# Estimating Time-Varying Potential Output and NAIRU Using a Multivariate Filter for Turkey

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# Estimating Time-Varying Potential Output and NAIRU Using a Multivariate Filter for Turkey

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**Abstract**

Potential output and NAIRU estimates are crucial to identify the state of the economy for both monetary policymakers and fiscal policy authorities. This paper extends the multivariate filter approach developed for Turkey by integrating the capacity utilization block into the model. Also, broader-defined unemployment rate is included as alternative in the model. The idea is that traditional measure of unemployment rate may not fully capture the cycle conditions of the labor market. The results show that long and deep recessions resulted in hysteresis in the labor market and reduced potential output. While estimate of the slack in the output was smaller in the recent shock (2018-3: 2018-4), the unemployment rate and NAIRU increased sharply with reaching the highest levels historically in recession periods. Due to weak foreign demand and composition of industrial sector products, the slack in capacity utilization rate was higher in the global financial crisis (2008-2: 2009-1).

**Özet**

Potansiyel çıktı ve NAIRU tahminleri, hem para politikası yapıcıları hem de maliye politikası yetkilileri için ekonominin durumunu belirlemek açısından önemlidir. Bu makale, kapasite kullanım bloğunu modele entegre ederek Türkiye için geliştirilen çok değişkenli filtre yaklaşımını genişletmektedir. Ayrıca, modele tanımı genişletilmiş işsizlik oranı alternatif bir kullanım olarak dahil edilmektedir. Buradaki fikir, geleneksel işsizlik oranı ölçüsünün, işgücü piyasasının döngü koşullarını tam olarak yakalayamayabileceğidir. Sonuçlar, uzun ve derin durgunlukların işgücü piyasasında histerezise neden olduğunu ve potansiyel büyümeyi azalttığını göstermektedir. Son şokta (2018-3: 2018-4) üretimin potansiyelinden sapması daha küçük olsa da, işsizlik oranı ve NAIRU keskin bir şekilde artmış ve durgunluk dönemlerinde tarihsel olarak en yüksek seviyelere ulaşmıştır. Zayıf dış talep ve sanayi sektörü ürünlerinin kompozisyonu nedeniyle küresel finansal krizde (2008-2: 2009-1) kapasite kullanım oranındaki gerileme daha yüksek olmuştur.

**JEL Classification:** C51, E32, E52

**Keywords:** Potential Output, Output Gap, NAIRU, Multivariate Filter, Bayesian Estimation

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The views expressed in this paper are those of the author and do not necessarily represent the official views of the Central Bank of the Republic of Turkey. All errors are the author's own.

## Non-Technical Summary

This paper estimates time-varying potential output and NAIRU extending the multivariate filter approach developed for Turkey by integrating the capacity utilization block into the model. Also, broader-defined unemployment rate is included as alternative in the model to fully capture the cycle conditions of the labor market. Our approach aims to identify the state of the economy precisely since the mid-2000s using well-known methods with significant extensions.

Our results and suggestions are summarized as follows. The results show that long and deep recessions resulted in hysteresis in the labor market and reduced potential output in Turkey. While estimate of the slack in the output was smaller in the recent shock (2018-3: 2018-4), the unemployment rate and NAIRU increased sharply with reaching the highest levels historically in recession periods. Due to weak foreign demand and composition of industrial sector products, the slack in capacity utilization rate was higher in the global financial crisis (2008-2: 2009-1). As suggestions, monetary policymakers and fiscal officials should concentrate on the developments in the labor markets except for developments in the goods markets during the recession periods since reflections of the downturn periods on the markets could differentiate and output gap could not be only indicator to identify business cycle conditions. What's more, using the broader-defined unemployment rate has important implications so we believe that it should be closely tracked by policymakers as well as traditional one.

## 1. Introduction

Potential output and the output gap[2] are so valuable to both monetary policymakers and fiscal officials that the precision of the estimates of them has important policy implications for the current and future dynamics of economies. A reliable output gap estimation enables central bankers to assess the appropriateness of their monetary policy stance. If the level of output gap implies upward (downward) pressure on the inflation, central banks whose primary objective is to maintain low and stable inflation should tighten (ease) its policy stance. Therefore, incorrect estimation of the output gap could result in monetary policies that lead to inflation or low growth rates. From the fiscal authorities' perspective, governments would like to know whether the budget deficit is sustainable or not to calibrate fiscal policy. To do this, cyclically-adjusted budget balance[3] whose calculation needs the output gap must be correctly estimated. Overoptimism and overestimation of the economy's potential capacity could lead to a substantial deterioration in budget deficits and public debt. Kangur et al. (2019) clarify that there exists a positive correlation between upward revisions to real-time output gaps with public debt levels and public debt. Therefore, identifying the state of the economy precisely is crucial to ensure macroeconomic stability. The first contribution of this paper is to provide potential output and output gap estimates by using well-known methods with significant extensions to identify business cycle conditions[4] of the Turkish economy and enrich the relevant literature for Turkey.

NAIRU[5] (Non-Accelerating Inflation Rate of Unemployment) is another key ingredient to evaluate inflationary pressure, which makes central banks to monitor its developments closely as well.

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[2] The growth cycle or output gap can be described as the percentage deviation of the actual output from the potential. The mystery on the output gap emerges from the definition since it includes potential output term, which is unobservable. Okun (1962) describes potential output as the maximum amount of output that can be produced without giving rise to inflation. Different potential output and output gap definitions are also available. The difference between actual output and a long term, steady state output path and deviation of actual output from the hypothetical level of output achieved when nominal rigidities in the economy are absent are some of the numerous definitions of the output gap (Melolinna and Tóth, 2016).

[3] For further details on the cyclically-adjusted budget balance calculations, see Van den Noord (2000) and Girouard and André (2005).

[4] Burns and Mitchell (1943) and Lucas (1977) put forward two different notions related to business cycles. While the classical view by Burns and Mitchell (1943) considers level data, the latter is interested in detrended data, i.e. growth cycles. Since it is thought to be more relevant to inflation and financial cycles, considering the growth cycle to construct the business cycle models has been more common recently among the policymakers, central bankers, and academicians.

[5] NAIRU, unveiled by Modigliani and Papademos (1975), is the improvement over the natural rate of unemployment, the level of unemployment consistent with the equilibrium of the real wages, introduced by Phelps (1967) and Friedman (1968). Ball and Mankiw (2002) declare that there must be some level of unemployment, NAIRU, which is consistent with a stable inflation. Natural rate and NAIRU are two different concepts although NAIRU converges to the natural rate of unemployment in the long-run when shocks fade. While the former is affected by structural and institutional changes so it

Moreover, it is considered as the labour market slack and utilized to measure the capacity pressure. Although there exists a developing and enriching literature of the output gap and potential output estimations for the Turkish economy, there is a great deficiency in NAIRU estimates. Filling the gap and enlightening the authorities about labor market and its implications make the second contribution of the paper. To improve the finding of the study, we also use alternative definition of unemployment rate to estimate output gap and compare their outcome to the results obtained by using traditional unemployment rate. Then, we mention how the policy implications would be different if the policymakers follow alternative definition rather than simple one. We believe that this extension is one of the most significant pillars of the second contribution. There are numerous approaches ranging from univariate decompositions, which utilize simple statistical techniques, to multivariate decompositions containing structural economic relationships and models as well as micro-founded work for estimating the potential output, output gap and NAIRU. To capture typically economic relationships and get rid of the idiosyncratic problems of the other procedures, a multivariate filtering approach has been developed (Benes et al. (2010); Blagrave et al. (2015); Alichi et al. (2015, 2019)). The filter incorporates relevant empirical relationships between several macroeconomic indicators within the framework of a New Keynesian open macroeconomic model. By adopting these approaches, we construct a model including data on output, inflation, unemployment and capacity utilization rate for 2005-Q1 and 2019-Q4 to identify the business cycle conditions of the Turkish economy. Our model differs from other studies on Turkey in several ways. Our model employs domestic and foreign demand gaps along with the output gap since Alp et al. (2012) indicate that assessing the output gap individually may result in monetary policy error. Moreover, the relationship of the output gap with the capacity gap is an extension showing the richness of the model. Integrating the capacity utilization gap block into the model is another and probably the most important differentiation of our model from other studies and it makes the third contribution of the paper.

One of the most important interests of the paper is to review the course of the macroeconomic outlook of the Turkish economy. It is believed that such an examination would be interesting and informative for the readers. Despite positive developments, the Turkish economy has experienced two cyclical downturns since 2001. The first one was due to the global financial crisis, which spans the period 2008-Q2 and 2009-Q1, while the second one took place between 2018-Q3 and 2018-

is accepted constant and time-invariant, the latter is a time-varying variable due to its derivation exploiting the trade-off between inflation and unemployment in the short-run. Therefore, central banks could affect the NAIRU but not the natural rate.

Q4[6] when strong and abruptly depreciation in Turkish Lira and high country's risk premium existed. Although the depth and duration of the latter downturn are shorter than the former, both periods left major scars on the labor market, as unemployment rates rose to historically high levels due to employment losses resulted from a slowdown in economic activity and rising uncertainty. Our empirical findings reveal that estimate of the output gap is smaller in the 2018 downturn than the estimate observed during the global financial crisis since foreign demand is more supportive for the latter due to competitive exchange rate and strengthening market diversification flexibility in exports. Potential growth decreased in both periods. NAIRU moves in tandem with the actual unemployment rate which has been above trend for a long time during both downturns. Also, this with unemployment duration and Beveridge Curve indicates the existence of hysteresis in the labor market after shocks. Due to weak foreign demand and composition of industrial sector products, slack in capacity utilization rate is higher in the 2008 downturn.

The organization of the paper is as follows: Chapter 2 provides background information on Turkey's macroeconomic outlook by exploiting some stylized facts about the two largest cyclical downturn periods. The literature review on the estimation of the potential output, output gap, and NAIRU is given in Chapter 3. Chapter 4 introduces the model and data. Chapter 5 discusses the results. Finally, Chapter 6 concludes.

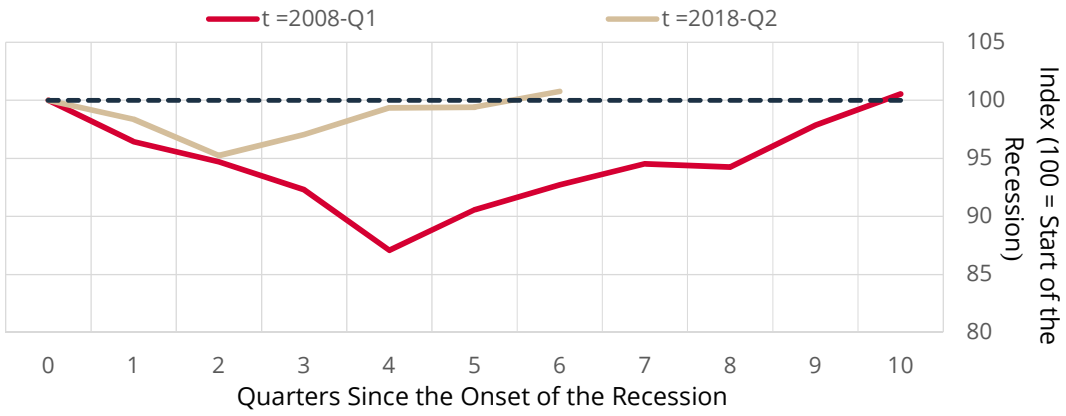
## 2. Background on Macroeconomic Outlook in Turkey

A new economic program was implemented in the early 2000s to mitigate the adverse effects of the macroeconomic instability resulted from defects in economics basics, high debt dynamics, and problems of financial sectors in Turkey. There existed a significant budget deficit, very short borrowing terms, high real interest rates, accumulated domestic and foreign debt and high current account deficit. The program could not fix these disorders and the crisis in which foreign exchange rate and interest rates rose considerably broke out in February 2001. During the crisis, economic activity contracted sharply, unemployment rates rose to high levels, inflation rates elevated and financial indicators deteriorated. In the aftermath of the crisis, thanks to a great number of structural reforms adopted to ensure macroeconomic stability, the Turkish economy experienced favorable developments. Beginning from the first quarter of 2002, consecutive quarterly growth

[6] Although the quarterly growth figures adjusted for seasonally and calendar effects started to increase as of the date, the direct and indirect effects of macroeconomic events during the related period continued to reflect especially on the economic activity, labor market and price developments within the next year.

rates, rapid decline in the inflation rate, improvement in the labor markets and public budget have been realized. Although high growth rates have continued, the Turkish economy has experienced two large cyclical downturns since 2001: the first one began in the second quarter of 2008 and lasted for four quarters due to the repercussions of the global financial crisis in 2008, while the second one took place in the second half of the 2018. Comparing the two episodes will allow us to identify similarities and differences between both periods, which helps to understand the effects of macroeconomic shocks on macro variables. Such a comparison will make easier to understand the results. The main points of the comparison are listed as follows:

- **The recovery to pre-crisis economic activity level was shorter in the 2018 downturn.** It took 10 and 6 quarters for GDP to return to its former level in the first and second cyclical downturn, respectively.
- **The level of contraction was deeper in the 2008 downturn.** The loss in output from peak to trough was around 13 percent in the former, and around 5 percent in the latter (Figure 1).

