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Abstract

This paper presents a time-varying parameter methodology for constructing an estimate of output gap for Turkey. We employ the extended Kalman filter technique in a multivariate setting in which economic content is utilized by the inclusion of inflation and output gap dynamics. As a by-product, we characterize time varying nature of output gap and inflation dynamics. Several results emerge: First, we show that estimating the potential output and output gap in a multivariate setting has several advantages over univariate techniques such as the HP filter. Second, our output gap estimates confirm the historical boom-bust cycles in Turkey and point out that business cycle displays sharp turning points rather than exhibiting a smooth pattern. Third, output gap seems to have contributed dramatically to the disinflation process in 2002-2004. Fourth, estimated time varying parameters suggest that, recently, the relation between real interest rates and the output gap seems to have been converging to a more conventional one. What is more, relative impact of output gap on inflation dynamics has been rising since 2001. Putting aside the “fiscal dominance” argument, these latter findings bode well for the effectiveness of the monetary policy within the prospective inflation-targeting framework.

I. Introduction

This study seeks to develop an output gap measure for the Turkish economy. The emergence of price stability as the overriding goal of the monetary policy in the last decade has led central banks to utilize all available information in the economy to foresee the future course of price dynamics. In this respect, the output gap, which can be defined as the difference between the actual output and its "potential" level, is closely monitored by the central banks for the implementation of the monetary policy. Output gap is a key indicator of inflationary pressures among various measures of resource utilization. As far as inflation dynamics are concerned, potential output is often defined as the level of output that can be sustained without putting pressure on production costs and thus on inflation. Therefore, a level of actual output above potential may signal inflationary pressures in the near future.

Output gap has gained popularity in the "monetary policy rules" literature, which has been subject to considerable interest in the recent years. The progress following the pioneer work of Taylor (1993) and especially the success of inflation-targeting regimes, which require effective use of short-term interest rates as the policy instrument, has attached a significant role to the output gap as a response variable in feedback rules. A positive output gap is often perceived as a signal of "excess demand", which may require an increase in the interest rate to prevent the economy from overheating.

The primary issue to be tackled, while conducting an output-gap estimation exercise, would pertain to the underlying technique in question. After all, the information content of the conventional output gap measures (especially for emerging market economies) may be limited.[1] First, these series cannot be directly observed. It is not surprising to see a wide range of detrending methodologies utilizing univariate models as well as multivariate filtering models to come up with alternative estimates of the output gap. The studies about developing proper alternative techniques have further intensified after the shortcomings of the Hodrick-Prescott (HP) filter–the most commonly used methodology–have been realized.[2] Specifically, the values suggested by Hodrick and Prescott are criticized as they are appropriate for the US

[1] See Billmeier (2004) and Orphanides (1999) for an account of the information content of the output gap estimates widely used in the literature.

[2] The weighting parameter in the objective function, which in fact represents the relative magnitude of aggregate demand and supply shocks, is subjectively determined by the user. As stated by Butler (1996), rather than imposing the weighting parameter, it is also possible to estimate this parameter in a multivariate setting. Boone *et al.* (2001) also shows that the optimization procedure utilized by the HP filter can be specified as a univariate unobserved components model where the smoothing parameter represents the relative variances of a shock to trend component and a shock to temporary component, which can be estimated by prediction error decomposition via the Kalman filter.

data and may lead to misspecification of the underlying economic structure of other economies. Also, since the HP filter is a two-sided optimization procedure, which uses both lead and lagged information, the accuracy of the filter diminishes at the end of sample due to missing lead information. In fact, this is unfortunate given that the last observations are often the most vital ones for monetary policy analysis in the sense that these are the ones used for forecasting inflation. In addition, HP filter is subject to criticisms as being purely statistical and having no economic content since it does not exploit any additional information other than the series to be detrended. Moreover, the cyclical component always sums up to zero in HP filter; ruling out the case that actual output is below the potential for a longer time than it is above it. These criticisms make it necessary to handle the issue of measuring output gap within the context of more structural models, which also take country-specific factors into account.

In this context, the production function approach can be seen as more appropriate to estimate the potential output. However, these kinds of applications need accurate and healthy data for at least capital, labor and productivity, which is fairly not so in our case. In that sense, statistical methods remain as a natural candidate to estimate the output gap for the emerging markets, including the Turkish economy. However, one can still enrich the structural content of the output gap estimates by using macroeconomic relations that are supposed to be relevant for inflation and output gap dynamics. At this point, multivariate filtering techniques utilizing information from theoretical macroeconomic relationships, such as the Phillips curve, enter into the picture.[3] As stated by Kuttner (1994), the problem is to estimate the parameters to obtain the unobserved variable, the output gap, which is most consistent with the observed inflation. In this respect, one appropriate estimation technique is the Kalman filter, which is a recursive algorithm for optimally forecasting the unobserved component, given the observed variables and the imposed economic structure.

However, these techniques often impose strong restrictions in defining the relationships between key macroeconomic variables. For example, it is assumed that the relationships that govern the dynamics of the economy stay intact over the sample period. Although these models address–and hence improve upon–the criticisms made for both HP filter and other statistical procedures, there is still room for improvement, especially for economies experiencing frequent structural changes. There is no doubt that this argument applies

[3] As an example Öğünç and Ece (2004) find in their study that incorporating the supply side into the output gap system reduces the parameter uncertainty and the total standard error, hence improves output gap estimate.

strongly for emerging markets: Adopting different monetary policy regimes and experiencing frequent fiscal and financial restructuring periods affect the behavior of economic agents over time. For example, the effects of the transition to an inflation-targeting framework after the collapse of the exchange rate based stabilization program and the intensified attempts to ensure fiscal discipline cannot be adequately captured in a model where the system parameters are assumed to be constant over time. Therefore, relaxing the typical restriction that system parameters stay constant over time may provide insightful results if the output gap in question is pertaining to an emerging market economy.

