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Modeling the Inflation of Türkiye Considering the Impact of Maritime Transport Costs

Abdullah Açık[1]✉ • Muhammet Rıdvan İnce[2]

[1] Dokuz Eylül University, Maritime Faculty, Department of Maritime Business Administration, 35390, İzmir, Türkiye, abdullah.acik@deu.edu.tr
[2] Kocaeli University, Faculty of Economics and Administrative Sciences, Department of Economics, 41380, Kocaeli, Türkiye, muhammet.ince@kocaeli.edu.tr

✉ Corresponding Author: abdullah.acik@deu.edu.tr

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ABSTRACT

We modeled Turkish inflation using causality analysis by considering the impact of maritime transport costs. We also supported the results with impulse and response, and variance decomposition analyses. The results show that the exchange rate, commodity price, dry bulk freight rate and container freight rate have significant effects on inflation, and their shocks cannot be eliminated from the system for a long time. The most important factor affecting inflation is its historical value and the effect of exchange rates is also quite high. The container freight rate has a greater impact on inflation than the dry bulk freight rate. The forecast made using the vector autoregressive (VAR) model showed that inflation will continue to increase, but the rate of increase will slow down. It is important to implement appropriate policies to break the effect of expectations on inflation due to the new economic policies. Additionally, it is important to develop stabilizing tools to protect freight rates from the permanent effects of unexpected shocks.

INTRODUCTION

The concept of globalization is a concept based on minimizing costs and increasing total welfare by specializing countries in different raw materials, products, or services (Kütting, 2004). However, in this system, it is assumed that the supply chain functions perfectly (Hult et al., 2014). Based on this assumption, the dependence of countries on each other is high. However, events such as the current COVID-19 pandemic (Arunmozhi et al., 2021) and the Ukraine-Russia war (FAO, 2022) have shown that globalization does not actually eliminate borders completely, and that the struggle between countries can generate major problems in supply chains. Disruptions in the supply chain have also extended product and service lead times and increased transportation and capital costs (Zemmrich & Hofmann, 2022). These increased transportation costs generated inflationary pressures in countries (Carriere-Swallow et al., 2022). However,

the economic policies implemented by the Federal Reserve (FED), considering the current global economic situation, necessitated an increase in interest rates (Bloomberg, 2022a). Developing countries, which are highly dependent on foreign exchange and investment, were the most affected by this policy. Increasing interest rates caused hot money to come out of developing countries and depreciation of national currencies against the dollar (Akhtaruzzaman, 2019). For countries that are depend on raw materials and energy and often have budget deficits, domestic prices have increased and an inflationary situation has emerged.

Expectations are critical in inflation modeling and expectations are generally based on backward-looking and forward-looking theories. In one of the backward-looking models, expectations are based on extrapolations of past behavior. Future expectations are formed based on past inflation rates and the reaction of inflation to past policies. It therefore consists of a moving average of past rates and has a slow response to prices. In another backward-looking model, going one step further, the margin of error between the past situation and the realized inflation is also considered in the next expectations. This can be defined as adaptive expectations. In forward-looking modeling, rational expectations come to the fore. The players rationally calculate the future inflation by analyzing the current situation, considering every new information and the results of the policies implemented in past (Lipsey & Chrystal, 2020). Although it is assumed that people make rational decisions most of the time, their irrational aspects are also high and the influence of people's expectations on the shaping of inflation is huge.

While modeling inflation, factors such as money supply (e.g. Van, 2020; Matthews & Ong, 2022; Samal et al., 2022), demand (e.g. Osorio & Unsal, 2013; Charef & Ayachi, 2018), interest rates (e.g. Dogan et al., 2020; Egilsson, 2020), raw material prices (e.g. Chen & Yang, 2021), energy prices (e.g. Bachmeier & Cha, 2011; Aloui et al., 2018), exchange rates (e.g. Guo, 2013; Khan et al., 2019; Şen et al., 2020), public sector prices (e.g. Berument, 2003; Us, 2004), fiscal deficit (e.g. Metin, 1998; Okoye et al., 2019), economic policy uncertainty (e.g. Balcilar et al., 2017; Ghosh et al., 2021), expectations (e.g. Stockhammar & Österholm, 2018; Ciccarelli & García, 2021) and domestic transport costs (e.g. Kpodar & Liu, 2022) are generally taken into consideration to explain the formation of the inflation. However, the problems experienced in the supply chains in the last period have led to an incredibly high level of freight, especially in container transportation. This shows that international transportation costs can also contribute significantly to an inflationary environment in countries. Since the price of transportation constitutes a cost item in both the supply of raw materials and the delivery of final products, it affects the final prices of the products in the market and this situation is reflected in the market as a price increase. The ability to access non-local markets also depends on transport costs (Press, 2006). Under normal conditions, while the share of transportation costs in the final price for manufactured products is between 2-4%, it occurs between 20-40% for raw materials such as iron ore, coal, timber, and phosphate (Jansson & Shneerson, 2012). However, in some extraordinary periods, transportation costs reach very high levels. This situation has been felt in the global sense, especially in recent times. In our study, we dealt with inflation from a Keynesian perspective. Keynes classifies the factors affecting inflation as demand-pull and cost-push. According to demand-pull view, because of increased demand for goods in the market, supply may become insufficient and this may cause prices to rise. According to cost-push view, the increase in costs in the market affects the final prices of the products and the general level of prices may increase. Additionally, Keynes points out that expectations and agreements such as labor wages, are also important in inflation (Comley, 2015). In this study, we have positioned our perspective and analyzes according to the concept of cost-push view.

In this study, we modeled the Turkish economy, whose inflation has increased at an extraordinary rate both to the policies implemented and global developments, in terms of cost-push inflation, considering the transportation costs. Unlike the literature, we included both the costs of raw material supply and the costs of delivery of the final product in the model. We also added the exchange rate and global commodity prices to enrich the model. Both increased

input and transportation costs can cause final prices to rise. Additionally, even if global prices are stable, increases in exchange rates may cause domestic prices to rise.