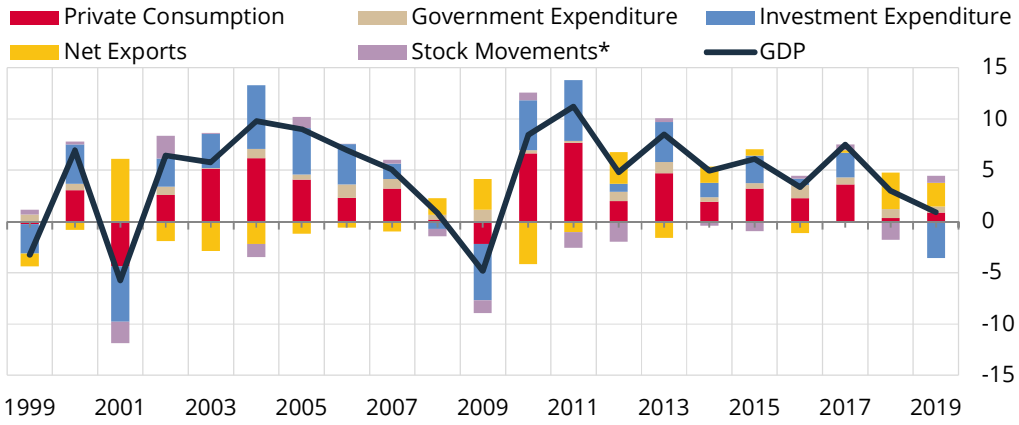



Source: Turkstat, author's own calculations.

***Figure 1:*** Real GDP Dynamics during the Two Cyclical Downturns

- **While foreign demand contracted sharply in the 2008 downturn, domestic demand was deteriorated in the 2018 downturn**. Although the first downturn began in 2008-2 and ended in 2009-1, its effect was felt more in 2009. While annual GDP increased by 0.8 percent in 2008, the economy contracted at a very high rate throughout 2009 when the annual GDP decreased by 4.8 percent. Annual limited positive growth in 2008 was driven mainly by net exports and public consumption. The rather sharp contraction in private consumption and investments resulted in a strong negative contraction in 2009. As for the second one, although low growth rates are observed annually, there is no annual contraction in the economy due to positive growth in the first half of the 2018 and carry-

over effect of the high growth in 2017. While the annual GDP increased by 3.0 percent in 2018, it increased by 0.9 percent in 2019. As in 2009, investment expenditures had a negative contribution to annual growth in 2019 due to high risk premium and financial constraints. As can be seen, it was the worst affected growth components in both periods (Figure 2).




Source: Turkstat, author's own calculations.

*Contains residuals.

***Figure 2:*** Annual Growth and Contributions (% Points)

- **Cost-induced factors for the increase in inflation became more significant in the 2018 downturn.** Although the contraction in economic activity and the high course of unemployment rates decreasing demand-side pressures on inflation, cost-induced factors resulted in inflation to rise significantly during recession periods. While headline inflation, the consumer price index (CPI), peaked at 12.06 percent in the first recession, it increased by more than almost 12 percent and reached 25.24 percent in the 2018 downturn. Indicators for the CPIs having specified coverages[7] accompanied to this increase and deterioration in core inflation indicators were quite evident (Figure A-1). There are several reasons why the inflation rate has increased to such a high level in the 2018 downturn. The first one is that strong and abruptly depreciation in Turkish Lira was the main determinant to subsequently deterioration in pricing behavior of the price-makers, becoming higher and faster than historical averages pass-through to prices[8]. The second

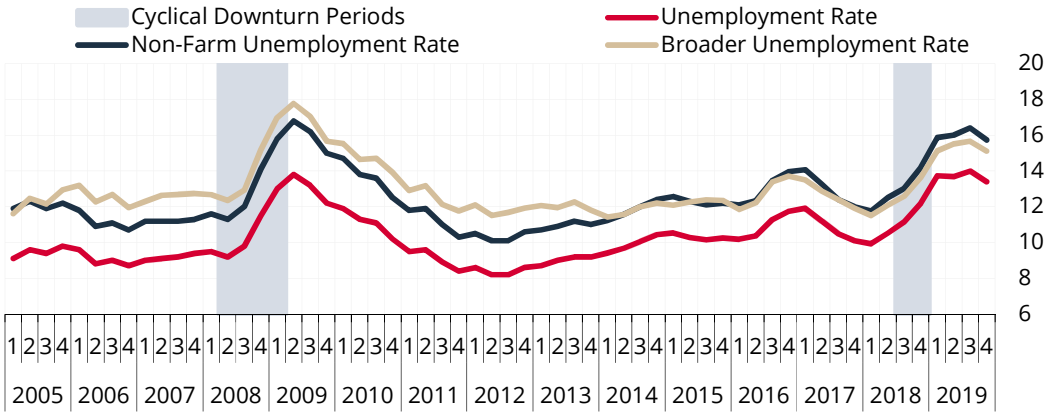
[7] B index is equal to CPI excluding CPI unprocessed food, energy and alcoholic beverages, tobacco products and gold. C index equals to CPI excluding energy, food and non-alcoholic beverages, alcoholic beverages and tobacco products and gold. D index means that CPI excluding unprocessed food, alcoholic beverages and tobacco products.

[8] For further details, see CBRT Inflation Report in 2019-2.

one is that the price of commodities fell very much in 2008 and so it mitigated negative effects of the exchange rates on inflation. Moreover, differentiation in inflation expectations became a matter. These show that cost-induced factors play a decisive role in formation of inflation alongside the demand pressure in Turkey.

- **In both periods, monetary policy tightened to take the exchange rate under control and alleviate the inflationary impact of the exchange rate**. In the first period, a significant decrease in interest rates was observed with the decrease in inflation, even they are well below their pre-crisis levels. The reason for this might be that interest rates in developed countries were very low and the effects of the crisis were tried to be got rid of for a while. For the 2018 downturn, the sharp rise in inflation rates led to a rapid rise in interest rates. With the decline in inflation rates, the central bank started to cut interest rates. On the fiscal policy side, it is observed that fiscal policy tended to eliminate the effects of the crisis in both periods and eased the budget.
- **There was a greater loss in the capacity in former period**. Due to composition of manufacturing sectors in Turkey and weak foreign demand in the first period, while the capacity utilization rate decreased by almost twenty percent in global financial crisis, it slightly declined for the second period with almost five percent (Figure A-2).
- **Although the contraction width and duration of both periods were different from each other, the labor market was affected severely in both periods**. Unemployment rates continued to increase for a while even after downturn periods which means that the effects of the downturns on the labor market are delayed. We see this more clearly in the 2018 downturn. Although unemployment rates started to decrease as soon as growth rates return to positive in the 2008 downturn, they began to reduce after three quarters in the 2018 downturn due to the composition of the growth, ongoing uncertainties and level of tightness in financial conditions. In addition to these, there was stronger use of credit channel to get rid of downturn in 2018 but tax incentives were given to revive in 2008. While seasonally adjusted unemployment rate[9] peaked at 13.8 percent in the first one, it elevated at historically the highest level (14.0 percent) in 2019-3 due to slowdown in economic activity starting from 2018-3. Moreover, non-farm unemployment rates and broader unemployment rates considerably increased in both periods (Figure 3).

[9] It took three years longer to return to the pre-downturn level.




Source: Turkstat, author's own calculations.

***Figure 3:*** Unemployment Rates (Seasonally adjusted, percent)[10]

- **Employment losses were observed intensely in both periods due to the slowdown in economic activity** (Figure A-3). For the first period, employment losses were mainly driven by employment losses in manufacturing sector especially export-oriented sectors (Figure A-4, left panel) due to shock in the foreign demand; however, it is observed that the deterioration in the labor market has spread across sectors for the 2018 downturn period which means that employment losses were observed in all industries namely manufacturing, service and construction sectors (Figure A-4, A-5, A-6, right panels). Especially, considerable losses in construction employment attracted attention. Structural problems can be thought to be effective to exacerbate deterioration of the labor market in such shocks. Therefore, in the next subsection, the course of structural indicators in Turkish labor market will be discussed.

## 2.1. Structural Outlook of The Turkish Labor Market

There are significant structural problems in the labor market of Turkish economy. The first is to identify what is the correct measurement indicator accurately capturing the labour market slack. In general, traditional unemployment rate can be used to assess the labour market conditions. However, this is not entirely true for some emerging countries. Korea is one of these countries. Traditional unemployment rate of Korea does not reflect cyclical conditions of the Korean labour market (Hansen et al. (2019)). Similar to Korean economy, traditional unemployment rate in

[10] Broader unemployment rate is equal to (unemployed+discouraged workers) / (labour force+discouraged workers).

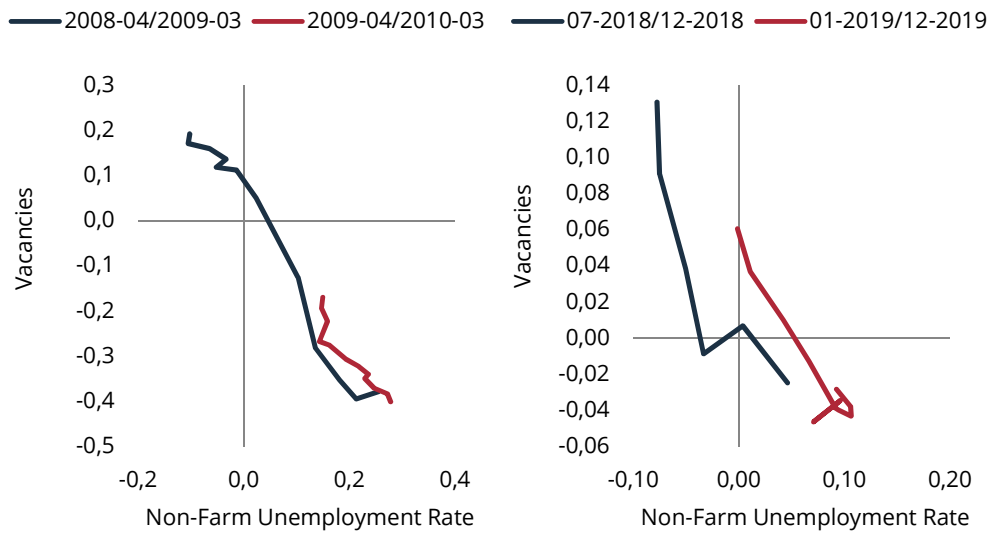
Turkish economy gives the poor signals about labour market conditions. The Phillips curve relationship between core inflation and traditional unemployment rate is relatively weak and it does not also show expected negative relationship. On the other hand, introducing the broader unemployment rate into the Phillips curve instead of official definition of unemployment rate gives the right and expected signal for the labour market (Figure 4). Therefore, considering the broader unemployment rate for labour market slack would have significant implications for Turkish economy.


Source: Turkstat, author's own calculations.

***Figure 4:*** Scatter Plots of the Core Inflation (Quarterly Percent Change) and Unemployment Rates (Seasonally Adjusted, Percent)

Another important problem is the permanent scars left on the labor market by the long-term slack in demand. The Beveridge Curve showing the relationship between unemployment rate and job openings[11] implies that recession periods created job mismatch (Figure 5). The outward shift in the Beveridge Curve means that vacancies after recession did not correspond to the unemployment rate before recession and consistent with the hysteresis effects. There might be several explanations for such a deterioration in labour markets. One explanation is that upward trend in unemployment duration resulting in the increase in discouraged workers may result in erosion of skills and weaker labor attachment (Figure A-7 and A-8).