On the other hand, it is not a trivial task to derive output gap in an unobserved components model, where parameters are also to be estimated in a time-varying fashion. For one thing, when the state variables (including output gap and/or potential output) and the system parameters are to be estimated simultaneously, the model takes a non-linear characteristic and the standard Kalman filter (SKF henceforth) needs to be modified. In this case, extended Kalman filter (EKF henceforth) emerges as an appropriate estimation procedure to be employed.

Estimation of the output gap by the extended Kalman filter methodology allows us to observe the changing dynamics in the economy in question. Accordingly, this study presents a multivariate unobserved components model to estimate both the output gap and the time-varying system parameters for the Turkish economy. Needless to say, the main motivation is the need for an output gap estimate in the construction of near term economic forecasts as a future indicator of inflationary pressures. Such pressures become even more important when the monetary authority is committed to maintain price stability in a forward-looking fashion.

We believe that the findings in this paper will serve as a reference in two distinct ways. First, we propose a new methodology that incorporates time-varying parameter framework into output gap estimation (an unobserved components model). Second, the resulting output gap series and its time-varying relationship with other variables will reveal important information for the changing transmission mechanisms in Turkey.

Needless to say, one should refrain from putting too much emphasis on a single output gap measure. While it is a functional tool in aiding the understanding and forecasting of inflation developments, it has some weaknesses as well. After all, it is an unobserved variable, highly model-specific, and also its link with inflation is not always stable. Moreover, it is not the main variable that drives inflation. For example, many recent studies that are based on micro-founded models point out that inflation is mostly driven by marginal costs, which is not necessarily correlated with *contemporaneous* output gap measures.[4] Also, there may be some factors, such as the exchange rate dynamics, which affect both inflation and the output gap at the same time. In this case, the seemingly positive relationship between the two variables can be derived by a third factor. Finally, and importantly, some recent studies cast doubt on the positive relationship between inflation and the output gap implied by the Phillips curve notion.[5] Therefore, the output gap measures derived in this paper should by no means perceived as the sole determinants of future inflation in Turkey. It should rather be evaluated together with a range of other indicators of inflationary pressures.

The rest of the paper is organized as follows. In the next section, we present and discuss the model along with a state-space representation. The estimation methodology is also introduced in this section. In section 3, we present both the estimated output gap series and the estimated time varying parameters. A sensitivity analysis is performed in section 4, where we analyze whether the results remain robust to different specifications about inflation and the output gap. The comparison of the estimated gap series with the ones obtained from the HP filter and the SKF procedure is also displayed in this section. Finally, section 5 concludes.

II. The Model

In this section, we present the general form of the model that is employed throughout the paper. Given the fact that univariate methodologies only make use of the information on the series to be detrended, thus lack economic content, we present a multivariate specification including a Phillips curve equation and a system of equations representing the output gap dynamics. Therefore, the parameters and the gap series are estimated to obtain consistent figures with the inflation rate and the underlying output gap dynamics. The general form of the model is as follows:

[4] See, for example, Clarida, Gali and Gertler (2002), in which this argument is forcefully demonstrated with special reference to European inflation dynamics.

[5] As an example, Özlale and Özcan (2003) find evidence about the validity of a time-inconsistency problem for the Turkish economy in the last decade, implying a negative relation between inflation and the output gap. Also, Özbek and Özlale (2004) show that there is not strong evidence regarding a positive relationship between these two variables.

(1) *Inflation-Output Gap Dynamics:*

$$\pi_t = \alpha_{1,t}\pi_{t-1} + \alpha_{2,t}\pi_{t-2} + \alpha_{3,t} gap_{t-1} + \alpha_{4,t} reer_t + v_t$$

(2) *Actual Output Decomposition:*

$$y_t = y_t^* + gap_t$$

(3) *Potential Output Equation:*

$$y_t^* = y_{t-1}^* + \mu_{t-1} + \eta_t$$

(4) *Potential Output Growth Rate Equation:*

$$\mu_t = (1-\rho_t)\mu_0 + \rho_t \mu_{t-1} + \varepsilon_t$$

(5) *Output Gap Dynamics:*

$$gap_t = \gamma_{1,t} gap_{t-1} + \gamma_{2,t} r_t + \gamma_{3,t} DI_t + \gamma_{4,t} reer_t + \zeta_t$$

where π_t is the inflation rate defined as the logarithmic difference of quarterly seasonally adjusted consumer price index (CPI), gap_t is the unobserved output gap, $reer_t$ is the logarithmic difference of the real effective exchange rate, y_t is the logarithmic seasonally adjusted real gross domestic product, y_t^* is the unobserved potential output, μ_t is the potential output growth rate, r_t is the ex-post real interest rate based on 3-month Treasury auction rates, and DI_t is the demand index, which is constructed from the Business Tendency Survey of the Central Bank of the Republic of Turkey. The derivation of the demand index along with other data descriptions are presented in Appendix 3. Finally, v_t, η_t, ε_t, and ξ_t represent shocks to the system, which are assumed to be i.i.d. with zero mean and constant variances.

It is important to remind that the parameters of the system are time varying. Therefore, one has to make a time-series specification for the evolution of these parameters. It is assumed that each time-varying parameter follows a random walk. Such a specification can be defended on theoretical grounds: Since any structural change on the dynamics of the model–thus the system parameters–cannot be known a priori, it is intuitive to specify a random walk process for each parameter. As a result, the system includes nine more equations, where each time-varying parameter follows a random walk process.

