RELATIONSHIP BETWEEN PPI AND CPI IN AZERBAIJAN: A WAVELET APPROACH

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ABSTRACT

This paper aims to study the relationship between producer price index (PPI) and consumer price index (CPI), as well as between components of producer prices and components of consumer prices in Azerbaijan by using monthly data covering the period from March 2004 to June 2023. Applying wavelet analysis approach, I find that there is a mixed relationship between CPI and PPI, and co-movement is observed mainly at medium and low frequencies. The results reveal that although there is a weak co-movement between aggregate PPI and CPI, a significant and strong relationship exists between food PPI and aggregate CPI, as well as between food PPI and food CPI. Additionally, producer prices of agricultural products demonstrates co-movement with consumer prices in certain periods. In terms of lead-lag relationship, producer prices lead consumer prices. Although wavelet methodology does not necessarily determine causality, this study provides insights for policymakers about the direction of possible causality between producer prices and consumer prices.

Keywords: Producer Price Index, Consumer Price Index, Wavelet analysis, agricultural products, relationship

JEL Codes: E31, E19, E39

INTRODUCTION

The primary goal of the monetary authorities in most countries is to achieve price stability by controlling inflation. To that end, finding out the main contributors of inflation is very important, as it allows the governments and central banks to conduct appropriate economic policies. Producer prices, among others, is considered as one of the main causes of consumer price inflation. Several authors have empirically investigated the relationship between producer prices and consumer prices earlier.

There is no consensus among researchers on the direction of causality between the two variables. Although, majority of them suggest that the correlation between producer prices and consumer prices is positive, and mainly the producer price causes consumer prices (for example, Clark, 1995, Ghazali *et al.*, 2018), there are studies (Fan *et al.*, 2009, Akçay, 2011) that have found the opposite causality suggesting that the consumer prices affect producer prices.

The CPI inflation has been widely investigated from different perspectives in the context of Azerbaijan (see for example, Rahimov *et al.*, 2018, Niftiyev, 2020, Rahimov *et al*., 2021 etc.). However, only a few studies have used producer prices as a causing factor of consumer inflation. Therefore, it is also important to investigate the relationship between producer prices and consumer prices. For that purpose, I utilize wavelet analysis to examine the relationship between two variables. This approach will allow me to conduct the study not only from time series perspective, but also through frequency scale. A lot of studies have applied wavelet approach in economic sciences to study a variety of relationships, as for example, Çepni *et al.* (2020) for relationship between credit decomposition and economic activity, Jiang *et al.* (2015) for relationship between money growth and inflation, Ramsey and Lampart (1998) for relationship between money and income, Rua (2011) for forecasting purposes etc.. In fact, Rua (2012) emphasizes that wavelet models can be considered promising tool in economic studies as this approach is absent from drawbacks that Fourier transforms possesses.

To best of my knowledge, this is the first paper that attempts to investigate the relationship between PPI and CPI in Azerbaijan using a wavelet approach. The rest of the paper is structured as follows. Section 2 is dedicated to a literature review, which is followed by data and methodological issues, respectively. In section 5, the findings are presented and discussed, and section 6 concludes.

LITERATURE REVIEW

The relationship between CPI and PPI has extensively and for long been examined in literature. For example, Silver and Wallace (1980), applying Hatanaka-Wallace procedure, try to identify lag relationships linking the consumer prices to producer prices in the U.S. They find that there is one-sided lag structure (due to Sim's test) between the variables and producer prices are leading factor. However, two years later Colclough and Lange (1982) find contrasting results for the U.S. producer and consumer prices suggesting that the relationship is bidirectional.

Differing results possibly stem from the fact that the coverage period of the studies is different. The similar result showing the bidirectional causality between producer and consumer prices in the U.S. is also reached by Jones (1985).

Caporale *et al.* (2002) show that the association between producer and consumer prices are not straightforward in G7 countries, as causality runs from PPI to CPI in France and Germany, bidirectional causality from between two variables exists in Italy, Japan, the UK and the U.S, and there is no association between the two series. Using monthly data for Malaysia over the period from January 1986 to April 2007, Ghazali *et al.* (2008) find that the PPI leads CPI. Fan *et al.* (2009) uses Chinese data for the period from January 2001 to August 2008. They report that CPI Granger causes the producer prices in China. The authors emphasize that the evidence shows the superior role of demand-side factors in price formation for the studied period.