[11] The Beveridge Curve shows the relationship between deviations of HP filter estimates of the vacancies and non-farm unemployment rate.




Source: Turkstat, Kariyer.Net, author's own calculations.

***Figure 5:*** Beveridge Curve

The low participation rates and the high ratio of non-registered employment are other structural problems on labor market conditions of the Turkish economy. Although we are aware of the importance of these indicators for the Turkish business cycle and labor market conditions, we leave analyzes including them to future studies.

## 3. Literature Review

### 3.1. Studies with Economic Approaches

Our approach is based on the multivariate filter literature covering economic relationships. Laxton and Tetlow (1992), Kuttner (1994) and Butler (1996) can be counted as the earlier studies estimating potential output and NAIRU simultaneously. Later, Benes et al. (2010) develop a model containing data on inflation, unemployment, and capacity utilization for measuring potential output and NAIRU for 10 countries besides the U.S. and Euro area in order to produce the results consistent with economic theory. Regularized maximum likelihood (Ljung, 1999) in the Bayesian methodology is used to keep the parameters out of nonsensical regions and measure them. The main aim of the study is to incorporate relevant empirical relationships between potential GDP, labor market slack, core inflation and capacity utilization. Since the revisions of the current estimates of the output gap estimated by multivariate filter are dramatically smaller than HP, they conclude that multivariate filter has comparative advantage over random walk and HP filter. Following Benes et al. (2010), Blagrave et al. (2015) show that additional information as consensus

forecasts for GDP and inflation can improve estimates at the end of the sample period which is probably the most interested in policymakers. Unlike Benes et al. (2010), they use annual data to estimate the potential output and NAIRU for 16 countries. Following previous studies, Alichi et al. (2018) extend the basic multivariate filter methodology by including structural economic relationships such as the Phillips curve, Okun's law and a monetary policy block to improve the robustness and reliability of the filter. Another extension on the structural multivariate filter methodology is given by Hansen et al. (2019). They use a broader labor market slack and take discouraged workers into account in the model. The rationale is that the traditional labor market slack does not reflect the precise relationship between the unemployment rate and inflation for the Korean economy. They find that the filter yields more negative output gap estimates compared to the one using traditional labor market slack, which implies that different filters may lead to different policy implications. Blanchard and Summers (1986) and Ball (2009) state that temporary shocks could create persistent output losses when shocks have hysteresis effects since long and deep recessions result in deterioration in the skills and weakening in labor market attachment. These feed the loss of the potential output gradually. Following this idea, Alichi et al. (2019) extend the multivariate filter approach for estimating potential output for U.S. developed by Alichi et al. (2018) with labor market hysteresis by comparing two episodes: the Volcker's recession period of the early 1980s and Great Recession that began in 2009. By the way, we have considered the approach in this paper when comparing the two periods in our study. They express that hysteresis created much larger movements in the NAIRU and output gap. In addition to the inflation rate, the unemployment rate and capacity utilization rate, financial variables could be included in the model identifying potential output since potential output may not be sustainable when financial imbalances exist even if low inflation rate holds (Borio et al., 2013). They employ credit growth, real interest rates and housing prices as financial variables to obtain more reliable estimates on the output gap. The result of the study is that financial factors play a key role in deriving potential output and the multivariate filter incorporating them and yield more robust estimates in real time. Following Borio et al. (2013), Melolinna and Tóth (2016) develop a model including macroeconomic relationships as well as financial indicators for estimating the potential output of the United Kingdom by using Bayesian methods. With regard to real-time performance and forecasting ability, a model augmented with financial indicators have strong relative to a basic model. In addition to financial indicators, trade balance could be important for identifying the potential output since tradeable and non-tradeable sectors could differentiate in terms of creating excess demand on the inflation and unemployment via the Phillips curve. The effect of the excess demand of the tradeable sectors could be absorbed by trade balance; however, excess demand of the non-

tradeables may put more upward pressure on the inflation. Therefore, Darvas and Simon (2015) extend global variables augmented Phillips curve by adding the current account block to the basic model. They estimate a model for 45 countries by using maximum likelihood estimation technique within the framework of unobserved components models. They find that the current account equation is more significant than the Phillips curve in obtaining the potential output. It seems that the multivariate filtering approach for estimating potential output and NAIRU is very flexible since any macroeconomic relationship could be included in the model.

In our setup, we use data on inflation, output and unemployment rate to identify the business cycle conditions and NAIRU for the Turkish economy. Although they have important information on determination of the business cycle conditions, we believe that there is also significant information in capacity utilization rate that can help to improve estimates of them. There exist statistical and economic relationship between unemployment rate and capacity utilization rate. The analysis shows that the two variables are Granger causes of each other. It means that each variable can be used to predict the other variable. Moreover, the results of the structural vector autoregression (SVAR) also indicates that there are negative short and long-term relationships between both variables. The cross correlation between them confirms this. Considering that the two variables are complementary to each other, it also economically seems reasonable.

We differentiate from other studies on the Turkish economy by adding the capacity utilization block to our model. This extension enables us to compare the course of the cyclicality of the output, capacity utilization and unemployment rate in the Turkish economy. Secondly, alternative definition of unemployment rate is used to estimate NAIRU and its outcome is compared to the results obtained by using traditional unemployment rates. Then, we mention how the policy implications would be different if the policymakers follow alternative definition of unemployment rate rather than simple one. Lastly, it is believed that our results also serve useful implications on the fiscal and monetary policies and are adaptable for whatever policy will be implemented.

In addition to multivariate filter procedure, there are several methods are widely used in the estimation of output gap and NAIRU. As one of them, univeriate filtering methods such as Beveridge and Nelson (BN) (1981), Hodrick-Prescott (HP) filter (1981, 1997), the unobserved components (UC) model introduced by Harvey (1985) and Clark (1987), BK (1999) and CF filter (2003), Hamilton (2018) have been widely adopted among economists and academicians to decompose an observed variable into trend and cycle. On the other hand, there are significant critiques and concerns on them. They are generally appealed due to simple ease of use and do not require any assumptions and structural economic model. However, they are considered as

purely statistical techniques and do not include economic relationships as Okun's law and Phillips curve. Further, they have problems with end-point estimations.

### 3.2. Studies for Turkish Economy

Thanks to the accumulation of data, relevant studies have been initiated since the early 2000s in Turkey[12]. Sarıkaya et al. (2005) estimate the output gap for Turkey by utilizing an extended Kalman filter technique to allow the parameter to change over time in a multivariate setting. They find that their filter has superiority over univariate filters like HP filter to capture boom-bust cycles for Turkey. Kara et al. (2007) use inflation and output gap dynamics within the nonlinear time series framework to estimate the output gap of Turkey. They allow parameters to be time-varying through the extended Kalman filter approach.

Further studies have employed more diversified methods to estimate the output gap. As an example, Öğünç and Sarıkaya (2011) estimate the output gap for the 2002-2010 period using Bayesian techniques within the framework of the New Keynesian model. The study indicates that the long recession period put downward pressure on the inflation during this period. Also, they highlight that monetary policy should consider domestic and external dynamics of the aggregate demand when assessing the business cycle of the economy. In addition, they find that tendency of the backward indexing on the inflation is high, global growth is the key variable to output gap and appreciation of the real exchange rate brings down the growth in the long run for the 2002-2010 period. Following this study, Alp et al. (2012) jointly estimate output gap components, domestic and external, for Turkey within a stylized New Keynesian small open economy for the period 2002q1-2011q3 by utilizing Bayesian methodology. Their findings show that components of the aggregate demand differentiated in which export component remained low for a while but domestic side converged to its potential in a shorter time due to some stimulus given to the economy to alleviate negative effects of the global crisis. Therefore, they propose that monetary policy should take these differentiations into consideration.

Next two studies differ from previous ones in terms of the data source. They use survey indicators to estimate the business cycle to eliminate the end-point problem and to yield timelier results. The first one, Coşar et al. (2013), estimate an output gap indicator for the period 2005q1-2013q1. Their procedure consists of two stages. In the first stage, they choose the variables that can be

[12] As a recent study, for an extensive review on potential growth estimation see Sevinc et al. 2021.

informative to business cycles. Then they estimate business cycle within the small dynamic factor model setting by using selected variables which are capacity utilization rate, change in purchasing power, the level of orders compared to their normal, the adequacy of production capacity with respect to orders and expected demand, the views of manufacturing firms on demand conditions and the number of job announcement. Following Stock and Watson (1991), Camacho and Perez Quiros (2010), they estimate the model and conclude that their filter-free measure is superior to HP filter. The second study, Şahinöz and Atabek (2016) suggest an alternative measure to assess the state of the business cycle by utilizing firm-level micro-data. Following Köberl and Lein (2011), they consider the capacity utilization gap as an alternative indicator to the output gap.

Andıç (2018) constructs a multivariate filter for Turkey similar to Blagrave et al. (2015) to capture some basic economic theory. While Andıç (2018) uses maximum likelihood estimation for a quarterly basis, Blagrave et al. (2015) use Bayesian estimation for annual data. The model consists of three blocks: output, unemployment and inflation and data span the 2005q1-2016q4 period. Her findings suggest that as in Öğünç and Sarıkaya (2011), potential growth fell significantly during the global financial crisis, improved later. Çelgin and Yılmaz (2019) derive the alternative output gap indicator which can be tracked on a monthly basis. They match the demand indicators with 4 and 5-digit level sub-items in CPI for the period 2006q1-2018q4. Then, they obtain the sectoral output gap series by using the HP filter and calculate aggregate sectoral output gap series. They suggest that policymakers should consider sectoral factors as well as other macroeconomic variables.

As for NAIRU estimations for Turkey, there are a few studies[13]. Temurlenk and Başar (2012) made a time-varying NAIRU estimate over the period of 2000-Q1:2007-Q4 for the Turkey based on a modified version of triangle model of Phillips curve by Gordon (1991). Similar to our technique, they used to Kalman filter. Similar to our findings, their results point to the NAIRU estimate for Turkey with minor fluctuations of around 9.5% between 2001 and 2007. An alternative technique was used by Yiğit and Gökçe (2012) to estimate NAIRU for Turkey over the period 1989-2011. Their method was based on the structural vector auto-regression (SVAR). Their results show that in the period up to the second quarter of 2008, NAIRU was estimated to be 9.6% on average. After the third quarter of 2008, NAIRU was estimated to be 12.50% on average. The forecast for the first quarter of 2011 is 10.75%. Their findings indicate that due to the shock of the 2008 crisis, NAIRU rose sharply and could not return to its pre-shock level for a while. This is in harmony with the

[13] Şıklar et al. (1999), Bildirici (1999), Yavan (1997), Kaya and Yavan (2007).

hysteresis effect we mentioned in our paper. In the nonlinear framework, Us (2014) estimates NAIRU for Turkey by using the Extended Kalman Filter (EKF). The model is based on the Phillips curve and the Okun's law. Its findings imply that NAIRU is more volatile than the actual unemployment rate and it harshly responds during the crisis. The weak link between unemployment and inflation, significant pass-through and rigidity in the inflation are the key findings of the study.

## 4. Data and Methodology

This chapter consists of two parts. Following a brief introduction of the data used in the study, we present details on the methodology of the multivariate filter.

### 4.1. Data

We use quarterly real gross domestic product, real domestic demand, real exports of goods and services, real imports of goods and services, core consumer inflation indicator (D index), import prices (TL denominated), nominal exchange rate basket, real unit labor costs, Brent oil prices, unemployment rate[14], real effective exchange rate, real commercial loan rates, export weighted global growth index[15], capacity utilization rate series for 2005Q1-2019Q4 to obtain output gap and NAIRU. If necessary, all series are used in seasonal adjusted form. If any variable is not published in seasonal adjusted form by officials, we use TRAMO-SEATS[16] for seasonally adjustment by using JDemetra 2.2.0 programme.

Table B-1 shows the variables used in the analysis and provides summary statistics for the quarter-on-quarter growth rate of these variables. Information on summary statistics guides us to choose the priors and calibrate some parameters required during the estimation process.

[14] Broader unemployment rate is used as an alternative to the traditional definition of unemployment rate.

[15] For further details on the series, see Çıplak et al. (2011) and Erduman and Ekşi (2018).

[16] For further details on the TRAMO-SEATS method for seasonal adjustment, see Gomez and Maravall (1998).

