
[4] Second item after spending on housing and rent, which is 26 percent of household expenditures. For more information regarding weights by main expenditure groups within CPI, see website at http://www.turkstat.gov.tr/PreIstatistikTablo.do?istab_id=1347

Henceforth, being motivated by findings of the study by Arora et al. (2013) and the evidence provided by Kara et al. (2017) regarding major role of unprocessed food prices in driving inflation in Turkey, we decided to search for the explosive behavior of food and energy prices to get insights about the behavior of inflation expectations in these periods. It is particularly mentioned by Kara et al. (2017) that managing expectations is crucial to achieve price stability in Turkey, considering four percentage points of inflation on average, which cannot be explained by macro fundamentals but persistence in pricing behavior due to expectation behavior. Henceforth, in this study, we initially aim to explore the periods where processed food and energy prices have explosively deviated from core inflation[5]. Core measures of inflation are monitored closely in conducting monetary policy in Turkey and will be widely discussed in the next section. Our particular concern will be on CPI, rather than gross domestic product (GDP) deflator[6], because inflation target in Turkey is set on the basis of CPI.

In order to identify explosive periods, among various econometric test procedures proposed in the literature, we decided to rely on a recent methodology developed by Phillips et al. (2015), which produce novel evidence on the testing and dating of multiple bubbles in the data. Along with this methodology, we basically search for the explosiveness as the statistical property of a time-series through recursive right-tailed Augmented Dickey-Fuller (ADF) unit root tests. Additionally, this innovative technique delivers an ex ante dating algorithm relying on a recursive backward regression technique, whereby one can time-stamp the origination and termination dates of explosiveness.

In order to address our ultimate concern of getting insights about the impacts of explosive behavior of food and energy prices on inflation expectations, we followed the framework proposed by Arora et al. (2013). As baseline specification for inflation expectations, we modify the inflation expectations framework proposed by Başkaya et al. (2012) in compliance with the specification proposed by Mankiw et al. (2004) to get a notion about adaptive expectations.

To the best of our knowledge, this article will be the first one that searches for the explosive behavior in processed food and energy prices relative to core inflation and its implications on consumers' inflation expectations for the Turkish economy. Our findings reveal that consumers rely both on past inflation and information coming from macroeconomic variables when forming inflation expectations during normal and explosive periods. Results indicate that consumers change their expectations when they observe explosive deviations of food and energy prices from core inflation.

[5] We consider as core inflation, the core index C, which is defined as CPI excluding energy, food and non-alcoholic beverages, alcoholic beverages, tobacco and gold. Afterwards, we mean core C index whenever we mention core inflation.

[6] GDP deflator is used frequently as an indicator of inflation in empirical studies. Arora et al. (2013) also use headline price index of personal consumption expenditures in their analysis rather than CPI.

This study is designed as follows. Section 2 presents the methodology for explosive deviations as well as findings. Section 3 discusses implications in terms of inflation expectations and provides empirical findings. Section 4 reviews our findings.

2. Methodology for Explosive Deviations, Data and Findings

2.1. Methodology

2.1.1. The right-tailed unit root tests

There have been many attempts to develop ex post econometric tests to detect 'rational' bubbles in the literature (see Gürkaynak (2008) for review). By the virtue of econometric techniques, it is possible to detect exuberance. Diba and Grossman (1988) were the first to propose a test to detect the explosive behavior of rational bubbles in the stock market. They employ unit root tests by looking at the right-tail distribution and testing unit root null against the explosive alternative. This approach is criticized by Evans (1991) arguing that unit root tests are not effective to detect periodically collapsing bubbles. It is recognized that linear unit root tests and cointegration tests generally reject the presence of bubbles, even when they exist.

To overcome this failure of traditional testing approaches, Phillips et al. (2011) proposed an approach built upon the idea of Diba and Grossman (1988), but getting rid of the failures of running a single test. They proposed an ex-ante approach and used right-tailed Augmented Dickey Fuller (ADF) tests to detect exuberance in asset price series during an inflationary phase. Instead of running a single test over the whole sample period, test is run over subsets of the sample incremented by one observation at each run. They called this method as the *Supremum Augmented Dickey Fuller* (SADF) test in which the alternative hypothesis is the point of interest unlike left-sided unit root tests.

This methodology is based on the standard ADF regression equation expressed as follows:

$$\Delta y_t = \alpha_{r_1,r_2} + \beta_{r_1,r_2} y_{t-1} + \sum_{j=1}^{k} \psi_{r_1,r_2}^{j} \Delta y_{t-j} + \varepsilon_t, \varepsilon_t \overset{iid}{\sim} N(0, \sigma_{r_1,r_2}^2)$$

where k is the lag order. r_1 and r_2 stand for the fractions of the sample. The recursive estimation involves the rolling window regression where the sample starts from the r_1^{th} fraction of the sample (T) and ends at the r_1^{th} fraction of the sample. The fractional window size of the regression r_w is greater than zero and related to r_1 and r_2 as follows: $r_2 = r_1 + r_w$.

