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Modelling Producer Prices Using Artificial Neural Network and ARIMA Methods for Türkiye

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ABSTRACT

The increase in the producer prices limits the activities of the companies and leads to the deterioration of the national product, employment and consumer prices. In this study, the relations between the oil price, exchange rate, interest rate, wages and the producer prices for the period of 2002Q01-2022Q03 in Türkiye were examined using autoregressive moving averages (ARIMA) and artificial neural network (ANN) methods. The employed ANN structure consists of an input layer, a hidden layer with 100 neurons and an output layer. The ANN is trained and then the modelling and forecasting performances of the traditional ARIMA and nonlinear ANN methods are compared. RMSE, MAE, MAPE and R^2 criteria were used to evaluate the predictive power of the ARIMA and ANN models. As a result of automatic ARIMA model estimation, it has been determined that the producer prices can be modelled using an ARMA(4.4) model, which is a subset of the ARIMA modelling. MAE, RMSE, MAPE and R^2 values of ARIMA and ANN models show that the ARMA(4,4) model has slightly better accuracy compared to the ANN model. In addition, according to the ARMA(4.4) model, it is shown that the interest rate, exchange rate, oil prices and wages affect producer prices. In this context, our policy recommendations are to follow a low interest policy and to encourage the use and production of electric vehicles to reduce the use of fossil fuels in order to reduce producer prices.

Keywords: Producer price index, artificial neural network ARIMA, economic modelling.

INTRODUCTION

Producer prices affect production costs which consist of fixed and variable costs. Infrastructure investments can be given as an example of fixed costs and payments made to production factors constitute variable costs. In this sense, the effects of exchange rate, oil prices, wages and prices of imported goods on production costs should be investigated. High production costs reduce the profitability of the enterprises and cause them to reduce the workforce. On the other hand, high producer price index (PPI) increases the price of finished goods. Increasing production costs and unemployment may lead countries to stagflation. In order to prevent such problems, it is important to determine the causes of production costs employing the right methods. Examination of linear and nonlinear methods together and comparison of their results obviously contribute to the literature.

Many developing countries have an inflation problem. Exchange rates and oil prices put pressure on production costs, especially in countries which are foreign-dependent in production and exports and are not oil producers. In addition, the increase in domestic interest rates increases producer costs. If the interest rates rise, the cost of using capital rises and the cost of production also rises. Producers obviously do not want to borrow with high interest rates, or if they do, they may reflect these rates on their prices of their products, causing the consumer prices of their products to increase.

Another factor that creates production costs is the wage payments. In economies where wages rise, the total supply decreases. The reason for this is that the enterprises reduce the demand for labour due to the increment in production costs.

Variations in producer prices in Türkiye are monitored using the PPI in this study. The stability of the PPI is important in terms for the prices of the final goods. From this viewpoint, determining the factors affecting the PPI and the effects of these factors on producer prices will enable policies to reduce the PPI. Figure 1 shows the variations in the consumer and producer price index until the third quarter of the 2002-2022 period in Türkiye.

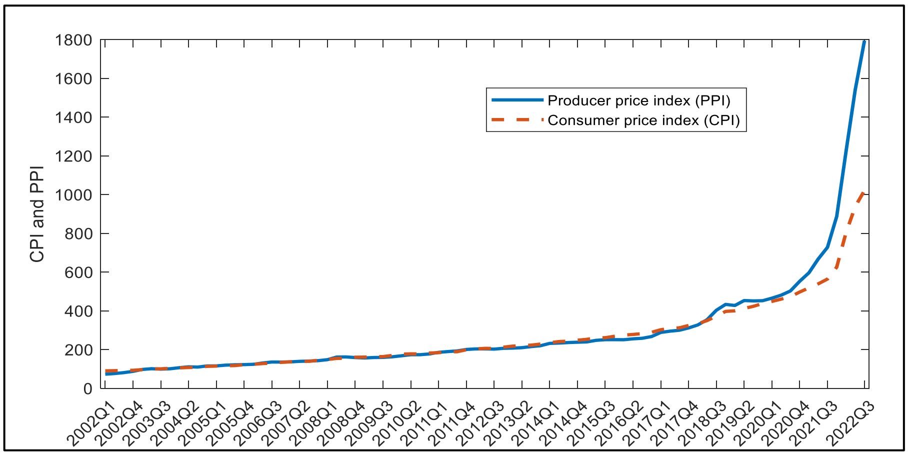

Figure 1. Variations in the consumer and producer price index in Türkiye

Source: Prepared from the Domestic Producer Price Index series included in the Central Bank of the Republic of Türkiye, Electronic Data Distribution System, Price Index Data. https://evds2.tcmb.gov.tr/index.php?/evds/serieMarket.