## 4.2. Methodology

Any real variable can be decomposed into trend and gap components. The trend component captures long term changes and low-frequency events. It is driven by structural changes and factors such as productivity etc. which are beyond the scope of the monetary policy. On the other hand, gap, related to output or unemployment, reflects the business cycle dynamics and varies from country to country and is within the scope of both monetary and fiscal policies. It is often measured as a percentage deviation from the trend. Both trend and gap are unobserved variables and need to be identified. As previously elaborated on in the literature chapter, filters are tools to extract trend and cycle parts of any series.

This section concentrates on the multivariate filter including structural equations created with macroeconomic motivation and simultaneously giving the estimation on the potential output and NAIRU. The basic idea behind multivariate filtration is that there exists a close relationship between macroeconomic variables and it should be considered during the decomposition process.

Following Benes et al. (2010), Blagrave et al. (2015), Alichi et al. (2015, 2019), we construct a multivariate filter by considering a stylized New Keynesian small open economy model including output gap and its components, capacity utilization rate, inflation, unemployment rate and rational formation of expectations for some variables, in other words, model-consistent expectations. Our model consists of structural equations such as the Phillips curve, dynamic Okun's law and an equation linking to output gap and capacity utilization slack. The multivariate filter consists of four blocks. The first block shows how to construct output gap equation with using components. The second one demonstrates the Phillips curve equation linking with inflation and output gap. The third includes dynamic Okun's law. The last one is the capacity utilization gap which could capture the slack that is not involved by the unemployment gap and has high correlation with the output gap (Alichi, 2019). The last block shows the link between output and capacity utilization gaps.

**The first block is given as follows:**

Natural logarithm of the output level (real GDP), $Y_t$ , consists of its potential level $(\overline{y_t})$ and output gap $(\tilde{y}_t)$ :

$$Y_t = \bar{y}_t + \tilde{y}_t \qquad (1)$$

Unlike Blagrave et al. (2015), Alichi et al. (2015), Andıç et al. (2018), Alichi et al. (2019), we use growth componets by following Alp et al. (2012). Policymakers may choose to stimulate domestic demand through incentives and adjustments when foreign demand does not sufficiently support economic activity. It is determined that such a situation has overcome the negative effects of 2008 global financial crisis on the economic activity in Turkey. In addition to tax incentives on certain commodity groups, monetary policy began to cut the interest rates in November 2008. Similarly, many precautions have been taken in order to impede the contraction in economic activity that has weakened since 2018-3. While the public sector has taken a more supportive stance, tax cuts have been applied to many durable goods groups. Supportive regulations and incentives such as restructuring credit card debts, installment of credit card spending and cash withdrawals and provision of additional credit opportunities to small and medium scale enterprises (SMEs) can be counted among the other measures taken. In this period, while net exports were the main driver of annual growth, domestic demand remained was weak due to high interest rates and high volatility in exchange rates (Figure 2). Accordingly, it is clear that it is of great importance to consider the distinction between domestic and foreign demand. Therefore, the output gap ($\tilde{y}_t$) is defined as the weighted average of domestic demand gap ($\tilde{d}_t$), export demand gap ($\tilde{x}_t$) and import demand gap ($\tilde{m}_t$)[17].

$$\tilde{y}_t = \omega_1 \tilde{d}_t + \omega_2 \tilde{x}_t - \omega_3 \tilde{m}_t \qquad (2)$$

Since domestic demand consists of consumption and investment, real exchange rate and real interest rate determining the consumption and investment decisions of the households and investors are used. While the increase in real interest rates negatively affects consumption and investments, the appreciation of the real exchange rate supports domestic demand due to the cheapening of imported goods. Therefore, domestic demand gap ($\tilde{d}_t$) equation consists of lagged values of domestic demand gap, rational expectations of domestic demand gap which is model-consistent, lagged values of real interest rate gap ($\tilde{r}_t$) and real exchange rate gap ($\tilde{q}_t$) and it is formed as:

$$\tilde{d}_t = \alpha_1 \tilde{d}_{t-1} + (1-\alpha_1)\tilde{d}_{t+1} - \alpha_2 \tilde{r}_{t-1} + \alpha_3 \tilde{q}_{t-1} + \varepsilon_t^d \qquad (3)$$

[17] The values of $\omega_1$, $\omega_2$, $\omega_3$ are calibrated as 1.02, 0.22 and 0.24 respectively, based on sample ratios of period 2005q2-2019q4.

The real interest rate determines the decisions to substitute between consumption and savings today to consume and save in the future. Higher real interest rate postpones the consumption and investments today because of its high cost. Since it encourages the savings, tight monetary conditions suppress the domestic demand. Therefore, the coefficient $\alpha_2$ enters the equation with a minus sign. The real exchange rate impacts decisions to demand between domestically and foreign produced goods. Due to its definition, the coefficient of $\alpha_3$ enters the equation with a positive sign.

Export demand gap ($\tilde{x}_t$) is defined as a function of lagged values of the export demand gap, real exchange rate gap, $\tilde{q}_t$, foreign output gap, $\tilde{y}_t^*$, oil gap, $\tilde{o}_t$[18] , shocks ($\varepsilon_t^x$) and it is formed as:

$$\tilde{x}_t = \varphi_1 \tilde{x}_{t-1} - \varphi_2 \tilde{q}_t + \varphi_3 \tilde{y}_t^* + \varphi_4 \tilde{o}_t + \varepsilon_t^x \qquad (4)$$

Coefficient of $\varphi_2$ enters with a minus sign in the equation since appreciation in domestic currency in real terms leads to more expensive domestically produced goods compared to foreign goods. Coefficient of $\varphi_3$ enters in the equation with a positive sign since more foreign output gap leads to more demand for goods produced by other countries.

Import demand gap ($\tilde{m}_t$) depends on its lagged values, aggregate demand[19] consisting of domestic demand gap and export gap and real exchange rate gap and shocks ($\varepsilon_t^m$) and it is as follows:

$$\tilde{m}_t = \vartheta_1 \tilde{m}_{t-1} + \vartheta_2(\vartheta_3 \tilde{d}_t + (1-\vartheta_3)\tilde{x}_t) + \vartheta_4 \tilde{q}_t + \varepsilon_t^m \qquad (5)$$

For Turkey, the presence of high number of imported goods in consumption and investment and high import content of exports leads coefficient of $\vartheta_2$ to enter with a positive sign in the equation. Sign of $\vartheta_4$ is positive since more appreciated domestic currency gives importers less domestic currency per one unit of foreign goods.

Similarly, the level of potential output ($\bar{y}_t$) is constructed as the weighted average of the level of the potential domestic demand, potential export demand and potential import demand.

[18] The flexibility of the market diversification recently Turkey has made a huge leap. While exports of goods and services continue to be at the forefront of the European region, exports of goods and services to the Middle East and North Africa (MENA) regions have increased. Oil prices are added to the equation as a proxy for the growth rates of these regions.

[19] The value of $\vartheta_3$ is calibrated as 0.82, based on sample ratios of period 2005q2-2019q4.

Following Öğünç and Sarıkaya (2011) and Kara et. al (2017), **the second block is given by the following equations:**

$$\pi_t = \sigma_1 \pi_{t-1} + (1-\sigma_1)\pi_{t+1} + rmc_t + \varepsilon_t^{\pi} \quad (6)$$

$$rmc_t = \sigma_2 \tilde{y}_t + +\sigma_3 \widetilde{rpm}_t + \sigma_4 \widetilde{ruw}_t + \sigma_5 \tilde{s}_t \quad (7)$$

The representation of the Phillips curve is based on 'triangle' model[20] of inflation by Gordon (1991). Seasonally-adjusted annualized quarter on quarter change of core inflation ($\pi_t$)[21] depends on its lagged values ($\pi_{t-1}$), its rational expectations with model-consistent ($\pi_{t+1}$) , real marginal costs (rmc) including the output gap ($\tilde{y}_t$), real import price gap ($\widetilde{rpm}_t$), real unit labour costs gap ($\widetilde{ruw}_t$) and the nominal exchange rate basket gap ($\tilde{s}_t$), and structural shock named as cost-push shock ($\varepsilon_t^{\pi}$) . While the coefficient of lagged core inflation ($\sigma_1$) represents the persistence of the inflation[22], the coefficient of the output gap ($\sigma_2$) indicates the sacrifice ratio which indicates how much output will be used by disinflation the economy. Higher output increases input costs for domestic producers since firms utilize higher capacity rates to deliver more output. Higher capacity utilization rate leads to depreciation in the capital more in the short run. Firms would like to replace and compensate depreciated capital, which would increase marginal costs. To preserve their profit margins, firms reflect increasing marginal costs into their prices. There are two channels, direct and indirect, in how the exchange rate affects inflation. For the former, if the domestic currency appreciates, imported goods become cheaper than domestically produced goods. Therefore, the lower cost of imported goods reduces inflationary pressures. $\tilde{s}_t$ captures this situation. For the latter, as domestic currency appreciates in real terms, foreign goods become cheaper compared to domestically produced goods. Since demand shifts away from domestically produced goods to imported goods, lower demand for domestic goods will

[20] The model assumes inflation having three drivers: built-in inflation, demand-pull inflation and cost-push inflation.

[21] We use CPI-D index rather than headline inflation since CPI and its sub-componets differ in shocks behind their dynamics and strength of business cycle. Most monetary policies follow CPI-sub components along with headline inflation rate since they enable them to understand the drivers behind inflation dynamics. For instance, food price inflation is less affected business cycle and highly volatile and also energy price inflation is determined by exogenous factors. Therefore, when constructing a Phillips curve, it is important to use the CPI sub-component, which is mostly related to the business cycle.

[22] It means that $\sigma_1$ captures inertia in firms' price setting behavior. A friction $\sigma_1$ of firms is backward-looking and relies on past inflation when deciding on current price changes. Lower $\sigma_1$ indicates that inflation returns to pre-shock level much faster.

determine lower domestic costs pressures. $\widetilde{rpm}_t$ captures this statement. Moreover, $\widetilde{ruw}_t$ shows pressures of the real labor cost on inflation since it leads to higher cost.

Following the Benes et al. (2010), Blagrave et al. (2015), Alichi et al. (2015, 2019), **the third block is given as follows:**

The actual seasonally adjusted unemployment rate ($u_t$) is the equilibrium unemployment rate ($\bar{u}_t$) , NAIRU, minus the unemployment gap ($\tilde{u}_t$):

$$u_t = \bar{u}_t - \tilde{u}_t \tag{8}$$

NAIRU has a stochastic process and it is a time-varying variable that depends on lagged values ($\bar{u}_{t-1}$) , variation in the trend ($G_{\bar{u},t}$), steady-state value ($\bar{u}^{ss}$)[23] and shocks ($\varepsilon_t^{\bar{u}}$):

$$\bar{u}_t = \bar{u}_{t-1} + (1-\tau)\bar{u}^{ss} + G_{\bar{u},t} + \varepsilon_t^{\bar{u}} \tag{9}$$

Variation in the trend of the NAIRU also follows an autoregressive process:

$$G_{\bar{u},t} = \tau G_{\bar{u},t-1} + \varepsilon_t^{G_{\bar{u}}} \tag{10}$$

Equation (11) represents dynamic Okun's law linking with unemployment gap and output gap:

$$\tilde{u}_t = \gamma_1 \tilde{u}_{t-1} + \gamma_2 \tilde{y}_t + \varepsilon_t^{\tilde{u}} \tag{11}$$

Following the Benes et al. (2010), Blagrave et al. (2015), Alichi et al. (2015, 2019), **the last block is as follows:**

The seasonally adjusted capacity utilization rate ($capu_t$) consists of equilibrium level of capacity utilization rate ($\overline{capu}_t$) plus capacity utilization gap ($\widetilde{capu}_t$).

$$capu_t = \overline{capu}_t + \widetilde{capu}_t \tag{12}$$

[23] By conducting similar approach in first block, steady-state value of unemployment rate ($\bar{u}^{ss}$) is determined as 10.3 percent. The coefficent $\tau$ is calibrated as 0.8.