Akçay (2011) investigates the direction of causality between CPI and PPI in selected five European countries - Finland, France, Germany, Netherlands, and Sweden. Using monthly data from January 1995 to December 2007 and applying Toda-Yamamoto causality test, he finds that causality runs from producer prices to consumer prices in the case of Finland and France, there are bidirectional causality in Germany. The paper also finds that no causality exists between two variables in case of Netherlands and Sweden.

The relationship between CPI and PPI has also been analyzed in South American countries. Cerquera Losada *et al.* (2018), employing Toda-Yamamoto no-causality test, building a vector autoregressive model or an error correction model depending on integration and using annual data depending on availability, test relationship between consumer prices and producer prices in Brazil, Colombia, Ecuador, Peru, Paraguay and Uruguay. The study concludes that there is no relationship between PPI and CPI in Brazil, Colombia, Ecuador and Uruguay, while there is a bidirectional causality between the variables in Peru and a unidirectional causality running from CPI to PPI in Paraguay.

Although the relationship between PPI and CPI has been studied for a long time and with different approaches (causality tests, single equation, and multi-equation models etc.), wavelet approach is relatively new. The research done by Tiwari *et al.* (2013) is probably the first study that used wavelet approach between producer prices and consumer prices (Islam and Kulkayeva, 2022). To analyse the relationship between consumer prices and producer prices in Romania, they use monthly data covering the period of January 1991-November 2011. The authors first check whether the variables Granger-cause each other.

They later decompose the series to further deepen the analysis through a continuous wavelet approach. They show the existence of cyclicality and lead-lag relationships between the variables at different frequencies. In another study, Tiwari *et al.* (2014) check the lead-lag relationship between CPI and PPI in Mexico for the period from January 1981 to March 2009. According to the results, there are bidirectional relationships between the series as, for example, in longer time scale (8-32 months), the PPI is leading, while in a short time scale (1-7 months), the CPI is leading.

Another frequency study between producer price index and consumer price index, using wavelet-based approach, has been conducted by Khan *et al.* (2018). They use monthly data over 1999-2016 for the Czech Republic. Additionally, the authors employ an exchange rate variable as a controlling variable. The findings reveal that relationships exist between the two series at short-term (higher frequencies). However, addition of exchange rate increases the time horizon of causality which shows the sensitivity of the price indices to external shocks in the Czech Republic.

Islam and Kulkayeva (2022) examine the topic in the case of Kazakhstan, which is also a resource-rich country like Azerbaijan. They use monthly data from January 2011 to December 2021. To find causality and reveal the relationship time-frequency domain, Toda-Yamamoto and wavelet approaches have been applied, respectively. While the causality test indicates a one-way causality from manufacturing producer prices and food producer prices to consumer prices, the wavelet approach suggests another pattern. Despite producer prices leading consumer prices in the short term, consumer price is a leading indicator of producer prices for a relatively longer period.

In a recent paper, Živkov *et al.* (2023) applies wavelet coherence to investigate the relationship between consumer prices and producer prices in eight emerging Eastern European countries, namely, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia. The sample covers the period from January 1998 to March 2022. They find that there is coherence between the variables in relatively longer horizons and high coherence is especially apparent during the crisis periods, such as the Global Financial Crisis and COVID-19 pandemics. Using wavelet-based Bayesian quantile regression, they also reveal that there are bilateral spillover effects between producer and consumer prices in all countries excluding Poland and Hungary.

DATA AND METHODOLOGY

Data

I employ monthly data spanning from March 2004 to June 2023. The variables used in this study are aggregate producer price index, manufacturing producer price index, food producer price index, agricultural producer price index, aggregate consumer price index, food consumer price index as well as non-food consumer price index.

All series have been collected from the bulletins of the State Statistical Committee of the Republic of Azerbaijan (SSCRA). I transform the series into year-on-year growth rates and in this way, the seasonality concern is addressed. Descriptive statistics is summarized in Table 1. All of the variables possess positive mean and median, where non-food inflation represents lowest mean and median values. Standard deviations suggest that the highest volatile variable is aggregate PPI, while non-food CPI is the lowest volatile variable.