In our analysis, we preferred the VAR model because we think that the relationship between costs and prices is not instantaneous, but also influenced by the past values of the variables. Using the obtained model, we applied Granger causality, impulse and response, and variance decomposition analyzes. Finally, we made an inflation forecast until December 2023 using the VAR equation. The results show that all the variables in the model have a significant effect on inflation, the most important factor feeding inflation is the exchange rate, and container transportation costs are more effective than dry bulk cargo transportation costs. It also shows that a countless proportion of the change in inflation is affected by its own past values and that inflationary perceptions have permanent effects on future values. The estimation results, on the other hand, show that inflation will continue to rise, but there will be a partial slowdown in the rate of increase.

DATA AND METHODOLOGY

The names, descriptions, units and sources of the data sets we used in the research are presented in Table 1. The dataset covers the period between January 2003 and July 2022 and consists of 235 monthly observations. Inflation, exchange rate and commodity price index variables were obtained monthly from their sources. China Containerized Freight Index (CCFI) and Baltic Dry Index (BDI) variables were formed by taking the monthly averages of daily observations. The effect of all the variables on inflation is expected to be positive. Past inflation affects expectations about future inflation and causes inflation to increase. An increase in the nominal exchange rate increases costs and this causes an increase in final prices of the products. Additionally, international demand for cheaper national goods increases and the supply and demand balance deteriorate in the domestic market, which consequently causes an increase in the price levels. BDI representing the raw material transportation cost and CCFI representing the final product transportation cost, on the other hand, cause an increase in the prices of the final products and make a positive contribution to inflation.

The GSCI is the price index calculated for 5 sectors based on the world's leading production-based commodity future contracts. The index determines a weight for each sector in each year, considering the annual production and trade volumes. Weights for 2022 are 53.47% for energy, 20.48% for agriculture, 7.36% for livestock, 12.71% for industrial metals, and 5.96% for precious metals (SPGLOBAL, 2022). With this inclusive feature, the GSCI variable can represent both energy and raw material in different dimensions at the same time. The effect of this variable on inflation is naturally positive. Increasing energy and raw material costs are expected to have a positive impact on price levels in the country.

The course of the variables with inflation over time can also provide preliminary ideas for possible results. Figure 1 presents the movements of inflation and the other 4 variables in the period under consideration. As can be seen, there is a parallelism between CCFI and inflation in the recent period (a). However, this

Table 1. Definitions of the variables

Variable	Definition	Source	Expected Impact
Inflation	Consumer Price Index (2003=100)	CBRT (2022a)	(+)
Exchange Rate	USD / TL Parity	CBRT (2022b)	(+)
CCFI	China Containerized Freight Index (1998=1000)	Bloomberg (2022b)	(+)
BDI	Baltic Dry Index (1985=1000)	Bloomberg (2022b)	(+)
Commodity	Commodity Price Index - S&P GSCI (the Goldman Sachs Commodity Index)	Bloomberg (2022b)	(+)

Table 2. Descriptive statistics of the variables

Statistics	Inf.	CCFI	BDI	Exc.	Com.	R Inf.	R CCFI	R BDI	R Exc.	R Com.
Mean	262.3	1145.3	2443.2	3.24	4249.5	0.010	0.004	0.0008	0.010	-0.0003
Median	211.6	1040.0	1710.4	1.80	4257.2	0.007	0.003	0.023	0.003	0.009
Maximum	1001.0	3510.8	10843	17.38	10558	0.127	0.268	0.874	0.251	0.179
Minimum	94.7	641.5	306.9	1.17	1349	-0.014	-0.098	-1.012	-0.087	-0.348
Std. Dev.	167.7	553.4	2070.4	3.01	1748	0.014	0.047	0.23	0.04	0.070
Skewness	1.91	3.05	1.91	2.41	0.63	4.13	1.57	-0.427	1.63	-1.12
Kurtosis	7.40	11.8	6.90	9.40	3.24	28.96	9.58	5.40	9.49	6.43
Jarque-Bera	333.2	1129.2	292.6	630.7	16.58	7241.3	519.8	63.6	514.8	163.91
Probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Observations	235	235	235	235	235	234	234	234	234	234

Note: Source: Bloomberg (2022b); CBRT (2022a;2022b).

