Prague Economic Papers
2023, Volume 32, Issue 5
https://doi.org/10.18267/j.pep.842

PRAGUE UNIVERSITY
OF ECONOMICS
AND BUSINESS

Symmetric and Asymmetric Dynamics of Output Gap and Inflation Relation for Turkish Economy

Burhan Biçer, Almila Burgac Cil

Department of Economics, Cukurova University, Turkey
email: bbicer@cu.edu.tr.

Abstract

This paper uses symmetric and asymmetric testing procedures to examine the issue of the relationship between the output gap and inflation for the Turkish economy using data from 2002:01 to 2021:09. First, it analyses the cointegration by applying different cointegration tests taking into account structural breaks and asymmetric behaviour to reveal whether the relation varies between sub-periods. Afterwards, it examines the asymmetric causality between different shocks. Our empirical results indicate that there is a long-run relationship between series in the existence of two structural breaks and asymmetry. The results also show asymmetric causality running from positive *(negative)* output gap to positive *(negative)* inflation shock, and running from negative inflation shock to negative output gap shock. The overall findings indicate the importance of having in mind the structural breaks and asymmetric behaviour of macroeconomic variables in policy-making processes, such as in Turkey during high and volatile inflation.

Keywords: Output gap, inflation, asymmetric effect, structural breaks, NARDL

JEL Codes: C01, C32, E31, E32, E58

1. Introduction

The relationship between economic activity and prices is an important measure for policymakers since it determines the impact of aggregate demand changes on nominal and real variables, especially in an inflation targeting regime. Although this theoretical relation is generally attributed to Phillips's (1958) seminal paper, the studies of Lipsey (1960), Samuelson and Solow (1960), Hansen (1970) and Lipsey (1978) have contributed to the theoretical foundations of the relation and to the development of the inflation model which is defined as the "missing link" of Keynesians. Even though the Phillips curve has been subjected to various criticisms such as not taking into account the expectations emphasized by Friedman (1968) and Lucas (1972, 1973), and failing to explain the stagflation phenomenon seen in the 1970s, some variants of the Phillips curve are still used to investigate the relationship between economic activity and inflation, to determine optimal monetary policy as well as to forecast inflation (e.g., Fisher et al.,1996; Beaudry and Doyle, 2000; Önder, 2004; Sbordone, 2005; De Veirman, 2007).

Since the early 1990s, the relationship between inflation and real variables has regained importance in tandem with the emergence of inflation targeting strategies (see Roberts, 1995; Gali and Gertler, 1999; Walsh, 2001; Sbordone, 2002, 2005; Svensson, 1997, 2003). Svensson (1997, 2003) has given detailed explanations regarding the role of the output gap in flexible inflation targeting strategy and central banks' loss function. Similarly, King (2005) argued for elements such as numerical targets for inflation and responding to economic shocks, which the inflation targeting strategy deals with. Accordingly, central banks base their inflation targets on three factors: the output gap, the interest rate rule, and the forward-looking process (Walsh, 2001). Firstly, the output gap is an important element among domestic inflation drivers and is frequently used as a measure of aggregate demand pressures on inflation, in monetary policy-making processes, depending on its pro-cyclical nature. Positive output gaps are regarded as a sign of upward pressures on inflation, while negative output gaps as a sign of downward pressures. Thus, policymakers use the output gap as a tool for medium-term inflation targets (e.g., Roberts, 1995; De Masi, 1997; Claus, 2000; Orphanides, 2003; Neiss and Nelson, 2005; Saraçoğlu et al., 2014). Secondly, the interest rate rule implies that the central banks follow a certain rule referring to the reaction function that expresses the behaviour of the interest rate in monetary policy implementation (Allsop and Vines, 2000). The interest rate rule is frequently used in literature, such as the Taylor rule, saying that the nominal interest rate is a function of the deviation of the inflation rate from the target and the output gap. And thirdly, the forward-looking process refers to the consideration of future marginal cost, demand, and inflation expectations (Roberts 1995, Gali and Gertler 1999, Whelan, 2005; Gali, 2008; Sill, 2011).

Following increasing interest in central banks' objective functioning, the effects of the output gap and inflation expectations on inflation have been extensively discussed in the New Keynesian Phillips Curve (NKPC) and Hybrid New Keynesian Phillips Curve (HNKPC) literature since 1990s. The main features of the NKPC and HNKPC models are imperfect competition, rational expectations and a money bias based on price rigidities due to price adjustment models such as Taylor's (1980) and Calvo's (1983) staggered contract models, and Mankiw and Reis's (2002) sticky information model (Biçer et al., 2021). At the same time, the money bias also implies macroeconomic linkages between real activity and price movement, and the monetary policy is effective on the real and nominal variables (e.g., Mankiw and Reis, 2002; Neiss and Nelson, 2005; Rudd and Whelan, 2005; Gali, 2008). A growing body of NKPC and HNKPC literature reports that the output gap has a significant effect on demand-side inflation; see, e.g., Roberts (1995), Neiss and Nelson (2005), Zhang et al. (2008), Liu (2011), and Lai (2017) for the USA; Neiss and Nelson (2005) for the USA, UK and Australia; Zhang and Murasawa (2011) for China; Öğünç and Sarıkaya (2011), Alp et al. (2012), Saraçoğlu et al. (2014), Atuk et al. (2018) and Biçer et al. (2021) for Turkey. The common feature of these studies is that they are based on symmetrical assumptions implying that a positive and negative output gap have similar effects on inflation and that the relation is independent of conditions of the economy such as structural changes, high inflation, high volatility, and business cycles. However, increasing financial liberalization and the complexity of the relationships between macroeconomic variables have led to increasing discussions of an asymmetric/nonlinear relationship. In accordance, a vast amount of literature points out the asymmetric/nonlinear response of inflation to real activity depending on the rigidities arising from capacity constraints, price and wage rigidities, imperfectly competitive markets, etc. (e.g., Turner, 1995; Razzak, 1997; Dupasquier and Ricketts, 1998; Filardo, 1998; Eliasson, 2001; Huh and Jang, 2007).

Within the scope of asymmetric/nonlinear relation arguments, some pioneering studies have provided detailed theoretical explanations of the asymmetry and its policy implications and differences from linear assumptions. Firstly, Laxton et al. (1995) highlighted that on the one hand, the assumption of linearity has several features including its simplicity, tractability, and statistical robustness to mismeasurement of the level of potential output. On the other hand, the linear model fails to express that the response of inflation to changes in demand is high in full employment and lower in deep recessions, which also shows the differences between the classical and Keynesian approaches. Secondly, Dupasquier and Ricketts (1998) argued that the relation based on linear assumptions means that the effect of the output gap on inflation is independent of the initial inflation level *(regime-dependent asymmetry)* and the sign of the output gap *(sign-dependent asymmetry)*. They also introduced shapes of different asymmetric relations and detailed explanations of the theoretical sources of asymmetry such as concavity and convexity. Thirdly, Razzak (1997) emphasized the importance of policies convenient to the properties of the relation in terms of output volatility and cumulative output loss. Fourthly, Filardo (1998) briefly summarized the features and policy implications of asymmetric relation. Depending on the nature of the asymmetry, the monetary policy has different properties in terms of timing and extent.

In addition to nonlinearity/asymmetry literature, some papers have pointed out consideration of structural changes in this type of modelling. For instance, Bai and Perron (2003) discussed that Phillips curve parameters can change over time due to structural changes. These types of models are of importance in macroeconomic modelling as they allow parameters to change over time, based on the Lucas critique, which states that the model parameters are not policy invariant. Similarly, Tsong and Lee (2011), Chortareas et al. (2012), Riggi and Venditti (2015), and Lee and Yoon (2016) have argued that when the structural and cyclical factors behind economic activities are not taken into account, the response of inflation to the output gap cannot be measured accurately. By considering properties such as asymmetry/nonlinearity and structural changes, expanding empirical literature has confirmed that the effects of the output gap on inflation change depending on the sign of the output gap, the inflation regime, or the cycle of the economy; see, e.g., Laxton et al. (1995) and Turner (1995) for the G7 economies; Ball et al. (1988), Filardo (1998), Stimel (2009), and Xu et al. (2015) for the USA; Fisher et al. (1996) for the UK; Razzak (1997) for New Zealand; Dupasquier and Rickets (1998) for Canada; Eliasson (2001) for Australia, Sweden and the USA; De Veirman (2007) for Japan; Villavicencio and Mignon (2013) for Canada, France, Italy, England and the USA; Abbas (2022) for Australia, Canada, New Zealand, the UK and the USA; Fabiani et al. (2006), Binder and Gross (2013), Musso et al. (2009), Riggi and Venditti (2015) and Gross and Semmler (2017) for the Eurozone; Kobbi and Gabsi (2017) for Tunisia; Hasanov et al. (2010), Bilman and Utkulu (2010), and Arabacı and Eryiğit (2012) for Turkey.

As discussed in detail above, the relationship between the output gap and inflation is an indicator for the monetary policy-making process, especially in the inflation targeting strategy. Additionally, comprehensive literature also emphasizes the importance of the characteristics of the relation for optimal monetary policy in terms of the timing and extent of the policies, and the costs of reducing inflation. Therefore, this study deals with the possible asymmetry and structural changes on the relationship between the output gap and inflation for the Turkish economy by using different approaches. The Turkish economy has several facts important for this type of modelling.

The first strand of these facts is the increasing interest in recent research into the relationship between the output gap and inflation. The Central Bank of the Republic of Turkey (CBRT) has reported inflation and real activities movements by forecasting the output gap in its inflation reports, and academics and researchers have studied the trade-off and alternative output gap measurements. For example, Öğünç and Sarıkaya (2011), Alp et al. (2012), Coşar et al. (2013) and Saraçoğlu et al. (2014) have pointed out that the output gap is an appropriate tool to explain inflation dynamics and that the backward-looking indexation is dominant in inflation expectations. Correspondingly, Özbek and Özlale (2005), Kara et al. (2007), Şahinöz and Atabek (2016), Akkoç (2018), Andıç (2018), and Kayacan and Birecikli (2018) have focused on the alternative output gap measurements. The above studies on the Turkish economy implicitly act on linear assumptions and do not consider asymmetry. There have been a few studies investigating the nonlinear relationship between the output gap and inflation or the stability of this relationship. Önder (2009) attained some evidence of instability and nonlinearity, but no evidence of asymmetry based on the structural change and Markov regime-switching models. Similarly, Hasanov et al. (2010) reported that the trade-off is regime- and time-dependent by using time-varying smooth transition regression. While Bilman and Utkulu (2010) presented the asymmetric and unstable relationship using Markov regime-switching models, Arabacı and Eryiğit (2012) found that the trade-off differs depending on the level of capacity utilization rate using threshold regression. Yet, none of these studies has considered the asymmetric effects of negative and positive changes in the output gap. Considering the importance of asymmetric behaviours regarding convenient policy implementation, our study differs from previous research and deals with the *sign-dependent asymmetry* between the output gap and inflation using the nonlinear autoregressive distributed lag (NARDL) cointegration test proposed by Shin et al. (2014) and the Hatemi-J (2012) asymmetric causality test.