Table 1. Descriptive Statistics (Annual change)

Variables	Mean	Median	Max	Min	Std. Dev.	Skewness	Kurtosis
Aggregate CPI	7.32	5.04	25.38	-2.00	6.16	0.79	2.87
Food CPI	9.32	7.51	37.46	-6.33	8.47	0.72	3.43
Non-Food CPI	5.35	3.42	21.75	-1.40	5.00	1.06	3.10
Aggregate PPI	16.60	10.58	172.63	-63.12	37.15	1.34	5.46
Manufacturing PPI	10.21	7.69	41.69	-16.86	11.76	0.28	2.56
Agricultural PPI	6.10	6.37	26.47	-11.08	7.11	0.01	2.68
Food PPI	9.20	5.58	62.11	-18.19	13.21	0.99	4.40

Background information on price indices in Azerbaijan

The statistics on price indices are published on a monthly basis. According to the SSCRA[2], as of 2023, there are 528 goods and services in the consumer basket of Azerbaijan. The composition of the basket and the number of products change from time to time and the weights are determined in accordance with the household budget survey. The basket is mainly divided into three main components, namely, food, non-food, and services components. Price monitoring encompasses the whole country and price movements of food products are registered three times a month, while collection of price information of non-food products and paid services are carried out once a month.

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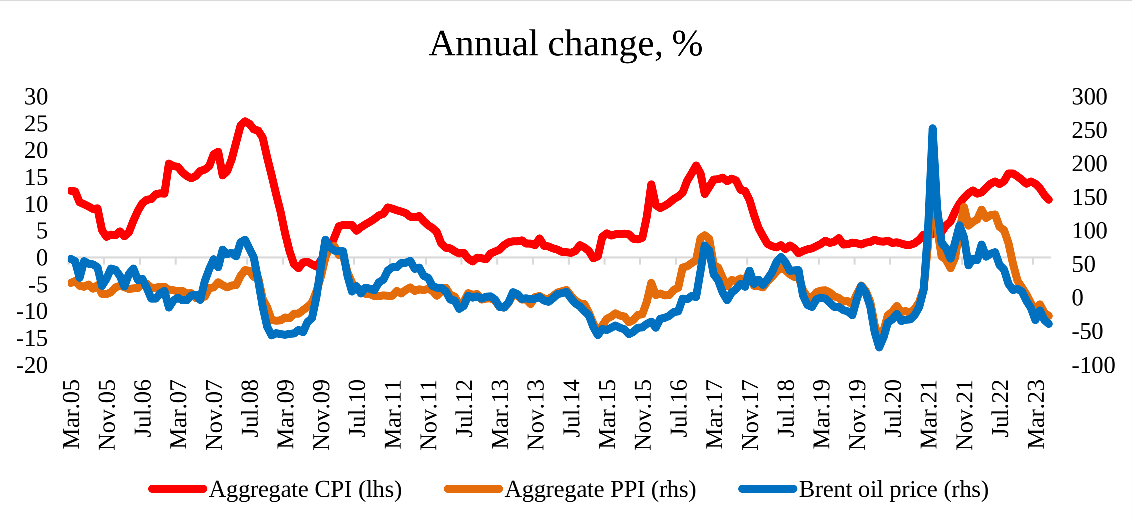
[2] https://stat.gov.az/source/price_tarif/?lang=en

On the other hand, the producer price index is divided into four broad categories: (i) industrial producer price indices; (ii) agricultural, fishery and forestry products; (iii) producer price indices of transport, warehouse, postal, communication, information and communication technologies and advertising services; and (iv) producer index in construction and installation works. As per the SSCRA, *"producer price does not include value-added, excise etc. taxes and transportation costs not related to the cost of the product"*[3].

At this point, some country-specific features of the economy are worth noting. Azerbaijan is an oil-rich country with oil and gas sector making up some 40% of the total gross domestic product (GDP) and 90% of export. The high share of energy sector also affects the PPI significantly as it is exposed to the volatility in the world oil markets. However, it is not reflected in the consumer prices as approximately 10% of consumer basket is composed of administered prices, including natural gas, gasoline & diesel products. And it hinders the pass-through from aggregate PPI to the consumer prices. In fact, Figure 1 shows the plots between the annual change in producer prices, consumer prices and raw oil prices. However, the other components of the PPI can possess the relationship between aggregate, as well as other components of inflation. Particularly, I think manufacturing component of the PPI can be used as a proxy for industrial prices as these prices are determined freely in the market. Besides, as already mentioned, food and agricultural producer prices will also be examined.

Figure 1. Relationship between annual change of CPI, PPI and Brent Oil Price



Sources: SSCRA, EIA

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[3] "Methodological explanations" prepared by the SSCRA.