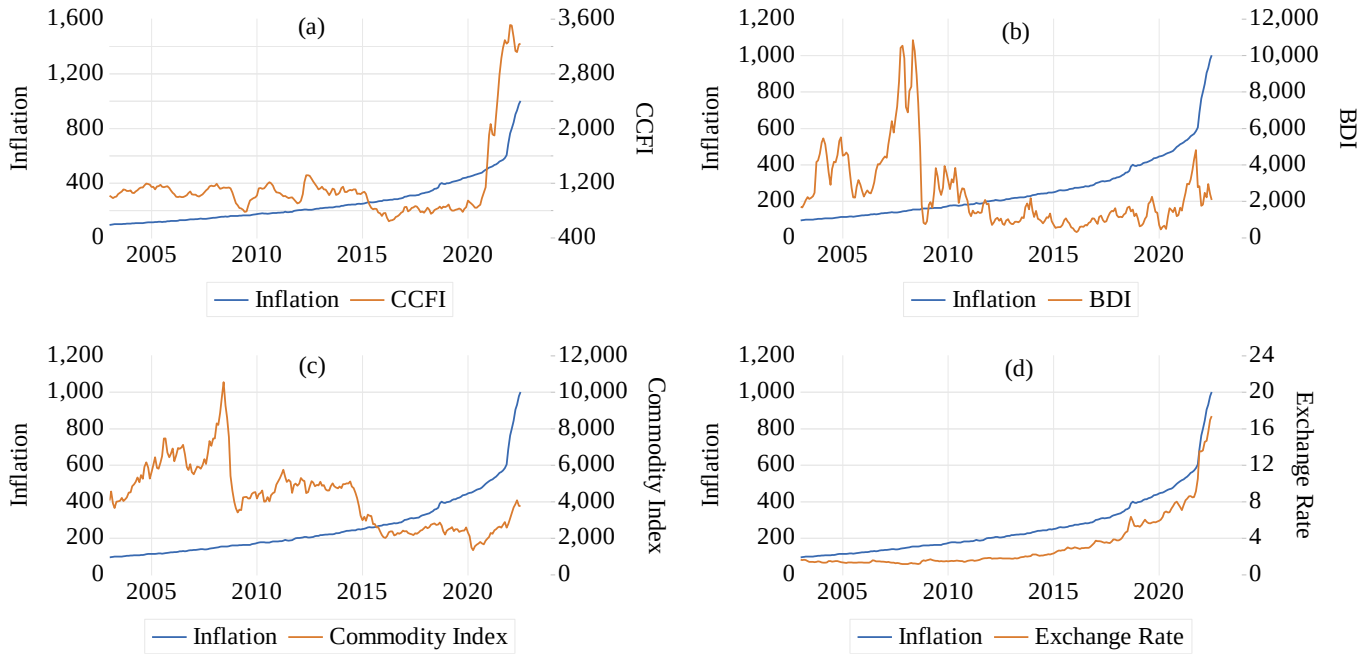

Figure 1. Historical movements of the variables

situation arises not only from the increased freight rates, but also from the increased exchange rates due to the economic policies implemented. Until the start of the COVID-19 period, there was no clear parallelism between the CCFI index and inflation. In this regard, the correlation between them is positive, but it is insignificant (r: 0.06, p: 0.36). Similarly, although a parallelism has been observed recently with the BDI variable, it is difficult to talk about co-movement in general (b). Correlation between them is positive, but it is insignificant (r: 0.06, p: 0.31). The most striking graphic is the one about the nominal exchange rate. The movements of the exchange rate and inflation show a regular parallelism (c). There is a positive and significant correlation between them (r: 0.42, p: 0.00). Finally, although there does not seem to be a clear relationship between the commodity price index and inflation (d), the correlation analysis reveals that there is a low degree of positive and significant correlation between them (r: 0.16, p: 0.01). Additionally, a significant positive correlation is observed between the commodity index and BDI (r: 0.15, p: 0.01). This may be due to the transportation of products such as coal, grain, industrial metals by dry bulk carriers. Increasing demand for commodities may increase commodity prices, while at the same time increasing bulk freight

rates. The decline in commodity demand may also have the opposite effect.

The fact that the graph is misleading is because the correlation analysis was performed between stationary series with first difference taken. While applying the correlation analysis, variables were included in the analysis by considering the unit root test results in Table 3. To make a general assessment, variables that seem meaningless one-on-one can become meaningful by including lagged values and other variables in the model. Market players cannot be expected to react immediately to the shocks. For example, shipping times can sometimes take weeks. Additionally, there are protective instruments against exchange rate volatilities. Since future agreements are made according to current market conditions, there may be a dependency between time intervals. For this reason, the selection of the VAR model is considered a correct approach. In addition, this structure ensures that the forecasts made with the VAR models are more accurate (Brooks, 2014).

Descriptive statistics of the variables used in the analysis for the period under consideration are presented in Table 2. In addition, statistics on log return versions are also presented. The coefficient of variation (standard deviation/mean) can provide explanatory information about the volatility and stability of the variables. This coefficient was calculated as 64% for inflation, 48% for CCFI, 85% for BDI, 93% for the exchange rate and 41% for commodity price. Exchange rate (93%) has the highest volatility. As shown in Figure 1, especially after July 2016, the volatility of the exchange rate has highly increased. Undoubtedly, the military coup attempt in the country was also effective in this situation. This volatility naturally showed a spillover effect toward inflation. Another variable that is most volatile is BDI (85%). Since dry bulk cargo transportation has the characteristics of a perfectly competitive market, the imbalances between supply and demand change very rapidly. This situation causes freight rates to change very quickly. However, the volatility of the container market (48%) is much lower, as it sometimes shows monopoly and sometimes oligopoly characteristics in the short run. However, the recent trade imbalances between countries and the container crisis due to COVID-19 have caused container freight rates to rise dramatically with a historical record. On the other hand, commodity prices seem to follow a decreasing trend considering the monthly log returns (-0.0003). However, in this price index, it is necessary to consider the situation of the U.S. dollar against other currencies. Increasing commodity prices with the increasing dollar exchange rate recently put the trade balances of developing countries in a very difficult situation. Parallel to this, considering the monthly log returns, the variables that increased the most were inflation (0.010) and exchange rate (0.010). Finally, the exploded kurtosis values show that the tail effects of the series are very high. In other words, outliers and changes are high, especially in the inflation.

Table 3. Unit root test results

		Level		First Difference		
		Intercept	**Intercept & Trend**	**Intercept**	**Intercept & Trend**	**Conclusion**
ADF	Inflation	2.702	3.220	-4.710***	-5.318***	I (1)
	CCFI	0.095	-0.076	-8.937***	-9.121***	I (1)
	BDI	-3.023**	-3.650**	-12.129***	-12.109***	I (0)
	Exchange	3.381	-0.260	-10.707***	-11.711***	I (1)
	Commodity	-1.627	-2.389	-12.097***	-12.072***	I (1)
PP	Inflation	3.685	5.905	-7.381***	-8.015***	I (1)
	CCFI	0.051	-0.126	-8.358***	-8.458***	I (1)
	BDI	-2.633*	-3.236*	-11.880***	-11.843***	I (0)
	Exchange	3.799	-0.063	-9.845***	-10.109***	I (1)
	Commodity	-1.585	-2.547	-12.151***	-12.127***	I (1)

Note: (1) CVs: -3.458 for ***1%, -2.873 for **5%, -2.573 for *10% at Intercept; -3.998 for ***1%, -3.429 for **5%, -3.138 for *10% at Intercept & Trend. (2) Bartlett kernel spectral estimation method and Newey-West Bandwidth were selected.