The second strand of these facts is the possible effects of structural changes, such as high and volatile inflation, and policy changes on the relation. After nearly three decades of a high inflation period, the CBRT has started to implement an implicit inflation-targeting regime and price stability has become the primary objective since 2002. Following this policy change, the inflation rates fell to single digits in 2004. However, the actual inflation rates have been above target rates except in 2009–2010, and the average annual inflation rate was nearly 14% in the explicit inflation targeting regime implemented since 2006. In addition, the inflation rate has increased rapidly due to the fluctuations in the exchange rate since 2018 and has exceeded 20% annually. Therefore, it is very clear that Turkish inflation dynamics show some properties such as volatility arising from sensitivity to policy changes, domestic or external events, and different average inflation in sub-periods. Önder (2004) emphasized that accurately forecasting inflation may be difficult in a country with high and volatile inflation such as Turkey. The results of her study reveal that inflation forecasts based on the Phillips curve, which includes the output gap, are more accurate than forecasts based on other macroeconomic variables. Önder (2009) similarly found that the relation has been unstable, nonlinear, and more significant after 2002, when inflation targeting started to be implemented. Thus, she argued that the instability of the curve should be kept in mind for a better estimation for Turkey. In parallel with these studies, Bilici and Çekin (2020) reported that while a decrease in inflation persistence and volatility was accompanied by a decline in inflation after 2003, there is a significant rise in inflation persistence starting in 2016, following the upward trend in inflation. Considering inflation dynamics such as policy changes, volatility and persistence in inflation, our study also deals with the structural breaks of both symmetric and sing-dependent asymmetric relations by using the version of Kejriwal's (2008) cointegration test with structural break model augmented with a deterministic trend by Lopcu et al. (2013), and the NARDL model with structural breaks.

The third and perhaps most important strand of these facts is that the scatter diagram depicting the output gap-inflation relationship in the Appendix shows that the highest inflation rates are in the periods which coincide with the negative output gap. This phenomenon has been discussed with the expression "*speed limit effect*" in the literature. The speed limit effect means that inflation may depend as much on the changes in the output gap as on the level. More clearly, if the output gap is closed quickly, inflation may increase even if there is no positive output gap (see Turner, 1995; Fisher et al., 1996; Walsh, 2003). The number of studies dealing with the speed limit effect for the Turkish economy is also limited. Kuştepeli (2005) reported no significant evidence for linear and nonlinear relationships as well as the speed limit effect between unemployment and inflation. Differently, Malikane (2014) found that the labour share and output gap have speed limit effects in his analysis based on the new Keynesian tringle Phillips curve for six emerging markets, including Turkey. Considering the above phenomenon, this study deals not with effects of the sign of the output gap level but with signs of the changes in the output gap. Since we use dynamic methods in our sign and regime-dependent asymmetry analysis, the results also provide clues as to the possible speed limit effect.

Therefore, the objective of this article is to test the sign-dependent asymmetry, the stability of the symmetric and asymmetric relation in sub-periods, and speed limit effects for the Turkish economy for the period from 2002:01 to 2021:09 by using different approaches such as asymmetric cointegration, asymmetric causality, and the regime-trend shift model (C/S/T).

The remainder of the paper is organized as follows. Section 2 deals with the empirical literature. Section 3 presents variables and methods. Sections 4 and 5 deal with the empirical findings and conclusions, respectively.

2. Literature Review

The complexity of the relationship between the real and financial spheres, nominal wages and price rigidity discussed since the 1990s have contributed to the asymmetry literature on the relationship between the output gap and inflation (Kobbi and Gabsi, 2017). In the literature, the output gap-inflation asymmetry/nonlinearity has been considered in two different ways, depending on the nature of the asymmetry. The first strand of this literature emphasizes the *asymmetry* according to the sign of the output gap, namely *sign-dependent asymmetry*. As stated in Mayes and Chapple (1995), Laxton et al. (1995), Turner (1995) and Razzak (1997), this asymmetry expresses the differentiation of the effect of the output gap on inflation. The inflationary effect of a positive output gap is different from the disinflationary effect of a negative output gap. A second strand of the literature considers the *nonlinearity* according to the threshold, smooth threshold, or Markov-type transition effects of variables, also defined as a *regime-dependent asymmetry,* as in Dupasquier and Ricketts (1998), Filardo (1998), Musso et al. (2009), Hasanov et al. (2010), Villavicencio and Mignon (2013), and Gross and Semmler (2017). Likewise, the sources of asymmetry/nonlinearity have been clarified by various pricing approaches in the context of macroeconomic conditions such as the capacity constraint model (Phillips, 1958), the signal extraction model (Lucas, 1972; 1973), the cost adjustment model (Ball et al*.,* 1988), the downward nominal wage stickiness (Stiglitz, 1986; Fisher, 1989), and the monopolistic competition model (Stiglitz, 1984). While the monopolistic competition model implies concavity, the others imply convexity (Yates, 1998; Dupasquier and Rickets, 1998; Eliasson, 2001).

Just as the policy implications of the linear and asymmetric/nonlinear relations are different, the policy implications are also different according to the type of the asymmetric/nonlinear relation. A convex relation means that as the economy strengthens, the effect of demand changes on inflation increases. Shock policies implemented against inflationary pressures prevent a faster inflationary process. In the case of a concave relationship, however, as the economy becomes stronger, the sensitivity of inflation to changes in demand decreases. Since the output gap required to reduce inflation increases, gradual policies are needed to prevent large drops in output (Filardo, 1998; Dupasquier and Rickets, 1998). The asymmetric relation is also closely related to the output costs of disinflationary processes. According to the asymmetric findings of his study, Razzak (1997) remarked that in the case of slower reactions to the demand shock, output volatility and cumulative output loss are higher compared to the prompt policy reactions. In addition, policies convenient to economic conditions not only reduce the volatility of output but also increase the average level of output (Bank of Canada, 1997). Moreover, Gross and Semmler (2017) highlighted that policies implemented by taking into account inaccurate estimations of a linear relation can increase the size and duration of the business cycle. Therefore, the output gap-inflation asymmetry literature has generally been developed with an emphasis on Phillips curve asymmetry. The pioneering empirical literature on the asymmetric relation extends to studies such as Razzak (1997) for New Zealand; Ball et al. (1988), Clark et al. (1995, 1996) and Filardo (1998) for the USA; Laxton et al. (1995) and Turner (1995) for the G7 countries; and Dupasquier and Rickets (1998) for Canada.

The first group of studies has analysed the role of the output gap by using nonlinear threshold methods. Thus, Eliasson (2001) reached the findings of a nonlinearity for Australian and Swedish economies and a linearity for the US economy, and also stated that inflation expectation has a major effect on nonlinearity. Similarly, Villavicencio and Mignon (2013) observed that the asymmetric relation depends on the trend of inflation for Canada, France, Italy, the UK and the USA. On the one hand, both studies of Aguiar and Martins (2005) and Musso et al. (2009) have reached linearity, but Gross and Semmler (2017) reported a nonlinearity for the Eurozone countries. According to Gross and Semmler's (2017) findings, the sensitivity of inflation to the output gap is four times higher in the expansion phase compared to the contraction phase. Therefore, a gradual contractionary policy should be implemented during the expansion periods of the economy, and rapid expansionary policies should be implemented during the contraction periods. On the other hand, for Tunisia, a smaller economy relative to the examples of above, Kobbi and Gabsi (2017) concluded that the drivers of inflation are the output gap in high inflation regimes, and inflation persistence in low inflation regimes, respectively. Huh and Jang (2007) and Stimel (2009) could be given as examples of papers focusing on the unemployment or growth rate for the USA and UK. The findings of Stimel (2009) imply that the Phillips curve becomes negatively sloped during low-inflation periods and flat or positively sloped during high-inflation periods.

The second group of studies tries to explain the properties of the relationship between output gap and inflation with structural breaks or quantile methods. Riggi and Venditti (2015) applied econometric methods such as structural break and time-varying parameters to the euro area, stating that the failure to accurately predict the response of inflation to economic activities in the euro area during the global crisis is due to inappropriate statistical methods. The findings report a significant increase in the sensitivity of inflation to the business cycle after global crises. For the US economy, Xu et al. (2015) highlighted that the effectiveness of monetary policy mainly depends on the phase of the economic cycle and the inflation uncertainty based on the nonlinear quantile regression analysis. On the other hand, other studies such as Bai and Perron (2003), Chortareas et al. (2012) and Lee and Yoon (2016) have focused on other demand indicators by using structural breaks for different country groups.

The third group of studies applies the NARDL methods to reveal possible asymmetric effect of the output gap on inflation. Mihajlovic (2019) investigated the nexus between the output gap and inflation rate in the case of six Western Balkan countries. The findings show the symmetric relation in the majority of the observed countries in the given period except Serbia. Similarly, Mihajlovic and Marjanovic (2020) state that while inflation responds more significantly to positive changes in the output gap in Estonia and Lithuania and strongly to negative changes in the unemployment gap in Estonia, Lithuania, and Latvia. They also reported an asymmetric causality between different signs of the shocks, based on the Hatemi-J (2012) asymmetric causality test. Differently, Bildirici and Ozaksoy (2016), and Bildirici and Ozaksoy Sonustun (2018) focused on the other demand indicators in their analyses. While the former reported an asymmetry for Canada, the latter revealed an asymmetry for Japan, France, Turkey, and the USA. Finally, the fourth group of studies deals with the Phillips curve asymmetry in the context of dynamic stochastic general equilibrium models or system equations using different types of demand indicators (see Lepetit, 2018; L'Huillier et al., 2022; Cao et al., 2023).