Methodology

To analyse relationship between producer prices and consumer inflation, I apply wavelet analysis. Wavelet analysis has been popularized in scientific fields since 1980s as an alternative to Fourier transform. The wavelet approach allows us to study the relationship between the variables both over time and frequency domain.

Basically, the Fourier transform can be represented in the following way:

$$F_x(\omega) = \int_{-\infty}^{+\infty} x(t)e^{-i\omega t}dt \quad (1)$$

where ω is the angular formula and $e^{-i\omega t} = \cos(\omega t) - i\sin(\omega t)$ according to Euler's formula.

Despite Fourier transform is widely used in frequency analysis in economics, it does not reveal the relationship between the variables over time. Furthermore, Fourier analysis requires stationarity conditions which is easy to be violated in economic series. In this regard, wavelet analysis can be considered a useful tool which does not suffer these drawbacks.

The continuous wavelet transform can be expressed as follows:

$$W_x(\tau, s) = \int_{-\infty}^{+\infty} x(t)\psi^*_{\tau,s}(t)dt \quad (2)$$

where * denotes the complex conjugate. In this context, $\psi^*_{\tau,s}(t)$ represent the conjugate functions of the daughter wavelet functions of $\psi_{\tau,s}(t)$ (Jiang, *et al.*, 2015). As a starting point, so-called mother wavelet can be derived as:

$$\psi_{\tau,s}(t) = \frac{1}{\sqrt{s}}\psi\left(\frac{t-\tau}{s}\right) \quad (3)$$

where s denotes scaling factor that determines the length of the wavelet and τ indicates the position of wavelet, i.e., time. (Aguiar-Conraria *et al.* 2008). There are different types of mother wavelets that can be employed for different analysis. Jiang *et al.* (2015) state that the most common mother wavelet used for feature extraction purposes is Morlet wavelet which is defined in simplified form as

$$\psi(t) = \pi^{-1/4}\omega^{i\omega_0 t}e^{-t^2/2} \quad (4)$$

with parameter ω_0. The parameter ω_0 governs the number of oscillations within Gaussian envelope. As shown in Çepni *et al.* (2020), in practice, the preferred value of the parameter is 6, as it creates balance between time and frequency localization. Interesting quantities, such as variance and covariance, can be captured wavelet domain. Since, in this study, I focus on two series case, say $x(t)$ and $y(t)$, I can construct the cross-wavelet power spectrum in the following way:

$$W_{xy}(\tau, s) = W_x(\tau, s) W_y^*(\tau, s) \quad (5)$$

As discussed in the previous studies, such as Rua (2012), Jiang *et al.* (2015), Çepni *et al.* (2020), wavelet coherency can be expressed as:

$$R^2(\tau, s) = \frac{\left| S\left(s^{-1} W_{xy}(\tau, s)\right) \right|^2}{S(s^{-1}|W_x(\tau, s)|^2) S\left(s^{-1}\left|W_y(\tau, s)\right|^2\right)} \quad (6)$$

where $S(.)$ represents smoothing parameter both in time and scale. $R^2(\tau, s)$ measures the strength of relationship between the series and varies between 0 and 1 in a time frequency space, where the higher the value, the stronger the relationship between the variables.

Wavelet coherence phase differences between the two series can also be described as follows:

$$\theta(\tau, s) = tan^{-1}\left(\frac{\Gamma\left(W_{xy}(\tau, s)\right)}{\aleph\left(W_{xy}(\tau, s)\right)}\right) \quad (7)$$

where Γ and $\aleph$ are imaginary and real parts, respectively, of the smoother cross-wavelet transform. Phase differences are shown by the arrows, where arrows pointing to the right indicate that the two series are positively correlated (in phase) and arrows pointing to the left represent negatively correlated (out of phase) variables. In addition, the lead-lag relationship can also be shown with the arrows, where arrows positioned upward mean the first variable leads the second one, while arrows positioned downward suggest that the second variable leads the first one.

RESULTS AND DISCUSSION

This section presents the results for wavelet coherence analysis. Figure 2 reports the relationships between different pairs of producer and consumer prices over time-frequency domain.