Equation (1) is a fairly standard reduced form Phillips curve specification including lagged inflation terms, lagged output gap, and the change in the real effective exchange rate. Accordingly, persistence in inflation is reflected in inertial terms up to two lags. Output gap is assumed to affect inflation with a lag since it takes time for the pressure on production costs to be revealed and for prices to be adjusted in response to a demand shock. On the other hand, changes in the real effective exchange rate capture the effects of the exchange rate dynamics on the inflation both through the "cost of production channel" and through the prices of imported final goods [6].

Equation (2) is the identity defining output as the sum of the potential output (trend component) and the output gap (transitory component). Equation (3) defines potential output as a random walk with a drift model, implying that shocks to trend output are permanent. Moreover, the drift term, trend growth, is allowed to vary over time and the persistence can be shaped with respect to different values of ρ. Needless to say, trend growth may change over time along with labor force, productivity or technology developments. Moreover, in a recent study, Aguiar and Gopinath (2004) state that emerging markets are subject to extremely volatile shocks to the stochastic trend and provide evidence that emerging market business cycles are driven by shocks to the trend growth rate which may result from extreme and relatively frequent changes in economic policies. Taking these factors into account, potential growth rate is modeled as time-variant. In this respect, equation (4) defines potential growth as a first-order autoregressive process with long-run average growth rate of μ_0 and autoregressive coefficient $0 \langle \rho \langle 1$ representing the persistence in trend growth. The magnitude of ρ shows the persistence of the deviations from the long run growth rate μ_0 [7]. The system allows for a time-varying estimation of the persistence parameter. An estimated ρ close to one means the potential output can deviate from the steady state for substantially long periods. In this respect, the setting also provides a framework to test the "cycle is the trend" hypothesis in emerging market economies, which is discussed in Aguiar and Gopinath (2004).

Equation (5) specifies the output gap dynamics. Rather than modeling the output gap by a purely stochastic process–as most models do–we include variables that can provide extra information on the evolution of the output gap. We choose the variables employed in the

[6] See Leigh and Rossi (2002) for more on exchange rate pass-through in Turkey.
[7] The sustainable steady-state real growth rate for the economy is assumed to be 4.5 percent on annual basis, which corresponds to 1.106 percent per quarter. As shown in the sensitivity part, our output gap computations are fairly robust to the underlying assumption for the steady state growth rate.

equation so as to characterize a set of broad macroeconomic variables that may affect the actual output, but not the potential output. The main variables included are the lagged output gap, real interest rate, the expectations of the business sector participants in the economy and the changes in the real effective exchange rate. Although these factors are vital in explaining the output performance in the short-run, they are viewed to be more effective on the demand side, and thus, neutral for the behavior of potential output in the short run. Therefore, these variables appear in the output gap equation to account for the deviation of actual output from its potential level.

In this respect, the real interest rate undertakes its traditional role as affecting the consumption and the investment behavior in the economy. The inclusion of DI_t captures the information content that is embedded in the private sector expectations. In other words, expectations index is supposed to capture the firms' prospects about demand conditions, which may be a major determinant of the output gap along with the real interest rate.

Although the role of expectations and the real interest rates in the whole system are clear, the role of the exchange rate dynamics on the output gap is less certain and thus should be discussed in details. As mentioned in the first section, the seemingly positive relationship between inflation and the output gap can partly be driven by another factor, which could affect both of the variables contemporaneously. In this context, since the real exchange rate can play such role, it is included both in the first and the fifth equations. Moreover, the real exchange rate affects the output gap through two distinct and opposite channels. First, an appreciation leads to a decline in the relative prices of imported goods and leads to a temporary hike in actual demand, raising the gap between the actual and the potential. Second, in a country where capital goods are mostly imported, *ceteris paribus*, an exchange rate appreciation induces firms to substitute capital for labor, leading to an increase in labor productivity, and thereby increasing the potential output as well. Also, such an appreciation will lead to a decrease in the cost of imported intermediate goods, which would increase the supply in the economy. The question of which of these factors dominates may depend on the specific state of the economy. Therefore, the net effect of the changes in the exchange rate on the output gap is not clear, at best. Various factors such as the exchange rate elasticity of net exports, the magnitude of the exchange rate pass-through, the importance of imported capital goods in the overall production should be taken into account in order to reach a robust conclusion.

It can also be argued that several other exchange rate measures could be used both in the inflation specification and the output gap equation. For example, import price inflation could be a better candidate in explaining the exchange rate pass-through to prices while deviations of the real exchange rate from its long-run trend could be used in the output gap specification[8]. However, we believe that a common variable, which could be effective on both the inflation and the output gap dynamics, could be more appropriate to identify the inter-linkages among the dynamics of output, inflation and the exchange rates. Therefore, the changes in the real effective exchange rate have been used in both the inflation and the output gap specification.

State-Space Representation of the Model

State-space modeling has been extensively used in the estimation of potential output in recent years. It does not only provide the opportunity for building encompassing models, but also simplifies the formulation of rather complicated problems. Besides, once the model is written in a state-space form, it becomes straightforward to obtain the required estimates by utilizing the Kalman filter algorithm. The general form of the state-space formulation can be represented as:

$$
\begin{aligned}
x(t) &= Fx(t-1) + Gu(t) + e_1(t) \\
z(t) &= Hx(t) + e_2(t)
\end{aligned}
$$

where e_1 and e_2 denote vectors of normally distributed i.i.d. shocks which are assumed to be uncorrelated and have covariance matrices R_1 and R_2, respectively. Furthermore, u(t) is the vector of exogenous variables. In this respect, our measurement equation, where the evolution of the observed variables (inflation and output) is described as a function of the unobserved state variables, is as follows:

$$
\begin{bmatrix} \pi_t \\ y_t \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 \end{bmatrix} \begin{bmatrix} \pi_t \\ \pi_{t-1} \\ y_t^* \\ \mu_t \\ gap_t \end{bmatrix}
$$

[8] Employing Prior Consistent filter, Benes and N'Diaye (2003) uses such a measure. However, following Meese and Rogoff (1983) and Edwards and Savastano (1999), there is not a commonly agreed methodology in determining the equilibrium real exchange rate, and thus the deviations from such equilibrium.