For the Turkish economy, a few studies have investigated the nonlinear response of inflation to real macroeconomic variables. The common point of these studies is that they take into account the periods when inflation is higher for the Turkish economy compared to our study. On the one hand, Kuştepeli (2005) reported that there is neither a linear nor a nonlinear relation between unemployment and inflation, but that inflation expectations have significant effects on actual inflation. On the other hand, based on alternative regime shifting methods, Önder (2009) pointed out an unstable and nonlinear relationship between the output gap and inflation. Her findings also state that while the relationship weakens in high-inflation regimes, it becomes insignificant in high inflation and volatility regimes. Using smooth transition regression analysis, Hasanov et al. (2010) reported that the convexity depends on the initial value of inflation period for the 1980–2008. The effect of inflation (output gap) on the output gap (inflation) is greater in periods of low inflation than in high inflation. As a result of the analysis of the sub-regimes, linear, concave and convex relations were obtained for 1981–1991, 1994–1996, and 1998–2008, respectively. Similarly, Bilman and Utkulu (2010) revealed an asymmetric and unstable relationship between the output gap and inflation using data from 1990 to 2008 using the Markov switching model. Arabacı and Eryiğit (2012) used capacity utilization rates as well as the output gap, and demonstrated that the effects of output gap and capacity utilization rates on inflation differ between high and low regimes for the period 1991–2010 based on the threshold regression and flexible nonlinear inference methods.

3. Model, Dataset and Methodology

3.1 Model and dataset

Effects of asymmetries/nonlinearities and structural change on the relationship between economic activity and inflation have attracted a great attention of researchers in recent years. While some authors have focused on the asymmetries/nonlinearities (Eliasson, 2001; Aguiar and Martins, 2005; Musso et al., 2009, Hasanov et al., 2010; Bildirici and Ozaksoy, 2016; Bildirici and Ozaksoy Sonustun, 2018; Gross and Semmler, 2017; Mihajlovic, 2019; Mihajlovic and Marjanovic, 2020), others have dealt with structural changes (Önder, 2009; Chortareas et al., 2011; Riggi and Venditti, 2015; Xu et al., 2015; Lee and Yoon, 2016). To determine the model, the present paper follows studies such as Önder (2009), Hasanov et al. (2010) and Mihajlovic and Marjanovic (2020), focusing only on the relationship between output gap and inflation.

Although above studies deal with structural breaks, nonlinearities or asymmetries, our approach here differs from previous research in that we use the structural breaks of both symmetric and sing-dependent asymmetric relations by using the version of Kejriwal's (2008) cointegration test with a structural break model augmented with a deterministic trend by Lopcu et al. (2013), and the NARDL model with structural breaks.

The functional form of the estimated model appears as:

$$INF_t = f\ (GAP_t) \tag{1}$$

Inflation *(INF)* is measured by an annualized total consumer price index. The value of the output gap *(GAP)* is calculated by applying the Hodrick Prescott (1980) filter to the industrial production index following the literature. The graph of the estimated output gap is shown in the Appendix. The inflation and industrial production index are acquired from the Turkish Statistical Institute (TURKSTAT).

The dataset consists of monthly and seasonally adjusted data for the period 2002:01–2021:09. The starting date of the estimation period is determined by considering the date on which the inflation targeting regime began to be implemented. The data period also excludes time after 2021:09, when the level of inflation increased significantly. The dramatic depreciation of the domestic currency has caused the inflation rate to increase rapidly, especially since last quarter of the 2021.

3.2 Methodology

The analyses are carried out in several stages. The first stage is to investigate the linearity of the series and then to test their stationarity with tests suitable for their properties. We investigate the linearity by using tests developed by Harvey and Leybourne (2007) and Harvey et al. (2008), and stationarity with unit root tests formulated by Ng-Perron (2001), Kapetanios et al. (KSS) (2003) and Kruse (2011).

The second stage is to investigate the properties of the possible relation. To this, we applied the following tests:

- Kejriwal's (2008) cointegration test augmented by Lopcu et al. (2013), which allows testing the long-run relationships with structural breaks (regime and trend shift model, C/S/T). This test informs us whether the possible symmetric relationship changes between sub-periods.
- NARDL cointegration test to analyse the sign-dependent asymmetry. This test shows us whether negative and positive changes in the output gap have a similar effect on inflation.
- NARDL augmented with structural breaks obtained from Lopcu et al. (2013) to analyse whether the sign-dependent asymmetry changes between sub-periods.
- The Hatemi-J (2012) asymmetric causality test to determine the asymmetric causality between positive and negative shocks.

In the first part of the analysis, the version of Kejriwal's (2008) cointegration test, augmented with a deterministic trend by Lopcu et al. (2013). While Kejriwal's (2008) cointegration test is based on Gregory-Hansen's (1996a) regime shift (C/S) model for identifying structural change stability, Lopcu et al. (2013) allow shifts in the trend as well. The cointegration equation which tests the long-run relationship between *GAP* and *INF*, based on the regime and trend shift model (C/S/T), is shown in Equation (2).

$$INF_t = c_j + \delta_j trend + \beta_j GAP_t + u_t \quad \text{if } T_{j-1} < t \leq T_j \quad \text{for } j = 1, ..., k+1 \tag{2}$$

where *INF* is the inflation, *GAP* is the output gap, k is the number of breaks, c is the constant term, δ the trend coefficients, and β are the slope coefficients, t shows the time period, and T is the sample size by convention, $T_0 = 0$ and $T_{k+1} = T$. In the study, we also use dynamic OLS regression (DOLS), where the leads and lags of the first differences of the regressors deal with the simultaneity bias, as stated by Kejriwal and Perron (2008, 2010). The leads and lags are equal to one.

$$INF_t = c_j + \delta_j trend + \beta_j GAP_t + \sum_{j=-l_T}^{l_T} \Delta GAP_{t-j} \psi_j + u_t^* \tag{3}$$

The test statistic with *k* breaks is given by:

$$\tilde{V}_k(\hat{\lambda}) = \frac{T^{-2}\sum_{t=1}^{T} S_k(\hat{\lambda})^2}{\Omega_{11}} \tag{4}$$

where Ω_{11} is a consistent estimation of the long-run variance of u_t^*, $\hat{\lambda} = (\hat{T}_1 / T, \ldots\ldots, \hat{T}_k / T)$ and $\hat{T}_1, \ldots\ldots \hat{T}_k$ are obtained by minimizing the sum of the squared residuals. The null hypothesis of the test is cointegration with the structural breaks between series against the alternative hypothesis of no cointegration.

In the second part of the analysis, NARDL proposed by Shin et al. (2014) based on the ARDL specifications, is applied. The NARDL method allows us to test whether the inflationary effect of positive changes in the output gap is different from the disinflationary effect of negative changes in the output gap. This model, which detects the asymmetric effects of the independent variable of *GAP* on the dependent variable *INF*, is shown in Equation (5).

$$\Delta INF_t = c + \beta_1 INF_{t-1} + \beta_2 GAP_{t-1}^{+} + \beta_3 GAP_{t-1}^{-} + \sum_{i=1}^{m}\beta_{4,i}\Delta INF_{t-i} + \sum_{i=0}^{n}\beta_{5,i}\Delta GAP_{t-i}^{+} + + \sum_{i=0}^{q}\beta_{6,i}\Delta GAP_{t-i}^{-} + \varepsilon_t, \tag{5}$$

where:

– GAP_i^+ = positive changes in the output gap gauged by $\sum_{i=0}^{t}\max(\Delta GAP_i^+, 0)$;

– GAP_i^- = negative changes in the output gap gauged by $\sum_{i=0}^{t}\max(\Delta GAP_i^-, 0)$

We summarize the steps for estimating Equation (5) using NARDL:

1. Cointegration is identified if the null hypothesis is rejected $(H_0 : \beta_1 = \beta_2 = \beta_3 = 0)$
2. Asymmetry is identified if the null hypothesis is rejected by using Wald statistics $\left(H_0 : -\beta_2/\beta_1 = -\beta_3/\beta_1\right)$.
3. The coefficients β_2 and β_3 are divided into $-\beta_1$ to obtain long-run impacts $\left(-\beta_2/\beta_1 = 0, -\beta_3/\beta_1 = 0\right)$

Following testing the sign-dependent asymmetry, we apply NARDL with structural breaks. In the literature, a few studies, for example, Kisswani (2017), Fasanya et al. (2018), Okere et al. (2021), and Musa et al. (2021) have augmented the model using the break dates obtained in different ways. Following these studies, we augment the NARDL model with structural breaks in regime and trend (C/S/T) using the break dates obtained by Lopcu et al. (2013). The NARDL model with structural breaks estimated is shown in Equation (5).

$$\Delta INF_t = c_j + \delta_j trend + \beta_1 INF_{t-1} + \beta_{2,j} GAP^+_{j,t-1} + \beta_{3,j}\, GAP^-_{j,t-1} + \sum_{i=1}^{m} \beta_{4,i}\, \Delta INF_{t-i} + \\ + \sum_{i=0}^{n} \beta_{5,ji} \Delta GAP^+_{j,t-i} + \sum_{i=0}^{q} \beta_{6,ji} \Delta GAP^-_{j,t-i} + \varepsilon_t \tag{6}$$

where c and δ are the constant and trend coefficients respectively, j is the number of sub-periods, $j = 1, \ldots\ldots k + 1$. Accordingly, $\beta_{2,j}$ and $\beta_{3,j}$ represent the long-run dynamics of GAP^+ and GAP^- for each sub-period. The definitions of the parameters follow the NARDL model without structural breaks.

In the third and final part of the analysis for the relation, to determine the possible asymmetric causality between different shocks, we apply the Hatemi-J (2012) asymmetric causality test. The test is based on the Hacker and Hatemi-J (2006) bootstrap symmetric Granger causality test taking into account the risk of errors not being normally distributed and, analysis with level states of non-stationary series. The lag number is determined by adding the optimal lag number obtained from the VAR system and the maximum stationarity order of the variables. In this context, the Hatemi-J asymmetric causality test (2012) is a differentiated form of the positive and negative shocks of the Hacker and Hatemi-J (2006) bootstrap Granger causality test.

