

THE PRICE GAP–INFLATION RELATIONSHIP: EVIDENCE FROM TÜRKİYE ON VALIDITY OF THE P–STAR MODEL¹

**Fiyat Açığı–Enflasyon İlişkisi: P–Star Modelinin Geçerliliğine Dair Türkiye’den
Kanıtlar**

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ABSTRACT

The purpose of this study is to examine the P–Star model validity in the Turkish economy. The study covers the period of 2005:04–2019:01 quarterly. The aim of the study is shaped by three fundamental questions. Firstly, is the P–Star model valid for the Turkish economy? Secondly, is the price gap an indicator of potential inflation for the Turkish economy? Thirdly, which monetary aggregate provides optimal direction for policymakers in inflation prediction? In this study firstly, four different price gaps were calculated under monetary aggregates M0, M1, M2, and M3. Secondly, four different P–Star models were estimated by using GMM and the optimal P–Star model was determined. Finally, the validity of P–Star model was tested for the Turkish economy and the empirical findings were discussed in the context of the purpose of the study. In this study, the empirical findings indicate that the P–Star Model is valid in Turkish economy.

Keywords: P–Star Model, Inflation Rate, Price Gap, Monetary Aggregates, Inflation Indicator, GMM.

ÖZET

Bu çalışmanın amacı Türkiye ekonomisi için P–Star modelinin geçerliliğini sınamaktır. Çalışma 2005:04–2019:01 üçer aylık dönemi kapsamaktadır. Çalışmanın amacı üç temel soru çerçevesinde şekillenmiştir. Birincisi, P–Star modeli Türkiye ekonomisi için geçerli midir? İkincisi, Türkiye ekonomisi için fiyat açığı, potansiyel enflasyonun bir göstergesi midir? Üçüncüsü ise enflasyonun öngörüsünde politika yapıcılara hangi parasal büyüklük optimal yönü sağlamaktadır? Bu çalışmada ilk olarak M0, M1, M2 ve M3 parasal büyüklükleri için dört farklı fiyat açığı hesaplanmıştır. İkinci olarak, GMM yöntemi kullanılarak dört farklı P–Star modeli tahmin edilmiş ve optimal P–Star modeli belirlenmiştir. Son olarak, P–Star modelinin Türkiye ekonomisi için geçerliliği test edilmiş ve çalışmanın amacı bağlamında ampirik bulgular tartışılmıştır. Çalışmanın bulguları P–Star modelinin Türkiye ekonomisi için geçerli olduğunu göstermektedir.

Anahtar Kelimeler: P–Star Modeli, Enflasyon Oranı, Fiyat Açığı, Parasal Büyüklükler, Enflasyon Göstergesi, GMM

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INTRODUCTION

The inflation phenomenon may differ from country to country in terms of reasons and dimension. Nevertheless, it has become a common problem for the economies of all countries. Therefore, nowadays most of the central banks and policymakers aim to maintain a stable structure of inflation by controlling. Turkish economy is one of the example economies that aim to ensure price stability. Following the severe economic crisis in 2001, it was aimed to provide a positive change in many areas of the national economy, including central banking. In this direction, the main objective of the Central Bank of the Republic of Türkiye has been stated as achieving and maintaining price stability. In order to maintain price stability, central banks should implement monetary policies very effectively. In this regard, monetary aggregates have an important place in monetary implementations. In particular, there are opinions claiming that the monetary aggregates may be an important indicator for policy implementations in the relevant literature (Woodford, 2007; 2008). Nevertheless, many researchers were concerned about the decreasing role of monetary aggregates in monetary implementations, recently (Goodhart, 2007; Issing, 2007).

The quantity theory is undoubtedly one of the most important theories about inflation. The fundamental assumption of quantity theory is the steady relationship between changes in the amount of monetary aggregate and the general price level. Because of this relationship, the quantity theory has become a remarkable theory in the implementation of monetary policy and the evaluation of implementation results. Nevertheless, according to the findings of some studies, it has been determined that after the 1980s, the relationship between monetary aggregates and the general price level was lost or weakened (Friedman, 1988; Friedman & Kuttner, 1996). Therefore, the validity of quantity theory has become a highly controversial topic. Following this development, Hallman et al. (1989, 1991) have again drawn attention to the quantity theory together with their two remarkable studies. The P-Star model, developed in their studies, is based on the long-run version of the quantity theory. Furthermore, it handles short- and long-run quantity theory together. P-Star is defined as the long-run equilibrium price level. Long-run equilibrium price level is defined as the consistent price level with the current amount of monetary aggregate, long-run equilibrium velocity of monetary aggregate and potential real output level. In the P-Star model, Hallman et al. (1989, 1991) have assumed that current prices would move towards equilibrium prices in the long-run and consequently current prices and equilibrium prices were co-integrated. Thus, the P-Star model implies that the inflation will increase (decrease) if the current price level is below (above) the equilibrium price level. In order to predict the inflation, the P-Star model uses the price gap, which is defined as the deviation of equilibrium prices from current prices. The price gap will converge to zero as a result of the co-integration assumption. Therefore, the price gap has a negative effect on the general price level. The P-Star model can be used as an indicator of that if the price gap is negative, the general price level will increase in the next period or if the price gap is positive, the general price level will decrease in the next period.