The second measurement equation is the identity specified in equation (2) of the model, which states that the actual output is equal to the sum of the potential output and the output gap. The unobserved variables (potential output, potential output growth rate and the output gap) and inflation rate evolve according to the following transition equation:

$$\begin{bmatrix} \pi_t \\ \pi_{t-1} \\ y_t^* \\ \mu_t \\ gap_t \end{bmatrix} = \begin{bmatrix} \alpha_{1,t} & \alpha_{2,t} & 0 & 0 & \alpha_{3,t} \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & \rho_t & 0 \\ 0 & 0 & 0 & 0 & \gamma_{1,t} \end{bmatrix} \begin{bmatrix} \pi_{t-1} \\ \pi_{t-2} \\ y_{t-1}^* \\ \mu_{t-1} \\ gap_{t-1} \end{bmatrix} + \begin{bmatrix} \alpha_{4,t} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & (1-\rho_t) & 0 & 0 \\ \gamma_{4,t} & 0 & \gamma_{2,t} & \gamma_{3,t} \end{bmatrix} \begin{bmatrix} reer_t \\ \mu_0 \\ r_t \\ DI_t \end{bmatrix} + \begin{bmatrix} v_t \\ 0 \\ \eta_t \\ \varepsilon_t \\ \zeta_t \end{bmatrix}$$

where η_t, ε_t, ξ_t and v_t are assumed to be independent and identically distributed normal white-noise processes.

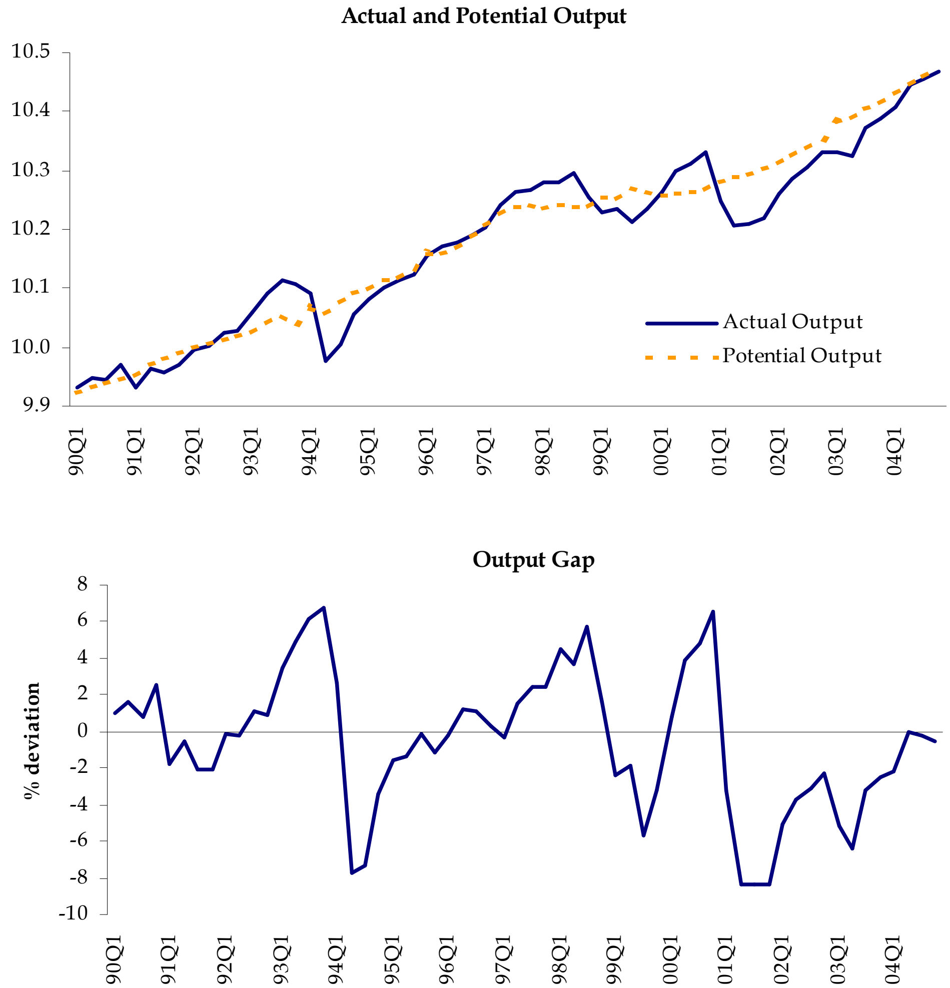
Non-Linearity in State Space Models and EKF

Transition matrix contains time-varying parameters to be estimated. Moreover, both these parameters and the state variables, which are to be estimated simultaneously, are presented in multiplicative form. Such a representation causes the state space model to take a non-linear form, where SKF becomes inappropriate to employ. In this context, EKF emerges as the estimation methodology, which consists of using the SKF equations to the first-order approximation of the non-linear model about the last estimate. In this case, the time-varying parameters, which were all assumed to follow random walk, are treated as a new state vector and added to the initial transition equation. Then, EKF procedure can be applied to estimate the new state vector, which contains the parameter vector as one of its components. The EKF procedure, its application and the smoothing algorithm are described more comprehensively in Appendix 1.A.