In our research, we preferred to use the causality analysis of the suggestions by Granger (1969) as the method. Assuming that analysis is applied between 2 variables and we call the dependent variable Y and the independent variable X. It can be said that X is the cause of Y if the past values of X contribute to explaining the present and future values of Y in a significant way (Yu et al., 2015). Granger causality testing simply tests this situation. In other words, it tests the correlation between the past values of the first variable and the current and future values of the second one (Chiou-Wei et al., 2008). If there is a mutual interaction between Y and X, it is defined as a feedback relationship. The Granger causality test can also be used to determine the direction of information flow. For example, in order to test the random walk in financial markets, there should be no causality from any other variable to the financial asset (Kirchgässner & Wolters, 2007).

Simple VAR models consisting of 2 variables and estimated with 1 lag can be shown as follows:

$$y_t = \beta_{10} + \beta_{11} y_{t-1} + \propto_{11} x_{t-1} + u_{1t} \quad (1)$$

$$x_t = \beta_{20} + \beta_{21} x_{t-1} + \propto_{21} y_{t-1} + u_{2t} \quad (2)$$

The selected method requires the series to be stationary in the VAR estimations (Brooks, 2014). Various unit root and stationarity tests can be used to determine whether the series are stationary or not. If any of the series contains a unit root, it is made stationary by applying the difference taking operation. The appropriate lagged vector autoregressive (VAR) model should then be determined. In the determination of this model, information criteria are used and the number of lag(s) that minimizes the relevant information criterion is determined as the most appropriate value (Kočenda & Černý, 2015). The roots of the predicted VAR model are then expected to be less than 1. Additionally, various diagnostics related to residues can also be checked. After ensuring the reliability and validity of the model, the relationship between the variables is modeled by applying analysis such as causality, impulse and response, and variance decomposition.

Impulse and response analysis allows us to determine how the dependent variable responds to shocks from other variables. Since the coefficients from the VAR equation are useless in determining the direction of the effect, the impulse and response analysis is very practical for determining the direction of the shock and how long it remains in the system. The variance decomposition method allows to determine how much proportion of the movement in the dependent variable is caused by its own shocks and how much is caused by shocks in other variables. Often the proportion of the dependent variable's own shocks is determined to be greater, but the method is a practical tool for comparing the effect of other variables (Brooks, 2014).

RESULTS AND DISCUSSION

Augmented Dickey-Fuller (1979) and Phillips-Perron (1988) tests were applied to all variables to test their stationarity, which is a requirement of Granger causality analysis. Augmented Dickey-Fuller (ADF) is one of the most common unit root tests. However, if the series has a root of moving average (MA), the Phillips-Perron (PP) test is considered more reliable because it is a nonparametric test that corrects for long-term variance (Cross, 1995). The results of the tests performed are presented in Table 3. Both the ADF and PP tests presented parallel results. The results obtained show that the null of the unit root hypothesis was rejected only in the BDI variable at the level, while in the other variables it was rejected at the first difference. Here, the BDI variable was determined as I (0) and the remaining variables were determined as I (1).

The unit root hypothesis can also provide information about the effect of shocks. For example, inflation data contains a unit root. This shows that inflation carries the shocks it is exposed to, that these shocks have permanent effects and that inflation does not tend to return to the average in the long run. Similarly; exchange rates, commodity prices and container freight also carry permanent shocks which they are exposed. Only dry bulk freights tend to return to the average in the long run. Of course, these results may vary depending on the period covered and the frequency of the data. In addition, breaks in the series can also be effective in the results. However, it can be said that especially inflation and exchange rate are a result of the new economic policies and have permanent effects.

After analyzing the unit root levels of the variables, the VAR model was estimated. As a result of the information criteria and sensitivity controls, it was determined that the most appropriate lag was 2 with the smallest Akaike value (-16.35). To use the VAR model in a proper way, autoregressive (AR) roots must remain within the unit circle. In Figure 2, the positions of the roots within the unit circle are presented. Accordingly, the requirement for roots has been met and the model can be used. However, when the autocorrelation and heteroscedasticity conditions of the residuals were tested, inadequacies were observed in meeting some assumptions. This is probably due to the tail effects in the variables and magnitude of the shocks. At this stage, these shortcomings have been neglected and it is recommended to use nonlinear models for future studies.

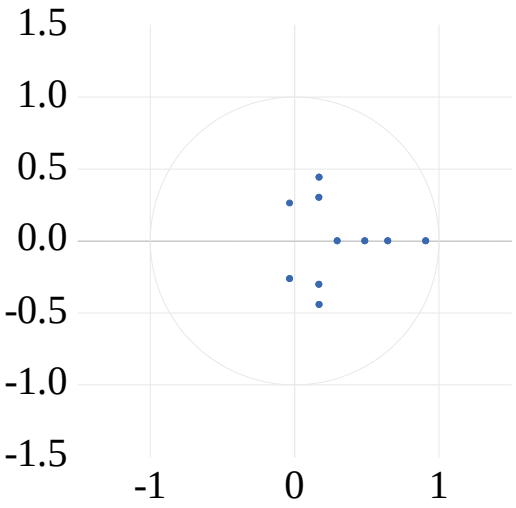

Figure 2. Inverse roots of AR characteristic polynomials

Table 4. Granger causality test results

Dependent	Excluded	Chi-sq	Df.	Prob.
Inflation	dlog CCFI	5.916156	2	0.0519*
	log BDI	1.232898	2	0.5399
	dlog Exchange	45.74104	2	0.0000***
	dlog Commodity	2.800670	2	0.2465
	All	52.86423	8	0.0000***
CCFI	dlog Inflation	4.274682	2	0.1180
	log BDI	2.870919	2	0.2380
	dlog Exchange	0.381899	2	0.8262
	dlog Commodity	4.859630	2	0.0881*
	All	16.88032	8	0.0314**
BDI	dlog Inflation	1.776595	2	0.4114
	dlog CCFI	1.928074	2	0.3814
	dlog Exchange	12.09025	2	0.0024***
	dlog Commodity	12.97618	2	0.0015***
	All	35.17240	8	0.0000***
Exchange	dlog Inflation	7.801047	2	0.0202**
	dlog CCFI	2.052452	2	0.3584
	log BDI	2.500047	2	0.2865
	dlog Commodity	6.517111	2	0.0384**
	All	20.02219	8	0.0103**
Commodity	dlog Inflation	0.433800	2	0.8050
	dlog CCFI	0.911844	2	0.6339
	log BDI	5.617484	2	0.0603*
	dlog Exchange	0.366856	2	0.8324
	All	7.439890	8	0.4900