This study aims to fill some gaps in the literature about the studies examining Turkish economy. As Central Bank of the Republic of the Türkiye (CBRT) changed its monetary definitions in 2005, current monetary definitions were used in line with the period discussed in the study. In this study, we used both the narrow and the broad definition of monetary aggregates for the Turkish economy. In the econometric analysis of the study, P-Star model was estimated by the Generalized Method of Moments (GMM) and the optimal P-Star model was determined as a result of empirical findings. In econometric analysis, food inflation, energy inflation, exchange rate volatility and lagged values of inflation rate were used as instrumental variables. These variables are thought to cause inflation in the short-run.

The aim of the study is shaped by three fundamental questions. Firstly, is the P-Star model valid for the Turkish economy? Secondly, is the price gap as an indicator of inflation really an indicator of potential inflation for the Turkish economy? Thirdly, which monetary aggregate provides optimal direction for policymakers in inflation prediction? The study covers the period of 2005:04–2019:01 quarterly. This study includes three important econometric processes. In this study firstly, four different price gaps were calculated under monetary aggregates M0, M1, M2, and M3. Secondly, four different P-Star models were estimated by using GMM and the optimal P-Star model was determined. Finally, the validity of P-Star model was tested for the Turkish economy and the empirical findings were discussed in the context of the purpose of the study. Rest of the study continues as follows: The theoretical framework about the P-Star model is presented in detail and clearly. The studies examining the P-Star model theoretically and empirically are discussed comparatively. Then data set, econometric models, and econometric methods are introduced. In the next chapter, the empirical findings related to P-Star

model are obtained and then the validity of the P-Star model is determined for the Turkish economy. In the last chapter, the empirical findings are discussed together with the recommendations.

THEORETICAL FRAMEWORK OF THE P-STAR MODEL

Hallman et al. (1989, 1991) have introduced a new approach to quantity theory. The basis of the approach known as the P-Star model is based on the quantity theory of money. Nevertheless, short- and long-run quantity theories are considered together in the P-Star model. The P-Star model which moves from the long-run version of the quantity theory, has been developed as an indicator of the potential inflation for the U.S. economy by Hallman et al. (1989, 1991).

Since the P-Star model is based on the quantity theory, the starting point of its theoretical framework is the quantity theory. The quantity theory of money is expressed in equation (1). In the quantity theory; general price level, money supply, potential output level, and velocity are represented by P, M, Y, and V respectively. The general price level is defined in equation (2) by adding time index (t) to the variables.

$$P * Y = M * V \quad (1)$$

$$P_t = M_t * V_t / Y_t \quad (2)$$

Hallman et al. (1991; 842) have described the long-run quantity theory as in equation (3). In equation (3), the symbol (*) represents the long-run equilibrium level of the respective variables. Therefore; P* represents the long-run equilibrium price level, V* represents the long-run equilibrium velocity of monetary aggregates, and Y* represents potential real output level.

$$P_t^* = M_t * V_t^* / Y_t^* \quad (3)$$

The P-Star model bases the equation of quantity theory on two hypotheses and explains the price level movements with the growth in the amount of monetary aggregates. In the first one, the real output level fluctuates around the potential real output level. In the second one, the velocity has an equilibrium level in long-run, independent of time (Hallman & Anderson, 1993; 14–15).

The price gap is defined as the deviation between the general price level and the long-run equilibrium price level. It is expressed in equation (4) with the combination of the logarithmic versions of the equation (2) and (3). In the equation (4), the lower case variables represent the logarithmic versions of the related variables. As seen in equation (4), the price gap is derived from the sum of the velocity gap ($v_t - v_t^*$) and the real output gap ($y_t^* - y_t$), respectively (Hallman et al., 1991; 843).

$$(p_t - p_t^*) = (v_t - v_t^*) + (y_t^* - y_t) \quad (4)$$

The P-Star model predicts the direction of movements of the current prices by using the price gap and makes this prediction based on whether the current price are above or below the equilibrium price level. In the theory of the P-Star model, Hallman et al. (1989, 1991) assumes that the general price level will move towards the long-run equilibrium price level. Furthermore, the current prices in the long-run will move towards the equilibrium prices as a result of the pressure arising from growth in money supply. Therefore, the price gap theoretically converges to zero. Because of the converging assumption, the general price level and the equilibrium price level should be cointegrated. Following the assumptions, if the general price level is below (above) the equilibrium price level then the future price level is expected to increase (decrease). In this direction, the negative price gap means increase in the general price level, while the positive price gap means decrease in the general price level (Hallman et al., 1991; 842–843).