III. Empirical Findings

Based on the discussion above, first, the parameter vector, which contains nine equations, is formed. Next, the state vector and the parameter vector are combined to produce the new enhanced transition equation. Finally, EKF is applied to obtain the estimates for both the state variables and the time-varying parameters in the model. This section displays and interprets these estimation results. Initially, we start with the estimated potential output and the output gap, which are presented below in Figure 1.

Figure 1. Actual Output, Potential Output and Output Gap



The output gap estimate displays the fact that the Turkish economy has been subject to severe shocks–economic crises that created an unstable environment, ending with rapid contractions in the economic activity–for several times in the sample period. As a consequence, output gap estimates exhibit sharp movements. Moreover, estimated potential output is far less smooth than a potential output that could be obtained using a standard filtering technique. These findings are also in line with Aguiar and Gopinath (2004), which argue that shocks to potential output are vital in explaining the business cycles in emerging markets.

According to the output gap figure, expansion periods were generally interrupted by economic crises so that the last decade seems to have witnessed three separate periods of recession. Such an observation validates both the excessive boom-bust cycle peculiar to emerging markets and the "unsustainable growth path" that the Turkish economy followed in the last decade.

At the second quarter of 1994, due to the deep financial crisis, output declined drastically. Our measures point to a negative output gap, which almost reached to 8 % in this period. Following the trough at 1994Q2, the economy started to recover and actual output exceeded its potential level approximately after seven quarters. Between 1996 and 1998, the actual output remained above its potential level where 1998Q3 was a peak for the economy. This was a period, where high interest rates attracted short-term capital, fiscal policy was expansionary and the real exchange rate was being targeted in the pursuit of financial stability with an accommodative monetary policy. However, it was obvious that such an expansionary period increased the fragility of the economy, and thus destined to be rather short-lived. The period starting from 1998Q3 has witnessed several internal and external shocks hitting the Turkish economy. The Russian crisis at 1998Q3 and the devastating earthquake at 1999Q3 were the major shocks driving the economy into a recession, which manifested itself as a trough at 1999Q3.

One common feature of 1994 and 1998 crisis was the short-lived negative output gap (less than 4 quarters) and relatively fast recovery of economic activity after the crisis. Perhaps this explains why those contraction periods did not lead to a decline in inflation. In order to permanently solve the prolonged problem of high inflation and unsustainable growth, Turkey announced an IMF-supported exchange rate-based stabilization program in the context of a crawling peg regime to be adopted by the beginning of 2000. It did not take a long time for the economy to recover. Indeed, the revival was quick, characterized by a rapid expansion in the output and thus the output gap. The early stages of the program witnessed a sizeable drop in the interest rates, rapid credit growth, and appreciation of the Turkish lira in real terms, eventually boosting the domestic demand. Consistent with the underlying story, our measures point out a positive output gap by the beginning of 2000Q1.

In the year 2000, the high-rated rises in imports, due to the expanding domestic demand and production, caused concerns about the sustainability of the current account. Moreover, due to the fragile structure of the banking sector, having potential problems such as maturity mismatches and open foreign exchange positions, the economy was even more vulnerable to speculative attacks. In addition to the anxiety associated with economic dynamics, the political problems such as the reluctance of the government in delivering structural reforms became evident. As perceptions of the vulnerability of the economy became more pronounced, the economic agents were already questioning the prospects of the macroeconomic program. The first signal of the breakdown of the program came in November 2000. Succeeding collapse of the crawling peg regime at February 2001 dragged the economy into the deepest recession that Turkey has ever experienced. The crisis had been extremely detrimental to the economic activity, which led to a trough at 2001Q4. In the post-crisis period, a new economic program was implemented. The main pillars of the program was banking sector reform, central bank independence and maintaining fiscal discipline. These macroeconomic policies induced significant achievements on the way to economic stability. In this respect, along with the declining inflation, high growth rates were attained after 2002. As a consequence, output gap has closed significantly, approaching to zero as of the second quarter of 2004.

The figures reveal that, although the output gap seems to have closed as of the first quarter of 2004, its slow convergence has contributed dramatically to the disinflation process since the February 2001 economic crisis. Indeed, one major difference between 2001-2004 period from 1994 and 1998-1999 periods was definitely the gradual recovery of the economy in the former. Tight fiscal and monetary policies have surely contributed to this process. [9]

Time-Varying Parameter Estimates

Time-varying parameter estimates of the system are consistent with the observations of the last decade and thus easy to interpret. The evolutions of these parameters, which can be analyzed due to the recursive nature of the extended Kalman filter algorithm, are displayed in Appendix 2. The common emphasis of the recursive estimates is that economic crises had a significant influence on the parameters. Especially, dramatic changes in the parameter estimates can be observed after the 1994 crisis.

The autoregressive coefficient of potential growth is estimated between 0.75 and 0.85 through the whole sample, and 0.77 at the end, implying that potential growth is fairly persistent. This means, in the absence of shocks, output growth would converge within 1 percent of the steady-state rate in just about 5 years. Therefore, we can interpret shocks to the

[9] On the other hand, one should be careful in interpreting our output gap measures. The measure we present does not capture explicitly the labor market conditions in the economy. In that sense, as we noted earlier, it may be incomplete to make judgments on future inflation just by looking at the output gap. One should also carefully evaluate the labor market conditions, unemployment rate, and the other cost factors such as exchange rates, wages and energy prices to have a more reliable assessment of future inflationary pressures.

trend growth as “near-permanent” in Turkey. On the other hand, the sum of the coefficients regarding π_{t-1} and π_{t-2} is high, pointing to a significant degree of persistence implying a strong inflationary inertia (Table 1).