From Figure 1, it is seen that the consumer price index (CPI) and PPI increase rates were low in the 2003-2004 period. The contractionary macroeconomic policies implemented after the economic crises in Türkiye in 2001 and 2002, the balanced budget policy and the stable course of world commodity prices contributed to this situation. On the other hand, the rate of increase in producer prices started to increase again in the period of 2004-2008, and the increase in both PPI and CPI accelerated after 2008. The world economic crisis experienced in this process also led to cost increases in Türkiye. In the third quarter of 2022, the increase in PPI and CPI reached 80%-100%. In the post-2020 period, when the pandemic was effective, there were problems in the supply of many intermediate goods, oil prices increased, and the exchange rate increased. All these effects are 157.64% of PPI and 85.41% of CPI as of October 2022 (Turkstat, 2022).

In this study, producer prices were estimated using linear and nonlinear models, which are Auto-Regressive Integrated Moving Average (ARIMA) and Artificial Neural Network (ANN) methods, for the period of 2002Q01-2022Q03 in Türkiye. From this viewpoint, the predictive performances of the linear and nonlinear models are evaluated. Furthermore, the oil prices, exchange rate, interest rate and the wage variables are included as regressor variables. In this context, the effects of these variables on producer price predictions are also studied.

LITERATURE REVIEW

There are limited number of studies in the literature investigating the causes of producer price index. Ito and Sato (2006), Mc. Carty (2000), Mihaljek and Klau (2001), Sekine (2006), Stulz (2000), Bayraktutan and Arslan (2003), Işık, Acar and Işık (2004), Kara et al. (2005), Gül and Ekinci (2006), Güven and Uysal (2013), Zhang (2013), Peón and Brindis (2014), Muhammed et al. (2015) can be given as an example. Ito and Sato (2006) determined that in East Asian countries, the pass-through effect of exchange rate on prices varies according to price indices, the said effect is mostly reflected on import prices, and then producer and consumer prices are affected. Mc. Carty (2000), while there is a positive relationship between exchange rate and import prices, the effect of exchange rate on domestic inflation is weak. Mihaljek and Klau (2001) examined the relationships between exchange rates, import prices and domestic inflation data for 13 countries, including Türkiye, for the period 1995-2000. As a result of the study, it was concluded that the relationship between exchange rate and inflation is stronger than import prices. In addition, it was stated that the effect of exchange rate on prices was the highest in the first four and lasted for more than one year. It has been determined that the reflection of this effect on consumer prices is stronger than on producer prices. Similar to Sekine's (2006) study, Stulz (2007) examined the effect of pass-through from exchange rate to prices in Switzerland for the period 1976-2004, and stated that the effect of pass-through from exchange rate to consumer prices gradually decreased. Bayraktutan and Arslan (2003) found a two-way causality relationship between the wholesale price index, exchange rate and import volume in Türkiye for the period 1980-2000. Işık, Acar, and Işık (2004) concluded that inflation and exchange rate variables are cointegrated for the 1982-2003 period. In another study, the effects of the exchange rate and interest rate on producer price index in Türkiye is investigated by Surekci Yamacli (2016). Kara et al. (2005), for the period 1995-2005, reached the conclusion that the pass-through effect from the exchange rate to prices decreased due to the floating exchange rate and anti-inflationary policies implemented in Türkiye since 2001. Gül and Ekinci (2006) determined a one-way causality relationship from exchange rate to inflation for the 1984-2003 period. Güven and Uysal (2013) found a bidirectional relationship between the consumer price index and the real effective exchange rate for the 1983-2012 period. Using VAR analysis for the period 1990-2011, Zhang (2013) found the relationship between domestic prices and exchange rate weak in India. Using the SVAR=X model, Peón and Brindis (2014) found that the exchange rate pass-through has a rather small but rapid effect on consumer prices. Mohammed et al. (2015) investigated the effect of exchange rate pass-through on producer and consumer price index by examining the 2002-2011 period for the Algerian economy. As a result of the study, it is stated that the exchange rate pass-through has a significant but negligible response on the producer price index.