Similar to NAIRU, the equilibrium level of capacity utilization has a stochastic process and it is a time-varying variable. It depends on lagged values ($\overline{capu}_{t-1}$) , variation in the trend ($G_{\overline{capu},t}$), steady-state value ($\overline{capu}^{ss}$)[24] and shocks ($\varepsilon_t^{\overline{capu}}$):

$$\overline{capu}_t = \overline{capu}_{t-1} + (1-\mu)\overline{capu}^{ss} + G_{\overline{capu},t} + \varepsilon_t^{\overline{capu}} \quad (13)$$

Variation in the trend of the $\overline{capu}_t$ also follows an autoregressive process:

$$G_{\overline{capu},t} = \mu G_{\overline{capu},t-1} + \varepsilon_t^{G_{\overline{capu}}} \quad (14)$$

Equation (15) represents dynamic link between capacity utilization gap and output gap:

$$\widetilde{capu}_t = \gamma_3 \widetilde{capu}_{t-1} + \gamma_4 \tilde{y}_t + \varepsilon_t^{\widetilde{capu}} \quad (15)$$

Equations (1-15) comprise the core of our model for output gap, NAIRU, unemployment gap and capacity utilization gap. Following Benes et al. (2010), Öğünç and Sarıkaya et al. (2011), Alp et al. (2012), Blagrave et al. (2015), Alichi et al. (2019), Bayesian methodology is employed to estimate the model for the period 2005q2-2019q4. The why we use this methodology instead of maximum likelihood (ML) estimation is in part Appendix C. In addition, that part covers the priors identification and posterior results of the model using the traditional definition of the unemployment rate (Table C-1).

## 5. Empirical Results

This chapter consists of two parts. The first part describes the properties of the cyclical components of the output gap, unemployment gap, and capacity utilization gap extracted by multivariate filters using the traditional and alternative definition of the unemployment rate[25]. The final part documents the course of the potential output and NAIRU for Turkey.

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[24] By conducting similar approach in the previous block, steady-state value of capacity utilization rate ($\overline{capu}^{ss}$) is determined as 77.0 percent. The coefficient $\mu$ is calibrated as 0.85.

[25] While MF-O represents the model results using the original definition of the unemployment rate, MF-A shows the model results using the alternative definition of the unemployment rate.

### 5.1. The Outlook of Cyclical Components of Macroeconomic Real Variables

Figure D-1 shows the output gap estimates extracted by the lots of the univariate filters and multivariate filters. It is clear that there is a consensus that the global financial crisis has dragged the Turkish economy far below its potential further compared to the recent downturn. Turmoil in the international credit markets and deterioration in the expectations of the global economic outlook has intensified slowdown in the economy and restrained both domestic and export demand during the global financial crisis. Considering the export composition, Turkey is a country that is largely an exporter of manufactured products. Automotive, machinery, transportation vehicles, iron and steel products have a high share in exports. The countries that are importers for such products were the ones most affected by the crisis, which caused the foreign demand to decrease considerably during the global crisis. For the recent downturn, there has been a sharp depreciation in the Turkish Lira (TL) and uncertainties have increased since 2018-3. Perceptions of uncertainty and tight financial conditions, which strengthened significantly due to financial volatility, suppress domestic demand as well as decrease in credit momentum and in real wages, worsening employment opportunities and increase in unemployment. Therefore, the slowdown in economic activity was driven by domestic demand. On the other hand, net exports compensated for the slowdown in domestic demand due to the relatively strong course in the global economic outlook, the increasing competitiveness due to the long-term depreciation in TL, and the flexibility of market diversification during the period. After 2018-4, significant acceleration in loans as well as remarkable improvement in the risk premium, exchange rate volatility and uncertainty indicators supported domestic demand (Figure D-2). In both periods, total demand conditions contribute to the disinflation process. While the shock during the global economic crisis is demand shock, the recent shock is a cost-push shock. Differentiation of shocks resulted in different developments after the slowdown. For the former, when the output gap is closing, inflation has a moderate course. This is compatible with the divine-coincidence discourse[26]. For the latter, while the output gap is closing, an increase in inflation is observed for a while.

Figure 8 shows the output gaps extracted by models using different definitions of unemployment rates. It is seen that output gap based on original definition of the unemployment rate (MF-O) is more negative than alternative definition (MF-A) in the global financial crisis. On the other hand, the opposite is true for recent downturn. It means that the broader measure of labor market slack

[26] Divine coincidence means that there is no trade-off between the stabilization of inflation and the stabilization of the welfare-relevant output gap for central banks (Blanchard and Gali, 2007).

gives a more negative output gap. If policymakers chose to follow alternative definition of the unemployment rate, it would give more stimulus for the economy to return to its full potential for the recent downturn.

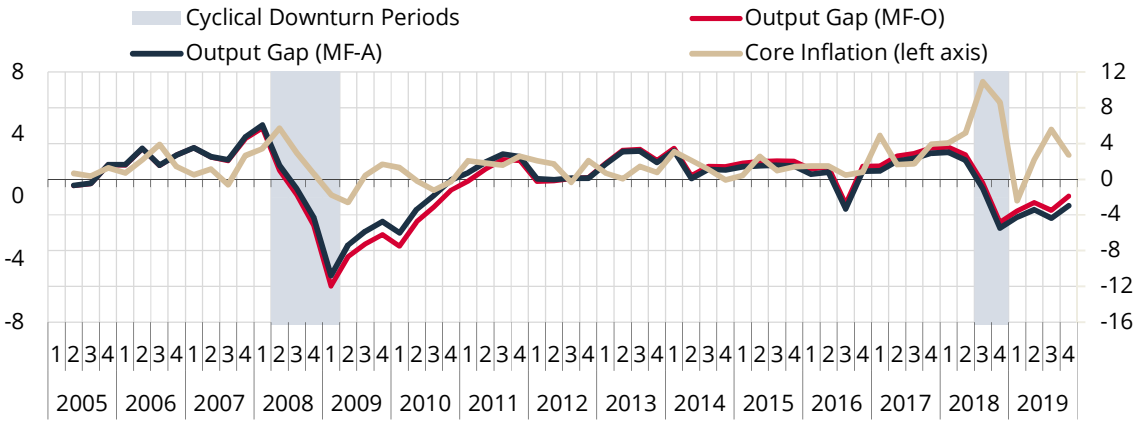


***Figure 8:*** Estimates of Output Gap (Percent) and Core Inflation (Annualized quarterly change, percent)

Broader measure of labor market slack yields a more negative unemployment gap for both periods (Figure 9). As for capacity utilization rate gap, traditional measure of labor market slack is more negative than alternative measure only for recent downturn (Figure 10). Both measurements continued to worsen for a while after the shocks in both periods.

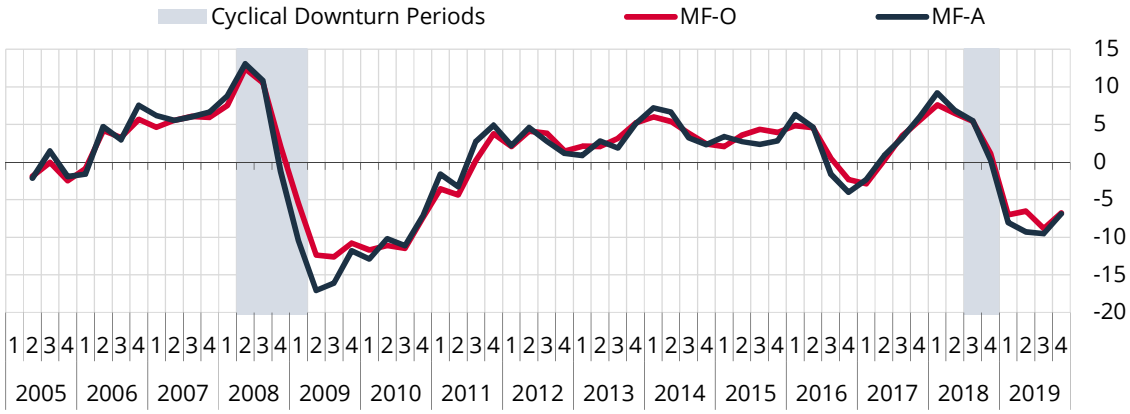


***Figure 9:*** Estimates of Unemployment Rate Gap (Percent)

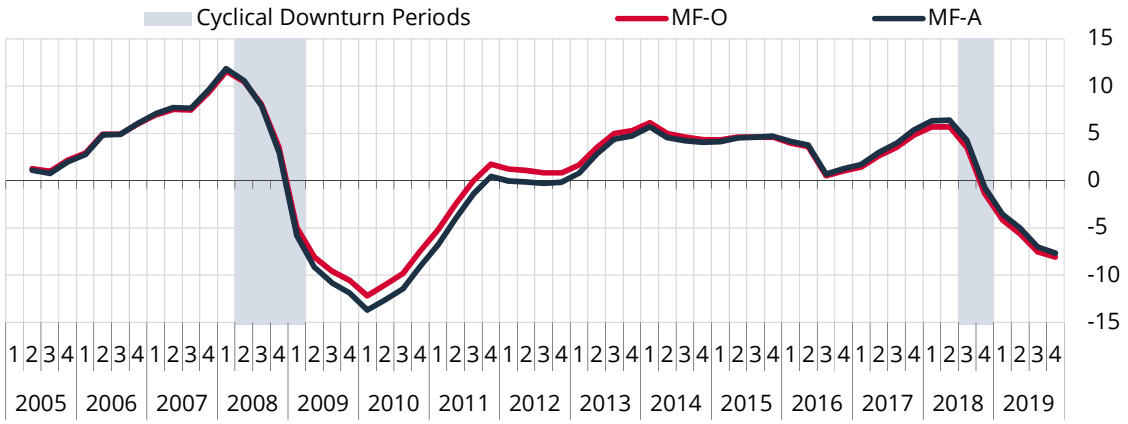


***Figure 10:*** Estimates of Capacity Utilization Rate Gap (Percent)

The MF estimates of the output gap, unemployment gap and capacity utilization gap based on original definition of the unemployment rate are shown in Figure 11. It easily seems that goods market leads the labor market and manufacturing industry. It means that recovery in goods market begins earlier than other markets. As stated in the Coşar and Yavuz (2019), firms determine the time of recruitment and increasing the capacity utilization rate depending on the sustainability of the recovery of economic activity. The deepest slack in the labor market in both periods exists. There are several reasons why unemployment is more responsive than the output gap and capacity utilization gap. As discussed in Chapter 2, one reason is that employment has deteriorated with a sectorial diffusion in recent periods and so it might be longer to recover. Second, the decline in risk premium and exchange rate volatility as well as improvement in financial conditions and momentum of the credit growth in 2019-4 backed up the economic activity and firms considerably. Due to weak external demand in the global financial crisis, more decline is observed in the capacity utilization rate throughout the period.

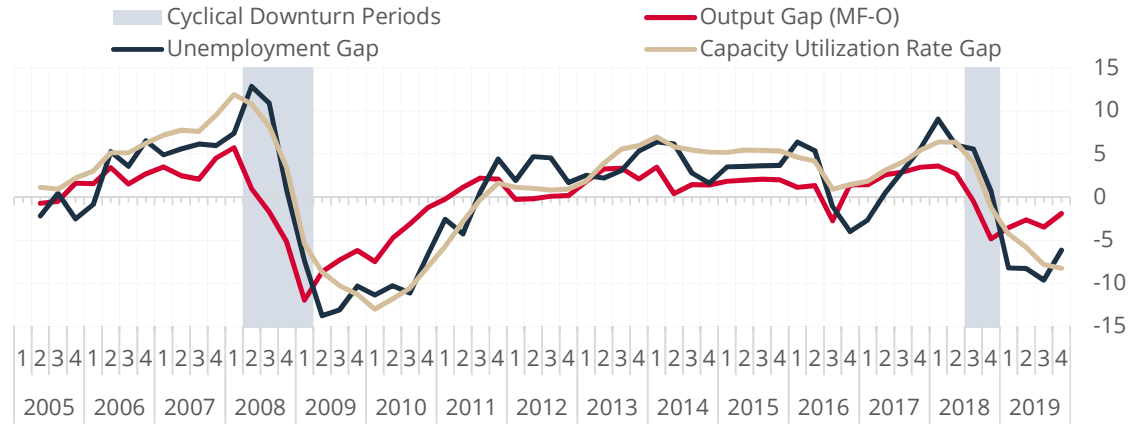


***Figure 11:*** Output Gap, Unemployment Gap and Capacity Utilization Rate Gap (Percent)

The next subsection shows the course of the potential output and NAIRU for Turkey.