The SADF test sets the starting point r_1 fixed at zero. Sample size for the first regression will be $[Tr_o]$ and expand one observation at each run until the sequence reaches the end of the sample $[Tr_w = T]$. In other words, there is repeated estimation on forward expanding sample sequence as the window size r_w expands from r_0 to 1 in the recursion. r_0 stands for the smallest window width fraction whereas 1 is the largest window fraction. Then, r_2, which is the endpoint of each sample, is equal to r_w and changes from r_0 to 1. $ADF_0^{r_2}$ represents the ADF test statistics for a sample that runs from 0 to r_2. Subsequently, the SADF test statistic is expressed as follows:

$$SADF(r_0) = \sup_{r_2 \in [r_0, 1]} \left\{ ADF_0^{r_2} \right\}$$

Phillips et al. (2011) argue that this approach can assist central bank surveillance teams and regulators due to its early warning diagnostics. Furthermore, it is claimed that this "procedure can detect market exuberance arising from a variety of sources, including mildly explosive behavior that may be induced by changing fundamentals such as a time-varying discount factor" (Phillips et al., (2015):1045). Although this real-time bubble detection algorithm has greater power than other recursive procedures, it is realized that it may suffer from reduced power when there are multiple episodes of exuberance and collapse in the data.

This weakness is overcome by Phillips et al. (2015) through proposing a new method called a *generalized sup ADF* (GSADF) test. This new procedure also relies on recursive right-tailed ADF tests and allows to time-stamp the bubble origination and termination dates. However, unlike the SADF, this new procedure uses flexible window widths and extends the sample coverage through changing both the start (r_1) and end point (r_2) of the recursion over a flexible windows range in real-time analysis. GSADF is defined as the largest ADF test statistic obtained from a right-sided double recursive test over all feasible ranges from r_1 to r_2 given a minimal window size r_0. $ADF_{r_1}^{r_2}$ is the ADF test statistics obtained from each recursive sequence, defining supremum of this sequence. Hence, GSADF test is expressed as follows:

$$GSADF(r_0) = \sup_{\substack{r_2 \in [r_0, 1] \\ r_1 \in [0, r_2 - r_0]}} \left\{ ADF_{r_1}^{r_2} \right\}$$

In the literature, Homm and Breitung (2012) compare the power of various methods to detect bubbles. What they found is that the SADF test has the maximum power as well as being able to detect alternative forms of bubbles including that of Evans (1991). Later, Phillips et al. (2015) show through a Monte Carlo study that the GSADF test outperforms the SADF test in the presence of multiple bubbles.

2.1.2. The date-stamping strategy

The date-stamping strategy proposed by Phillips et al. (2015) is to perform SADF tests in a backward expanding window where the endpoint of each sample is fixed at r_2 and the starting point varies from 0 to r_2-r_0. For a given r_2, the so-called *backward sup ADF* (*BSADF*) statistic sequence is defined as:

$$BSADF_{r_2}(r_0) = \sup_{r_1 \in [0, r_2 - r_0]} \left\{ ADF_{r_1}^{r_2} \right\}$$

Then, the estimated origination date of an explosive period, r_e, is defined as the first observation in which *BSADF* statistic exceeds the critical value of the *backward sup ADF* statistic:

$$\hat{r}_e = \inf_{r_2 \in [r_0, 1]} \left\{ r_2 : BSADF_{r_2}(r_0) > scu_{[r_2 T]}^{\alpha} \right\}$$

and estimated termination date of explosive period, r_f, is calculated as the first observation after r_e where the *BSADF* statistic falls below its critical value:

$$\hat{r}_f = \inf_{r_2 \in [\hat{r}_e, 1]} \left\{ r_2 : BSADF_{r_2}(r_0) < scu^{\alpha}_{[r_2 T]} \right\}$$

where $scu^{\alpha}_{[r_2 T]}$ is the 100(1-α) % critical value of the sup ADF test. α is the chosen level of significance.

Then, the backward sup ADF statistic is related to GSADF statistic as follows:

$$GSADF(r_0) = \sup_{r_2 \in [r_0, 1]} \left\{ BSADF_{r_2}(r_0) \right\}$$

Unlike the conventional multivariate analysis, this methodology does not necessitate the understanding of the mechanism, while yielding higher accuracy. Recursive right-sided unit root tests seem to be quite effective in detecting mildly explosive behavior and market exuberance in data, irrespective of its origins. On the other hand, one should not come up with the expectation that this methodology predicts whether a price bubble will arise. They can however tell whether one has occurred.