There are also studies in the literature examining the relationship between domestic prices and the interest rate (Atkins and Coe 2002; Bajo-Rubio et al., 2005; Dutt and Ghosh, 1995; Fisher, 1930; Granville and Mallick, 2004; Güneş and Tunçal, 2002; Junttila, 2001; Mishkin, 1992; Şimşek and Kadılar 2006; Yamak and Tanrıöver 2007). Atkins and Coe (2002), for the 1953-1999 period, found a relationship between the interest rate and the consumer price index in Canada and the USA, supporting the Fisher Effect. Similarly, Granville and Mallick (2004), for the period 1900-2000, in England; Bajo-Rubio, Diaz-Roldan, and Esteve (2005) concluded that for the 1963-2002 period, high interest rates positively affected consumer prices in Spain. Şimşek and Kadilar (2006) determined a long-term relationship between the nominal interest rate and the inflation rate for the 1987-2004 period, and Bolatoğlu (2006) for the 1990-2005 period, and they concluded that the Fisher Effect is also valid for Türkiye. Yamak and Tanrıöver (2007) determined that there is a unidirectional and positive relationship from the interest rate to the general price level in the long run for the 1990-2006 period. There are also studies investigating the effect of exchange rate and interest rate on domestic prices together (Taylor, 1993; King and Wolman, 1996; Fisunoğlu and Çabuk, 1997; Dibooğlu and Kibritçioğlu, 2004; Sever and Mızrak, 2009; Karagöz and Ergün, 2010; Yapraklı and Kaplan, 2012). Taylor (1993), by examining these variables in the USA for the period 1987-1992; He concluded that the effect of exchange rate on inflation is very low, and that the main monetary policy instrument affecting inflation is the interest rate. King and Wolman (1996) found that for the 1915-1992 period in the USA, the interest rate and money supply were effective on inflation, while the exchange rate was not. Similar to these studies, in Türkiye, Fisunoğlu and Çabuk (1997) for the period 1987-1997, Dibooğlu and Kibritçioğlu (2004) for the period 1980-2002, Sever and Mızrak (2009) for the period 1987-2006, Karagöz and Ergün (2010)) for the period 1987-2007, Yapraklı and Kaplan (2012) for the period 2006-2011, Bal (2012) for the period 1994-2008, determined that interest and exchange rates are effective on inflation. For example, Yapraklı and Kaplan (2012) found a two-way causality relationship between inflation, interest rate and real effective exchange rate index, and according to the results of cointegration and error correction model, they determined that it is negatively affected by inflation, interest rate and exchange rate, albeit small, in the short and long term.

MATERIALS & METHODS

In time series analysis, it is necessary to determine the stationarity structures of the variables (Gujarati, 1995: 750). The stationarity of the variables was investigated using Extended Dickey-Fuller (ADF, Augmented Dickey-Fuller) and Phillips-Peron (PP) unit root tests.

Firstly, ARIMA method was used in the study. Eviews software was used for this modeling. In ARIMA (p,d,q) analysis, p indicates the degree of autoregression (AR) model, d the number of differentiating operations, q the degree of moving average (MA) model. The ARIMA model is expressed as in equation (1):

$$y_t = c + \sum_{i=1}^{p} \phi_i x_{t-i} + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} + \varepsilon_t \quad (1)$$

In Eq. (1), y_t represents the data to which the ARIMA model is applied, x_t represents the difference series in the order of d, the moving average parameters, the coefficients of the autoregressive terms, and the error term.

The second method of the study is the regression using artificial neural networks (ANN). Computational software was used for this modeling. The ANN regression model of the study is a two-layer feed-forward model. In this model, sigmoid functions are used in the hidden layer and linear functions are used in the output layer. The number of neurons in the hidden layer is taken as 100. The minimization method in the training phase is the Levenberg-Marquardt backpropagation algorithm. The structure of the artificial neural network is as shown in Figure 2.