In the P-Star model, the econometric expression of the hypothesis about the dynamic relationship between inflation rate and price gap is error-correction model in equation (5). In equation (5), Δ is the difference operator, Δp is the inflation rate, β_0 is the constant-term coefficient, β_1 is the price gap coefficient, γ_i is the lag coefficient related to the inflation rate and ε is the error-term. According to P-Star model, the price gap coefficient β_1 should be negative ($\beta_1 < 0$) and statistically significant. Lag or lags of the inflation rate are included in order to determine short-run dynamics.

$$\Delta p_t = \beta_0 + \beta_1(p_{t-1} - p_{t-1}^*) + \sum_{i=1}^n \gamma_i \Delta p_t + \varepsilon_t, \quad \varepsilon_t \sim N(0, \sigma^2) \quad (5)$$

LITERATURE REVIEW

The P-Star model which is based on quantity theory was first introduced by Hallman et al. (1989, 1991). P-Star model was developed as a dynamic model of inflation and has been applied as an indicator of potential inflation since its introduction. In this direction, the P-Star model has composed a wide range of theoretically and empirically literature. The P-Star model was supported with its standard expression by many studies in the empirical literature (Hallman et al., 1989; 1991; Hoeller & Poret, 1991; Tödter & Reimers, 1994; Hewarathna, 2000; Yamak & Ceylan, 2005; Tawadros, 2007; Cronin, 2018). Nevertheless, there are also some studies in which the P-Star model was criticized in the empirical literature (Christiano, 1989; Tatom, 1990; Pecchenino & Rasche, 1990). The view claiming that the P-Star model is more valid for large economies rather than small economies, was supported by some studies (Hoeller & Poret, 1991; Tatom, 1992). The P-Star model is highly sensitive to monetary aggregates (Tödter & Reimer, 1994; Becsi & Duca, 1994; Broer & Caputa, 2004; Yamak & Ceylan, 2005; Rusek, 2008).

Later on, important developments took place in the theory of P-Star model. Kool & Tatom (1994) have stated that the P-Star model was more compatible for countries which had large closed economy assumption and flexible exchange rate system. Therefore, Kool & Tatom (1994) have emphasized that the P-Star model with standard expression was not compatible for countries which had small open economy assumption and fixed exchange rate system. Kool & Tatom (1994) have stated that the money supply had become endogenous under that assumption and the domestic equilibrium price level was determined by the large country which was the anchor of the system. In this context, Kool & Tatom (1994) have adapted the P-Star model by including the foreign price gap. The P-Star model developed with the foreign price gap was tested and supported by many studies in the empirical literature (Kool & Tatom, 1994; Garcia-Herrero & Pradhan, 1998; Frait et al., 2000; Rodriguez, 2004). Mihalicova (2011) argued that both domestic and foreign price gap was highly effective on inflation. Wesche (1998) and Tsianos (2001) argued that the domestic price gap was more effective than the foreign price gap on inflation. Rusek (2008) and Kiptui (2013) emphasized that only the domestic price gap had an impact on inflation.

Another important development of the theory of P-Star model was introduced by Svensson (2000) and Gerlach & Svensson (2003). Gerlach & Svensson (2003) used the real money gap as the inflation indicator instead of the price gap. As the most important cause of this change, Gerlach & Svensson (2003) have emphasized that the real money gap referred directly to monetary aggregates. The P-Star model developed with the real money gap was tested and supported by many studies in the empirical literature (Altimari, 2001; Trecroci & Vega, 2002; Gerlach & Svensson, 2003; Belke & Polleit, 2006; Gonzalez et al., 2009). The P-Star model along with different versions have been tested as an indicator of potential inflation for the Turkish economy. Within the examination of the literature on the Turkish economy, the P-Star model is valid and the model has an important role in explaining dynamics of inflation (Yamak & Ceylan, 2005; Ozdemir & Saygili, 2009; Islaitince & Siklar, 2015).

