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RESEARCH ARTICLE

Alternative price and quantity indices for fresh fruits and vegetables

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Abstract

For central banks, whose main objective is price stability, it is crucial to expand information sets that support monitoring price development and advance methods that contribute to timely and sound predictions. Fruit and vegetable prices, which make up about a quarter of the food and non-alcoholic beverages group with the highest weight in the CPI basket, exhibit high seasonal and irregular changes due to unbalanced demand and supply conditions. Although monitoring developments in the fruit and vegetable sub-group is important due to both food security and the weight structure of the basket, available data sets and indicators are quite limited. This study aims to introduce new leading indicators that we have developed that enable monitor supply, demand and price developments of fruits and vegetables closely.

Keywords: Fresh Fruits and Vegetables, Unprocessed Food Inflation, Alternative Indicator, Price Index, Quantity Index

JEL Codes: C81, E31, Q11

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1. INTRODUCTION

Food prices have surged significantly during the post-2019 era with the pandemic. Increasing food prices has been felt more profoundly in developing countries due to high share of food consumption in total spending. This in turn caused deterioration in the inflation expectations (Goyal and Parab, 2021). Therefore, the development in food prices is not only the primary agenda of the general public and the policy makers but also followed closely by the central banks whose main objective is to attain price stability.

Food prices are an essential part of Türkiye's economy with its impacts on various sectors of the economy. For Türkiye, with 24.98% of direct and 7.40% of indirect share, the food and non-alcoholic beverages group is primarily important due to its high share in the consumption basket. Fluctuating food prices especially for critical goods like fresh fruits and vegetables affect consumers, farmers as well as the policymakers with critical consequences on food security and inflation. In this regard, understanding the dynamics of these prices, from farm to retail is important for policymakers to mitigate the volatility and promote more stable food prices.

Türkiye plays an important role in fruit and vegetable production due to its large, fertile and productive agricultural lands with ecological diversity. In 2023, approximately 59.2 million tons of fresh fruits and vegetables produced in Türkiye, which is among the top 10 countries in total fruit and vegetable production, were consumed in both domestic and foreign markets (TURKSTAT, 2023). According to FAOSTAT (2022), Türkiye with a share of 2.3% in total global production, ranks the 6th in global fruits and vegetables production after China, India, Brazil, the USA and Indonesia.

In Türkiye with an aim to contribute cost reduction and price stability in unprocessed food prices in the short and medium terms Law No. 5957 on "Regulating the Commerce of Fruits and Vegetables and Other Goods Having Enough Supply and Demand Level" was enacted in 2010 (Official Gazette of Türkiye, 2010). Pursuant to this law, the Ministry of Trade in Türkiye established the Wholesale Market Registration System (WMRS). This study aims to introduce new indicators based on this data from the Republic of Türkiye Ministry of Trade's Wholesale Market Registration System (WMRS) in order to closely monitor the supply, demand and price developments of fresh fruits and vegetables. Those proposed new indicators are expected to make an important contribution for monitoring the supply and demand balance and prices of fresh fruits and vegetables and may serve as an input for modelling and forecasting studies.

There exist a considerable body of literature on food prices focusing on fresh fruits and vegetables in Türkiye. Moreover, various theories have been proposed to construct alternative prices and quantity indices which can be applied for agricultural products. However, as to our knowledge, there is no alternative indicator to observe supply and demand dynamics in the fresh fruits and vegetables market. The next section provides a literature review on alternative indices and summarizes the previous research on fresh fruits and vegetable prices in Türkiye. Literature review is followed by introducing our comprehensive and up-to-date dataset and how we used it to construct alternative price and quantity indices for fresh fruits and vegetables.