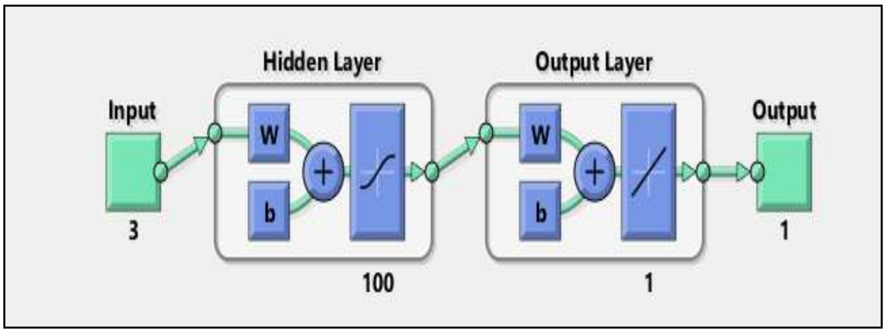

Figure 2. Two-layer feed-forward artificial neural network used for the ANN regression model

The green boxes in Figure 1 are the input and output layers, and the blue boxes are the hidden layers. The non-linearity in the modelling is introduced by the use of the sigmoid functions in the hidden layers. In addition, linear activation functions are used in the second hidden layer to improve the predictive power.

RESULTS AND DISCUSSION

The aims of the study are to predict the PPI using linear and linear modelling methods and to determine the effects of exchange rate, oil prices, interest rate and wage variables on producer prices. The dependent variable of the study is the 2003 base year domestic PPI based price index. The independent variables are the 2003 PPI-based real effective exchange rate index (exchange rate) and the 2-14 day repo rate (interest), the European Brent oil price index (oil), and the ratio of wages to workers to domestic product (wage/gdp). Variables are obtained from the Electronic Data Distribution System of the Central Bank of the Republic of Türkiye (EVDS of CBRT). The "sa" in the names of the variables indicate that they are adjusted for seasonality effects using the exponential correction method.

The effects of variables on producer prices can be summarized as follows within the scope of economic expectations:

- The interest rate is the cost of using capital. Capital is an input for producers. The rise in interest rates is expected to increase producer inflation.

- Changes in exchange rates affect input costs. It is expected that there will be a positive relationship between the exchange rate and producer prices, especially in industries that are dependent on imported goods.

- The economic expectation is that the relationship between producer inflation and exchange rate is positive. The exchange rate variable in the model is the real effective exchange rate index calculated by the CBRT. The increase in the value of this index shows the appreciation of the Turkish Lira. In this context, the sign of the coefficient showing the relationship between the real effective exchange rate index and producer prices will be negative. -

- A positive relationship is expected between the increase in labor costs and producer prices. As wages rise, production costs will rise.

The results of the unit root tests of the variables are presented in Table 1. According to this, interest rate and the oil price variables are stationary at the level stage while exchange rate and wage variables are stationary at the first differences stage.

Table 1. Results of The ADF and PP Unit Root Tests

Variables/Tests			**PPI_SA**	**OIL_SA**	**EXC_SA**	**INT_SA**	**WAGE_SA**
ADF	Level	Constant Prob. t stat.	3,301 1,00 -3,522	-2,647 0,10 -2,900	-1,602 0.47 -3,520	-3,543 0,01 -3,520	-0,803 0,81 -3.529
		Constant &trend Prob. t stat.	2,897 1,00 -4,093	-4,85 0,30 -2,540	-2,788 0,21 -4,085	-2,535 0,31 -4,085	-3.151 0.10 -4,093
	1st Difference	Constant Prob. t stat.	-3,369 0.02 -2,900	-9,342 0,00 -3,522	-10,319 0,00 -3,522	-7,474 0,00 -3,522	-4,548 0,00 -3,529
		Constant &trend Prob. t stat.	-4,322 0.00 -4.087	-9,359 0,00 -4,087	-10,49 0.00 -4,087	-7,810 0,00 -4,087	-4,448 0,00 -4,087
PP	Level	Constant Prob. t stat.	4,478 1,00 -3,520	-2,567 0,10 -3,520	-1,446 0,56 -3,520	-3,487 0,01 -2,901	-1,930 0,29 -3.520
		Constant &trend Prob. t stat.	2,529 1,00 -4,085	-2,442 0,35 -4,85	-2,715 0,233 -4,085	-2,536 0,31 -4,085	-3,422 0,06 -4,085
	1st Difference	Constant Prob. t stat.	-3,400 0,01 -3,522	-9,745 0,00 -3.521	-10,439 0,00 -3.522	-7,475 0,00 -3,521	-12,810 0,00 -3,521
		Constant &trend Prob. t stat.	-4,357 0,00 -4,086	-10,317 0,00 -4,87	-12,156 0,00 -4,087	-7,802 0,00 -4,087	-13,496 0,00 -4,068