Table 1. Summary of The Chosen Empirical Literature

<i>Author</i>	<i>Country</i>	<i>Period</i>	<i>Monetary Aggregate</i>	<i>Result</i>
Hallman et al., (1989, 1991)	USA	1955:01-1988:04 (quarterly)	M2	P-Star model is valid as long as the M2 monetary aggregate is used.
Christiano, (1989)	USA	1959:01-1989:03 (quarterly)	M2	The P-Star model performs better than the T-Bill model in terms of the root mean square error, nevertheless the T-Bill model performs better than the P-Star model in terms of the average absolute error.
Tatom, (1990)	USA	1955:01-1988:04 (quarterly)	M1, M2	P-Star model is valid if M1 monetary aggregate is used rather than M2 monetary aggregate.
Pecchenino & Rasche, (1990)	USA	1955:01-1988:01 (quarterly)	M2	P-Star was found to be insufficient to explain inflation dynamics.

Hoeller & Poret, (1991)	20 OECD Countries	1960:01-1990:02 (semi-annual)	USA, Italy, Canada: M2; Japan: M2+CD; Germany, France: M3; UK: M4.	P-Star model was found to be valid for large economies rather than small economies.
Tatom, (1992)	Austria	1960-1990 (annually)	M3	P-Star model was found to be invalid. Nevertheless, there is a significant long-run relationship between Australia's inflation and Germany's inflation.
Kool & Tatom, (1994)	Austria, Belgium, Denmark, Holland, Switzerland	1960-1992 (annual) (quarterly)	M1, M2	Because of that countries fit the small open economy assumption and adopt fixed exchange rate system, P-Star model was found to be invalid. Nevertheless, the prices of these countries were determined to vary depending on German foreign price gap.
Tödter & Reimers, (1994)	Germany	1971:01-1992:04 (quarterly)	M1, M2, M3	The P-Star model was found to be valid for M3 monetary aggregate while it was found to be invalid for M2 and M1 monetary aggregate.
Becsi & Duca, (1994)	USA	1959:02-1993:03 (quarterly)	M2, M2B	M2B monetary aggregate was determined to have better estimation power than M2 monetary aggregate. In the study, it was emphasized that M2B monetary aggregate increased performance of the P-Star model.
Garcia-Herrero & Pradhan, (1998)	Spain	1970:01-1989:02; 1989:03-1996:04 (quarterly)	ALP	P-Star model was determined to be valid for the first sample period. However, the compatibility of the model increased with the addition of the German foreign price gap for the second sample period. The domestic price gap was the most important variable in explaining price movements in both periods.
Frait et al., (2000)	Czech Republic	1991:01-1999:01 (quarterly)	M2	The German foreign price gap is much more important than the domestic price gap, and the equilibrium price level is highly influenced by Germany's monetary policy.
Hewerathna, (2000)	Australia, New Zealand	1970:01-1999:04 (quarterly) 1982:01-1998:04 (quarterly)	M3	The P-Star model was found invalid in Australia, it was found valid in New Zealand for M3 monetary aggregate. The Central Bank of New Zealand is able to control the price movements by changing the money supply.
Altimari, (2001)	Euro Area	1981:01-2000:02 (quarterly)	M1, M2, M3, Credit Aggregate	The real money gap based on M3 monetary aggregate was found to perform very well in predicting inflation. The claim that the real money gap should be the focal point of the monetary policy was rejected.
Trecroci & Vega, (2002)	Euro Area	1980:04-1998:04 (quarterly)	M3	According to findings, it was determined that there is a relationship between real money gap and inflation, and M3 monetary aggregate contains important information about future price movements for the Euro Area.
Gerlach & Svensson, (2003)	Euro Area	1980:01-2001:01 (quarterly)	M3	The P-Star model and the real money gap as an indicator of future inflation was supported for the Euro Area.