2. LITERATURE REVIEW

Developing alternative price and quantity indices for food prices has become significantly important as the complexities in agricultural markets are being observed more profoundly. The existing literature on alternative indices for food prices mainly focus on measuring the price changes for food products especially the products experiencing high volatility. Traditional price and quantity index models (e.g. Laspeyres, Paasche and Fisher Indices) has long been used to estimate food inflation especially in volatile markets such as fruits and vegetables. While these indices provide essential information on how prices evolve over time, traditional methods come with trade-offs. Using traditional methods in agricultural markets come with challenges due to the unique nature of the products. Traditional indices often fail to capture the quality changes especially in perishable goods like fresh fruits and vegetables. Moreover, incorporating seasonality is lacking in using traditional models. Lastly, the models might fail to capture the substitution effect associated with demand shifts due to changes in prices.

Constructing alternative indices seek to address the limitations of traditional indices mentioned above particularly

in the highly volatile sectors like agriculture and especially fresh fruits and vegetables. There are numerous studies in regards to developing alternative index construction in economic theory applied to agricultural products. The US Bureau of Economic Analysis has established models to develop alternative price and quantity indices using index number theory and its applications (Kornfeld, 2021). They use chain-type indices which updates the weights more often to reflect consumption and production patterns more up-to-date. Regression models are also widely used to capture the price changes. Volpe (2013) focuses on the dynamics between transportation costs and wholesale prices of fresh produce, finding a significant impact. Wohlgenant (2001) analyzes the transmission system in beef prices which can be adopted to fresh produces as well. He explores how price changes at different levels of the supply chain impact consumer prices using linear regression models.

Another point to mention is to incorporate weather variations. It is well-known that fresh fruit and vegetables production is highly sensitive to sudden and unexpected weather changes. In this regard, there are weather and risk-based indices to incorporate climate variability. These indices mainly focus on meteorological data or satellite data to capture the impact of climate variability on quantity and price. For instance, Climate Risk Index combines data on storm intensity, flood frequency and drought conditions making it an essential tool for understanding how changing climate patterns affect food security and agricultural production (Germanwatch, 2020). Another example is Agricultural Stress Index System by Food and Agriculture Organization (FAO) using satellite data to monitor agricultural stress which is shown to be useful in early warning systems for global agricultural production (Kogan, 2000). There are significant amount of weather and risk-based indices highlighting the growing importance of weather changes in agricultural markets. Another type of index is crop-specific price indices. These indices require weighting methodologies that reflect both price and quantity changes over time. The shares are mostly driven by expenditure shares emphasizing the importance of different products in a region. Studies show that selecting weighting schemes is particularly important to accurately reflect market conditions (Diewert, 2010). Holt and Craig (2006), using dynamic pricing models, incorporates real-time data to adjust crop price indices dynamically. FAO Food Price Index uses a similar methodology with an aim to create a global indicator (FAO, 2024). Unites States Department of Agriculture's Fruit and Vegetable Reports include price indices for major fruits and vegetables which are used to track market movements and inform trade policies (USDA, 2023). European Union's Fresh Produce Index is another example tracking the retail and wholesale prices of fresh fruits and vegetables helping to analyze supply chain efficiency (EU, 2024). Crop specific indices are highly valuable in terms of providing useful insights on market dynamics and support the policymakers in managing the price risks. In this study, we aim to construct an alternative price and quantity index based on Wholesale Market Registration System.

Food prices in Türkiye play key roles in maintaining economic stability and food security. Within food prices, fresh fruits and vegetable prices is particularly important. Fruits and vegetables constitute a significant portion of agricultural output and is important for the overall performance of the economy. Moreover, Türkiye is a major exporter of fresh produces. In this regard, stability in domestic prices is important with its potential impacts on trade. Several studies have analyzed fruit and vegetable prices in Türkiye identifying the factors influencing changes in prices, market structure and policy impacts. Some studies indicate inefficiencies due to high transaction costs, inadequate infrastructure and the role of intermediaries causing an increase in the food prices (Uçak et al., 2018). Sayin et al. (2010), evaluate the effect of Türkiye's wholesale market laws on pricing efficiency and producer incomes. Their findings find that regulatory frameworks might cause additional cost for producers. Studies using econometric models such as VAR and GARCH approaches indicate that exchange rate fluctuations and global food prices significantly impact Türkiye's food price indices. Dudu and Cakmak (2018) demonstrate that proximity to key export markets and trade agreements positively influence export volumes. On the other hand, political instabilities like the Arab Spring and economic crises found to have negative impacts.