The difference stationary structure of the dependent variable is consistent with the assumptions of the ARIMA model. Based on the automatic ARIMA forecasting, the ARMA (4.4) model was deemed appropriate for the estimation of producer prices (Appendix: Automatic ARIMA Model Selection). Table 2 presents the ARMA (4.4) model results.

According to the ARMA (4.4) model in Table 2, there is a statistically significant relationship at the level of 1% between the variables of interest rate, real exchange rate, oil prices and producer prices, and at the level of 5% for the wage indicator. These findings suggest that studies aiming at estimating producer prices should focus not only on past values of producer prices but also on these variables as regressors. Furthermore, Figure 3 presents the estimation plots of the ARIMA and ANN models which enable the visual comparison of the predictive performances of the linear ARIMA and nonlinear ANN models.

Table 2. Results of the Automatic ARIMA Forecasting

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.049007	0.038421	-1.275530	0.2079
INTSA	0.001820	0.000606	3.004102	0.0041
D(EXCSA)	-0.000813	0.000295	-2.753650	0.0081
OILSA	0.000689	0.000160	4.293934	0.0001
D(WAGESA)	0.003770	0.001779	2.118459	0.0390
AR(1)	0.473895	0.410383	1.154763	0.2536
AR(2)	-0.374306	0.319403	-1.171894	0.2467
AR(3)	0.319359	0.345887	0.923306	0.3602
AR(4)	0.447983	0.363774	1.231487	0.2238
MA(1)	0.234226	16.36492	0.014313	0.9886
MA(2)	0.182380	96.93478	0.001881	0.9985
MA(3)	0.119796	9.519419	0.012584	0.9900
MA(4)	-0.828358	626.4208	-0.001322	0.9990
SMA(4)	0.577397	1339.974	0.000431	0.9997
SMA(8)	-0.422590	1536.503	-0.000275	0.9998
SIGMASQ	0.000319	0.153590	0.002075	0.9984

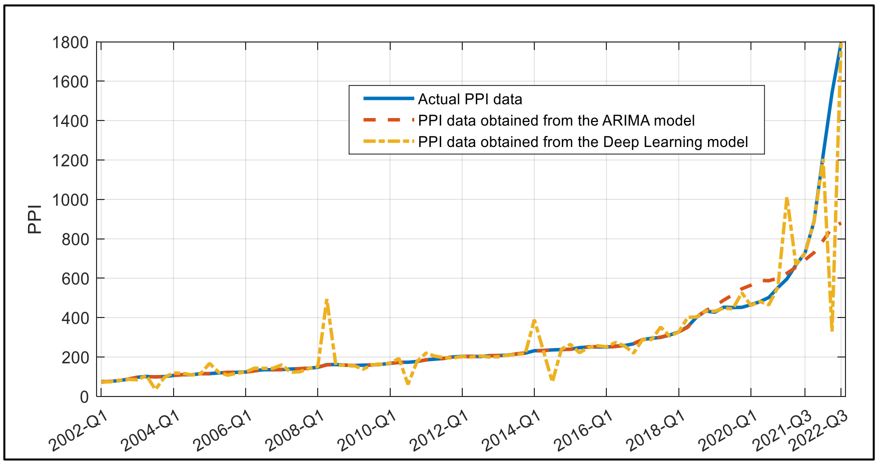

Figure 3. Estimation plots of the ARIMA and ANN models

As it can be observed from Figure 3, the linear ARIMA and the nonlinear ANN models can be used to model the variation of the PPI. However, it is imperative to compare their modelling accuracies using performance metrics. In this study, the four performance metrics namely MAE, RMSE, MAPE and R^2 values are utilized for comparison. Table 3 presents MAE, RMSE, MAPE and R^2 values for the ARIMA and ANN models.