This data driven methodology has been applied rapidly in the literature across various areas due to its ability to identify whether there exist periods of explosive behavior and multiple bubbles. One of the papers using that methodology and close to our study in terms of its area of interest, i.e., inflation, is by Liu et al. (2014). They have applied these recursive unit root tests to confirm the presence of inflation and to identify inflationary periods in China. This is a new perspective in that they propose to judge existing inflation through identifying CPI bubbles. CPI bubble is supposed to indicate inflationary pressure. It is argued that CPI cannot differentiate between sector specific shocks and aggregate shocks. Furthermore, it is claimed that a great deal of high frequency noise embodied in typical measures of inflation prevents to a great extent the detection of sustained movements in inflation, which would serve as early warning signals.[7]

2.2. The Data

In this study, we use monthly data covering the period from January 2003 to March 2017. This whole period corresponds to different monetary policy regimes in Turkey. From 2003-2006, there was implicit inflation targeting regime, which was then followed by inflation targeting period from 2006 to 2017. Inflation targeting regime period in itself is also characterized by two different approaches: conventional period from 2006 to 2011 and flexible regime afterwards integrating financial stability objective as well.

The Central Bank of Turkey announces inflation forecasts related to core inflation measures as well as forecasts of headline inflation. There exist different indicators of core inflation in

[7] For references in the literature such as Bryan and Cecchetti (1994) and Christadoro et al. (2005), see Liu et al. (2017).

Turkey[8]. Among these core inflation measures, we have chosen C and D core inflation measures as the relevant ones in terms of the scope of this study. Core index C is defined as CPI excluding energy, food and non-alcoholic beverages, alcoholic beverages, tobacco and gold. On the other hand, core index D is an index which excludes unprocessed food, alcoholic beverages and tobacco from CPI.

Since we aim to examine periods where food and energy prices display explosive behavior, we deal with the relative price series, obtained first by deflating headline inflation by core C index and then core D index by core C index (Figure 1b). Hence, we have two relative price measures to explore in this study. The reason that we choose core D index rather than headline inflation to calculate the relative price series is that although increases in unprocessed food prices are the main factor behind rapidly rising food prices in Turkey, unprocessed food prices are the most volatile sub-group within the CPI (Figure 1a). The extent of volatility of unprocessed food prices can be five times higher than the volatility of headline inflation[9] (Öğünç, 2010). Thus, this volatile pattern poses a difficulty for policymakers while making food inflation forecasts as well as conducting monetary policy. Given the unprocessed foods are subject to temporary shocks as well, policymakers establish their medium-term policies through examining price movements excluding the part affected by volatile and temporary shocks. Therefore, we choose core D index as a broad inflation measure, while getting rid of the volatility coming from unprocessed food prices.

Both the headline CPI and core inflation indicators (C and D) are taken from the Turkish Statistical Institute[10]. All price series are seasonally adjusted and base year is 2003.

Figure 1a) Food Price Indexes in Turkey

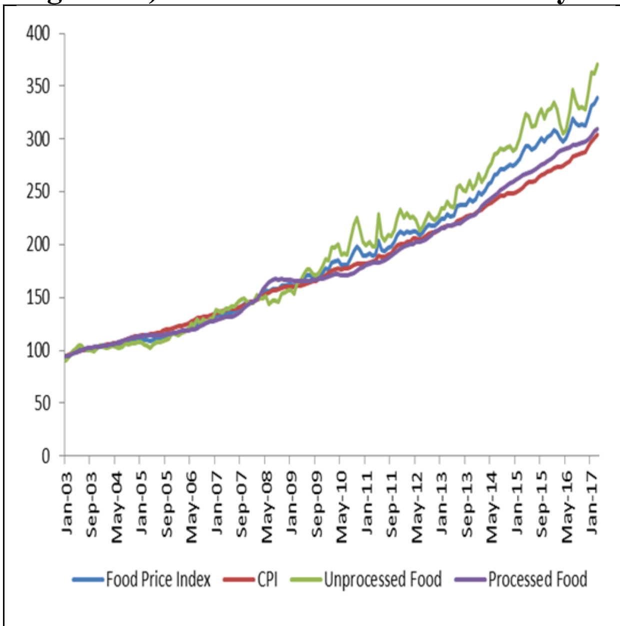
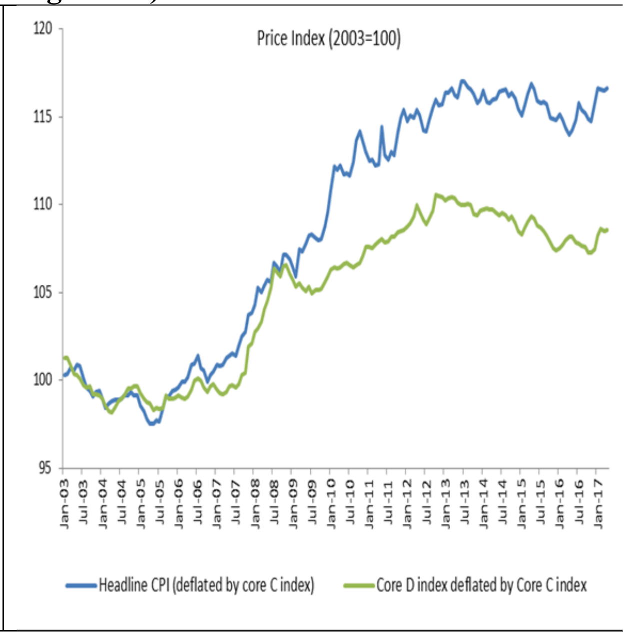


Figure 1b) Relative Prices



[8] See Atuk and Özmen (2009).