4 Empirical Findings

In this section, we summarize the results of the analysis of the relationship between the output gap and inflation. The following results are included: (1) linearity test, conventional and nonlinear unit root tests, (2) examining the relationship between inflation and output gap with structural breaks, asymmetric cointegration and (3) asymmetric causality tests.

4.1 Linearity and unit root tests

We start testing with a linearity test of the output gap and inflation, and the results of this test are reported in Table 1. The linearity test reveals that the null hypothesis of linearity is rejected only for the *GAP* series.

Table 1: Linearity test

Variables	Harvey et al. (2008)	Harvey and Leybourne (2007) 1%	5%	10%
INF	0.72	1.83	1.82	1.82
GAP	21.87*	22.73*	22.62*	22.57*

Notes: Harvey et al. (2008) test critical values are 9.21, 5.99 and 4.60 for 1% (*), 5% (**) and 10% (***), respectively. Harvey and Leybourne's (2007) critical values are 13.27, 9.48 and 7.77 for 1% (*), 5% (**) and 10% (***), respectively.
Source: author's calculations

Having established the nonlinear properties of the *GAP* series, we apply the KSS (2003) and Kruse (2009) nonlinear unit root tests. As can be seen from Table 2, the findings suggest that the null hypothesis of the unit root is rejected at the 1% significance level.

Table 2: Nonlinear unit root test

	KSS (2003)		Kruse (2011)	
	k	**KSS_τ**	**k**	**KRUS E_τ**
GAP	1	–5.81	1	34.40
Critical Values	1%	–3.93	1%	17.10
	5%	–3.40	5%	12.82
	10%	–3.13	10%	11.10

Notes: τ indicates detrended model.
Source: author's calculations

In order to test the integrating level of the *INF* series, the Ng and Perron (2001) test is used. The results, given in Table 3, show that the *INF* series has a unit root at all significance levels.

Table 3: Ng-Perron (2001) unit root test

	Constant and trend			
Variables	**MZ_a**	**MZ_t**	**MSB**	**MPT**
INF	–0.97	–0.54	0.56	63.16
1%	–23.80	–3.42	0.14	4.03
5%	–17.30	–2.91	0.16	5.48
10%	–14.20	–2.62	0.18	6.67

Notes: critical values are obtained from Ng-Perron (2001).
Source: author's calculations

4.2 Results of symmetric and asymmetric cointegration tests

In what follows, we try to investigate the properties of the relationship between the output gap and inflation. First, we analyse whether there is a structural break in the long-run symmetric relation. The analysis in this method consists of several steps. The first step is the determination of the number of breaks and stability in the relation. We use 15% trimming for the maximum number of breaks. The intercept, trend, and the slope in Equation (2) are allowed to change. The results of the test for stability and the number of breaks are reported in Table 4. Both *BIC* and *LWZ* criteria select two optimal numbers of breaks.

Table 4: Structural break test

	Sub F (1)	Sub F (2)	Sub F (3)	Sub F (4)	Sub F (5)	UDmax	BIC	LWZ
C/S/T	14.15*	8.76	5.99	4.60	3.72	14.15*	2	2

Notes: critical values are from Kejriwal and Perron (2010), **, *, # denote significance at the 1%, 5% and 10% levels, respectively.

Source: author's calculations

The second step is to reveal break fractions and dates endogenously taking into account two breaks, and then to test the relation in the presence of these breaks. According to the results given in Table 5, endogenously estimated break dates are 2004:01 and 2018:04, respectively. These dates are considered to be significant in such a way that they point to 2004, when single-digit inflation figures were reached after inflation targeting, and 2018, when the exchange rate-inflation jump took place. The null hypothesis of cointegration between series is not rejected at any significance level. Therefore, this finding indicates that there is a long-run symmetric relationship between the output gap and inflation in the existence of two structural breaks and three sub-periods.

Table 5: Cointegration test results

	Two breaks		
	$\hat{V}_2(\hat{\lambda}_2)$	$\hat{\lambda}_1$	$\hat{\lambda}_2$
C/S/T	**0.046**	0.15 (2004:11)	0.83 (2018:04)
** **1%** * **5%** # **10%**	0.093 0.062 0.050		

Notes: critical values are obtained by simulations using 100 steps and 2500 replications.

Source: author's calculations

In the third and final step, to determine the coefficients in sub-periods, the model is estimated taking into account three sub-periods. The estimated cointegration regression results are given in Table 6. The indices *c*, *δ* and *β* represent the constant, trend and slope coefficients in the sub-periods, respectively. The test results show the shifts in regimes and trend of the symmetric relation, implying that the significance and magnitude of the relation may vary in sub-periods and is not stable in the whole period. The coefficient of the output gap is not significant in the first sub-period (2002:01–2004:11), while coefficients of the second (2004:12–2018:04) and third sub-period (2018:05–2021:09) are statistically significant and have positive signs, indicating that increases in the output gap lead to an increase in the inflation. Additionally, trend coefficients are statistically significant except for the second sub-period. Having in mind that the second sub-period covers 2004:12–2018:04, the insignificant trend coefficient is compatible with Turkey's inflation dynamics. With the implementation of the inflation targeting regime in 2002, the inflation rate showed a rapid decline and fell to single digits in 2004. Although it shows deviations from expectations in the period until 2018, it oscillated around a certain average.

Table 6: Estimated cointegration regression results

c_1	c_2	c_3	δ_1	δ_2	δ_3	β_1	β_2	β_3	T_1	T_2
0.492 (0.00)	**0.078** (0.00)	**0.620** (0.00)	**−0.013** (0.00)	0.00 (0.19)	**−0.002** (0.00)	0.331 (0.11)	**0.181** (0.00)	**0.362** (0.00)	2004:11	2018:04

Notes: *p-values* are in parentheses. c_1, c_2 and c_3, δ_1, δ_2 and δ_3 and β_1, β_2 and β_3 show the estimated coefficient of constant, trend and gap for sub-periods 1, 2 and 3, respectively. T_1 and T_2 are break dates.

Source: author's estimations

Secondly, the NARDL method is also applied to see whether the relationship between the output gap and inflation changes according to the sign of the changes in the output gap. As can be seen from Table 7, the *F* statistic indicates that there is a long-run relationship between the variables. Following the long-run relationship finding, the null hypothesis of the linear relationship is tested. The DW_{LR} statistic shows that the null hypothesis of linearity is rejected at least at the 10% level. This means that the effects of negative and positive changes in the output gap on inflation are different for the period questioned. The long-run coefficients referring to the effects of positive changes ($LGAP^+$) and negative changes ($LGAP^-$) on inflation are statistically significant. The inflationary effect of the positive changes (0.600) is larger than the disinflationary effect of the negative changes (0.549). These findings point out the presence of a convex sign-dependent asymmetry and speed limit effects. The dummy variable that covers September 2018 is also statistically significant at the 10% level and has a positive coefficient of 0.066.

Table 7: NARDL results

Long-run dynamics		Short-run dynamics	
Variables	**Estimated coefficient**	**Variables**	**Estimated coefficient**
c	0.001 (0.516)	ΔINF_{t-1}	0.209 (0.000)
$D2018{:}\ 09$	0.066 (0.000)	ΔINF_{t-3}	0.091 (0.083)
INF_{t-1}	−0.104 (0.000)	ΔINF_{t-4}	−0.090 (0.077)
GAP^{+}_{t-1}	0.062 (0.000)	ΔINF_{t-12}	−0.286 (0.000)
GAP^{-}_{t-1}	0.057 (0.001)	ΔGAP^{+}_{t-3}	−0.061 (0.044)
		ΔGAP^{-}_{t-1}	−0.052 (0.066)
		ΔGAP^{-}_{t-2}	−0.049 (0.051)
		ΔGAP^{-}_{t-7}	−0.064 (0.004)

Long-run coefficients

2002:01–2021:09	DW_{LR}	18.479 (0.000)	
	$LGAP^{+}$	0.600 (0.000)	
	$LGAP^{-}$	0.549 (0.000)	
F statistic	23.214 (0.000)	*BG LM*	0.892 (0.639)
R^2 *statistics*	0.4652	*ARCH LM*	1.671 (0.195)
Ramsey Reset	0.556 (0.578)		

Notes: the critical values are obtained from Pesaran et al. (2001)
Source: author's estimations

Additionally, the effects of the positive and negative changes in the output gap on inflation changes in sub-periods was analysed by using NARDL with structural breaks. The results are presented in Table 8.

Table 8: Results of NARDL with structural breaks

Long-run dynamics		Short-run dynamics	
Variables	**Estimated coefficient**	**Variables**	**Estimated coefficient**
D2018:09	0.062 (0.000)	ΔINF_{t-1}	0.176 (0.000)
INF_{t-1}	−0.137 (0.000)	ΔINF_{t-12}	−0.418 (0.000)
First sub-period			
constant	0.026 (0.083)	ΔGAP^{+}_{t-3}	−0.796 (0.000)
trend	−0.001 (0.024)	ΔGAP^{+}_{t-4}	−0.945 (0.000)
GAP^{+}_{t-1}	0.155 (0.123)	ΔGAP^{+}_{t-7}	−0.808 (0.000)
GAP^{-}_{t-1}	0.053 (0.558)		
Second sub-period*			
constant	0.009 (0.000)		
trend	−0.001 (0.003)		
GAP^{+}_{t-1}	0.068 (0.000)		
GAP^{-}_{t-1}	0.021 (0.218)		
Third sub-period			
constant	0.149 (0.005)	ΔGAP^{+}_{t-3}	−0.254 (0.000)
trend	−0.001 (0.006)	ΔGAP^{-}_{t-3}	0.082 (0.001)
GAP^{+}_{t-1}	0.053 (0.006)	ΔGAP^{-}_{t-4}	−0.061 (0.048)
GAP^{-}_{t-1}	0.001 (0.826)	ΔGAP^{-}_{t-7}	−0.041 (0.082)
Long-run coefficients			
2002:01–2004:11		DW_{LR}	5.561 (0.019)
		L^{+}_{GAP}	1.129 (0.159)
		L^{-}_{GAP}	0.390 (0.569)
2004:12–2018:04		DW_{LR}	7.125 (0.008)
		L^{+}_{GAP}	0.500 (0.001)
		L^{-}_{GAP}	0.157 (0.216)
2018:05–2021:09		DW_{LR}	8.053 (0.004)
		L^{+}_{GAP}	0.389 (0.008)
		L^{-}_{GAP}	0.012 (0.826)
F statistics	7.204 (0.000)	*BG LM*	0.794 (0.672)
R^2 *statistics*	0.597	*ARCH LM*	0.266 (0.605)
Ramsey Reset	1.610 (0.118)		

Notes: the critical values are obtained from Pesaran et al. (2001). *p-values* are in parentheses. *There are no significant short-run coefficients for the second sub-period.