Table 1. End-Sample Estimates for the Model Parameters

Model Parameters	Baseline Model	Alternative Model 1	Alternative Model 2
α_1	0.37	0.26	0.61
α_2	0.59	0.65	0.31
α_3	0.43	0.12	0.27
α_4	-0.03	-0.07	-
ρ	0.77	0.71	0.78
γ_1	0.21	0.52	0.25
γ_2	-0.08	-0.07	-0.02
γ_3	0.19	-	0.21
γ_4	0.02	-	0.02

Parameter estimates in the inflation specification reveal that depreciation of the currency and the positive output gap exert pressure on inflation, as expected. The depreciation of the domestic currency increases inflation both by an increase in the prices of imported final goods and by an increase in the cost of production through imported capital goods. On the other hand, the positive relationship between inflation and the output gap is consistent with the standard Phillips curve notion.[10]

The role of the real exchange rate on the output gap measures, which is shown with the parameter γ_4, should also be discussed. Keeping in mind that an increase in the series point out an appreciation of the Turkish Lira, we find a positive relationship between the real exchange rate changes and the output gap. Such a finding is consistent with the view that the cost channel of the exchange rate on the output gap dominates the demand channel. In other words, appreciation of the domestic currency leads to a significant decline in the cost of the imported capital goods, thereby results in an increase in the production. Such an increase outweighs possible decrease in the net exports that may be caused by the appreciation of the Turkish Lira.

As a result, these findings suggest that, the periods of low inflation and positive output gap coincide with the periods of appreciation. This may be due to the heavy importance of the imported goods on both the production process and the consumer basket. In addition, even

[10] In a previous study, Öğünç and Ece (2004) also find a positive relation between inflation and output gap with a parameter estimate of 0.24.

after controlling for the role of the exchange rates, we still find that a positive output gap causes an inflationary pressure in the economy.

Real interest rate is of expected sign in explaining the output gap dynamics, except for the beginning of the sample period. Moreover, the effect of real interest rate on output gap as of 2004Q2 is estimated as –0.08. Until 1996, we observe that real interest rates and output gap have a positive relationship. It is interesting to observe that, after 1996, the relationship between real interest rate and output gap turns out to be negative, in line with economic theory. The unstable empirical coefficient of the effect of the interest rate on output gap in Turkey can be attributed to several factors. First of all, interest rates had never been used as a policy instrument to attain the inflation target, prior to the floating regime. Instead, most of the sample period is dominated by crawling pegs/fixed exchange rate regimes, where the exchange rate developments have been the primary determinant of inflation and output dynamics in Turkey. Second, in an unstable economy with high and persistent inflation and uncertainty, real interest rates generally remained at excessively high levels. This, in turn, rendered the economic agents' decisions as insensitive to intertemporal shifts in the real interest rates, weakening the link between the interest rates and spending decisions. In this respect, during 80's and 90's, interest rate sensitivity of aggregate demand was limited and conventional monetary transmission mechanism was not evident in Turkey.

Time varying parameter estimates suggest that, transition to a financial restructuring period and a new policy regime--implicit inflation targeting along with the floating exchange rate regime-- in February 2001 have had significant effects on underlying economic dynamics in Turkey. Since then, short-term interest rates have been actively used as the policy instrument to attain announced targets for the inflation rate. Moreover, there is evidence on weakened exchange rate pass-through on prices.[11] As a consequence, developments after 2001 crisis indicate that, the impact of interest rates on inflation and output gap has significantly risen. Therefore, our findings on time varying parameter of the real interest rate may be a sign of increased effectiveness of interest rate as a policy instrument in expectations management and output dynamics.

As a result, all of the parameter estimates in the model are reasonable when the characteristics of the Turkish economy in the last decade are taken into account. Moreover, the changing impact of the real interest rate on the output gap signals that interest rates are more relevant as a policy instrument in the recent years than they used to have been.

[11] See Kara, Küçük, Tuğer, Özlale and Yücel (2004) for more evidence on reduced exchange rate pass-through.

IV. Sensitivity Analysis

In order to analyze whether the results presented in the previous section are sensitive to the specification of the model (and to the magnitude of the shocks), we estimate both the output gap and the system parameters along with the other two specifications about the output gap dynamics. Also, we analyze whether our output gap estimates are sensitive to the underlying steady state growth rate of potential output. It turns out that, our output gap computations are fairly robust to the underlying assumption for the steady state growth rate. Finally, in order to test our results against alternative methods, we estimate the output gap with both the HP filter and the SKF to make a sound comparison.

Alternative Models

As mentioned above, in view of the inherent uncertainty regarding the main characteristics of Turkish economy, we have developed two alternative models in addition to the one described above. One of these models implies a distinct output gap dynamics while the other one excludes real exchange rate from the inflation equation. Monitoring the results of different specifications will provide flexibility for better evaluation and interpretation of the output gap estimates.

Given the theoretically ambiguous sign of the relationship between output gap and the real exchange rate, and the ad-hoc nature of the demand index, as a first alternative model, we dropped the demand index and the real exchange rate from the output gap dynamics. Therefore, in the first alternative model, only the lagged value of the output gap and the real interest rate appear in the output gap specification. Such a restriction imposes the assumption that the output gap is affected solely by the monetary policy actions. Finally, in our second alternative, we specify inflation only as a function of its lagged values and the output gap while remaining equations appear as in the benchmark model. Assuming that changes in the exchange rate affect prices with a lag, it can be argued that the effects of the exchange rate are already inherent in the lagged values of the inflation.