[9] Furthermore, monthly food price changes in Turkey are four times more volatile than those in EU-27 and that difference in volatility rises to six times when unprocessed foods are concerned (Ögünç, 2010).

[10] Data are available at http://www.turkstat.gov.tr/PreIstatistikTablo.do?istab_id=648

2.3. Findings for Explosive Behavior

Table 1 report the GSADF statistics for relative price measures, i.e., headline inflation deflated by core C index as well as core D index deflated by core C index for the full sample from January 2003 to March 2017. The critical values are obtained from Monte Carlo simulations with 2000 replications. The minimum window size, r_0, is chosen by the rule of thumb of Phillips et al. (2015), $r_0=0.01+1.8/\sqrt{T}$.[11] Concerning lag selection, Phillips et al. (2015) recommends applying fixed lags, Bayesian information criterion (BIC) order selection and sequential significance testing. As regards to BIC order selection, they note that "use of BIC lag order selection satisfactorily controls size for SADF but is less adequate for GSADF where the test is oversized". The choice of a fixed lag length approach is appealing, since Phillips et al. (2012) also indicate that more sophisticated lag length selection procedures based on information criteria[12] and sequential hypothesis testing[13] could result in severe size distortions as well as a reduction in the power of both SADF and GSADF tests. Furthermore, it should be noted that such procedures have higher computational cost. Hence, in this study, fixed lag length approach is followed as suggested by Phillips et al. (2015). They express that the size of SADF and GSADF tests is reasonably well controlled when a small fixed lag length is used in the recursive tests and find having best size properties with either no or one lag. Furthermore, omitting lags overall deals with the size distortion issue as claimed by Phillips et al. (2015) that "when k = 0 (no transient dynamics are present in the system), there are no serious size distortions in the tests". On the basis of these recommendations by Phillips et al. (2015), the test statistics are estimated using fixed lag length of zero.

On the basis of the test results in Table 1, the null hypothesis is rejected in favor of the existence of explosive periods. Thus, there is evidence for multiple explosive periods in both relative price series. GSADF results reveal that regarding the relative prices of core D index deflated by core C index, null hypothesis is strongly rejected at all significance levels, whereas concerning headline inflation deflated by core C index, the null hypothesis is rejected at 95% and 90 % significance levels only.

Table 1: The Generalized Sup ADF Test Results

	Headline CPI (deflated by core C index)	**Core D index deflated by Core C index**
GSADF	2.741182**	4.575191***
*Test critical values**		
99% level	2.892961	2.792436
95% level	2.185939	2.111662
90% level	1.904162	1.827864

*Critical values are based on Monte Carlo simulations with 2,000 replications

[11] Our results are robust to different choices of window sizes at specific lag lengths such as zero and one. As different window sizes, we run for 16, 17, 24 and 25 and found robust test results.
[12] Such as the Modifed Information Criteria of Ng and Perron (2001)
[13] See for instance Ng and Perron (1995)

After getting evidence for the existence of multiple explosive periods, we proceed with the backward SADF statistics of Phillips et al. (2015) to identify the origination and termination dates of the explosive periods. Figure 2a and 2B plot the backward SADF statistics against its 95% critical value sequence for the relative prices, which are again obtained from Monte Carlo simulations with 2000 replications. Blue lines and red lines in Figure (2a) and (2b) are the corresponding BSADF test statistics and 95% critical values respectively. On the basis of these statistics, we identified explosive periods in the series wherever the BSADF test statistics exceed their 95% critical value. We blue colored these periods.

Figure (2a) plots the explosive periods pertaining to core inflation D deflated by core inflation C, which gives the relative price movement of processed food and energy with respect to core inflation. It appears that there exist three such events: NOV07-JUN09, AUG09, NOV09-AUG13.

In Figure (2b), identified explosive periods for the headline inflation deflated by core C inflation are MAY06-JUL06, SEP07-MAY12, SEP12-APR13, JUNE13-JULY13. It can easily be noticed that there exist small breaks between explosive periods, most probably reflecting the noisy and volatile nature of unprocessed foods.

Therefore, we will focus on the explosive periods obtained from the analysis on core inflation D deflated by core inflation C, i.e. divergence of processed food and energy prices relative to core inflation. The first episode that starts in November 2007 lasting until June 2009, involves the period of Great Draught. As can be noticed from Figure (3a), the first price spike registered in the period of 2007-2008 corresponds to the Great Draught that brought about by more than 50 percent price hikes in the nominal prices of almost all international food commodities, reaching its peak in June 2008. Likewise, starting from 2007 during that whole period, food prices recorded increases in real terms in Turkey.

Thereafter, following a few months break recorded in 2009 except the month of August, processed food and energy prices start presenting explosiveness relative to other prices again in November 2009 that lasts until August 2013. The most dramatic explosive deviation happens in this episode that stays about almost four years. Within that period, world food prices recorded their second spike in December 2010.