There are several different studies conducted by the Central Bank of the Republic of Türkiye (CBRT) on unprocessed food prices which is a major component of the food and non-alcoholic beverages group. In a study by Başkaya et al. (2008) analyzing the impacts of various variables including supply, demand, cost and trade on unprocessed food price developments, production and trade were found to be the main determinants of the price developments in unprocessed foods group. Öğünç (2010) mentions that unexpected volatility in unprocessed food prices is 5 times higher than that of the headline inflation. The study by Orman et al. (2010) on the structural factors that cause high volatility in fresh fruit and vegetable prices points out that the concentration of production in certain regions of the country and inadequate warehousing activities may cause sudden price movements. Eren et al. (2017) argue that the main factors that put the greatest pressure on food prices are the amount of production and producer prices. Another important cause of price increase is the high consumer-producer price margins. Atabek-Demirhan and Bayraktar (2024) assess that increased temperature and extreme weather events due to climate change are

associated with fresh fruit and vegetable production, costs and prices.

As the general literature and existing studies indicate, the main determinants of fresh fruit and vegetable prices are the demand and supply levels in which influenced by many different factors such as climatic conditions, production quantity, wastage rate and stocks. To our best knowledge, there is no available indicator for supply and demand conditions for fresh fruits and vegetables. In addition to supply and demand, it is also important to monitor price developments in the fruit and vegetable subgroup due to its high weight in the consumer basket. However, it is also difficult to monitor and forecast fresh fruit and vegetable prices, which exhibit high seasonal and irregular variations due to weather conditions as well as unbalanced demand and supply conditions.

3. DATA AND METHODOLOGY

The data used in this study come from the Wholesale Market Registration System (WMRS). WMRS was established by the Ministry of Trade of Türkiye in 2010 pursuant to the Law No. 5957. This law was enacted in order to prevent informal trade and increase traceability in vegetable and fruit production together with the aim to contribute cost reduction and price stability, which has become increasingly important in terms of food safety and sustainability.

According to the Law No. 5957, it is mandatory to report all wholesale purchases, sales and shipment transactions to the WMRS and to buy and sell fruits and vegetables from the wholesale market, with some exceptions. Provided that the WMRS is notified, fruits and vegetables sold by producer organizations, used in industrial production,

Table 1. Fruits and Vegetables Products Contained in WMRS and CPI Basket*

Subcomponents of Fruits CPI (2024)				Subcomponents of Vegetables CPI (2024)			
	Code	Product	Contained in the WMRS**		Code	Product	Contained in the WMRS**
Fresh Fruits (01161)	0116101	Orange	1	Fresh Vegetables (Including Potatoes) (01171 & 001172)	0117114	Banana Pepper	1
	0116102	Grapes	1		0117115	Bell Pepper	1
	0116105	Pear	1		0117117	Green Pepper	1
	0116107	Quince	1		0117121	Dill	1
	0116110	Strawberry	1		0117122	Tomatoes	1
	0116112	Apple	1		0117125	Green Beans	1
	0116121	Watermelon	1		0117130	Carrots	1
	0116122	Melon	1		0117134	Spinach	1
	0116128	Kiwi	1		0117135	Zucchini	1
	0116130	Lemon	1		0117139	Cauliflower	1
	0116131	Tangerine	1		0117146	Onion	1
	0116134	Banana	1		0117148	Cabbage	1
	0116135	Pomegranate	1		0117150	Red Cabbage	1
	0116137	Peach	1		0117151	Mushroom	1
Dried fruit and nuts (01162)	0116201	Almond Kernel	0		0117152	Lettuce	1
	0116202	Walnut Kernel	0		0117153	Parsley	1
	0116203	Hazelnut Kernel	0		0117155	Mint	1
	0116204	Pistachio	0		0117158	Eggplant	1
	0116206	Peanuts	0		0117160	Leek	1
	0116207	Roasted Chickpea	0		0117161	Arugula	1
	0116208	Sunflower Seed	0		0117162	Cucumber	1
	0116209	Pumpkin Seed	0		0117164	Garlic	1
	0116210	Raisins	0		0117174	Radish	1
	0116212	Dried Apricot	0		0117201	Potatoes	1
				Legumes (01174) and Canned or processed (01175)	0117401	Dried Beans	0
					0117402	Chickpea	0
					0117403	Lentil	0
					0117501	Canned Food	0
					0117504	Pickles	0
					0117505	Tomato Paste	0
					0117506	Olives	0
					0117507	Chips	0