Figure 2. Output Gap Estimates Under Different Models

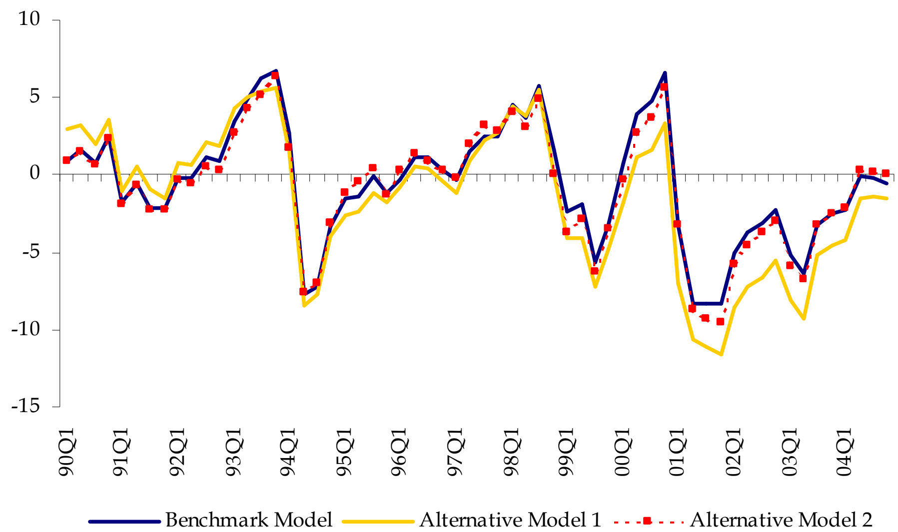


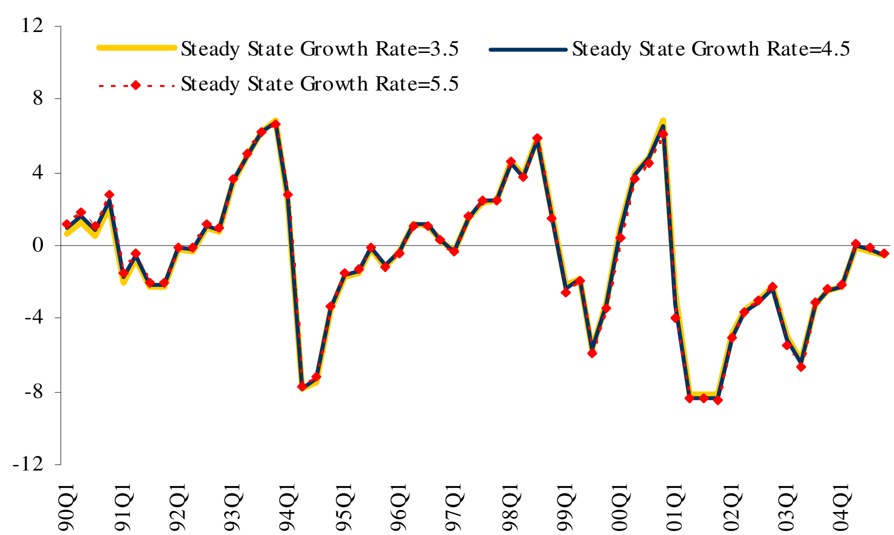
Figure 2 displays the output gap estimates obtained under our benchmark model and two alternative models. The end-sample coefficient estimate of the output gap in the inflation specification for the first alternative model is 0.12. On the other hand, in the second alternative model, when the coefficient of the real exchange rate is restricted to zero, output gap still remains to be a significant determinant of inflation with an estimated coefficient of 0.27 at the end of the sample (Table 1). Therefore, the exercise of estimating the output gap under different model specifications implies that the role of the output gap on the inflation dynamics is robust regardless of the presence of the exchange rate dynamics in the inflation specification. In other words, irrespective of the role of the exchange rate in the output gap dynamics, positive (negative) output gap is inflationary (disinflationary) in Turkey.

The figure reveals that, the three models exhibit a similar pattern qualitatively, whereas there are only minor differences in quantitative terms. Moreover, these discrepancies mostly occur in the peak or the trough of the cycle. All of the contractionary and expansionary periods are evident. All in all, it can be conveniently claimed that all of the models point out a similar output gap path and the results are fairly robust to different specifications about output gap and inflation dynamics.

Alternative Steady State Growth Rate Assumptions

The method employed in this paper primarily focuses on estimating the output gap along with its own dynamics as well as its relationship with inflation. Although this method is more structural compared to purely statistical methods, the whole process can be named as quasi-structural as the potential output is defined as following a purely stochastic process with a long run steady state potential growth rate of μ_0.[12] Given the *ad-hoc* nature of such a specification, one have to check whether the output gap estimates are sensitive to long-run potential growth rate parameter, μ_0. The figure points to the robustness of the output gap estimate to alternative steady state trend growth assumptions (Figure 3). The output gap measures are almost identical in all of the specifications in question, implying that our output gap estimates are fairly robust to the assumption on long run potential growth rate.

Figure 3. Output Gap Estimates Under Different Steady State Growth Rate Assumptions