Source: author's estimations

The relationship between the variables in the three different sub-periods exhibits asymmetrical features. In the first sub-period, the coefficients of positive and negative changes are statistically insignificant. Having in mind the high inflation uncertainty and inflation inertia of the period in question, the relationship between real activities and price movements may deviate from theoretical expectations. In addition, the relation may be affected by factors such as the initial value of inflation and inflation expectation, as stated in the literature. In the second and third sub-periods, while the effects of the positive changes on inflation (0.500 and 0.389, respectively) are significant at the 1% level and have a positive sign, the effects of the negative changes are insignificant. The findings of NARDL with structural breaks report that positive changes in output gap have an inflationary effect, while negative output gap has no significant disinflationary effect on inflation, implying a sign-dependent asymmetry in favour of convexity and speed limit effects. Considering the breaks in the regime and trend, the asymmetric relationship is not stable, and the size and statistical significance of the relationship varies across periods.

4.3 Asymmetric causality test result

Thirdly and finally, we examine the asymmetric causality between different shocks by using the Hatemi-J (2012) asymmetric causality test. The test results are given in Table 9.

Table 9: Causality test results

Hatemi-J (2012) asymmetric causality test					
	Wstat.	**Critical values**			**Optimal lags + Dmax**
		1%	**5%**	**10%**	
GAP $^{+}$ → ***INF*** $^{+}$	7.487***	14.608	9.268	7.162	2+1
GAP $^{+}$ → ***INF*** $^{-}$	2.900	12.239	7.510	5.639	2+1
GAP $^{-}$ → ***INF*** $^{-}$	24.896*	11.821	6.971	5.264	2+1
GAP $^{-}$ → ***INF*** $^{+}$	6.328	13.107	8.444	6.593	2+1
INF $^{+}$ → ***GAP*** $^{+}$	0.873	12.606	6.759	4.694	2+1
INF $^{+}$ → ***GAP*** $^{-}$	0.470	10.985	6.347	4.755	2+1
INF $^{-}$ → ***GAP*** $^{-}$	5.735*	10.191	6.336	4.844	2+1
INF $^{-}$ → ***GAP*** $^{+}$	0.261	11.560	6.796	4.832	2+1

Notes: the number of bootstraps is 10,000.

Source: author's calculations

According to the results of the Hatemi-J asymmetric causality test (2012), there is a causality running from a positive (negative) output gap shock to a positive (negative) inflation shock. In addition, there is a causality running from a negative inflation shock to negative output gap shocks. The findings provide clues that positive (negative) shocks in the output gap cause an increase (decrease) in inflation.

All the analyses in the study reveal that this relation may differ considering the period and the sign of the changes in the output gap. In addition to the fact that the direction of the change in the output gap has different effects on inflation, the size and significance of this effect change in periods of high and volatile inflation. These findings are in parallel with studies by Önder (2009), Hasanov et al. (2010), Bilman and Utkulu (2010), and Arabacı and Eryiğit (2012) in terms of reaching results such as asymmetry, non-stability and time variance for the Turkish economy.

5. Conclusion

In this paper, we investigated properties such as structural breaks and asymmetry of the relationship between the output gap and inflation in Turkish economy for the period 2001:01–2021:09 using monthly data. To this end, we first analysed the symmetric cointegration with structural breaks to see the possible effects of the shifting in regimes and trends on the relationship, having in mind the existence of sub-periods with high and volatile inflation in the studied periods for the Turkish economy. The test results suggest a symmetric long-run relationship between the output gap and inflation in the existence of two breaks (2004:11 and 2018:04) and three sub-periods (2002:01–2004:11, 2004:12–2018:04, 2018:05–2021:09) determined endogenously. The estimated long-run coefficients are significant and have positive effects on inflation except for the first sub-period. Moreover, the significant trend coefficients in the first and third sub-periods, which have higher and more volatile inflation rates compared to the second sub-period, provide clues about the effects of trend on inflation. The findings point out both a symmetric relation with structural breaks where coefficients vary between sub-periods convenient to Turkish inflation dynamics such as single-digit inflation in 2004 and increasing volatility due to exchange rate fluctuations since 2018.

We then analysed the long-run sign-dependent asymmetric relationship between the output gap and inflation by using the symmetric cointegration test. According to the results, the inflationary effect of the positive change in the output gap is higher than the disinflationary effect of the negative change in the output gap, implying a convex sign-dependent asymmetry. While the findings suggest the importance of asymmetry for optimal monetary policy in monetary policy-making processes, they also point out the existence of a speed limit effect. Further analysis focused on the sub-periods to see the possible effects of the shiftings on the sign-dependent asymmetry by using an asymmetric cointegration test augmented with structural breaks. The results document that the output gap has no significant effect on inflation in the first sub-period, while only positive changes in the output gap have significant effects on inflation in the other sub-periods, pointing out the sign-dependent asymmetry and speed limit varying across sub-periods. The findings are of importance in that possible structural changes and asymmetric behaviours of macro variables should be taken into account in terms of the timing and scope of policies to be implemented in the monetary policy-making process.

Finally, we investigated asymmetric causality between different shocks. The findings show a causality running from a positive (negative) output gap shock to a positive (negative) inflation shock. Moreover, there is a causality running from a negative inflation shock to negative output gap shocks. The findings provide clues that positive (negative) shocks in the output gap cause an increase (decrease) in inflation. However, there is limited econometric methodology in the literature. It should be noted that the findings obtained here are based on estimates using the estimated output gap variable.

Overall, because the output gap has an effect on inflation, it is seen as a meaningful indicator in the monetary policy-making process. However, this effect is sensitive to the sign of the output gap and to structural changes. In this context, the speed of adjustment, duration of impact and possible results of policies to be implemented may differ from policies implemented without considering this sensitivity. It is thought that sign-dependent asymmetry and structural changes should be taken into account in order to achieve the desired targets in a less costly manner in policies implemented for inflation, particularly in economies with volatile inflation such as Turkey.

6. References

Abbas, S. K. (2022). Asymmetry in the Regimes of Inflation and Business Cycles: the New Keynesian Phillips Curve. *Applied Economics*, 1–14. https://doi.org/10.1080/00036846.2022.2107610

Aguiar, A., Martins, M. M. F. (2005). Testing the Significance and the Non-linearity of the Phillips Trade-off in the Euro Area. *Empirical Economics,* 30(3), 665–691. https://doi.org/10.1007/s00181-005-0250-z

Allsop, C., Vines, D. (2000). The Assessment: Macroeconomic Policy. *Oxford Review of Economic Policy,* 16(4), 1–32. https://doi.org/10.1093/oxrep/16.4.1

Alp, H., Öğünç, F., Sarıkaya, Ç. (2012). Monetary Policy and Output Gap: Mind the Composition. *CBT Research Notes in Economics,* No:07.

Akkoç, U. (2018). Recent Measurement Methods of the Output gap: An Application for Turkey. Güncel Yöntemlerle çıktı Açığının Hesaplanması: Türkiye Uygulaması. *Current Debates in Economics & Econometrics,* 2, 357–376.

Andıç, S. (2018). Multivariate Filter for Estimating Potential Output Gap and Output Gap in Turkey. *CBRT Working paper,* 18/07, 1–28.

Arabacı, Ö., Eryiğit, K. Y. (2012). A Threshold Regression Estimation of Phillips Curve: Turkey Case. *Eskisehir Osmangazi Üniversitesi İİBF dergisi,* 7, 29–47.

Atuk, O., Özmen, M. U., Sarikaya, C. (2018). A Disaggregated Analysis of the Impact of Output Gap on Inflation and Implications for Monetary Policy. *Prague Economic Papers*, 2018(6), 668–683. https://doi.org/10.18267/j.pep.677

Bai, J., Perron, P. (2003) Computation and Analysis of Multiple Structural Change Models. *Journal of Applied Econometrics,* 18, 1–22. https://doi.org/10.1002/jae.659

Ball, L. Mankiw, G. Romer, D. (1988). New Keynesian Economics and the Output Inflation Trade-off. *Brookings Papers on Economic Activity*, 1–65.

Bank of Canada (1997). Capacity Constraints, Price Adjustment, and Monetary Policy. *Bank of Canada Review, Spring*, 39–56.

Beaudry, P., Doyle, M. (2000). What Happened to the Phillips Curve in the 1990s in Canada*? Bank of Canada.*

Biçer, B. Burgaç, Çil, A., Dülger, F. (2021). New Keynesian Phillips Curve for Turkey: Estimation with Different Output Gap Filters. *Global Agenda in Social Sciences,* 8, 145–164.

Bildirici, M., Ozaksoy, F. (2016). Non-linear Analysis of Post Keynesian Phillips Curve in Canada Labour Market. *Procedia Economics and Finance,* 38, 368–377. https://doi.org/10.1016/S2212-5671(16)30209-X

Bildirici, M., Sonustun, Ozaksoy, F. (2018). Backward Bending Structure of Phillips Curve in Japan, France, Turkey and the U.S.A. *Economic Research-Ekonomska Istrazıvanja,* 31, 537–549. https://doi.org/10.1080/1331677X.2018.1441046

Bilici, B., Çekin, S. E. (2020). Inflation Persistence in Turkey: A TVP – Estimation Approach. *The Quarterly Review of Economics and Finance,* 78, 64–69. https://doi.org/10.1016/j.qref.2020.04.002

Bilman, A. S., Utkulu, U. (2010). Inflation and Output Gap Reconsidered: Asymmetries and Nonlinear Phillips Curve Evidence for Turkish Economy. *Journal of Yaşar University,* 5(19), 3155–3170.

Binder, M., Gross, M. (2013). Regime-switching Global Vector Autoregressive Models. *ECB Working Paper Series,* 1569, 1–56.