Rodriguez, (2004)	Puerto Rico	1964-1997 (annual)	M1	The results show that the price level in Puerto Rico was highly influenced by the real output and velocity of money. In addition, the price level was determined by the U.S. monetary policy.
Broer & Caputo, (2004)	Chile	1986:02-2004:02 (quarterly)	M0, M1A, M2A, M3, M7, M7exDBC	Although the P-Star model showed a good performance for the Chilean Economy, the performance of the model decreased during the 2000-2004 period.
Yamak & Ceylan, (2005)	Türkiye	1994:01-2004:12 (annual)	M1, M2, M2Y, M3	The P-Star model was supported for all monetary aggregates. The best result was determined to be the P-Star model that derived from M2Y monetary aggregate.
Belke & Polleit, (2006)	Sweden	1987:01-2005:01 (quarterly)	M3	The P-Star model was determined to be valid. Furthermore, the M3 monetary aggregate was an important indicator for explaining inflation movements.
Tawadros, (2007)	Egypt, Morocco, Jordan	Egypt, Morocco; 1972:01-2002:04 Jordan; 1976:01-2002:04 (quarterly)	Currency in circulation	The P-Star model is not supported if output and velocity are modeled with the deterministic trend. Nevertheless, the P-Star model is supported if output and velocity are modeled with the stochastic trend. According to empirical findings, the P-Star was supported for countries.
Rusek, (2008)	Poland	1997:01-2006:04 (quarterly)	M1, M2, M3	The P-Star model was invalid for M1 and M3 monetary aggregates, while it was valid for M2 monetary aggregate. The inflation dynamics of the Polish economy was determined by the domestic price gap.
Gonzalez et al., (2009)	Colombia	1980:01-2005:02 (quarterly)	M3	According to findings, it was emphasized that real money gap and real output gap had a positive effect on the inflation gap.
Ozdemir & Saygili, (2009)	Türkiye	1990:01-2007:03 (quarterly)	M2Y	The P-Star model was supported for the Turkish economy. In the study, it was stated that the P-Star model had better estimation power than the New Classic Phillips Curve.
Mihalicova et al., (2011)	Bulgaria	1997:01-2009:02 (quarterly)	M2	The German foreign price gap was found to have a significant effect on Bulgarian prices. Furthermore, the domestic price gap had a statistically significant effect on prices.
Czudaj, (2011)	Euro Area	1994:01-2005:04 (quarterly)	M3	The P-Star model was found to be a useful indicator for estimating inflation. Price gap performed better than real output gap.
Islatince & Siklar, (2015)	Türkiye	2002:01-2014:12 (monthly)	M1, M2	The P-Star model was found to be valid. According to the results, the most important factor affecting short- and long-run inflation is the money gap. In the study, M1 monetary aggregate gave better results than M2 monetary aggregate.
Cronin, (2018)	USA	1960:03-2016:02 (quarterly)	M2, MZM	The P-Star model was supported. Moreover, the velocity gap had more effect on inflation than the real output gap.

DATA AND ESTIMATION PROCESS

Data

The aim of this study is to test the validity of P-Star model for the Turkish economy. The study covers the period of 2005:04–2019:01 (quarterly). All of the variables used in the econometric analysis of the study are obtained from the Electronic Data Delivery System of the Central Bank of the Republic of Türkiye (CBRT–EDDS). In this study, all variables were seasonally adjusted by using Census X–12 method. All of the variables were used in logarithmic form. Abbreviations and definitions of all variables are presented in Table 2.

Table 2. Abbreviations and Definitions of Variables

Variable Abbreviation	Variable Definition
INF _{CPI}	CPI Inflation Rate: First Difference of the Log of the CPI (2003=100)
PRICE _{GAP0}	Price Gap 0: $(P-P^*) = (V_0-V_0^*) + (Y^*-Y)$
PRICE _{GAP1}	Price Gap 1: $(P-P^*) = (V_1-V_1^*) + (Y^*-Y)$
PRICE _{GAP2}	Price Gap 2: $(P-P^*) = (V_2-V_2^*) + (Y^*-Y)$
PRICE _{GAP3}	Price Gap 3: $(P-P^*) = (V_3-V_3^*) + (Y^*-Y)$
M0	M0 Monetary Aggregates (Thousand TL)
M1	M1 Monetary Aggregates (Thousand TL)
M2	M2 Monetary Aggregates (Thousand TL)
M3	M3 Monetary Aggregates (Thousand TL)
V0	Velocity of M0 Monetary Aggregates
V1	Velocity of M1 Monetary Aggregates
V2	Velocity of M2 Monetary Aggregates
V3	Velocity of M3 Monetary Aggregates
V0*	Long-Run Equilibrium Velocity of M0 Monetary Aggregates
V1*	Long-Run Equilibrium Velocity of M1 Monetary Aggregates
V2*	Long-Run Equilibrium Velocity of M2 Monetary Aggregates
V3*	Long-Run Equilibrium Velocity of M3 Monetary Aggregates
Y	Real Output Level: Real Gross Domestic Product (Thousand TL)
Y*	Potential Real Output Level: Potential Real Gross Domestic Product
USDV	Exchange Rate Volatility (USD/TL)
INF _{FOOD}	Food Inflation Rate: First Difference of the Logarithm of the Food Prices (2003=100)
INF _{ENERGY}	Energy Inflation Rate: First Difference of the Logarithm of the Crude Petroleum and Natural Gas Prices (2003=100)

Estimation Process

In order to examine the validity of P-Star model for Turkish economy, the following steps are used in the econometric process. In this study firstly, four different price gaps were calculated under monetary aggregates M0, M1, M2, and M3. The gaps of all variables were computed as the difference between the current value and the potential value by using a Hodrick–Prescott (HP) filter (Hodrick & Prescott, 1981). Secondly, four different P–