Source: TURKSTAT

* List of products contained in the main groups of CPI.

** "1" represents the products which are contained in the WMRS, "0" represents the products which are not contained in the WMRS.

procured from producers by retailers and establishments such as hotels and restaurants, or are exported and imported, may be bought and sold outside the wholesale market. The WMRS aims to monitor and record the vegetable and fruit trade, prevent informality in the sector and ensure transparency. In this context, data on average prices and transaction volumes on the basis of product, product category and product type are published daily as time series on the website www.hal.gov.tr and shared with the CBRT in 10-day intervals within the framework of the Early Warning System.

According to Turkish Statistical Institute's (TURKSTAT) Consumer Price Index Bulletin (TURKSTAT, 2023) there are 56 products in total under the Fruits and Vegetables group (Table 1). All 45 products under the fresh fruits (01161), vegetables excluding potatoes (01171) and potatoes (01172) groups under the CPI basket are covered in the WMRS database.

Ensuring stable food supply and price is not just an economic priority but also important for food security, social stability and the wellbeing of households. Türkiye is one of the major agricultural producers with staples such as wheats, fruits and vegetables. In 2023, approximately 59.2 million tons of fresh fruits and vegetables produced in Türkiye, which is among the top 10 countries in total fruit and vegetable production, were consumed in both domestic and foreign markets. In addition to its important role in supply chain, as a developing country, food prices are a significant component of consumer price indices and have a direct important impact on overall inflation. Hence, monitoring price and supply developments though high frequency and up-to-date indicators is a critical tool for governments and policymakers to address risks, design timely interventions and promote stability in food system. Timely detection of price spikes or supply shortages can prevent crises and give chance to intervene rapidly and on the spot. Despite its importance, up-to-date and timely quantity and price indicators are not currently available for monitoring. Yearly production data is published by the TURKSTAT Crop Production Statistics for selected products with a time lag (TURKSTAT, 2023). As a comprehensive and up-to-date data source for fresh fruit and vegetables, the WMRS is a unique resource with the potential to fill this important gap. Using the advantages of this unique and comprehensive dataset the WMRS data we construct new quantity and price indicators for fresh fruits and vegetables. WMRS dataset contains the supply amount (in terms of kilograms) and prices (in terms of Turkish Lira) of the products in type detail. The supply amount and prices are utilized for constructing the quantity and price indices respectively.

3.1. WMRS Based Fruits and Vegetables Quantity Indices

The quantity index for fresh fruits and vegetables group is constructed as a proxy for supply indicator. Using the supply amounts in WMRS for the products that are included in the CPI basket the quantity index is constructed. As mentioned before WMRS dataset contains products quantity supply and prices in product type details. For each product the supply amount is calculated by aggregating supply amounts by product type. Then in order to construct comparable indicator, products' total supply amounts are converted into an index with base January 2019.

$$Q_{it} = \sum_{j=1}^{J} Q_{ijt} \text{ and } QI_{it} = \frac{Q_{it}}{Q_{ib}} \times 100 \quad (1)$$

where Q_{ijt} is the quantity supplied of product type j of product i at time t, Q_{it} is the total quantity of product i at time t,Q_{ib} is the supply quantity of product i at January 2021 and QI_{it} is the quantity index of product i at time t.