Cao, D., Diba, B., Lee, D. (2023). Nonlinear Phillips Curve with Asymmetric Adjustment Cost.

Calvo, G. (1983). Staggered Prices in a Utility-maximizing Framework. *Journal of Monetary Economics,* 12(3*),* 383–398. https://doi.org/10.1016/0304-3932(83)90060-0.

Chortareas, G., Magonis, G., Panagiotidis, T. (2012). The Asymmetry of the New Keynesian Phillips Curve in the Euro-area. *Econ. Letters,* 114(2), 161–163. http://dx.doi.org/10.1016/j.econlet.2011.09.035

Clark, P., Laxton, D., Rose, D. (1995). Capacity Constraints, Inflation, and the Transmission Mechanism: Forward-looking Versus Myopic Policy Rules. *IMF Working Paper*, 75, 1–42. https://doi.org/10.5089/9781451849677.001

Clark, P., Laxton, D., Rose, D. (1996). Asymmetry in the U.S. Output-inflation Nexus. *IMF Staff Papers,* 43 (1), 216–251. https://doi.org/10.2307/3867358

Claus I. (2000). Is the Output Gap a Useful Indicator of Inflation? *Reserve Bank of New Zealand, Discussion Paper Series,* 5, 1–21.

Coşar, Erdoğan, S., Kösem S., Sarıkaya, Ç. (2013). Do We Really Need Filters in Estimating Output Gap? Evidence from Turkey. *CBRT Working paper,* 13/33, 1–28.

De Veirman, E. (2007). Which Nonlinearity in the Phillips Curve? The Absence of Accelerating Deflation in Japan. *Reserve Bank of New Zealand Working Paper*, 536.

De Masi, P. (1997). IMF Estimation of Potential Output: Theory and Practice. *Staff Studies for the World Economic Outlook,* 14, 1–14.

Dupasquier, C., Ricketts, N. (1998). Non-linearities in the Output-inflation Relationship: Some Empirical Results for Canada. *Bank of Canada Working Paper,* 98(14), 1–31. https://doi.org/10.34989/swp-1998-14

Eliasson, A. C. (2001). Is the Short-run Phillips Curve Nonlinear? Empirical Evidence for Australia, Sweden and the United States. Sveriges Riksbank. Working Paper Series, 124, 1–25.

Fabiani, S., Druant, M., Hernando, I., Kwapil, C., Landau, B., Loupias, C., Martins, F., Matha, T., Sabbatini, R., Stahl, H., Stokman, A. (2006). What Firms' Surveys Tell Us About Price-setting Behaviour in the Euro Area. *International Journal of Central Banking,* 2(3), 1–46.

Fasanya, I. O., Adetokunbo, A., Ajayi, F. O. (2018). Oil Revenue Shocks and the Current Account Balance Dynamics in Nigeria: New Evidence from Asymmetry and Structural Breaks. *SPOUDAI Journal of Economics and Business*, 68(4), 72–87.

Filardo, A. (1998). New Evidence on the Output Cost of Fighting Inflation. *Economic Review*, Federal Reserve Bank of Kansas City, 83, 33–61.

Fisher, P. G., Mahadeva, L., Whitley, J. D. (1996). The Output Gap and Inflation: Experience at the Bank of England. In BIS Model Builders Meeting, Basel.

Fisher, T. C. G. (1989). Efficiency Wages: A Literature Survey. *Working Paper,* 89–5. Bank of Canada, Ottawa.

Friedman, M. (1968). The Role of Monetary Policy. *American Economic Review,* 58(1), 1–17.

Gali, J., Gertler, M. (1999). Inflation Dynamics: a Structural Econometric Analysis. *Journal of Monetary Economics,* 44(2), 195–222. https://doi.org/10.1016/S0304-3932(99)00023-9

Gali, J. (2008). Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework. *Princeton University Press.*

Genberg, H., Pauwels, L. L. (2003). An Open Economy New Keynesian Phillips Curve: Evidence from Hong Kong. *Pacific Economic Review,* 10(2), 261–277. https://doi.org/10.1111/j.1468-0106.2005.00271.x

Gregory, A. W., Hansen, B. E. (1996). Residual-based Tests for Cointegration in Models with Regime Shifts. *Journal of Econometrics,* 70(1), 99–126. https://doi.org/10.1016/0304-4076(69)41685-7

Gross, M., Semmler, W. (2017). Mind the Output Gap: the Disconnect of Growth and Inflation During Recessions and Convex Phillips Curves in the Euro Area. *Working Paper Series, European Central Bank,* 1–58.

Hacker, R. S., Hatemi-J, A. (2006). Tests for Causality Between Integrated Variables Using Asymptotic and Bootstrap Distributions: Theory and Application. *Applied Economics,* 38(13), 1489–1500. https://doi.org/10.1080/ 00036840500405763.

Hansen, B. (1970). Excess Demand, Unemployment, Vacancies, and Wages. *The Quarterly Journal of Economics*, 84(1), 1–23. https://doi.org/10.2307/1879397

Hasanov, M., Araç, A., Telatar, F. (2010). Nonlinearity and Structural Stability in the Phillips Curve: Evidence from Turkey. *Economic Modelling,* 27. https://doi.org/10.1016/j.econmod.2010.03.009

Harvey, D. I., Leybourne, S. J. (2007). Testing for Time Series Linearity. *Econometrics Journal,* 10, 149–165.

Harvey, D. I., Leybourne, S. J., Xiao, B. (2008). A Powerful Test for Linearity When the Order of Integration Is Unknown. *Studies Nonlinear Dynamics and Econometrics,* 12(3). https://doi.org/10.2202/1558-3708.1582

Hatemi-J, A. (2012). Asymmetric Causality Tests with an Application. *Empirical Economics,* 43(1), 447–456. https://doi.org/10.1007/s00181-011-0484-x.

Hodrick, R. J., Prescott, E. C. (1997). Postwar U.S. Business Cycles: An Empirical Investigation. *Journal of Money, Credit and Banking,* 29(1), 1–16.

Huh, H. S., Jang, I. (2007). Nonlinear Phillips Curve, Sacrifice Ratio, and the Natural Rate of Unemployment. *Economic Modelling*, 24, 797–813. https://doi.org/10.1016/j.econmod.2007.02.003

Kapetanios, G., Shin, Y., Snell, A. (2003). Testing for a Unit Root in the Nonlinear STAR Framework. *Journal of Econometrics,* 112(2003), 359–379. https://doi.org/10.1016/S0304-4076(02)00202-6

Kara, H., Öğünç, F., Özlale, Ü., Sarıkaya, Ç. (2007). Estimating the Output Gap in a Changing Economy. *Southern Economic Journal,* 74(1), 269–289. https://doi.org/10.1002/j.2325-8012.2007.tb00837.x

Kejriwal, M. (2008). Cointegration with Structural Breaks: An Application to the Feldstein-Horioka Puzzle. *Studies in Nonlinear Dynamics & Econometrics,* 12(1). https://doi.org/10.2202/1558-3708.1467

Kejriwal, M., Perron, P. (2010). Testing for Multiple Structural Changes in Cointegrated Regression Models. *Journal of Business & Economic Statistics,* 28, 503–522. http://dx.doi.org/10.1198/jbes.2009.07220

King, M. (2005). Monetary Policy: Practice Ahead of Theory. The Mais Lecture 2005: Speech by the Governor. *Bank of England Quarterly Bulletin*, Summer 2005.

Kisswani, K. M. (2017). Evaluating the GDP-energy Consumption Nexus for the ASEAN-5 Countries Using Nonlinear ARDL. *OEPC Energy Review*, 318–343. https://doi.org/10.1111/opec.12113

Kobbi, I., Gabsi, F. B. (2017). The Nonlinearity of the New Keynesian Phillips Curve: The Case of Tunisia. *Economies, MDPI,* 5(3), 1–12. https://doi.org/10.3390/economies5030024

Kruse, R. (2011). A New Unit Root Test Against ESTAR Based on a Class of Modified Statistics. *Statistical Papers,* 52(1), 71–85. https://doi.org/10.1007/s00362-009-0204-1

Kuştepeli, Y. (2005). A Comprehensive Short-Run Analysis of a (Possible) Turkish Phillips Curve. *Applied Economics,* 37, 581–591. https://doi.org/10.1080/000368404200030749

Lai, Y. W. (2017). Output Gaps and the New Keynesian Phillips Curve: An Application of the Empirical Mode Decomposition. *Economics Bulletin,* 37(2), 952–961.

Laxton, D., Meredith, G., Rose, D. (1995). Asymmetric Effects of Economic Activity on Inflation: Evidence and Policy Implications. *IMF Staff Papers,* 42(June), 344–374. https://doi.org/10.2307/3867576

Lee, D. J., Yoon, J. H. (2016). The New Keynesian Phillips Curve in Multiple Quantiles and the Asymmetry of Monetary Policy. *Economic Modelling*, 55, 102–114. http://dx.doi.org/10.1016/j.econmod.2016.02.002

Lepetit, A. (2018). Asymmetric Unemployment Fluctuations and Monetary Policy Trade-offs. *HAL Working Paper,* 1–35.

L'Huillier, J.-P., Phelan, G., Zame, W. R. (2022). Flattening of the Phillips Curve and the Mandate of the Central Bank. http://dx.doi.org/10.2139/ssrn.4298975

Lipsey, R. G. (1960). The Relation Between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1862–1957: A Further Analysis. *Economica New Series.* 27(105), 1–31. https://doi.org/10.2307/2551424

Lipsey, R. G. (1978). The Place of the Phillips Curve in Macroeconomic Models. In A. R. Bergstrom ed. Stability and Inflation, Chichester: John Wiley.

Liu, D. (2011). Learning and Estimation of the New Keynesian Phillips Curve Models. *Southern Economic Journal,* 78, 2, 382–396. https://doi.org/10.4284/0038-4038-78.2.382

Lopcu, K., Dülger, F., Burgaç, A. (2013). Relative Productivity Increases and the Appreciation of the Turkish Lira. *Economic Modelling,* 35, 614–621. https://doi.org/10.1016/j.econmod.2013.08.005

Lucas, R. E. Jr. (1972). Expectations and the Neutrality of Money. *Journal of Economic Theory,* 4, 103–124. https://doi.org/10.1016/0022-0531(72)90142-1

Lucas, R. E. Jr. (1973). Some International Evidence on Output-inflation Trade-offs. *American Economic Review,* 63, 326–334.