Note: (1) Null of Granger Non-Causality is Rejected at *10%, **5%, ***1%. (2) Optimal lags according to information criteria when maximum lag is 18: SC=1, AIC=2, HQ=1 (Akaike was selected).

$$inflation_t = \beta_{10} + \beta_{11} inflation_{t-1} + \beta_{12} inflation_{t-2} + \propto_{11} CCFI_{t-1} + \propto_{12} CCFI_{t-2} + \delta_{11} BDI_{t-1} + \delta_{12} BDI_{t-2} + \theta_{11} Exchange_{t-1} + \theta_{12} Exchange_{t-2} + \alpha_{11} Commodity_{t-1} + \alpha_{12} Commodity_{t-2} + u_{1t} \quad (3)$$

The mathematical form of the VAR model estimated for inflation using 2 lags can be represented as shown in equation 3:

This equation is estimated separately for all variables and the results are obtained. It can be determined whether all the variables included in the model are significant for the others. These models, which are estimated according to the academic need, can also be used. The graphic of the inverse AR roots of the model estimated for 2 lags is presented in Figure 2. Findings show that all roots are less than 1 and the model can be used for further analysis.

After it was determined that the AR roots of the model were less than 1 and the optimal lag is 2, Granger causality analysis from VAR models was applied and the results are presented in Table 4. To enrich the results and to examine possible feedback situations, causality results are presented for all variables in the analysis. Nevertheless, obtaining statistically significant results does not mean that they are theoretically meaningful. There may also be relationships formed by chance or by internal correlation problems. Or there may be errors in the obtained data.

Considering the individual results for inflation, it has been determined that there are significant causal relationships from the CCFI and nominal exchange rate variables. There was no significant relationship between commodity price and BDI variable individually. However, when all independent variables are modeled, it can be said that they all carry determinant information for inflation levels in Türkiye. From the impulse and response analysis in Figure 3, the reaction of inflation to unexpected shocks from other variables can be interpreted. Inflation does not react to the 1 standard deviation unexpected positive shock in the CCFI variable in the first period, but gives a negative reaction in the second period. From the third period, the inflation starts to give a positive reaction to the CCFI. Then, this positive effect continues for 10 months and leaves the system. The negative reaction within the 2-month period may be due to a contraction in demand due to increased transportation costs. However, this cost increase may be taken for granted in the following periods and the recovery in demand may contribute positively to inflation. On the other hand, one standard deviation shock in BDI, which shows the cost of raw material transportation, has positive effect on inflation and this effect continues for about one year. However, this effect is not higher than that of the effect from the cost of the container transportation. The variable to which Turkish inflation reacts the most is naturally the nominal exchange rate. Moreover, changes in exchange rates directly affect transportation and commodity costs. Therefore, an unexpected shock in the exchange rate makes the inflation jump in the second period, and this effect disappears from the system after about 9 months. Of course, if the economy is repeatedly exposed to many shocks about the exchange rate due to political environment, it will take a long time for the effect to be removed from system. The reaction of inflation to the shock in the commodity index is naturally positive. The rising commodity price index points to both increased logistics costs as well as raw material costs. The effect of an unexpected one standard deviation shock in prices on inflation lasts approximately for one year.

When the CCFI variable is considered a dependent variable, a significant causality relationship has been determined from commodity price index. Naturally, no effect could be detected from inflation and exchange rate, which are the internal economic factors of Türkiye. The causality determined from commodity price index may be due to remarkable weight of energy prices in the index or the increase in commodity prices used in production due to increased demand, and the reflection of increased demand on maritime transport traffic. As can be seen in the left part of Figure 4, the response of container freight rate to the shock in commodity prices is positive and this effect loses its effect after about 7 months.

In the model where BDI is the dependent variable, significant causality relationships were determined from the USD/TRY nominal exchange rate and the commodity price index. the Turkish exchange rate may

carry information about international interest policies and these policies may affect the demand for bulk cargoes. Therefore, there may be an impression that there is an information flow. The response of the bulk freight rate to the USD/TRY exchange rate was seen as negative in the impulse & response analysis. Considering that the rising exchange rate carries information about the increase in interest rates and that the interest rate is increased against the increasing inflation in the world, it can be said that the consumption in the world is shrinking, and this situation is negatively reflected on the dry bulk transportation demand. On the commodity side, increasing or decreasing demand can be directly reflected in bulk cargo transportation as commodity prices carry information about their demands. Additionally, the oil prices included in the commodity price index can generate an information flow for ships whose most important input is fuel costs. This effect can be seen on the right side of Figure 4. The unexpected shock in the commodity price index generates a positive effect and this effect remains in the system for a very long time.

In the model where the exchange rate is the dependent variable, naturally a significant causality relationship from inflation has been determined. Increasing inflation can cause investors to increase demand by transferring their money to exchange rates to secure their purchasing power. In addition, manufacturing companies may be pushing their purchasing decisions forward or stocking foreign currency rather than buying their raw materials more expensive in the future. The right-hand side of Figure 5 shows that the exchange rate responds immediately to shocks from inflation. In addition, the unexpected shock effect in inflation is felt in the exchange rate for about 10 months. Additionally, it is seen that there is a feedback situation due to the mutual causality relations between the inflation and the exchange rate. There are mutual information flows from both variables and their behavior change according to these information flows.