Table 3. Quality metrics of the proposed model results

Model	MAE	RMSE	MAPE	R^2
ARIMA	34.83	137.21	0.04	0.77
ANN	90.61	145.93	0.49	0.74

It is seen from Table 3 that both the linear ARIMA and the nonlinear ANN models can effectively represent the variation of the PPI dependent on the oil price, exchange rate and the interest rate with the coefficient of determination values of R^2=0.77 and R^2=0.74, respectively. The quality metrics show that the ARIMA model has slightly better performance compared to the ANN model. It is worth noting that the methods used in this study can also be applied to the econometric data of other countries for the accurate modelling of the producer price index.

CONCLUSION

The increase in the producer price index affects the whole economy at both micro and macro economic scales. All economic actors such as companies are negatively affected by high production costs, and they cut production and lay off workers. Consumers expect the increase in producer price index to be reflected on the consumer price index and they tend to save instead of consumption. The national total demand is decreasing, the production loss is increasing, and the production loss affects the tax revenues of the state negatively. While the producer price index was stable between 2002 and 2004 in Türkiye, it started to increase again as of 2004 and reached quite high levels in recent years. Both the global supply shocks and the developments in the domestic market were effective in this trend. With the Covid-19 pandemic process, the supply of some goods has decreased, energy prices have increased, and the exchange rate has increased in most countries. These negative factors, which are still ongoing, maintain the importance of researches to determine the factors affecting producer prices. In this context, the relations between oil prices, exchange rates, interest rates, wages and the producer prices for the period 2002Q01-2022Q03 in Türkiye are modelled using autoregressive moving averages (Auto-Regressive Integrated Moving Average-ARIMA) and artificial neural networks (ANN) methods in this study. Based on the MAE, RMSE, MAPE and R^2 results of the ARIMA and ANN models, it was determined that the ARMA (4.4) model had slightly better predictive power than the ANN model. In addition, according to the ARMA (4.4) model, interest rate, exchange rate, oil prices and the wages affect producer prices. In this context, it can be recommended to use low interest, low-cost renewable energy resources, to provide support in electricity and natural gas bills for the current situation and to implement policies to encourage the production and use of electric vehicles in order to reduce producer prices.

Declaration by Authors

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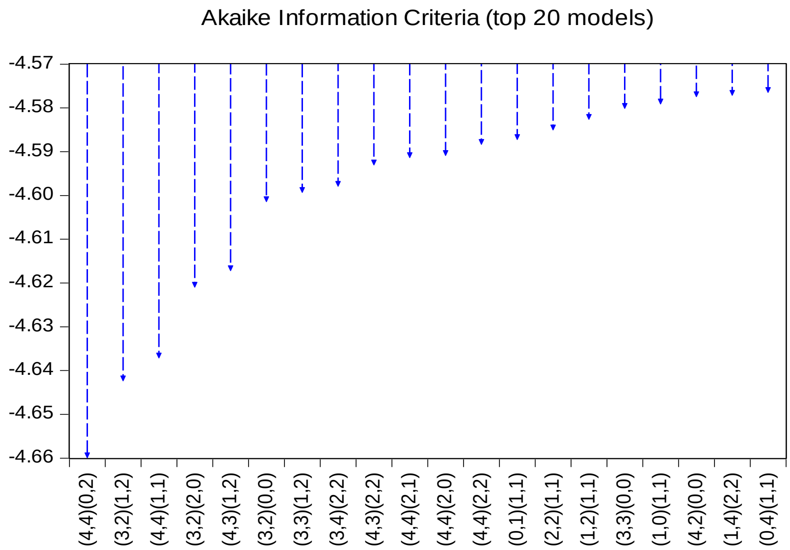
APPENDIX

Automatic ARIMA Model Selection Criteria



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