Malikane, C. (2014). A New Keynesian Triangle Phillips Curve. *Economic Modelling,* 43(C), 247–255. https://doi.org/10.1016/j.econmod.2014.08.010

Mankiw, N. G., Reis, R. (2002). Sticky Information Versus Sticky Prices: A Proposal to Replace the New Keynesian Phillips Curve. *Quarterly Journal of Economics,* 117(4), 1295–1328. https://doi.org/10.1162/003355302320935034

Mayes, D. G., Chapple, B. R. (1995). The Costs and Benefits of Disinflation: A Critique of the Sacrifice Ratio. *Reserve Bank of New Zealand Bulletin,* 58(1), 9–21.

Mihajlovic, V. (2019). Asymmetry in the Output Gap-inflation Nexus in the Western Balkan Countries: A Non-linear ARDL Approach. *11th International Scientific Conference: Econometric Modelling in Economics and Finance, 29th and 30th October 2019 Belgrade, Serbia*.

Mihajlovic, V., Marjanovic, G. (2020). Asymmetries in Effects of Domestic Inflation Drivers in the Baltic States: A Philllips Curve-based Nonlinear ARDL Approach. *Baltic Journal of Economics,* 20(1), 94–116. https://doi.org/10.1080/1406099X.2020.1770946

Musa, A., Salisu, A. A., Aliyu, A. O., Mevweroso, C. R. (2021). Analysis of Asymmetric Response of Exchange Rate to Interest Rate Differentials: The Case of African Big 4. *North American Journal of Economics and Finance,* 55, 1–10. https://doi.org/10.1016/j.najef.2020.101320.

Musso, A., Stracca, L., van Dijk, D. (2009). Instability and Nonlinearity in the Euro Area Phillips Curve. *International Journal of Central Banking,* 5, 181–212.

Neiss, K. S., Nelson, E. (2005). Inflation Dynamics, Marginal Cost, and the Output Gap: Evidence from Three Countries. *Journal of Money, Credit and Banking,* 37, 1019–1045.

Ng, S., Perron, P. (2001). Lag Length Selection and the Construction of Unit Root Tests with Good Size and Power. *Econometrica,* 69(6), 1519–1554. https://doi.org/10.1111/1468%2D0262.00256

Okere K. I., Muoneke, O. B., Onuoha, F. C. (2021) Symmetric and Asymmetric Effects of Crude Oil Price and Exchange Rate on Stock Market Performance in Nigeria: Evidence from Multiple Structural Break and NARDL Analysis. *Journal of International Trade and Economic Development,* 1–27. https://doi.org/10.1080/09638199.2021.1918223.

Orphanides, A. (2003). Monetary Policy Evaluation with Noisy Information. *Journal of Monetary Economics*, 50(3), 605–631. https://doi.org/10.1016/S0304-3932(03)00027-8

Öğünç, F., Sarıkaya, Ç., (2011). Görünmez ama Hissedilmez Değil: Türkiye'de çıktı Açığı. *Central Bank Review,* 11(2), 15–28.

Önder, A. Ö. (2004). Forecasting Inflation in Emerging Markets by Using the Phillips Curve and Alternative Time Series Model. *Emerging Markets Finance and Trade,* (40)2, 71–82. https://doi.org/10.1080/1540496X.2004.11052566

Önder, Ö. (2009) The Stability of the Turkish Phillips Curve and Alternative Regime Shifting Models. *Applied Economics,* 41(20), 2597–2604. https://doi.org/10.1080/0003684070122264.

Özbek, L., Özlale, Ü., (2005). Employing the Extended Kalman Filter in Measuring the Output Gap. *Journal of Economic Dynamics and Control,* 29(9), 1611–1622. https://doi.org/10.1016/j.jedc.2004.09.005

Pesaran, M. H., Shin, Y., Smith, R. J. (2001). Bounds Testing Approaches to the Analysis of Level Relationships. *Journal of Applied Econometrics*, 16(3), 289–326.

Phelps, E. S. (1967). Phillips Curves, Expectations of Inflation and Optimal Unemployment over Time. *Economica,* 34(8), 254–281. https://doi.org/10.2307/2552025

Phillips, A. W. (1958). The Relation Between Unemployment and the Rate of Change of Money Wage Rates in the UK, 1861–1957. *Economica, 25, November,* 283–299. https://doi.org/10.1111/j.1468-0335.1958.tb00003.x

Razzak, W. (1997). The Inflation-output Trade-off. Is the Phillips Curve Symmetric? A Policy Lesson from New Zealand. *Reserve Bank of New Zealand*, 2, 1–25.

Riggi, M., Venditti, F. (2015). Failing to Forecast Low Inflation and Phillips Curve Instability: A Euro-Area Perspective. *International Finance,* 18(1), 47–67. https://doi.org/10.1111/1468-2362.12062

Roberts, J. M. (1995). New Keynesian Economics and the Phillips Curve. *Journal of Money, Credit and Banking,* 27(4), 975–984. https://doi.org/10.2307/2077783

Rudd, J., Whelan, K. (2005). New Tests of the New-Keynesian Phillips Curve. *Journal of Monetary Economics,* 52(6), 1167–1181. https://doi.org/10.1016/j.jmoneco.2005.08.006

Saraçoğlu, B., Yiğit, Ö., Koçak, N. A. (2014). Türkiye İçin Çıktı Açığı Tahmininde Alternatif Yöntemler. *Business and Economics Research Journal,* 3, 43–65.

Samuelson, P.A., Solow, R.M. (1960). Problem of Achieving and Maintaining a Stable Price Level. *American Economic Review,* 50, 177–194. https://doi.org/10.4000/oeconomia.138

Sbordone, A. M. (2002). Prices and Unit Labour Costs: A New Test of Price Stickiness. *Journal of Monetary Economics,* 49, 265–92. https://doi.org/10.1016/S0304-3932(01)00111-8

Sbordone, A. M. (2005). Do Expected Future Marginal Costs Drive Inflation Dynamics? *Journal of Monetary Economics,* 52, 1183–97. https://doi.org/10.1016/j.jmoneco.2005.08.010

Shin, Y., Yu, B., Greenwood-Nimmo, M. (2014). Modelling Asymmetric Cointegration and Dynamic Multipliers in a Nonlinear ARDL Framework. In R. Scikles and W.C. Horrace (Eds.), Festschrift in honor of Peter Schmidt (s.281–314). New York: Springer.

Sill, K. (2011). Inflation Dynamics and the New Keynesian Phillips Curve. *Business Review, Federal Reserve Bank of Philadelphia,* 1, 17–25.

Stiglitz, J. E. (1984). Price Rigidities and Market Structure. *American Economic Review,* 74, 350–355.

Stiglitz, J. E. (1986). Theories of Wage Rigidity. In Keynes' Economic Legacy: Contemporary Economic Theories, edited by J. L. Butkiewicz, K. J. Koford, and J. B. Miller.

Stimel, D. (2009). An Examination of U.S. Phillips Curve Nonlinearity and its Relationship to the Business Cycle. *Economics Bulletin, Access Econ,* 29(2), 736–748.

Svensson, L. E. O. (1997). Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets. *European Economic Review,* 41(6), 1111–1146. https://doi.org/10.1016/S0014-2921(96)00055-4

Svensson, L. E. O. (2003). What is Wrong with Taylor Rules? Using Judgment in Monetary Policy Through Targeting Rules. *Journal of Economic Literature,* 41(2), 426–477. https://doi.org/10.1257/002205103765762734

Şahinöz, S., Atabek, A. (2016). An Alternative Micro-based Output Gap Measure for Turkey: The Capacity Utilisation Gap. *Economics Letters.* 143(C), 44–47. https://doi.org/10.1016/j.econlet.2016.03.008

Turner, D. (1995). Speed Limit and Asymmetric Inflation Effects from the Output Gap in the Major Seven Economies. *OECD Economic Studies,* 24, 57–87.

Walsh, C. E. (2001). The Science (and Art) of Monetary Policy. *Federal Reserve Bank of San Fransisco Economic Letter (May 4), 1.*

Walsh, C. E. (2003). Speed Limit Policies: The Output Gap and Optimal Monetary Policy. *American Economic Review,* 93(1), 265–78. https://doi.org/10.1257/000282803321455278

Whelan, K. (2005). The New-Keynesian Phillips Curve. EC4010 Notes, Topic 7.

Taylor, J. B. (1980). Aggregate Dynamics and Staggered Contracts. *Journal of Political Economy, 88,* 1–22.

Tsong, C. C., Lee, C. F. (2011). Asymmetric Inflation Dynamics: Evidence from Quantile Regression Analysis. *Journal of Macroeconomics,* 33, 668–680. https://doi.org/10.1016/j.jmacro.2011.08.003

Xu, Q., Niu, X., Jiang, C., Huang, X. (2015). The Phillips Curve in the US: A Nonlinear Quantile Regression Approach. *Economic Modelling,* 49, 186–197. http://dx.doi.org/10.1016/j.econmod.2015.04.007.

Villavicencio, A. L., Mignon, V. (2013). The Nonlinearity of the Inflation-output Trade-off and Time-varying Price Rigidity. *Working Papers,* 02, CEPII research center.

Yalçın Kayacan, E., Üçdoruk Birecikli, Ş. (2018). Türkiye çıktı Açığının Filtreleme ve Ayrıştırma Yöntemleriyle Tahmini. *UİİİD-IJEAS, 2018 (18. EYİ Özel Sayısı),* 325–338.