Star models were estimated by using Generalized Method of Moments (GMM) and the optimal P–Star model was determined. In line with the purpose of the study, using GMM allows more accurate and reliable results to be obtained. GMM eliminates possible endogeneity and exogeneity problems. In the method, the lags of variables in the system and/or outside the system can be determined externally and can also be used as instrumental variables. Another advantage of the method is that the regression model does not have to be a linear function of the parameter of interest. The GMM allows equation estimations to be made without resorting to linearization techniques and without losing valuable information in the process (Gan & Yu, 2009;169). $\emptyset$, ∂ , β , and δ are constant terms, γ , ϑ , π , and λ are the coefficients of price gaps. The coefficients of price gaps are expected negatively and statistically significant. The negative and statistically significant coefficients of price gaps indicate that the validity P–Star model. $\varepsilon_{t,1}$, $\varepsilon_{t,2}$, $\varepsilon_{t,3}$, and $\varepsilon_{t,4}$ are error terms and ρ , v , o , and η are the coefficients of expected inflation in all models.

MODEL 0

$$\Delta INF_{CPI_t} = \emptyset + \gamma(PRICE_{GAP0})_{t-1} + \sum_{i=1}^n \rho_i \Delta INF_{CPI_{t-i}} + \varepsilon_{t,1}, \quad \varepsilon_{t,1} \sim N(0, \sigma^2)$$

MODEL 1

$$\Delta INF_{CPI_t} = \partial + \vartheta(PRICE_{GAP1})_{t-1} + \sum_{i=1}^n v_i \Delta INF_{CPI_{t-i}} + \varepsilon_{t,2}, \quad \varepsilon_{t,2} \sim N(0, \sigma^2)$$

MODEL 2

$$\Delta INF_{CPI_t} = \beta + \pi(PRICE_{GAP2})_{t-1} + \sum_{i=1}^n o_i \Delta INF_{CPI_{t-i}} + \varepsilon_{t,3}, \quad \varepsilon_{t,3} \sim N(0, \sigma^2)$$

MODEL 3

$$\Delta INF_{CPI_t} = \delta + \lambda(PRICE_{GAP3})_{t-1} + \sum_{i=1}^n \eta_i \Delta INF_{CPI_{t-i}} + \varepsilon_{t,4}, \quad \varepsilon_{t,4} \sim N(0, \sigma^2)$$

Finally, the validity of P–Star model was tested for the Turkish economy and the empirical findings were discussed in the context of the purpose of the study.

EMPIRICAL FINDINGS AND DISCUSSION

In defining the P–Star model, it is emphasized that the general price level and the equilibrium price level are co-integrated. Therefore, the price gap should be stationary in P–Star model. In order to apply the P–Star model, the inflation rate should have a stationary process together with the price gap. Augmented Dickey–Fuller (ADF) (Dickey & Fuller, 1979; 1981) and Phillips–Perron (PP) (Phillips & Perron, 1988) unit root test results for stationary analysis are presented in Table 3. According to the ADF and PP unit root test results, it was found that all variables used in the analysis of the study were stationary at the level. In this respect, it is determined that inflation rate (INF_{CPI}) and the price gaps ($PRICE_{GAP0}$, $PRICE_{GAP1}$, $PRICE_{GAP2}$, $PRICE_{GAP3}$) provide the assumption of stationary in order to apply the restricted P–Star model.

Table 3. Unit Root Test Results

	ADF			PP		
	Intercept	Trend–Intercept	None	Intercept	Trend–Intercept	None
PRICE _{GAP0}	-3.273** (0)	-3.161 (0)	-3.324*** (0)	-3.273** [0]	-3.161 [0]	-3.324*** [0]
PRICE _{GAP1}	-4.186*** (0)	-3.867** (2)	-4.229*** (0)	-4.186*** [0]	-4.142*** [0]	-4.229*** [0]
PRICE _{GAP2}	-4.513*** (0)	-4.453*** (0)	-4.554*** (0)	-4.513*** [0]	-4.453*** [0]	-4.554*** [0]
PRICE _{GAP3}	-5.023*** (0)	-4.968*** (0)	-5.069*** (0)	-5.029*** [1]	-4.970*** [1]	-5.076*** [1]
INF _{CPI}	-4.819*** (0)	-5.008*** (0)	1.068 (6)	-4.792*** [3]	-4.761*** [5]	-1.778* [4]
INF _{FOOD}	-6.551*** (0)	-6.755*** (0)	0.230 (4)	-6.661*** [3]	-6.838*** [3]	-2.815*** [4]
INF _{ENERGY}	-6.016*** (0)	-5.949*** (0)	-5.863*** (0)	-5.957*** [3]	-5.885*** [3]	-5.873*** [1]
USDV	-5.366*** (1)	-5.499*** (1)	-0.435 (3)	-3.230** [2]	-3.373* [2]	-1.624* [2]

Note: ***, **, and * represent 1%, 5%, and 10% significance levels respectively. The lag length for the ADF test was determined according to the Schwarz Information Criteria (SIC). The maximum lag length is taken 9. The values in parentheses indicate the optimal lag lengths. The bandwidth for the PP test was determined according to the Newey–West bandwidth. The values in square brackets indicate the bandwidths.