The quantity index for fresh fruits and vegetables, Q_t, is calculated as the weighted average of the quantity indices of product that are included in the CPI basket.

$$Q_t = \sum_{i}^{\hat{I}} w_i Q_{it} \quad (2)$$

Where Q_t stands for the quantity index for fresh fruits and vegetables at time t, Q_{it} is the quantity index of product i at time t and is the weight of product i. Product weights are the latest publicly published product weights by TURKSTAT. WMRS-based quantity indices are calculated for fresh fruits and vegetables, fresh fruits and vegetables separately. For each group the weights are redistributed within the group to sum up 1.

3.2. WMRS-Based Fresh Vegetable and Fruit Price Indices

As mentioned earlier, it is compulsory to buy and sell products sold by producer organizations, exported and imported, used in industrial production, except for fruits and vegetables procured from producers by retailers and establishments such as hotels and restaurants, provided that they are notified to WMRS. In this context, WMRS exit prices are considered to be a good leading indicator for fresh vegetables and fruits consumer prices. In addition to the quantity indices, price indicators for fresh fruits and vegetables are also constructed using the price information contained in the WMRS dataset. First of all, for each product type price indices with base year 2019 are constructed as in the case of quantity index.

$$PI_{ijt} = \frac{P_{ijt}}{P_{ijb}} \times 100 \tag{3}$$

Where $\boldsymbol{PI_{ijt}}$ stands for the price index of type j of product i at time t and $\boldsymbol{P_{ijt}}$ and $\boldsymbol{P_{ijb}}$ are the prices of type j of product i at time t and base time January 2021 respectively. Then price index for particular product is calculated as the weighted mean of price indices of corresponding product types.

$$\boldsymbol{P_{it}} = \sum_{\boldsymbol{i}} \boldsymbol{PI_{ijt}} \cdot \frac{\boldsymbol{Q_{ijt}}}{\sum_j \boldsymbol{Q_{ijt}}} \tag{4}$$

$\boldsymbol{P_{it}}$ represents the price of product i at time t which is calculated by taking a weighted average of the prices of all varieties of product i in which weights are based on their WMRS exit quantities. After calculating a weighted average of monthly prices for each product that are included in the CPI basket, aggregation carried out as follows:

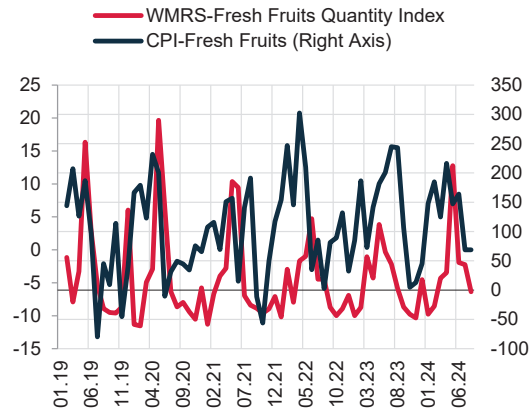
$$P_t = \sum_{i}^{I} w_i P_{it} \tag{5}$$

Where $\boldsymbol{P_t}$ represents the price index at time t and is the weight of product i. Product weights are the latest publicly published product weights by TURKSTAT. WMRS-based price indices are calculated for fresh fruits and vegetables, fresh fruits and vegetables separately. For each group the weights are redistributed within the group to sum up 1.

4. RESULTS

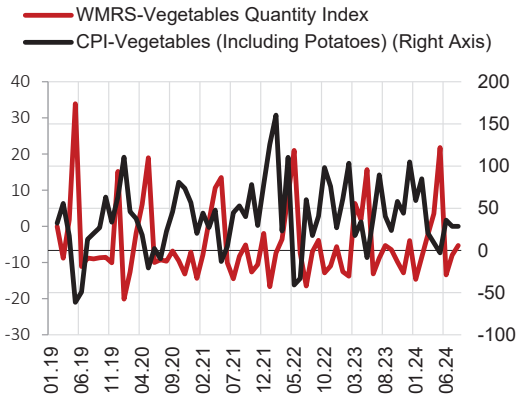
Food supply security has become increasingly important globally. In Türkiye, one of the world's and Europe's leading agricultural producers, "food supply security" and "sustainability" are among the prominent items in the new agricultural policy package announced. Food supply, which is related to production, stocks and demand, is critical for both sustainability and price stability. The monthly percentage change in the monthly supply indices for fresh fruits and vegetables based on the WMRS is presented in the graphs below along with the monthly consumer inflation of the relevant group.