During that whole period from 2007 till 2013, energy prices were on the rise in Turkey, registering great spikes except a small period at the end of 2008 and first half of the year 2009, as can be noticed from Figure (3b). Energy prices in Turkey stayed almost stable after August 2013 till their latest small peak in June 2014 and then followed by pursuing decline. In the same manner, world food prices displayed more or less a stable pattern after 2012, registering their final peak in March 2014 and then followed by a subsequent decline. Subsequently, shocks to both world food prices and energy prices in Turkey seem to be the decisive factors in creating explosive behavior in the prices of processed food and energy with respect to core inflation.

Figure 2a: Explosive Periods in Core Inflation D (deflated by Core Inflation C)

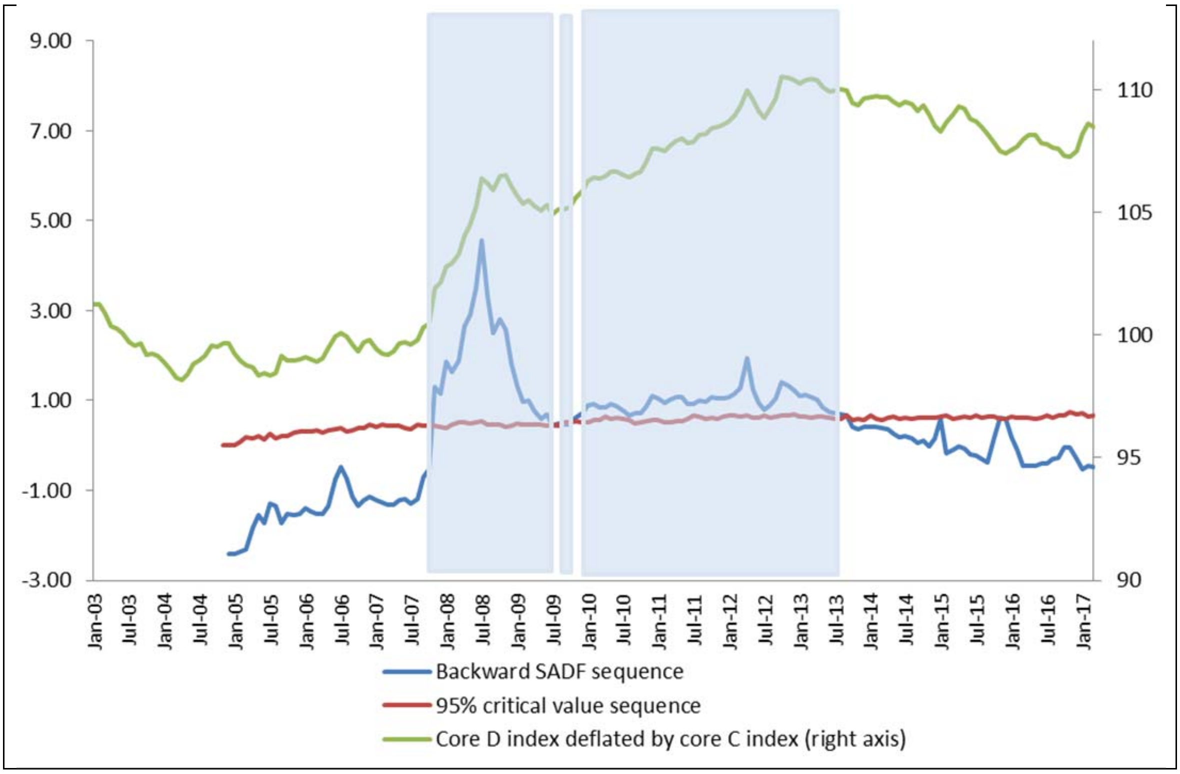


Figure 2b: Explosive Periods in Headline CPI (deflated by Core Inflation C)