The Models 0, 1, 2, and 3 which were established for the analysis of the P–Star model, were estimated by the GMM method and the findings of GMM were shown in Table 4, respectively. While the models were estimated by the GMM method, food inflation, energy inflation, exchange rate volatility, and inflation rate variables, which are thought to be related to explanatory variables, were used as instrumental variables together with their lagged values.

The J–statistic of Hansen (1982) shows whether there is over–identification problem in the equation. As seen in Table 4, J–statistics for all models were found to be statistically insignificant. The H_0 hypothesis for the J–statistic states that there is no any over–identification problem in an equation in other words the over–identification constraints are orthogonal to the error terms. H_0 hypothesis is not rejected statistically at the level of 1% for all models. In this respect, there is no over–identification problem in all models. In each of the models presented in Table 4, the price gap coefficients are statistically significant and negative. Thus, P–Star models were found to be valid in all models. If the performance criteria of the estimated models are compared, the models with the lowest root mean square error (RMSE) are Model 3, 2, 0, and 1, respectively. Therefore, according to performance criteria, Model 3 can be considered as the optimal model. Model 3 is the price gap equation calculated by using M3 monetary aggregate. Thus, the M3 monetary aggregate for the Turkish economy is considered to be a more effective tool as an indicator of potential inflation compared to the other monetary aggregates. Following the M3 monetary aggregate, it can be thought that M2 monetary aggregate is an effective monetary tool and M2 monetary aggregate can be used as an indicator of inflation. If the findings of Model 3 are examined in detail, it is seen that all the variables are statistically significant at least level of 1%. In addition, the price gap coefficient is negative and statistically significant. According to the results obtained from the GMM method, the coefficient of the price

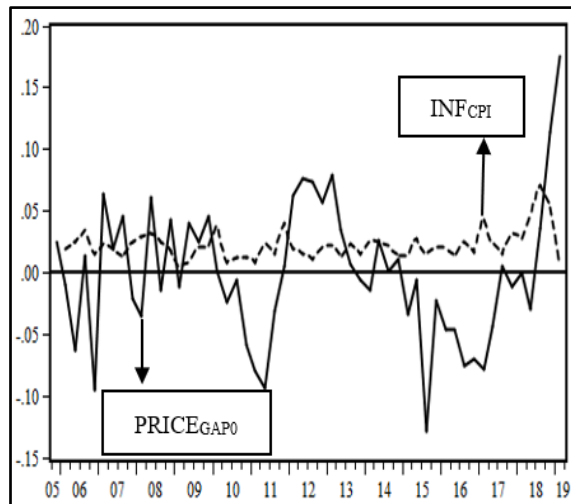
gap was found approximately -0.24. This coefficient is statistically significant at the level of 1%. Accordingly, the instability between the short- and the long-run will decrease by 24% at the end of a period.

Table 4. GMM Method Results

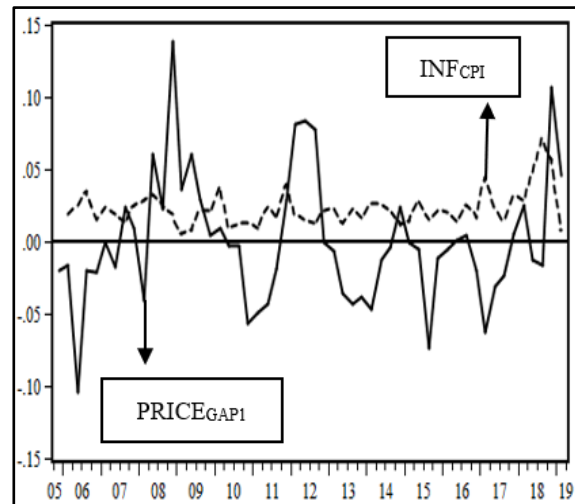
Independent Variable	Dependent Variable: INF_{CPI}			
	Model 0	Model 1	Model 2	Model 3
Constant Term	0.011897***	0.013822***	0.012993***	0.012648***
$PRICE_{GAP0(t-1)}$	-0.120137***	—	—	—
$PRICE_{GAP1(t-1)}$	—	-0.167606***	—	—
$PRICE_{GAP2(t-1)}$	—	—	-0.206273***	—
$PRICE_{GAP3(t-1)}$	—	—	—	-0.240937***
$INF_{CPI(t-1)}$	0.437720***	0.379244***	0.393079***	0.406248***
RMSE	0.013548	0.013698	0.013155	0.013042
J-statistic	10.04987	8.624500	10.32082	10.25852
J-statistic Prob.	0.816591	0.896319	0.799089	0.803171
P-STAR Model	Valid	Valid	Valid	Valid

Note: ***, **, and * represent 1%, 5%, and 10% significance levels respectively. RMSE: Root Mean Squared Error.