Figure 2a displays the wavelet coherence between annual change of producer prices and annual consumer inflation. There is some relationship over the medium frequency (about 8-12 months) from 2005 to 2010. The co-movement in that period is intiutive, because the period coincides with the high oil price cycle and a dramatic increase in government expenditures which ultimately accelerated inflation rates during the years from 2006 to 2008. Another noteworthy point here is that producer prices lead the consumer inflation. Since 2010 no significant relationship is recorded between the variables. The weak relationship can be explained by the significant share of mining and quarrying sector in aggregate PPI. Similar results were also reached by Islam and Kulkayeva (2022). To deal the issue, I use annual change in manufacturing producer prices and check its co-movement with the annual consumer inflation (Figure 2b). This analysis also shows that the two series move together during 2007-2010. However, there was no sign of lead-lag relationship over that period. It can be attributed to the fact that manufacturing non-food sector has lower share in aggregate consumer price, as the share of imported non-food products are high in consumer basket.

I further check the possibility of the relationship between other sectoral levels of the price indices. Figure 2c illustrates the relationship between manufacturing producer prices and non-food consumer prices. The figure suggests that in early periods of the study period, there was leading positive relationship in long-term horizons. This relationship is observed in medium term horizons during 2008-2010. In later periods, no significant relationship is recorded. Later in 2015-2016, the non-food consumer inflation leads the manufacturing producer prices.

Figure 2d indicates a strong association between food producer prices and food consumer inflation where the wavelet coherency is close to one. As it is visible, the series are in phase over the whole study period. Particularly, the series move together at the 16-32 months period over the years from 2007 to 2009. In terms of lead-lag relationship, food PPI leads the CPI. After 2011, the leading patterns of food producer prices disappears and again starting from 2017, the food producer prices lead consumer prices at lower frequencies. This effect is attributable to relatively higher share of locally produced food products in the consumption basket. It is also confirmed by Figure 2e where the co-movement between food producer prices and food consumer inflation demonstrates similar pattern.