The significant causality relationship between the exchange rate and commodity prices may be because Türkiye's imports are considerably higher than its exports. As commodity prices increase, trade balancing concerns may also increase, leading to further appreciation of the dollar. Since the international payments are made with the exchange rate and the

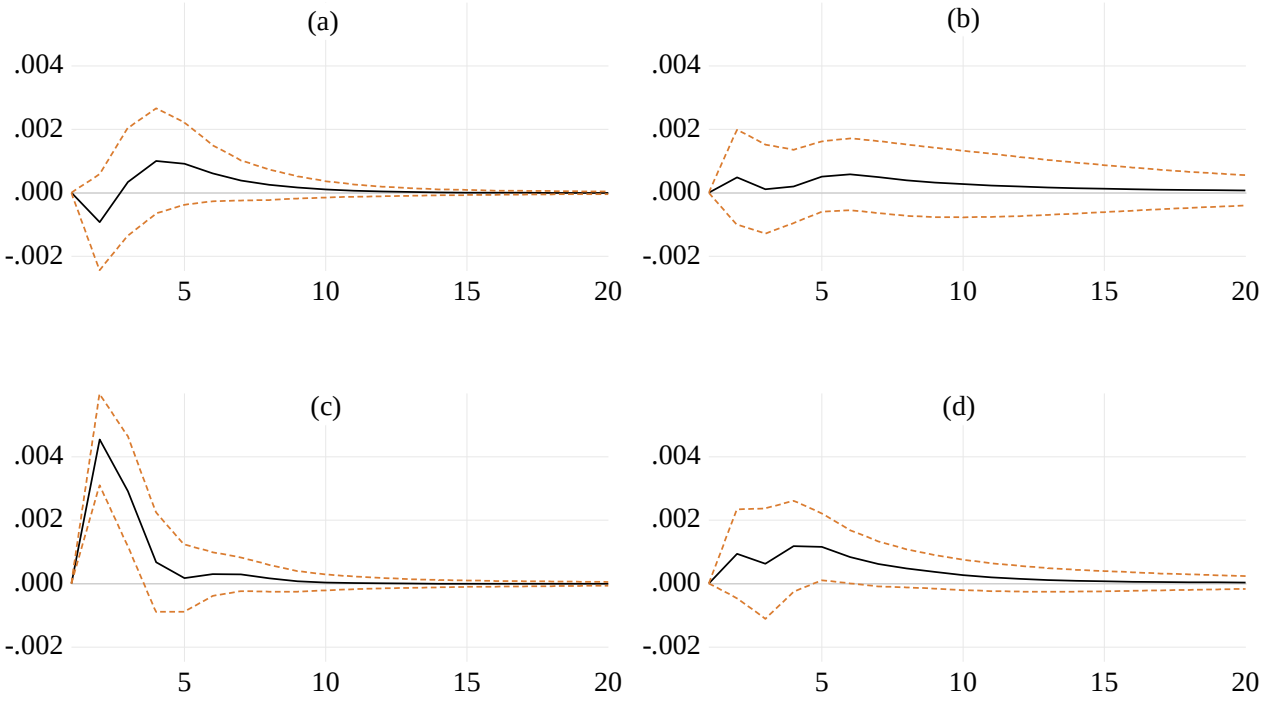

Figure 3. Results of impulse response analysis of inflation. a) Response of inflation to China Containerized Freight Index, b) Response of inflation to Baltic Dry Index, c) Response of inflation to Nominal Exchange Rate, d) Response of inflation to Commodity Price Index. (Response to Cholesky One S.D. (d.f. adjusted) Innovations ± 2 S.E.)