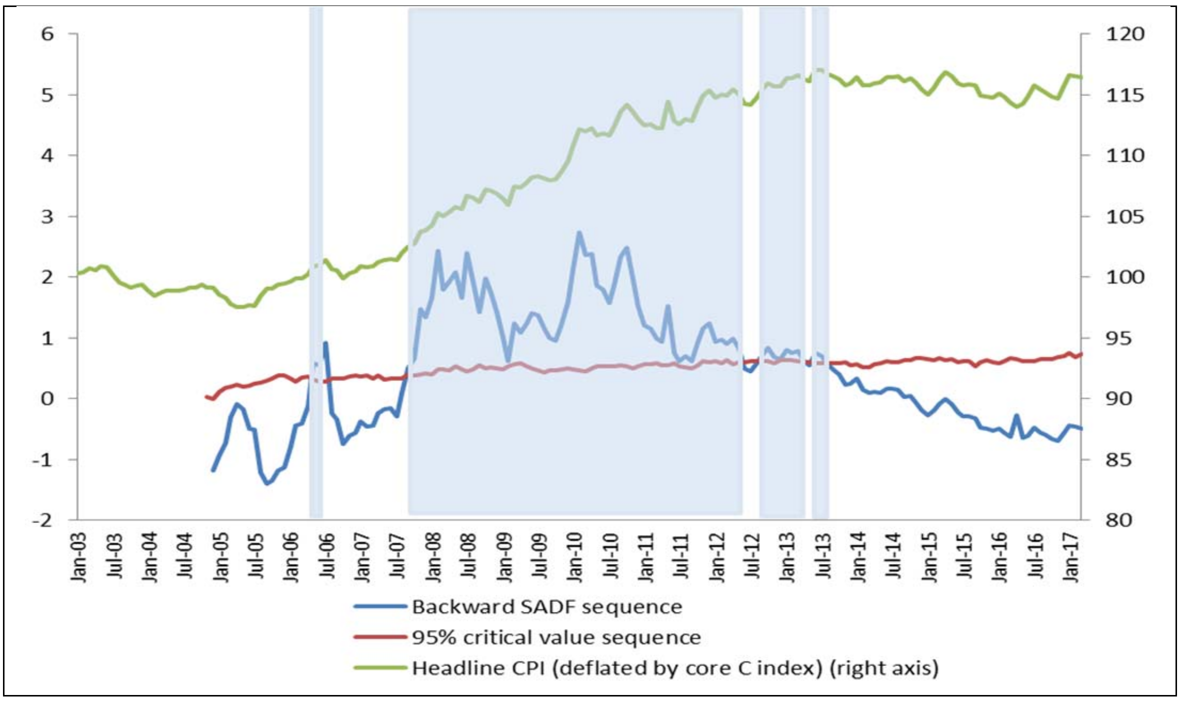


Figure 3a: World and Turkish Food Price Indexes

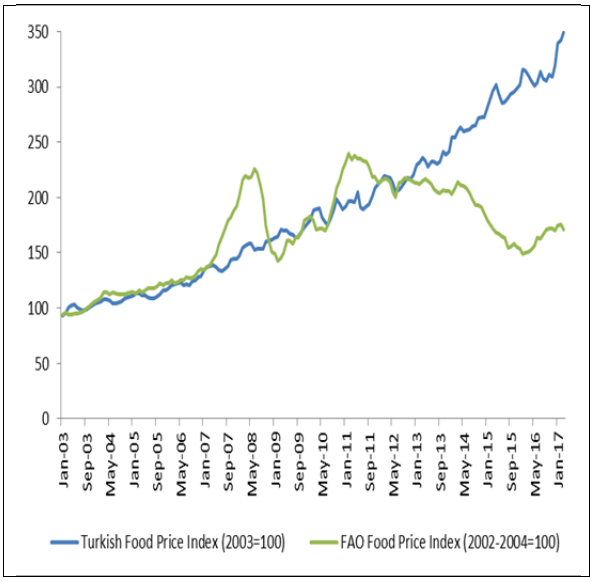
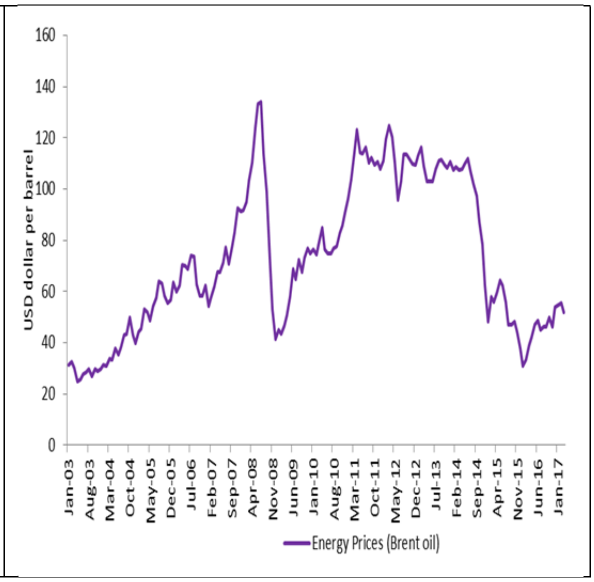


Figure 3b: Energy Prices in Turkey



3. Implications of Explosiveness on Consumers' Inflation Expectations

There exists an extant literature on how expectations are formed and respond to changes in the policy regime. Traditional macroeconomics textbook approach is to assume that everyone share a common information set on the basis of which their expectations are formed. Nonetheless, the fact that there might be disagreement among people about expectations, which also displays substantial variation over time, is generally ignored. This failure is overcome by Mankiw and Reis (2002) through introducing a "sticky-information" model with disagreement at its very heart. In this model, rational and forward-looking agents update their expectations only periodically due to costly information, thereby giving rise to inflation persistence.

Mankiw et al. (2004) explore whether this model is able to predict the disagreement observed in survey data. What they find out is that agents do not fully incorporate all past inflation information. These "sticky-information" expectations are influenced by macroeconomic variables, while recent macroeconomic data is not adequately incorporated in inflation expectations. More than that, in their analysis as regards to whether the survey data are consistent with adaptive expectations, they conclude that "observed inflation expectations are consistent with neither the sophistication of rational expectations nor the naiveté of adaptive expectations" irrespective of the sources of survey data used[14]. Correspondingly, their findings suggest that inflation expectations are not updated instantly but partially and incompletely in response to macroeconomic news, suggesting an updating scheme that occurs in a staggered manner. Finally, it should be mentioned that their analysis implies that disagreement will vary with macroeconomic conditions.