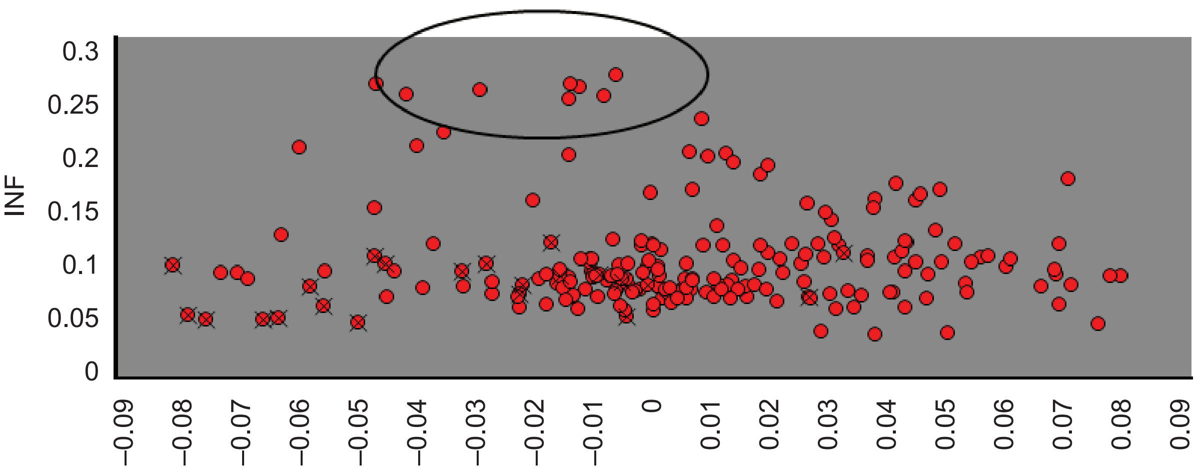
Yates, A. (1998). Downward Nominal Rigidity and Monetary Policy. *Bank of England Working Papers,* 82, Bank of England.

Zhang, C. S., Osborn, D. R., Kim, D. H. (2008). The New Keynesian Phillips Curve: From Sticky Inflation to Sticky Prices. *Journal of Money, Credit and Banking,* 40(4), 667–699. https://doi.org/10.1111/j.1538%2D4616.2008.00131.x

Zhang. C., Murasawa, Y. (2011). Output Gap Measurement and the New Keynesian Phillips Curve for China. *Economic Modelling,* 28, 2462–2468. https://doi.org/10.1016/j.econmod.2011.07.003

Appendix

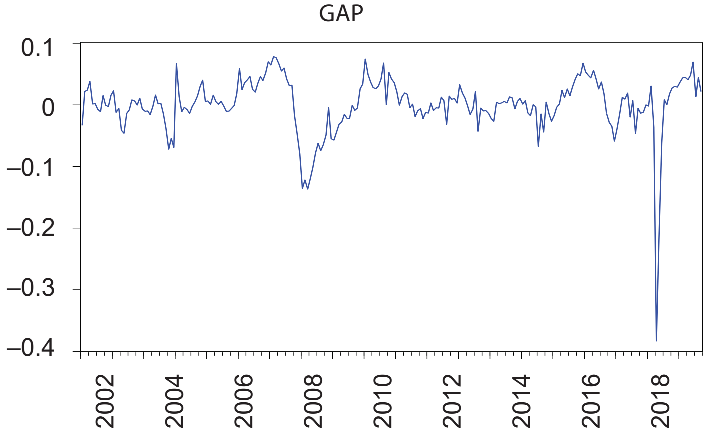
Figure A1: Inflation and output gap diagram



Note: The circle has shifted outside the graphic. It needs to be corrected.

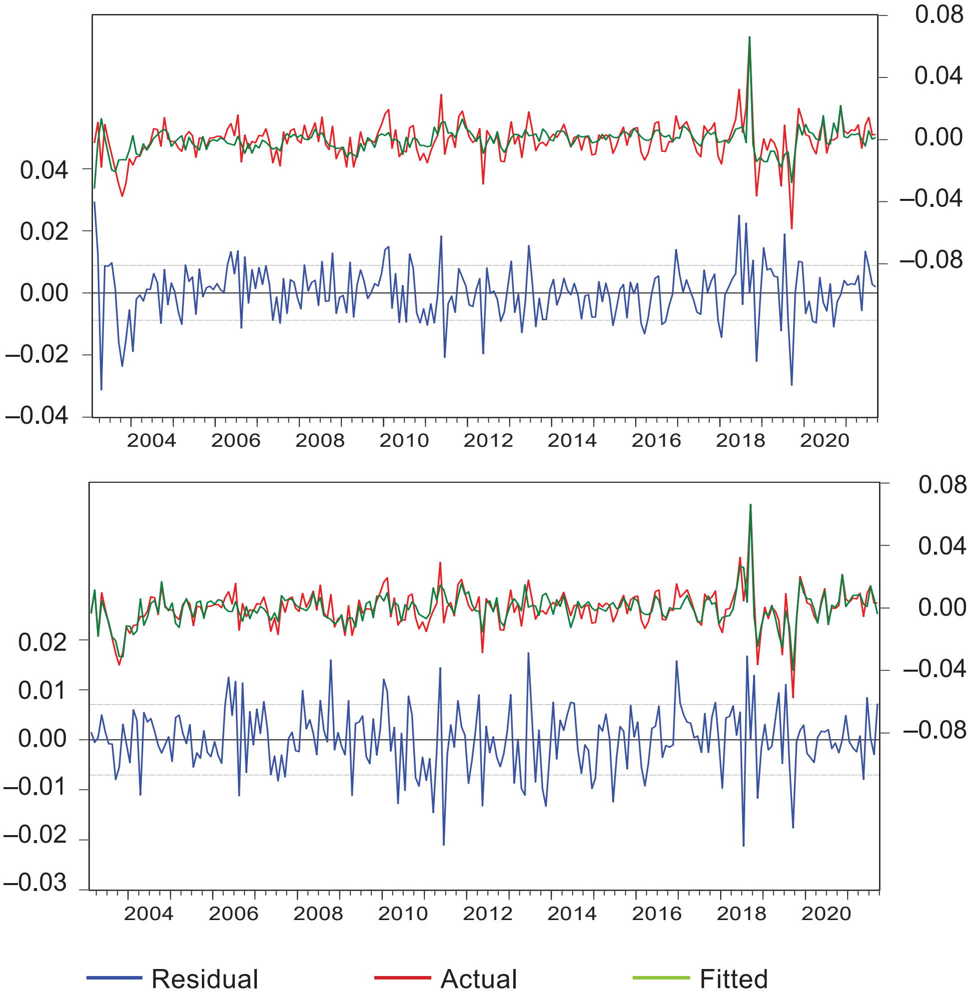
Source: author's calculation

Figure A2: Output gap graphs



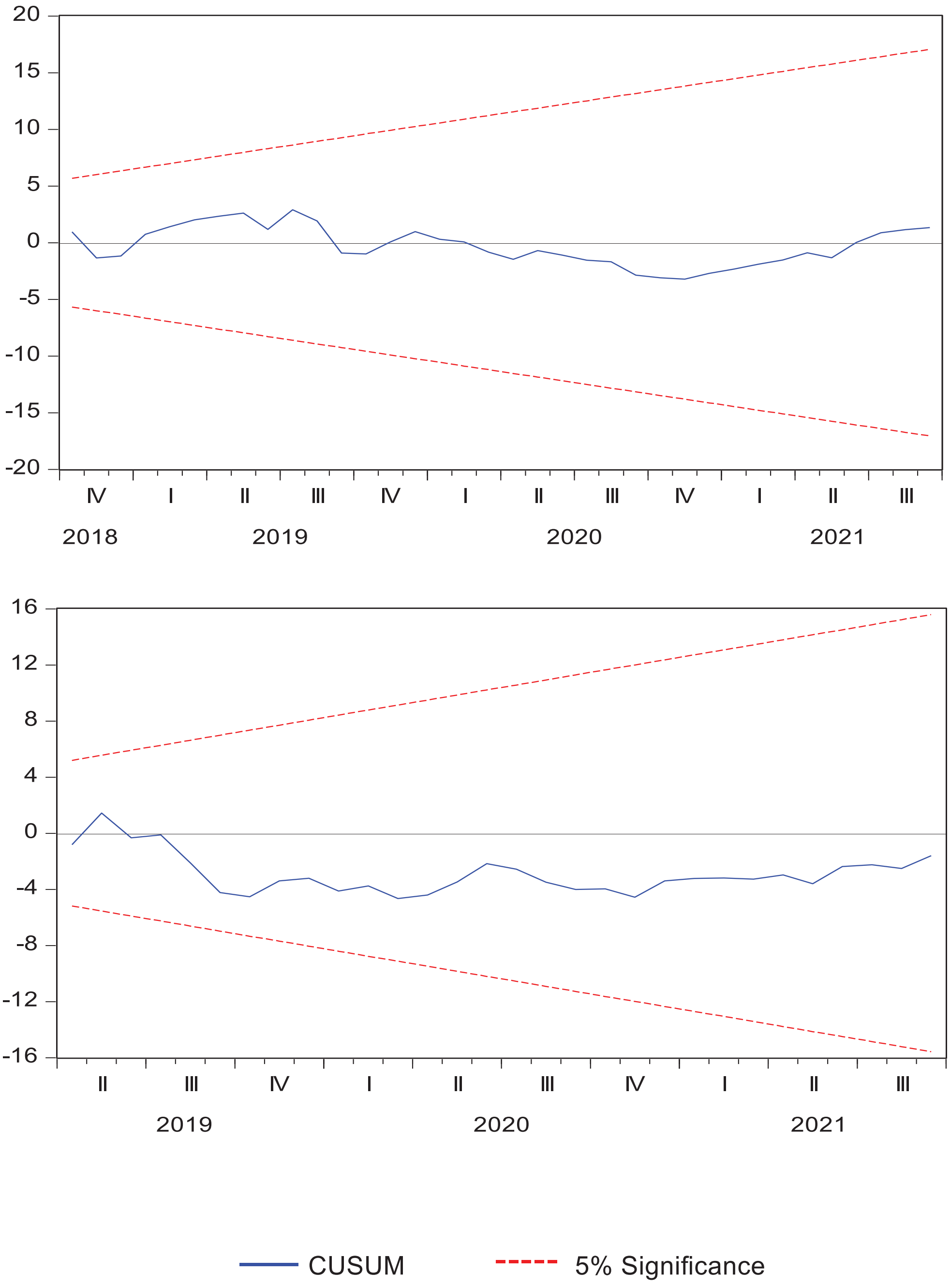
Source: author's calculation

Figure A3: Estimation graphs, NARDL and NARDL with structural breaks



Source: author's calculations

Figure A4: CUSUM graphs, NARDL and NARDL with structural breaks



Source: author's calculations