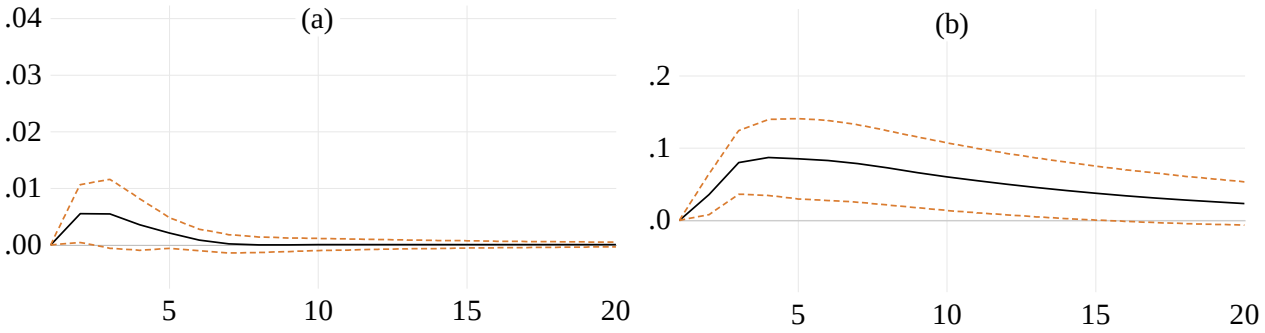

Figure 4. Response of freight indices to commodity price index

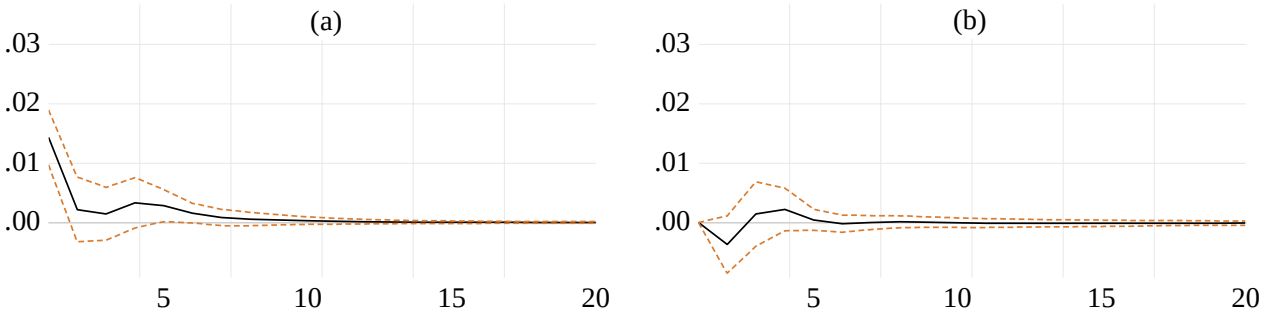

Figure 5. Response of exchange rate

foreign exchange income source of the countries is basically exports, higher imports ensure the pricing of the foreign currency. The right-hand side of Figure 5 shows that the exchange rate response to the unexpected shock in commodity prices was initially negative, but later turned positive and exited the system after about 5 months. Being a composite index makes interpretation difficult. Since precious metals such as gold are also included in this index, increasing gold prices may cause Turkish investors to exit foreign currency and switch to gold. However, the demand for the dollar, which has become cheaper after switching between investment tools, may increase due to the current account deficit and inflation in the country. In addition, volatilities in the exchange rate can change the demand for foreign currency by affecting the payment preferences of Turkish foreign trade stakeholders (Özçelik, 2022).

Finally, in the commodity-priced model, there is only one significant causality relationship from BDI to the commodity price index. This shows that there is a feedback situation between commodity prices and BDI and there is a mutual flow of information. Since the BDI is accepted as the leading indicator of world trade and economy, the slowdown in the dry bulk market may also be reflected as a slowdown in the demand for commodities. Changing expectations may also reflect positively or negatively on commodity prices. As shown in Figure 6, unexpected shock from BDI generates a positive reaction in the commodity price index and this effect continues for about 8 months.

We made some inferences about how much the unexpected shocks from other variables affect inflation. However, it is necessary to examine how much of the changes in inflation are caused by their own shocks and how much are by shocks in other variables. This analysis can be done with the variance decomposition method. Since our main research question is about the inflation, we only included the decomposition of the inflation variable here. The results of our analysis for 12 periods are presented in Table 5. The results show that about 82% of the change in inflation is due to its own shocks, 13% to exchange rate shocks, 2.5% to commodity price shocks, 1.5% to container transportation cost shocks and 0.7% to dry bulk transportation cost shocks. From this table, inferences can be made about the variables that affect inflation the most. It is seen that the most important factor is the changes in the exchange rate because the changes in the exchange rate also affect the costs of purchasing commodities and transportation services, which are supplied in dollars in the international area.

Table 5. Variance decomposition of inflation

Period	S.E.	Inflation	CCFI	BDI	Exchange	Commodity
1	0.010657	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.013334	87.29707	0.478379	0.134257	11.59772	0.492570
3	0.014137	84.19161	0.483514	0.125797	14.56226	0.636819
4	0.014486	83.56437	0.942049	0.138793	14.08543	1.269363
5	0.014713	82.92711	1.300955	0.254646	13.66813	1.849155
6	0.014828	82.50378	1.450976	0.405515	13.49785	2.141881
7	0.014881	82.24310	1.506880	0.511553	13.44000	2.298466
8	0.014906	82.09030	1.529788	0.578818	13.40668	2.394415
9	0.014919	81.99926	1.539254	0.624961	13.38548	2.451036
10	0.014926	81.94407	1.542709	0.657965	13.37337	2.481887
11	0.014930	81.90989	1.543739	0.681453	13.36653	2.498391
12	0.014933	81.88784	1.543920	0.698217	13.36243	2.507599

Note: Cholesky Ordering: Inflation CCFI Exchange BDI

Based on the findings in the variance decomposition analysis that the change in inflation is largely from itself, we also decided to examine the response of inflation to its own shocks. The impulse & response graph of inflation is presented in Figure 7. According to the result, an unexpected shock of 1 standard deviation in inflation causes a large positive reaction in inflation in the following period. It takes almost 12 months for the effect of this shock to be eliminated from the system. This situation reveals a result that is more suitable for the forward-looking based rational expectation theory. Market players hold high inflation expectations by considering historical data, current data in the market, past results of policies implemented and possible results of the policies to be implemented. Since the difference between expected inflation and actual inflation in the previous period is high due to the unexpected shock, inflation expectations for the next period are also higher.

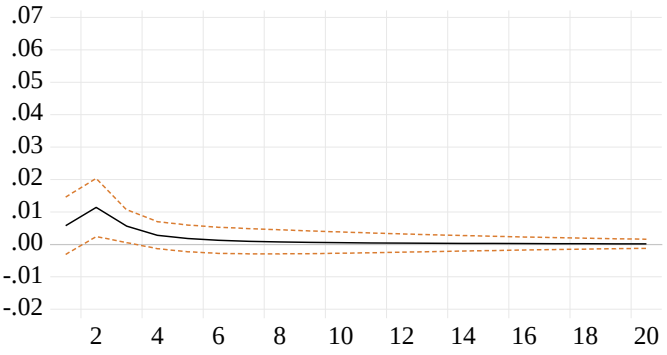

Figure 6. Response of the commodity price index to BDI

As the last step of our analysis, we estimated the Consumer Price Index for August 2022 and December 2023 using the VAR model we obtained. Our estimated result is presented in Figure 8. According to our estimate, inflation will continue to increase in Türkiye, but the rate of increase will decrease over time.

CONCLUSION

Due to the global instability, especially, energy prices have been on the rise in the world recently. In addition, the difficulties experienced in grain supply due to the Russia-Ukraine war caused incredible increases in grain prices, albeit temporarily. Of course, the contribution of these factors to inflation is indisputable and obvious. However, due to the container crisis in the COVID-19 period and the temporary closure of the Suez Canal, the freight rates, which increased to a record level due to the extended routes, have only just begun to be considered from an inflationary perspective. In this study, while modeling inflation with Keynes' push-up cost approach, we differentiated from the literature by including the costs of transporting raw materials and final products in our model. We used VAR models to reveal the effects of costs that we think are not considered in the inflationary environment. After determining the appropriate VAR model, we filtered the information with Granger causality, impulse & response, variance decomposition techniques.