[14] Mankiw et al. (2004).

3.1. Benchmark regression

Conforming to the questions asked about survey data by Mankiw et al. (2004) and later explored by Arora et al. (2013) for the US economy, we first aim to get a benchmark specification for inflation expectations in Turkey. So far, inflation expectations have been modelled for Turkey by Başkaya et al. (2010) and Başkaya et al. (2012).

Since our ultimate concern is to get a better insight about impacts of explosive behavior of food and energy prices on inflation expectations, we use a variation of the framework of inflation expectations proposed by Başkaya et al. (2012) as baseline specification. In order to get a notion about whether the survey data are in line with adaptive expectations, we modified their model in compliance with the specification proposed by Mankiw et al. (2004) for adaptive expectations.

In simplest terms, adaptive expectations can be defined as forming future expectations solely based on past events. In adaptive expectations model, people are expected to base their expectations of future inflation on recently observed inflation. Then, we can define baseline regression as follows:

$$E_t\pi_{t+12} = \alpha + \beta(L)\pi_t + \lambda Y_t \tag{1}$$

where $E_t\pi_{t+12}$ represents one-year ahead consumers' inflation expectation, π_t is inflation and L is the lag operator. Y_t stands for macroeconomic variables that are expected to affect inflation expectations in Turkey. These macroeconomic variables are exchange rate, industrial production, oil prices and interest rate[15]. Exchange rate, industrial production and oil prices are selected being specific to Turkey on the basis of the study by Başkaya et al. (2012). Interest rate is integrated to the model with reference to Mankiw et al. (2004).

More explicit representation of the benchmark regression is as follows:

$$E_t\pi_{t+12} = \alpha + \beta(L)\pi_t + \gamma Exchrate_{t-1} + \kappa Indprod_{t-2} + \delta OilP_{t-1} + \phi i_{t-1} \tag{2}$$

Here, exchange rate (*Exchrate*) variable is the annual percentage change in the monthly average TL/$ value. Industrial production (*Indprod*) variable represents the deviation of the seasonally adjusted industrial production from its trend calculated using HP filter. Oil price (*OilP*) variable is the annual change in crude oil prices. Finally, interest rate (*i*) variable stands for the monthly benchmark interest rate. The number of lags selected for the variables, *Exchrate*, *Indprod* and *OilP*, in this study exactly matches with those in the study of Başkaya et al. (2012). The period of analysis in regressions is from January 2004 to March 2017 due to annual percentage changes considered for some variables.

[15] See Table 3 in the Appendix for information about data sources.

3.2. Specification incorporating explosive period

In order to search for the change in expectations during periods of explosive deviations in relative prices, we use the benchmark setup mentioned above. On the basis of the information obtained in the previous section regarding explosive deviations in relative prices, we introduce dummy variables to capture these explosive periods as in Arora et al. (2013). In other words, the dummy variable D_t will take value of 1 when there is explosive deviation and zero otherwise. Date-stamping of explosive periods are explained in detail in the previous section together with the findings related to explosive behavior of processed food and energy prices relative to other prices in CPI.

$$E_t\pi_{t+12} = \alpha + \beta(L)\pi_t + \gamma Exchrate_{t-1} + \kappa Indprod_{t-2} + \delta OilP_{t-1} + \phi i_{t-1} + \alpha' D_t + \beta(L)' D_t\pi_t + \gamma' D_t Exchrate_{t-1} \\ + \kappa' D_t Indprod_{t-2} + \delta' D_t OilP_{t-1} + \phi' D_t i_{t-1} + \varepsilon_t \quad (3)$$

Lagged inflation term represents inflationary persistence. Regarding past inflation we have included observed annual inflation for each of the previous three months[16].

Table 2: Modelling Inflation Expectations

Dependent Variable: One-year ahead inflation expectations		
	Baseline Model (2)	**Model (3)**
Past inflation	0.199***	0.307***
	(0.058)	(0.057)
Exchange rate (t-1)	0.029***	0.034***
	(0.007)	(0.011)
Indus. Prod. Gap (t-2)	3.182*	-0.236
	(1.881)	(2.718)
Oil Price (t-1)	0.005*	0.003
	(0.003)	(0.004)
Interest rate (t-1)	-0.006	-0.048*
	(0.019)	(0.026)
Dummy*Past inflation		-0.126**
		(0.063)
Dummy*Exchange rate (t-1)		-0.012
		(0.016)
Dummy*Indus. prod. gap (t-2)		0.146
		(3.553)
Dummy*Oil Price (t-1)		0.006
		(0.006)
Dummy*Interest Rate (t-1)		0.088*
		(0.045)
Reject adaptive expectations ?		
(i) Normal periods[(i)]	F(4, 135) = 5.35***, Yes	F(4, 128) = 7.32***, Yes
(ii) Explosive periods[(ii)]		F(8, 128) = 6.83***, Yes
Joint significance (Dummies)		F(7, 128) = 2.33**

Note: Numbers in the parentheses are the Newey-West standard errors (lag truncation=4)
***, **, * represent statistical significance at the 1%, 5% and 10% respectively. (i) $H_0: \gamma = \kappa = \delta = \phi = 0$ (ii) $H_0: \gamma = \kappa = \delta = \phi = \gamma' = \kappa' = \delta' = \phi' = 0$.
Period of analysis: January 2004- March 2017

[16] Estimation results of the model (2) and (3) are not sensitive to the lag selection of the inflation variable.