Graph 1: WMRS Based Fresh Fruits Quantity Index and Consumer Price Index (Monthly % Change)



Source: MoT-WMRS, TURKSTAT, CBRT

Graph 2: WMRS Based Fresh Vegetables (Including Potatoes) Quantity Index and Consumer Price Index (Monthly % Change)

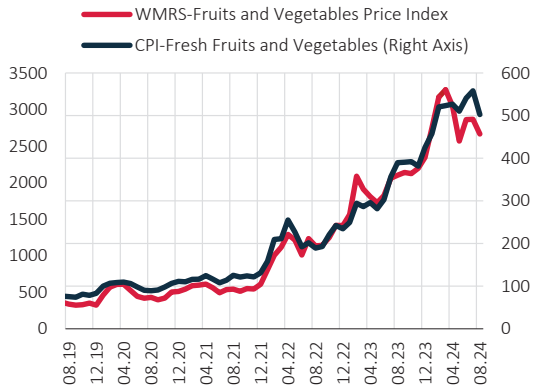


Source: MoT-WMRS, TURKSTAT, CBRT

As expected, the WMRS-based quantity indicators and consumer prices are negatively correlated (Graphs 1 and 2). Co-movement of quantity index and inflation against general pattern indicates the existence of shrinking supply pressure on prices.

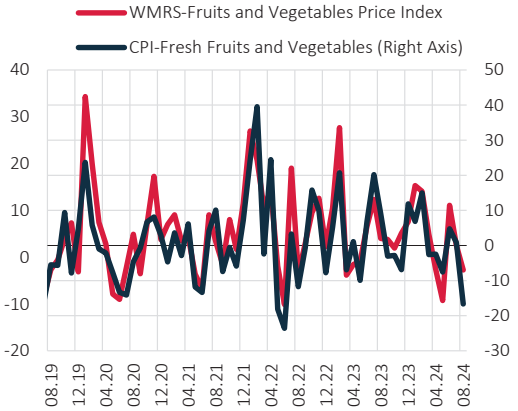
The indices constructed based on WMRS data provide high-frequency (10-day periods within a month) and timely information on fruit and vegetable prices. WMRS-based fresh fruit price indices move similarly to the CPI fresh vegetable price index, and monthly changes suggest that these indices are good indicators of monthly price developments (Graphs 3 and 4).

Graph 3: Fresh Fruits and Vegetables Price Indices



Source: MoT-WMRS, TURKSTAT, CBRT

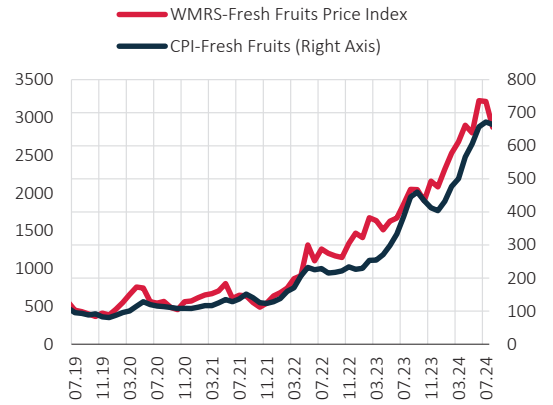
Graph 4: Fresh Fruits and Vegetables Price Indices (Monthly % Change)