Figure 2. Wavelet coherence between PPI and CPI

Figure 2a

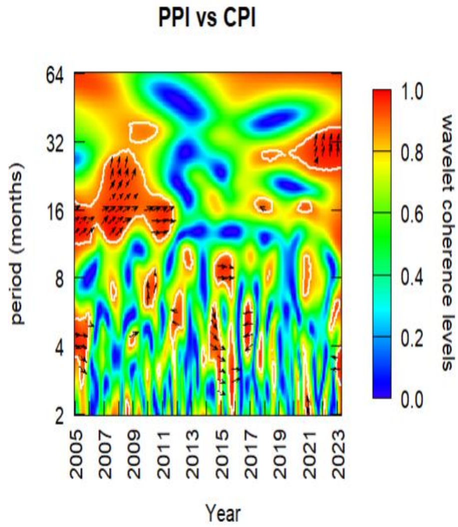


Figure 2b

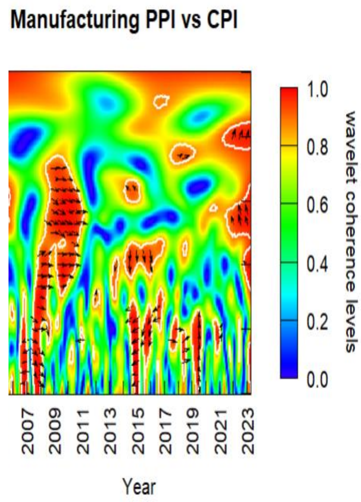


Figure 2c

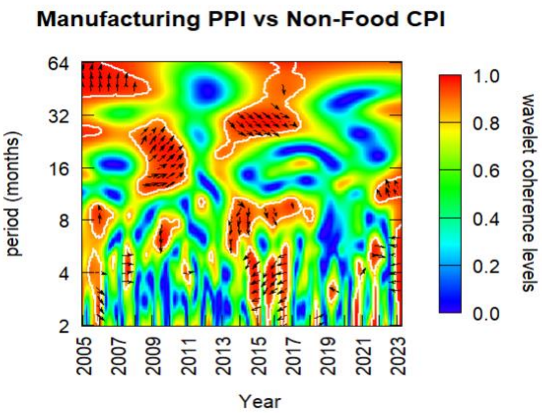


Figure 2d

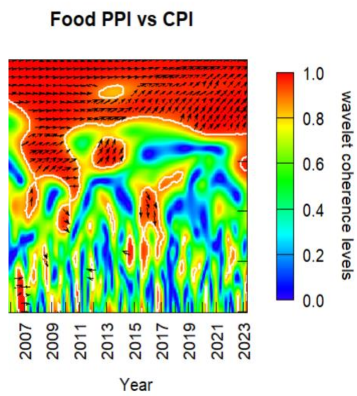
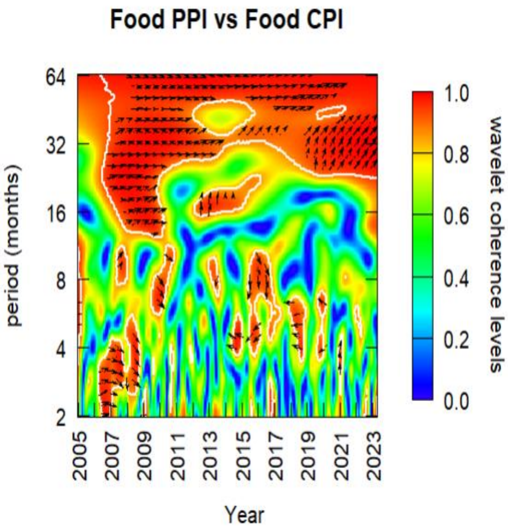


Figure 2e

Figure 2f



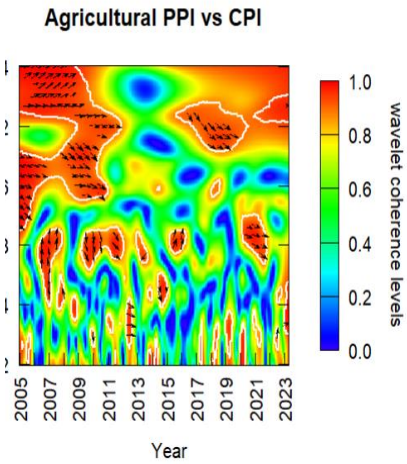
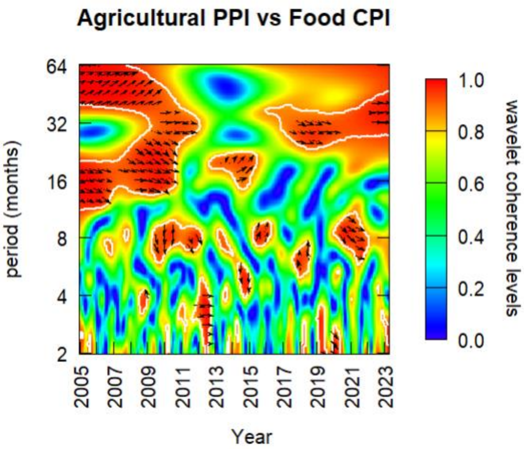


Figure 2g



Note: All variables are in annual change form. Horizontal axis shows time, while the vertical axis on the left is period in months. In the context of coherence levels on the right vertical axis, the higher number represents the higher co-movement. The white outline indicates a 5% significance level. The direction of the arrows shows the phase difference. The in-phase direction is the arrow to the right, while out-of-phase direction is the arrow to the left.

Finally, Figure 2f and 2g show the relationships between another component of producer prices, agricultural producer prices, and headline inflation, and agricultural producer prices and food inflation, respectively. The graphs show that agricultural producer prices and consumer inflation variables were in phase from 2005 to 2010 and consumer inflation leads the agricultural producer prices. However, no relations are visible between 2011 and 2017. Again after 2017 some co-movements appear at medium frequencies.

CONCLUSION

In this paper, using monthly data over the period from March 2004 to June 2023, I investigate the co-movement between PPI and CPI in Azerbaijan through wavelet approach. The main finding of this paper is that there is a mixed relationship between aggregate producer prices and aggregate consumer prices. The co-movement exists especially in the initial years of studied period as pass-through from oil prices, the main driver of aggregate PPI, to consumer prices was existent. By excluding oil factor, I find that manufacturing producer prices co-move with the aggregate CPI and non-food CPI at lower frequency in certain periods. Additionally, producer prices of agricultural products demonstrate relatively stronger relationship with consumer prices especially at a lower frequency at initial and late periods of the study period. Food producer prices series is the only component of the PPI that possesses strong and significant relationship with food producer prices and aggregate CPI for the entire period.

This study provides insights for policymakers about the direction of possible causality between producer prices and consumer prices. However, the results do not necessarily mean that there is a causal relationship between the variables. The scope of the study can be extended by time-varying causal relationship analysis, such as time-varying Granger causality or time-varying multivariate models.

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