## 5.2. Potential Output and NAIRU for Turkey

Figure 12 shows the course of the potential growth estimated by multivariate filtering procedure. Potential growth appears to be related annualized quarterly change in actual growth, though potential growth is smoother. The average potential growth over the period is 4.9 percent. Potential growth drops to 1.8 percent in 2009-1 and then recovers; however, it continued to decline until 2019-3 even after 2018-4, then became stable for the recent downturn. One explanation for the ongoing decline in potential output for a while in the 2018 downturn may be the continuation of the increase in unemployment. It fell to only 3.0 in 2019-3 due to more supportive external demand and more stimulus.

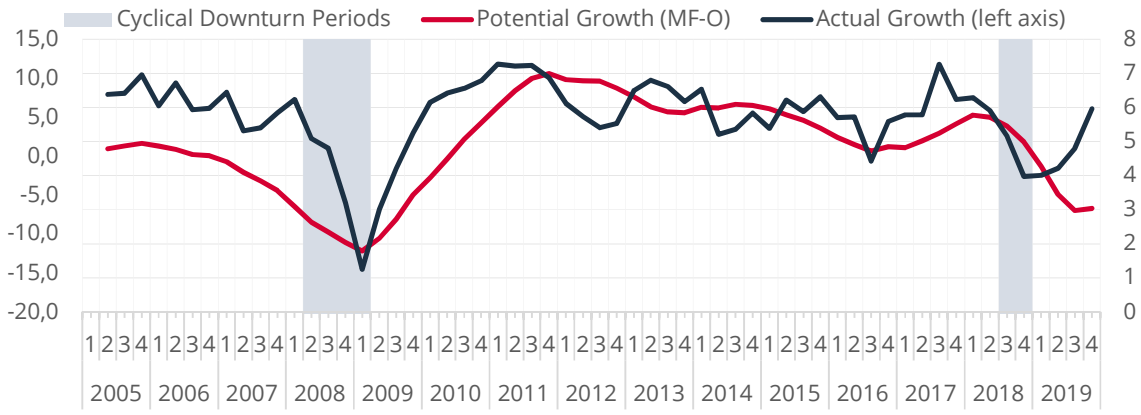


***Figure 12:*** Actual Growth (Annualized quarterly change, percent) and Potential Growth (Percent)

Figure 13 indicates the unemployment rate and time-varying NAIRU extracted by MF using original unemployment rate. As of the fourth quarter of 2008, the effects of the global crisis on the labor market began to be felt significantly, and the deterioration in the labor market continued until mid-2009. As of the third quarter of 2009, non-agricultural employment started to recover, while unemployment rates started to decline. While the effects of the global financial crisis focused on industrial employment, the impact on construction and services employment remained limited (Figure A-4, A-5 and A-6). Similar to the findings of Andıç (2018), the unemployment rate was below the NAIRU before the global financial crisis but it rose above its trend in 2008-4 and it stayed above the trend for a long period of time. Compared to the global financial crisis, the unemployment rate and NAIRU registered a sharp increase during the 2018 downturn. Despite the positive quarterly growth rates after 2018-4, NAIRU increases continued for a while. One of the most significant explanations for this is a widespread employment loss in this period, unlike the 2009 period.

Unemployment rates increased in 2019 since the second half of 2018 due to the slowdown in economic activity. The increase in unemployment rates was due to the decrease in employment observed in non-agricultural sectors, especially in the construction sector.

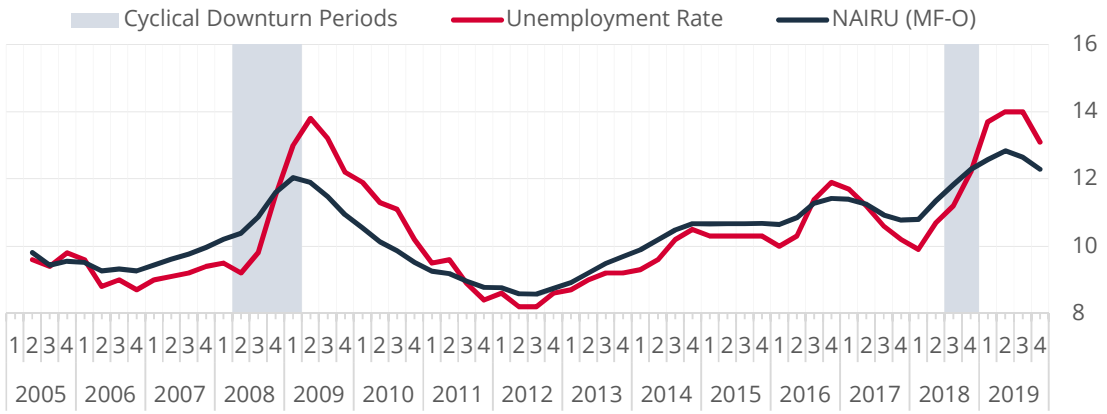


***Figure 13:*** NAIRU Estimate and Unemployment Rate (Percent)

## 6. Conclusion

It is crucial to identify the state of the economy for both monetary policy-makers and fiscal policy authorities. Central banks determine a policy stance that is compatible with their own objective function. Governments also would like to know whether the budget deficit is sustainable or not to calibrate the fiscal stance. To fulfill these requirements properly, we construct a multivariate filter to identify the business cycle conditions of Turkey over the 2005q2-2019q4. Our model takes structural macroeconomic relationships into account unlike univariate filters. In addition to Phillips Curve and Okun's Law, the model also includes the capacity utilization block. The addition of the new block to the model is probably the most important difference and extension of our model from other studies and it makes a significant contribution to the paper. This extension enables us to compare the course of the cyclicality of the output, capacity utilization and unemployment rate in in Turkey over the period shown.

This paper also uses broader measure of labor market slack taking discouraged workers into account as well as traditional one to construct output gap estimates. Using the alternative unemployment rate and comparing its results with original is the second contribution of the paper.

Although we aware of their shortcomings, we use a wide range of univariate filtering methods such as deterministically linear trend (DPT), the first-order differencing (FOD) method, Hodrick-Prescott (HP) filter, one-sided HP filter, Hamilton's regression filter, Baxter and King (BK) filter and Christiano-Fitzgerald filter to extract output gap. We compare their results with multivariate filter results. Using such a broad technique to estimate output gap is another contribution of the paper.

Lastly, we use the results obtained from our multivariate filters to compare two shocks that have occurred in Turkey in recent years. The first one was due to the global financial crisis, which spans

the period 2008-Q2 and 2009-Q1, while the second one took place between 2018-Q3 and 2018-Q4 when strong and abruptly depreciation in the Turkish Lira and high country's risk premium existed. Similar to previous studies, the filter results indicate that the global financial crisis dragged the Turkish economy far below its potential further than 2018 downturn. The output gap and capacity utilization gap do not decrease as much as the unemployment gap in both downturns. According to our multivariate filter results, estimate of output gap is smaller in 2018 downturn than global financial crisis since foreign demand is more supportive in 2018 downturn due to competitive exchange rate and strengthening market diversification flexibility in exports. Potential growth considerably decreased in both periods. NAIRU, unemployment rate consistent with stable inflation, moves in tandem with actual unemployment rate. It has been above the trend for a long time during the both downturns. It captures the idea that long and deep downturns in Turkey resulted in persistent damage to the labor market. It means that labor market hysteresis existed due to negative effects of the cyclical downturn periods. Also, unemployment duration and Beveridge curve indicate the existence of the labor market hysteresis. Though estimate of the slack in the output is smaller in recent period, unemployment rate and NAIRU increase sharply and reach the highest levels historically in both periods. While the employment losses in the labor market were predominantly in the industry sector during the global financial crisis, sectorial diffusion in the employment losses has been seen in the recent period. Due to weak foreign demand and composition of industrial sector products, slack in capacity utilization rate is higher in the global financial crisis. Therefore, monetary policymakers and non-monetary policy makers should concentrate on the developments in the labor markets as well as developments in the goods markets during the recession periods since reflections of the downturn periods on the markets could differentiate and output gap could not be only indicator to identify business cycle conditions. Also, using the broader labor market slack has important implications so we believe that it should be followed by policymakers as well as traditional labor market slack.

The future work can extend our study in several ways. Although our model tries to include many macroeconomic relationships and has high inclusiveness, some macroeconomic variables such as fiscal stance, credit growth, housing prices could be added to the model. To cover the foreign trade developments which are significant for the Turkish economy, the model can be augmented with current account equation. It is believed that such extensions improve reliability of the real-time estimates of the model and assist policy choice.

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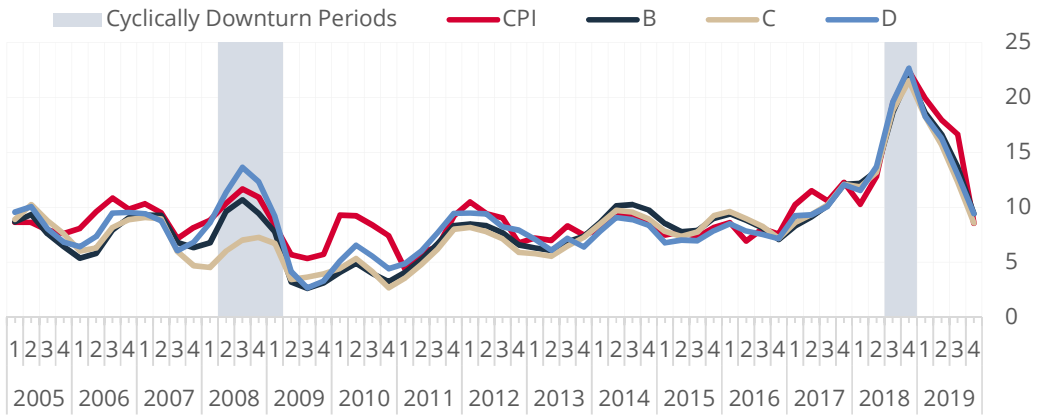
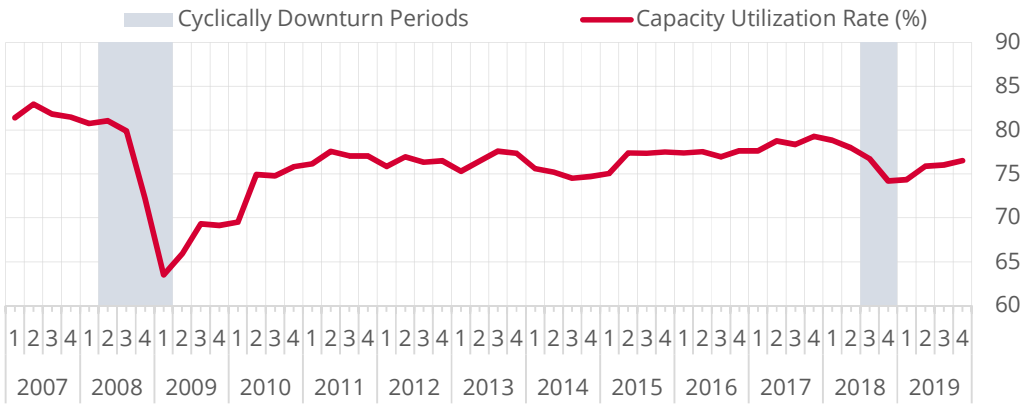
## Appendix A



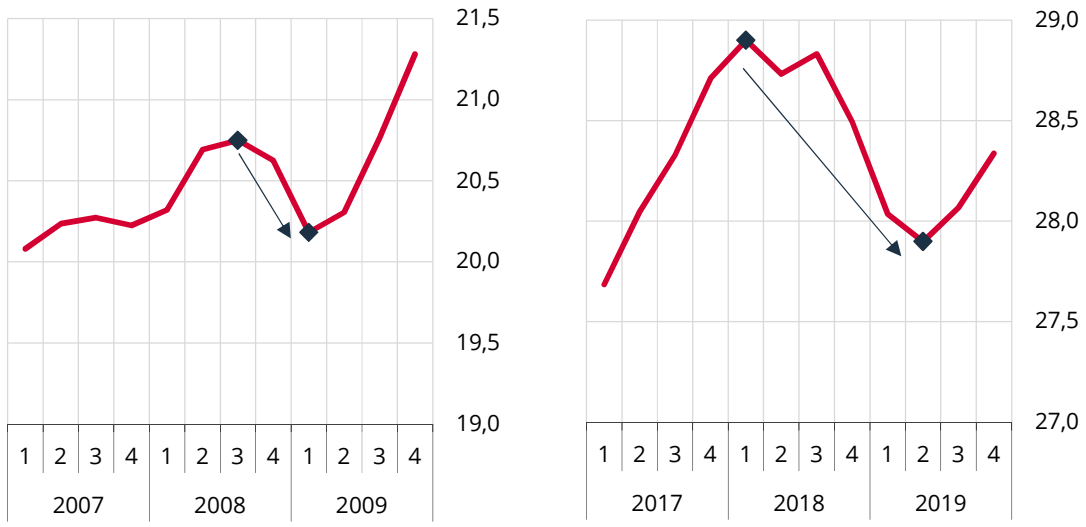

Source: Turkstat.