Source: MoT-WMRS, TURKSTAT, CBRT

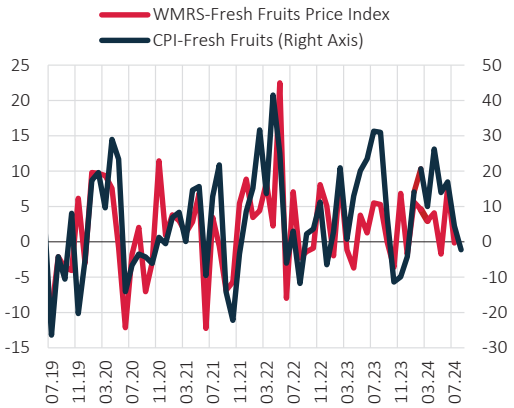
An analysis of the WMRS-based price indices for the fruits and vegetables subcategories reveals that both indices capture the general trend of the relevant consumer price index (Graphs 5,6 and 7,8). However, in the fruit group, the WMRS-based price index is generally higher than the CPI Fresh Fruits subcategory price index (Graph 5). The divergence observed in the fruit group may be mainly attributed to the higher export rate of the fruit group. As the WMRS based final consumption data suggests, in 2023 while 40.8% of total fruits were directed to exports, this number was limited to 13.4 for vegetables.

Graph 5: Fresh Fruits Price Indices



Source: MoT-WMRS, TURKSTAT, CBRT

Graph 6: Fresh Fruits Price Indices (Monthly % Change)

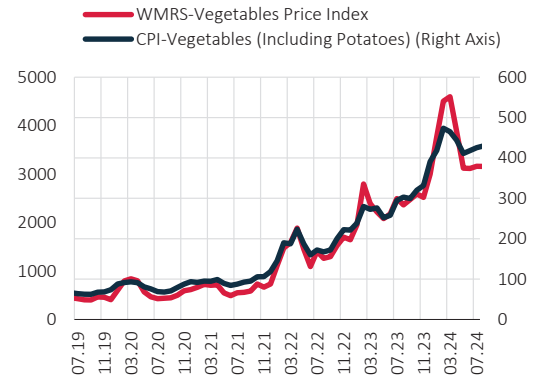


Source: MoT-WMRS, TURKSTAT, CBRT

Source: MoT-WMRS, TURKSTAT, CBRT

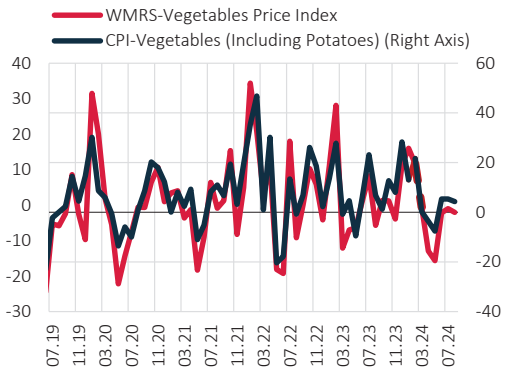
Source: MoT-WMRS, TURKSTAT, CBRT

Graph 7: Vegetables (Including Potatoes) Price Indices



Source: MoT-WMRS, TURKSTAT, CBRT

Graph 8: Vegetables (Including Potatoes) Price Indices (Monthly % Change)

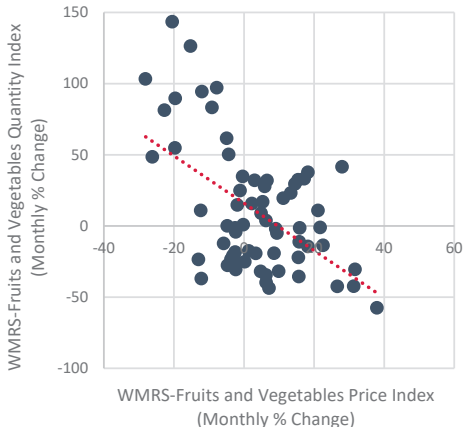


Source: MoT-WMRS, TURKSTAT, CBRT

WMRS-based fresh fruits and vegetables, fresh fruits and vegetables price indices, which are calculated using high-frequency current data, have a high capacity to reflect the general price trend.