Table 2 reports estimation results concerning the baseline model (2) and the model involving explosive periods (3). Following Mankiw et al. (2004) and Arora et al. (2013), we test for adaptive expectations during normal and explosive periods. Regarding the baseline model, in normal periods, we reject the null hypothesis of adaptive expectations, i.e., $H_0 : \gamma = \kappa = \delta = \phi = 0$. Hence, we can conclude that consumers take macroeconomic variables into account as well as past inflation when forming inflation expectations in normal periods.

Likewise, we reject the adaptive expectations hypothesis both for the normal period and the whole sample period in Model (3). This indicates that consumers rely on past inflation, information from macroeconomic variables as well as information related to explosive behavior in relative prices when forming inflation expectations.

Findings related to Model (3) also indicate that dummy variables of the explosive period are jointly significant, implying that the periods when processed food and energy prices deviate from core inflation explosively are taken into account when forming inflation expectations. In other words, expectations change during explosive periods.

Test results tell us that past inflation information significantly affects consumers' expectations both in normal and explosive periods. On the other hand, agents do not fully incorporate all past information of inflation ($\beta(1) < 1$). Consumers rely less on past inflation during explosive periods as compared to normal periods, since the overall effect on inflation expectations is 0.181, which is smaller than that in normal periods.

When explosive periods are taken care of in terms of expectations, both past exchange rate and past interest rate affects inflation expectations. Consumers receive different signals related to the interest rate in normal and explosive periods[17]. Consumers also use past exchange rate information, i.e., depreciation or appreciation of the Turkish lira, in forming expectations during both normal and explosive periods. However, there is no change in the behavior between these two periods. When people observe past currency depreciation, they raise their future inflation expectations. This confirms the fact that exchange rate through high pass-through effect is a major cost-push factor in driving consumer inflation (Kara et al., 2017).

[17] Impact of interest rate on inflation expectations for the overall period is 0.02, which is significant at 1% significance level.

4. Conclusion

Determining a certain tendency towards an explosive behavior in a market, if exists, gives policymakers vital information to mitigate the pressure on prices. This information gains more significance if consumers revise their inflation expectations in the face of explosive increases, posing difficulty in anchoring consumer inflation expectations that play an essential role for the monetary policy. Inspired with these ideas and along with the recent debate about the rising food prices in Turkey, in this study, we explore the periods where processed food and energy prices have explosively deviated from core inflation through a recent methodology developed by Phillips et al. (2015). The evidence indicates existence of three such episodes. When these periods are examined in terms of their influence on consumers' inflation expectations, it is realized that consumers rely both on past inflation and information coming from macroeconomic variables when forming inflation expectations during normal and explosive periods. Still the more important finding is that consumers' inflation expectations change during explosive periods. In other words, the periods when processed food and energy prices deviate from core inflation explosively are taken into account when forming inflation expectations. This behavioral change in inflation expectations during explosive periods necessitates close monitoring of the food and energy prices, while designing policies to anchor inflation expectations.

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APPENDIX

Table 3: Variable Definitions and Sources

Variable Name	Definition	Source
Inflation Expectations	One-year ahead consumers' inflation expectation	CBRT's Survey of Expectations available on http://www.tcmb.gov.tr
Inflation	Annual headline CPI inflation rate (calculated from seasonally adjusted headline CPI series)	Turkish Statistical Institute http://www.turkstat.gov.tr/PreIstatistikTablo.do?istab_id=650
Core inflation C	CPI excluding energy, food and non-alcoholic beverages, alcoholic beverages, tobacco and gold	http://www.turkstat.gov.tr/PreIstatistikTablo.do?istab_id=648
Core inflation D	CPI excluding unprocessed food, alcoholic beverages and tobacco	http://www.turkstat.gov.tr/PreIstatistikTablo.do?istab_id=648
Exchange Rate	Annual percentage change in the monthly average TL value of one US dollar	Central Bank of Turkey http://evds.tcmb.gov.tr/index_en.html
Industrial Production Gap	The deviation of the seasonal adjusted industrial production from its trend obtained using HP filter	Industrial production data available at Turkish Statistical Institute http://www.tuik.gov.tr/
Oil Price	Annual change of crude oil monthly prices (USD/barrel)	Bloomberg
Interest Rate	Monthly benchmark interest rate (available starting from April 2005)	Bloomberg

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