***Figure A-1:*** Inflation Rates (Annualized Quarterly Percentage Change)



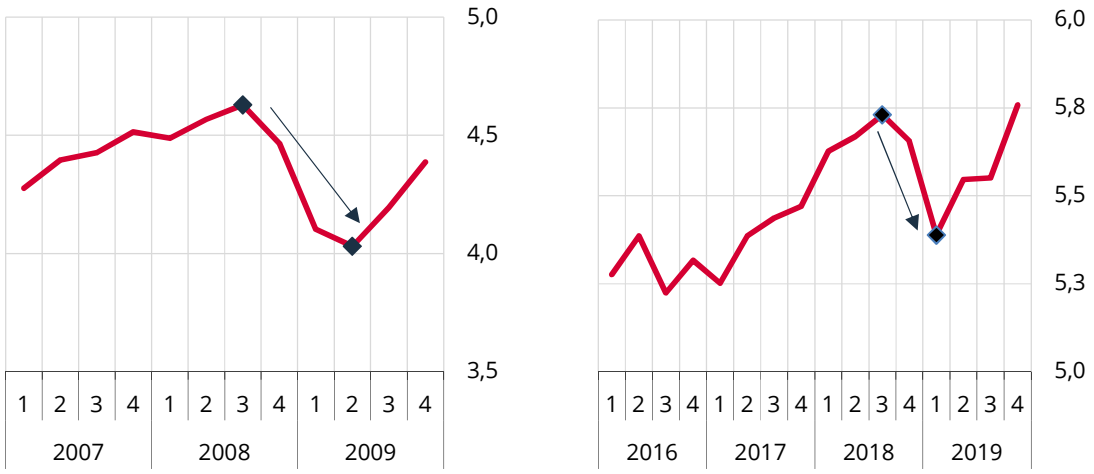

Source: CBRT.

***Figure A-2:*** Capacity Utilization Rate (Seasonally Adjusted, Percent)



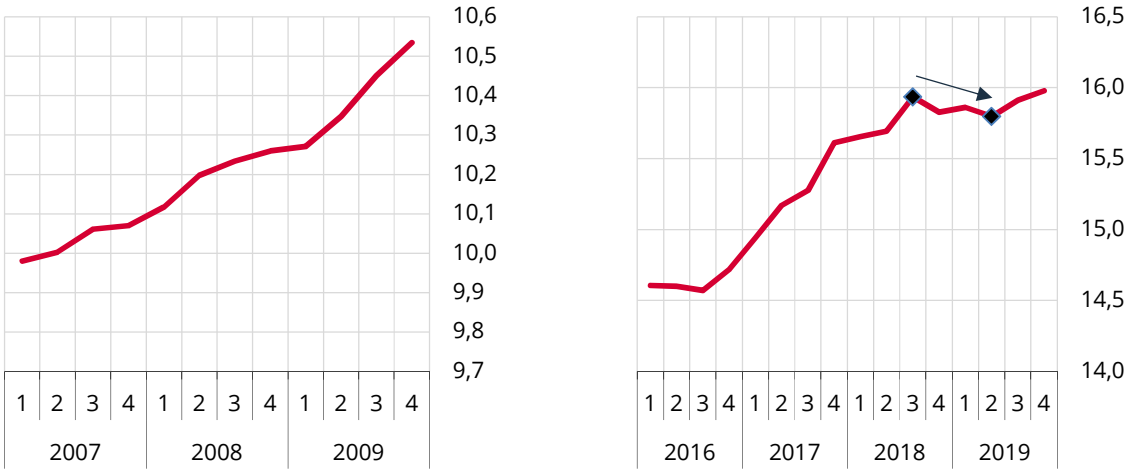

Source: Turkstat.

***Figure A-3:*** Total Employment (Seasonally adjusted, millions of persons)



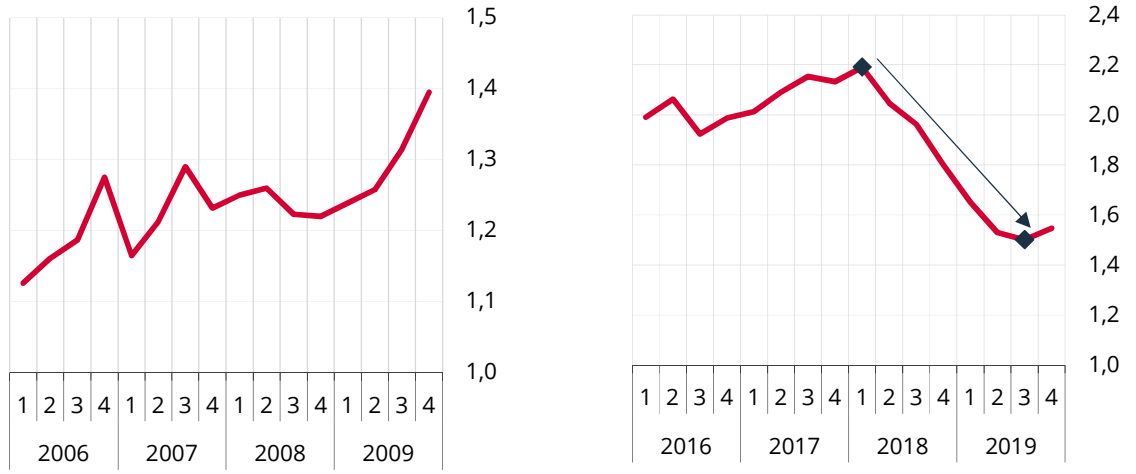

Source: Turkstat.

***Figure A-4:*** Manufacturing Sector Employment (Seasonally adjusted, millions of persons)



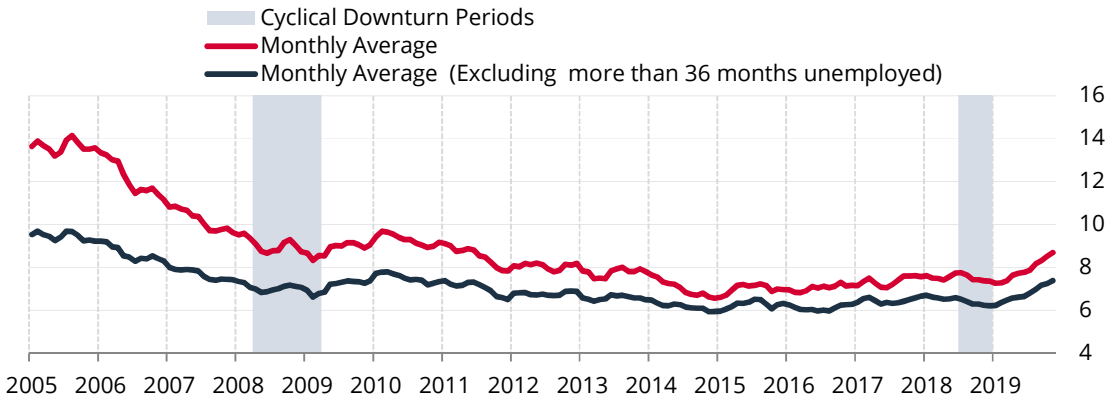

Source: Turkstat.

***Figure A-5:*** Services Sector Employment (Seasonally adjusted, millions of persons)



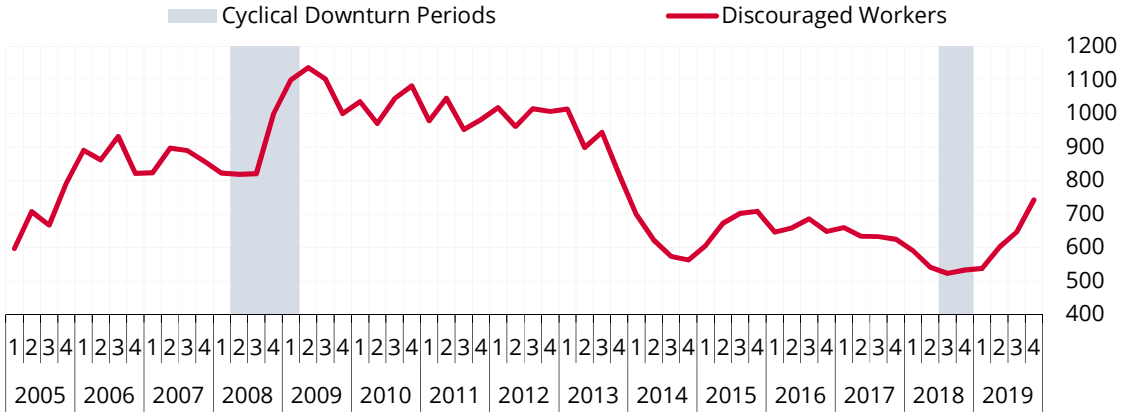

Source: Turkstat.

***Figure A-6:*** Construction Sector Employment (Seasonally adjusted, millions of persons)




Source: Turkstat, author's own calculations.

***Figure A-7:*** Unemployment Duration (Average)




Source: Turkstat.

***Figure A-8:*** Discouraged Workers (Seasonally adjusted, thousands of persons)

# Appendix B

## Table B-1. Descriptive Statistics for the Dataset (2005Q2-2019Q4)

| Series | Description | QoQ Growth Rates | | Source |
|---|---|---|---|---|
| | | Average | Standard Deviation | |
| Gross Domestic Product | Chain-linked volume index (2009=100), seasonally adjusted | 1.2 | 2.0 | TURKSTAT |
| Domestic Demand | Chain-linked volume index (2009=100), seasonally adjusted | 1.1 | 2.8 | TURKSTAT |
| Exports of Goods and Services | Chain-linked volume index (2009=100), seasonally adjusted | 1.5 | 5.4 | TURKSTAT |
| Imports of Goods and Services | Chain-linked volume index (2009=100), seasonally adjusted | 1.2 | 5.8 | TURKSTAT |
| CPI excluding Unprocessed Food and Tobacco | CPI-D price index (2003=100), seasonally adjusted | 2.2 | 1.3 | TURKSTAT |
| Import Prices | Import Unit Value Index (2010=100, TL) | 2.9 | 6.7 | TURKSTAT |
| Nominal Exchange Rate Basket | 0.5*US dollar/TL+0.5*Euro/TL | 2.5 | 6.0 | CBRT |
| Real Unit Labor Costs | Non-farm real unit labor cost indicator, seasonally adjusted | 0.2 | 2.9 | CBRT |
| Brent Oil Prices | Brent crude oil prices $ per barrel | 1.7 | 14.7 | Bloomberg |
| Unemployment Rate | Household Labor Force Survey, seasonally adjusted | 0.8 | 5.4 | TURKSTAT |
| Broader Unemployment Rate | Seasonally adjusted | 0.6 | 5.0 | TURKSTAT |
| Real Effective Exchange Rate | CPI-based, 2003=100 | -0.5 | 4.8 | CBRT |
| Real Commercial Loan Rates | Nominal Commercial Loan Rated deflated by 12-month ahead inflation expectations | -0.2 | 2.1 | CBRT |
| Export-weighted Global Growth Index | Seasonally adjusted | 0.6 | 0.6 | CBRT |
| Capacity Utilization Rate | Seasonally adjusted | -0.1 | 2.8 | CBRT |

## Appendix C

### C-1. Assessment of Model Properties and Methods in Model Parametrization

There are several reasons why we prefer to employ Bayesian methodology to obtain unobservable variables rather than the ML estimation procedure.