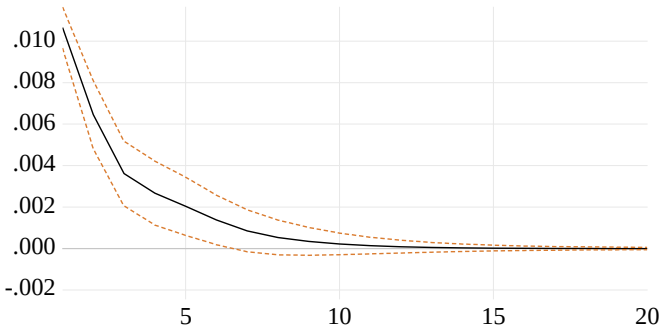

Figure 7. Response of inflation to inflation

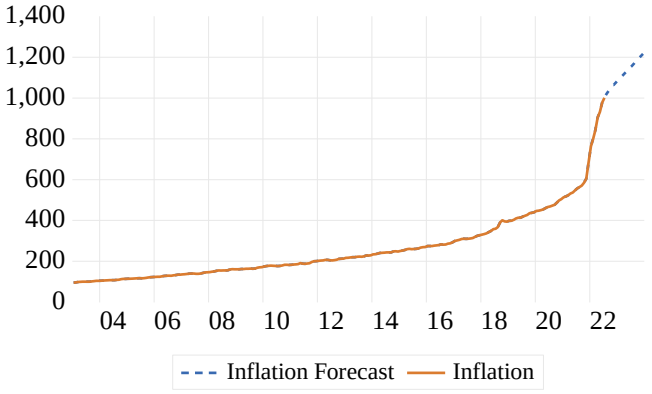

Figure 8. Inflation forecast

We chose Türkiye as the sample. In addition to the global inflationary environment in the world, Türkiye implements new policies as it switches to a new economic model that reduces to importance of hot money flow. These policies accelerated inflation by causing the dollar to appreciate even more in the short term. In this respect, we determined the role of exchange rate, commodity prices and transportation costs in Türkiye's inflation, and to reveal findings about the direction in which political energy should be spent in the near future.

Our results show that first, inflation is heavily affected by its own past shocks. One reason for this situation may be the positive (that will increase) expectations of the citizens and investors of the country about future inflation. The source of these expectations may be the experience of the results of the policies implemented in the past, unkept promises about the economy and the fueling of inflation by negative news in the country (Siebert, 2007). Of course, changes in global energy and commodity prices were also influential in the rate of increase in inflation. However, for example, while the oil price was $57.52 in January 2020, it doubled to $114.59 in June 2022, while the USD/TRY rate increased nearly three times in the same period (from 5.91 to 16.96). These examples were also seen in our causality, impulse & response, and variance decomposition analyses. A significant causal relationship from commodity price index to inflation could not be determined individually. There is a strong causality relationship from the exchange rate. Naturally, the response of inflation to an unexpected shock was highest in the exchange rate. Additionally, unexpected positive shock from the exchange rate generates permanent effects and this effect continues for about 9 months. For this reason, policies that increase the stability of the exchange rate and protection tools should be supported. Trade agreements that reduce the demand for the single exchange rate can also contribute significantly to this stability.

In the context of the effect of transportation on inflation, container transportation and dry bulk cargo transport differ. As a market type, they have a different structure from each other. In the results of the individual causality analysis, container transportation has a significant positive contribution to inflation. Although the first reaction is negative, the following periods turn into a positive dimension, causing inflation to rise. On the other hand, although dry bulk cargo transportation does not perform a significant causality in an individual sense, it has a significant positive contribution to inflation in the collective model. This may be because the Turkish economy is not very strong in terms of heavy industry. Industrial states such as China heavily import raw materials and produce with their developed industries and sell the final products to other countries. However, the Turkish economy's activities are limited to the extent that it will import a very large amount of dry bulk raw materials. There is a production model based mostly on the import of intermediate goods. Intermediate goods import is mostly carried out by container transportation. This may be due to the fact that the Turkish economy is less affected by bulk freight than container freight in terms of inflation. Additionally, in addition, the ratio of transportation costs to the value of the product is higher in raw materials than in manufactured items. Because the added value of manufactured products is higher (Reis & Macario, 2019), and compared to raw materials, manufactured

products are sent to shorter distances (Bairoch, 2006). Accordingly, the higher contribution of the CCFI index to inflation may be mainly due to the rise in exchange rates.

In this respect, it is important to develop the Turkish container transportation network. It is necessary not only to carry out intensive transportation activities by sea, but also to use alternative projects such as OBOR effectively. Additionally, business models that will strengthen national transport security should be developed. For example, with systems such as the pool system, the national fleet can be operated effectively and in a way that supports the national interests. This situation may save our country from the monopoly of international shipowners who exhibit monopoly and oligopoly behavior in the short term. Such players have the power to determine the freights in the market and naturally their primary aim is profit maximization, not the welfare of the countries. For example, the USA has recently enacted regulations regarding international container companies to increase national security.

As a limitation of the study, the used freight indices can be shown. Although BDI and CCFI are leading indicators of their internationally recognized markets, they may not perfectly represent Türkiye's transportation costs. For example, the freights of huge bulk carriers and small bulk carriers can differ greatly, and Turkish ports do not have the physical and economic infrastructure to accommodate huge ships. The same is true for container ships. In this respect, freight indices belonging to more characteristic ships can be used for Türkiye. Unfortunately, we could not reach these values. Suggestions for future studies are to carry out a similar study with a panel data set covering other countries and to support it with different methodologies.

Compliance with Ethical Standards

Authors' Contributions

Author AA designed the study, AA and MRİ wrote the first draft of the manuscript, AA performed and managed statistical analyses, MRİ performed writing - review & final editing. Both authors read and approved the final manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

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