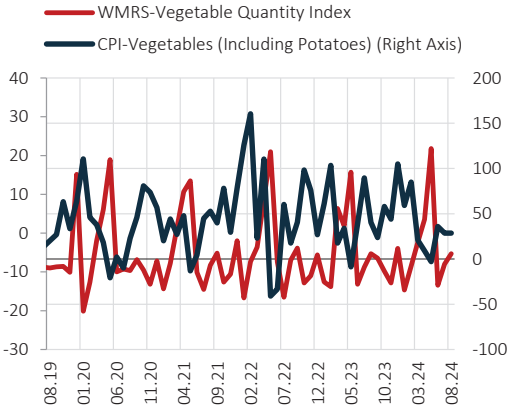
An analysis of the monthly changes in the quantity and price indices of fruits and vegetables constructed on the basis of the WMRS reveals a negative relationship between quantity and price, as expected (Graphs 9 and 10). For the periods in which the monthly changes in the quantity and price indices do not move in opposite direction as expected, non-supply factors may be the driver of price developments (Graph 10). For instance, the downward co-movement of the quantity and price indices of fruits and vegetables in July and August points to a contraction in consumer demand.

Graph 9: WMRS Fruits and Vegetables Quantity and Price Indices (Monthly % Change)



Source: MoT-WMRS, CBRT

Graph 10: WMRS Fruits and Vegetables Quantity and Price Indices (Monthly % Change)



Source: MoT-WMRS, TURKSTAT, CBRT

The CBRT tries to follow closely supply, demand and price developments in the fruit and vegetable group, which is important but not easy due to high volatility caused by weather conditions. Considering the relationship between the WMRS-based quantity and price indices both among themselves and with the CPI, it is assessed that they have a high information content for monitoring supply and price developments in the fruit and vegetable group and have the potential to provide input for forecasting studies.

5. CONCLUSION

Fruit and vegetable prices, which make up about a quarter of the food and non-alcoholic beverages group with the highest weight in the CPI basket, are among the most volatile components of Türkiye's inflation. They significantly influence food inflation, which is a major contributor to the overall inflation in the country. The unpredictability of the volatility caused by strong seasonality on overall consumer prices may pose difficulties for monetary policy communication. Therefore, forecasting the supply, demand and price movements of the fruit and vegetable subcategory is crucial for monetary policy. One of the most important factors in forecasting prices is supply and demand indicators. In Türkiye, there is no monthly indicator to monitor the supply of fresh fruits and vegetables and stocks for storable products. This study introduces the Wholesale Market Registration System, which provides a comprehensive data set on the supply and demand of fruits and vegetables, and alternative quantity and price indicators based on this system.

The dataset provided by the Wholesale Market Registration System is highly advantageous for analyzing the supply and demand dynamics in the fresh fruits and vegetables. Its higher frequency and detailed nature allow understanding price dynamics and their contribution to overall inflation. It enables policymaker to respond more quickly to the sudden price changes caused by potential supply shocks. Moreover, analyzing the quantity and price trends more detailed would enable to decompose inflation into its components, such as, seasonal patterns, weather shocks, regulatory shocks or trade shocks. Therefore, we believe this unique dataset is a valuable tool for improving demand and supply analysis in Türkiye.

This study shows that the fresh fruit and vegetable quantity and price indicators constructed from the Wholesale Market Registration System data, which contain comprehensive and timely quantity and price information on fresh fruit and vegetable products, are consistent with consumer prices. It is critical that these indices, which are considered to be consistent with the CPI, provide monthly indicators on the production, consumption and stocks of fresh fruit and vegetable products, which are difficult to forecast supply and demand due to their structure. We believe this paper makes a significant contribution to the literature by providing insightful information on market dynamics and policy-making. Forecasts based on these indicators can be used in different analyses as alternative leading indicators in addition to econometric models and expert judgements.

Conflict of Interest

All authors declare that they have no conflicts of interest.

Final Note

All views and opinions expressed here are of the authors and do not necessarily represent the official views of the Central Bank of Republic of Türkiye and its staff.

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