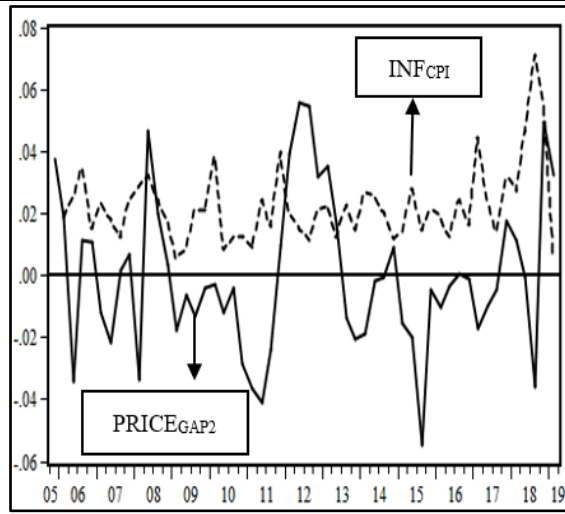
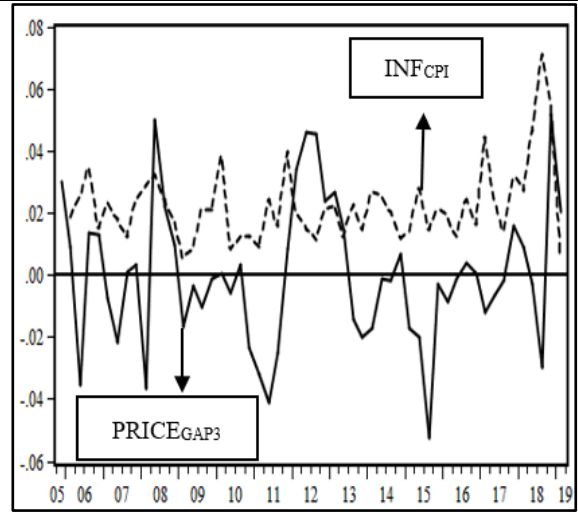
In addition to the results in Table 4, the price gap and the inflation rate are presented together in Graph 1, 2, 3, and 4. As can be seen from the graphs presented below, when the price gap is positive, the inflation rate generally decreases in the following period or when the price gap is negative, the inflation rate generally increases in the following period.



Graph 1. $PRICE_{GAP0}$ and INF_{CPI}



Graph 2. $PRICE_{GAP1}$ and INF_{CPI}

Graph 3. PRICE_{GAP2} and INF_{CPI}Graph 4. PRICE_{GAP3} and INF_{CPI}

CONCLUSION

The purpose of this study is to answer three questions: Is the P–Star model valid for the Turkish economy? Is the price gap as an indicator of inflation really an indicator of potential inflation for the Turkish economy? Which monetary aggregate provides optimal direction for policymakers in inflation prediction? For this aim, in this study, four different price gaps were obtained by using under monetary aggregates M0, M1, M2, and M3 and then, four different P–Star models were estimated by using GMM. Therefore, the optimal P–Star model was specified for Turkish economy. This study covers the period of 2005:04–2019:01 quarterly.

According to the findings obtained from ADF and PP unit root tests, the inflation rate and price gap variables were stationary at their levels. In this context, the stationarity assumption was provided for applying the P–Star model. According to the GMM results, the price gap coefficients in each of the models were found to be negative and statistically significant. In this regard, it was found that the P–Star model was valid for all models. By comparing the performance criteria of the estimated models, Model 3 (price gap equation calculated using M3 monetary aggregate) was determined as the most optimal model. The price gap coefficient obtained from Model 3 was calculated as approximately -0.24 and was found to be statistically significant. According to the coefficient, the instability between the short– and the long–run will decrease by 24% at the end of a period. Moreover, the inflation rate will return to equilibrium after approximately four periods.

According to the findings of this study, the best P–Star models are Model 3, 2, 0, and 1, respectively. Thus, it can be stated that the monetary aggregates that provide the optimal direction to policymakers in the prediction of inflation are M3, M2, M0, and M1, respectively. The policies to be implemented are very important in the fight against inflation and ensuring price stability. Accurate and reliable inflation indicators are needed for these policies to be implemented effectively. In this context, we can say that the M3 monetary aggregate for the Turkish economy is considered to be a more effective tool as an indicator of potential inflation compared to the other monetary aggregates. Other findings of this study give that the P–Star model is valid for Turkish economy and the model has an important role in explaining dynamics of inflation.

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