ML estimation maximizes the log likelihood function with respect to the unknown parameters. It means that it searches for 'the' parameter that produces the highest probability of observing data. It could be a powerful technique if the sample size is large enough and the data includes one extreme point. However, it might work poorly if the sample size scarce, the model is misspecified and the function has multiple extreme points. In the Bayesian methodology, on the other hand, the use of prior distributions in the model could help restrict parameters to reasonable areas and it could overcome problems confronted in ML estimation. Moreover, incorporating expert judgment in the model is quite easy and practical. The Bayesian methodology consists of prior probabilities, likelihood function and posterior probabilities. Prior probabilities ($p(\theta)$) , where $\theta$ denotes the set of parameters, describes the prior knowledge about the model and parameters and it does not depend on the data. Priors generally come from estimations on different datasets, expert judgment, or findings of previous studies. The likelihood function ($p(y\backslash\theta)$) is the density of the data conditional on the parameters of the model. Posterior distribution ($p(\theta\backslash y)$) revises prior probabilities by using information on data and likelihood function. It means that posterior is proportional ($\propto$) to likelihood times prior.

$$p(\theta\backslash y) \propto p(y\backslash\theta)p(\theta) \qquad \text{(C1)}$$

The algorithm of the Bayesian methodology has three steps. The likelihood function is evaluated for given parameters in the first step. The likelihood and prior density are combined in the second step. Lastly, the combination function is maximized with respect to $\theta$ to find the posterior mode. Blanchard-Kahn (1980) conditions ensure existence of a unique stable solution of the model. Following the related literature (Öğünç and Sarıkaya, 2011), the beta distribution is selected for the parameters considered to have a value in the range of (0, 1), the gamma distribution is determined for the parameters which are likely to receive a value greater than 1 and the normal distribution is used for parameters which can receive a positive or negative value. The inverse gamma distribution is adopted for the whole standard errors.

### C-2. Prior Identification and Posterior Results

In Bayesian methodology, information from the outside models can be used in the estimation process in the form of the priors. Therefore, priors are selected from the previous country-specific literature. In the Phillips Curve equation, Çebi (2011), Öğünç and Sarıkaya (2011), Alp et al. (2012)

and Blagrave et al. (2015) shows that firms' backward-looking behavior outweighs in the price-setting process. The findings of those studies for backward looking component ($\sigma_1$) of the Phillips Curve are 0.6, 0.8, 0.8 and 0.6, respectively. On the other hand, Kara et al. (2017)[27] and Andıç (2018) claims that forward-looking behavior is predominant. Therefore, it assumed that firms' backward and forward-looking behavior is the same in the price-setting process and the prior on the $\sigma_1$ is determined as 0.5. The result indicates that backward-looking behavior is somewhat more dominant and compatible with Çebi (2011), Öğünç and Sarıkaya (2011), Alp et al. (2012) and Blagrave et al. (2015). Although Öğünç and Sarıkaya (2011), Öğünç and Batmaz (2011), Blagrave (2015) find higher values, prior on the coefficient of the output gap ($\sigma_2$) in the Phillips Curve is set to consider the Alp et al. (2012) and Kara et al. (2017) [28]. Furthermore, the choice of the priors on the coefficient of the real import price gap ($\widetilde{rpm}_t$), real unit labour costs gap ($\widetilde{ruw}_t$) and the nominal exchange rate basket gap ($\tilde{s}_t$) is based on Kara et al. (2017). Following Alp et al. (2012), the real interest rate gap is included in the domestic demand gap equation as well as real exchange rate gap. It is assumed that the real interest rate gap is predominant. Recent studies such as Sarıkaya (2004), Coşar (2012), Atabek et al. (2014), Çulha et al. (2014), Gül (2018), Çelgin et al. (2019) reveal that exports are more sensitive to foreign demand compared to the real exchange rate. Findings show that while the price elasticity of exports changes between -2.0 and 0, the income elasticity of exports is between 0 and 4.5. Many studies on the import demand are based on Goldstein and Khan (1985)' imperfect substitutes' model. It assumes that the demand for imports is determined by income, the price of the imported goods and the price of the domestic substitution of the good. In this framework, there are many studies on the modeling of import demand such as Senhadji (1998), Kotan and Saygılı (1999), Togan and Berüment (2007), Aldan et al. (2012), Durmaz and Lee (2015), Çakmak et al. (2016), Çulha et al. (2018) and Çelgin et al. (2019) in Turkey. It is possible to talk about a consensus in the studies[29] on that the income elasticity of imports is higher than the price elasticity. The choice of priors for the unemployment gap equation is based on the Andıç (2018)'s findings.

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[27] Kara et al. (2017) investigates the key drivers of the inflation and constructs a Phillips Curve including time-varying parameter. Their findings suggest that coefficients in the Phillips Curve are quite stable over time except for import prices.

[28] These findings on the coefficient of the output gap in the Phillips Curve are 0.17, 0.25 and 0.3 respectively.

[29] While the price elasticity of imports takes the value between 0.21 and 1.12, income elasticity of imports changes from 0.37 to 2.0 in the studies.

**Table C-1.**

**Parameter Estimates**

| Parameter | Prior Distribution | | | Posterior Distribution | |
|---|---|---|---|---|---|
| | Distribution | Mean | Standard Deviation | Mean | %90 Confidence Interval |
| Domestic Demand | | | | | |
| $\alpha_1$ | Beta | 0.500 | 0.2000 | 0.4351 | (0.3697, 0.4914) |
| $\alpha_2$ | Beta | 0.300 | 0.1000 | 0.1734 | (0.1148, 0.2271) |
| $\alpha_3$ | Beta | 0.200 | 0.1000 | 0.0493 | (0.0221, 0.0793) |
| Export Demand | | | | | |
| $\varphi_1$ | Beta | 0.300 | 0.2000 | 0.2822 | (0.0888, 0.4900) |
| $\varphi_2$ | Beta | 0.500 | 0.2000 | 0.2847 | (0.1055, 0.4481) |
| $\varphi_3$ | Gamma | 2.000 | 0.2000 | 1.9592 | (1.6849, 2.2628) |
| $\varphi_4$ | Beta | 0.100 | 0.0500 | 0.0532 | (0.0191, 0.0838) |
| Import Demand | | | | | |
| $\vartheta_1$ | Beta | 0.200 | 0.1000 | 0.1690 | (0.0862, 0.2566) |
| $\vartheta_2$ | Gamma | 1.000 | 0.2000 | 1.7113 | (1.4887, 1.9772) |
| $\vartheta_4$ | Beta | 0.400 | 0.1000 | 0.3563 | (0.2507, 0.4611) |
| Phillips Curve | | | | | |
| $\sigma_1$ | Beta | 0.500 | 0.2000 | 0.5364 | (0.4214, 0.6593) |
| $\sigma_2$ | Beta | 0.120 | 0.0500 | 0.1246 | (0.0377, 0.1970) |
| $\sigma_3$ | Beta | 0.100 | 0.0500 | 0.1029 | (0.0275, 0.1769) |
| $\sigma_4$ | Beta | 0.100 | 0.0500 | 0.0961 | (0.0226, 0.1621) |
| $\sigma_5$ | Beta | 0.100 | 0.0500 | 0.1118 | (0.0259, 0.1919) |
| Okun's Law | | | | | |
| $\gamma_1$ | Beta | 0.800 | 0.1000 | 0.6672 | (0.5219, 0.8332) |
| $\gamma_2$ | Gamma | 0.800 | 0.2000 | 0.8552 | (0.5763, 1.1289) |
| Capacity Utilization Gap | | | | | |
| $\gamma_3$ | Beta | 0.800 | 0.1000 | 0.7778 | (0.6368, 0.9439) |
| $\gamma_4$ | Gamma | 0.800 | 0.2000 | 0.7667 | (0.4991, 1.0187) |
| Shocks | | | | | |
| $\varepsilon_t^d$ | InvGamma | 0.020 | Inf | 0.0120 | (0.0100, 0.0138) |
| $\varepsilon_t^x$ | InvGamma | 0.050 | Inf | 0.0450 | (0.0371, 0.0515) |
| $\varepsilon_t^m$ | InvGamma | 0.030 | Inf | 0.0210 | (0.0163, 0.0254) |
| $\varepsilon_t^\pi$ | InvGamma | 0.745 | Inf | 0.7858 | (0.6157, 0.9438) |
| $\varepsilon_t^{\bar{u}}$ | InvGamma | 0.006 | Inf | 0.0052 | (0.0016, 0.0096) |
| $\varepsilon_t^{G_{\bar{u}}}$ | InvGamma | 0.005 | Inf | 0.0250 | (0.0127, 0.0383) |
| $\varepsilon_t^{\tilde{u}}$ | InvGamma | 0.025 | Inf | 0.0247 | (0.0115, 0.0371) |
| $\varepsilon_t^{\overline{capu}}$ | InvGamma | 0.004 | Inf | 0.0024 | (0.0010, 0.0038) |
| $\varepsilon_t^{G_{capu}}$ | InvGamma | 0.003 | Inf | 0.0372 | (0.0313, 0.0430) |
| $\varepsilon_t^{\widetilde{capu}}$ | InvGamma | 0.015 | Inf | 0.0073 | (0.0038, 0.0108) |

## Appendix D

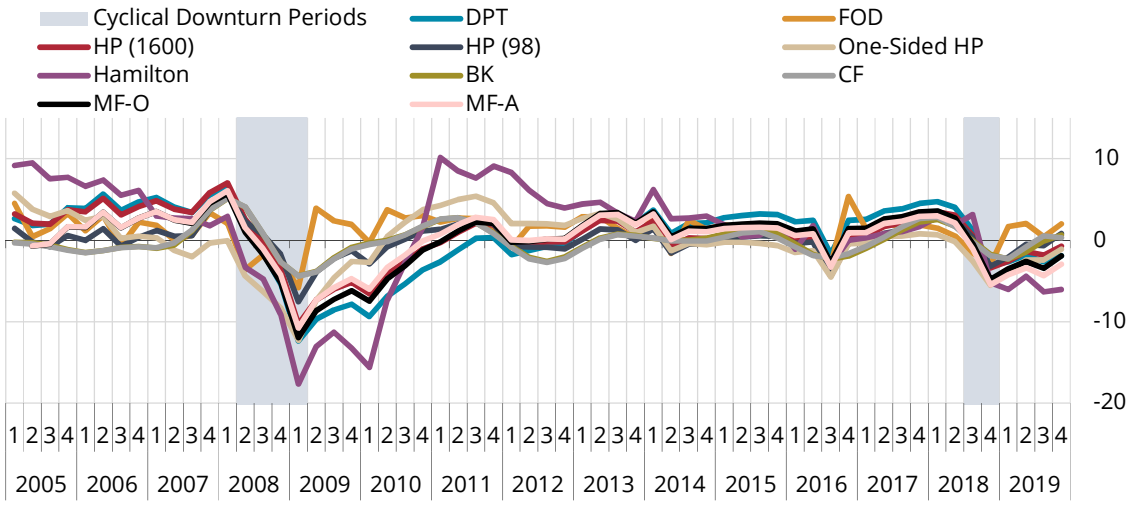


***Figure D-1:*** Estimates of Output Gap (Percent)

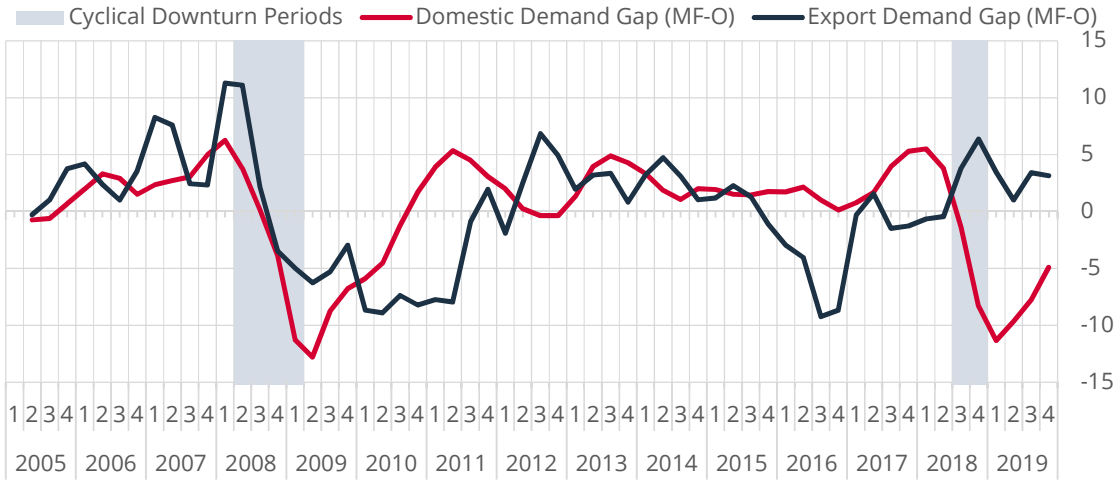


***Figure D-2:*** Domestic Demand Gap and Export Demand Gap (Percent)

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