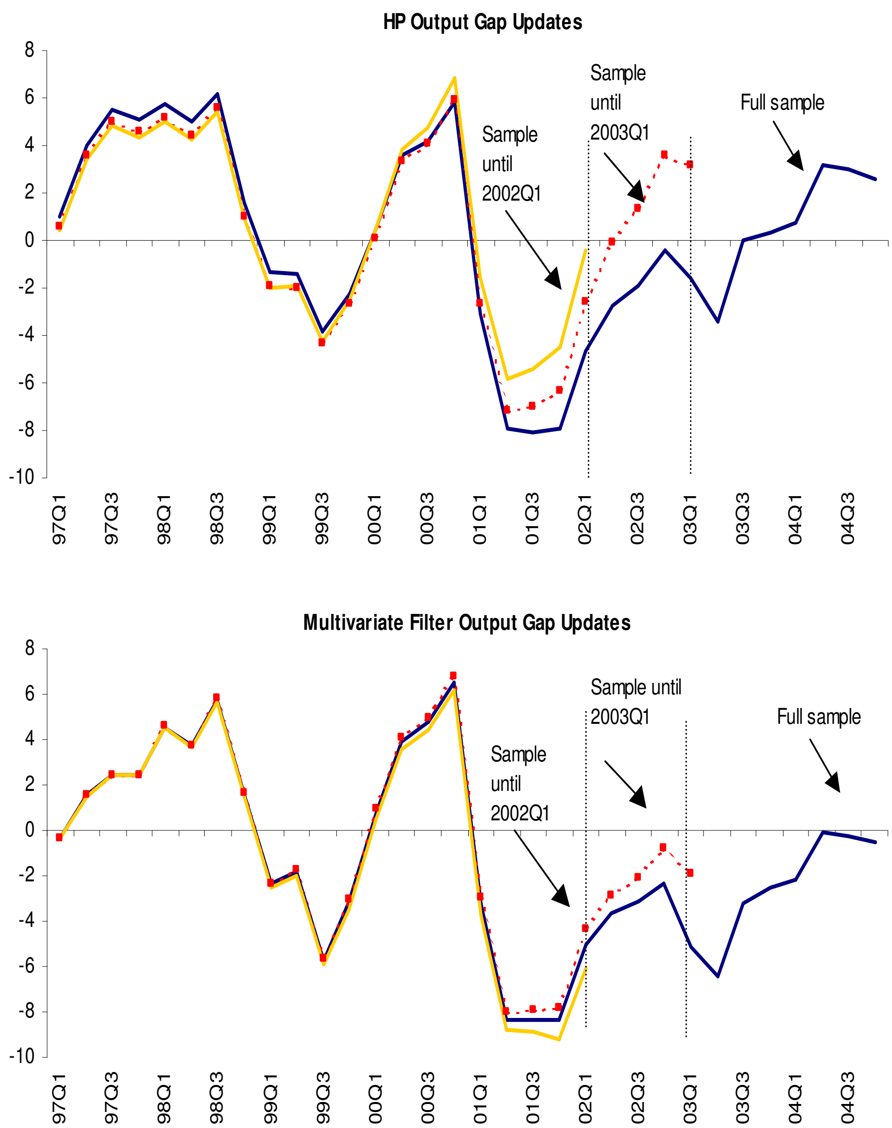
Sensitivity to Data Revisions (Comparison with HP Filter)

One major drawback of the typical output gap estimates used in the literature is the sensitivity to the data revisions or new data. Moreover, because the filters use both past and future data, there is a problem at the end of a sample due to absent future data. This problem

[12] An alternative way to approach this problem could be the production function approach; in other words, deriving potential output from structural models integrated with main determinants of growth such as physical and human capital, labor, and technology. We do not attempt to estimate potential output using such measures since we do not have access to a reliable capital stock data for the Turkish economy.

is generally entitled as “end point” problem. In order to assess whether our results suffer from the same syndrome and to see how sensitive they are to the inclusion of new data or revisions, our estimates will be compared with the HP filter results.

Figure 4. HP versus MV Filter Revisions



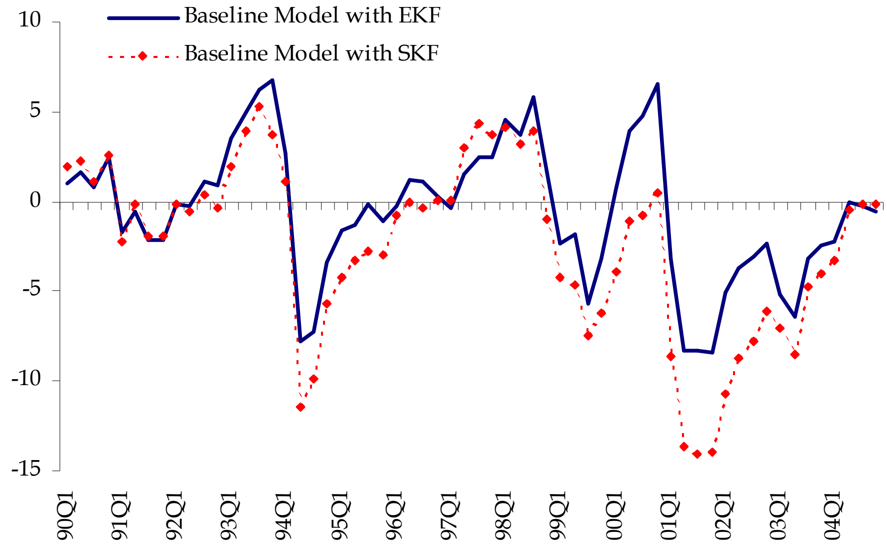
Ideally, the output gap estimates should neither be revised drastically nor exhibit large swings when new observations are added into the analysis. Figure 4 compares the results from two filtering methods, when the sample is cut at two alternative points–2002:Q1 and 2003:Q1. The resulting HP filter estimates exhibit major differences. Just to give a striking example, when the sample is cut at 2003:Q1, output gap is positive with a magnitude of 3.2 percent, where as the full sample estimates point to a negative gap with a magnitude of 1.6. However, the same exercise for the multivariate filter does not produce diverging results. The gap estimates are close to each other and fairly insensitive to the inclusion of new data.

These findings reveal that purely statistical findings may be misleading in output gap estimates. Especially when the economy is subject to large swings, the revisions in the output gap as the new data arrives can be surprisingly large. On the other hand, multivariate filters relying on more structural macroeconometric relationships may improve drastically on their purely statistical counterparts.

Extended vs. Standard Kalman Filter

We have already argued that, in a country that is subject to severe shocks and regime shifts, model coefficients are not expected to stay constant, which was our main motivation for using the EKF method. Accordingly, the major contribution of this study to the existing literature on the estimation of output gap is the time-varying parameter framework, which is believed to be more appropriate regarding the economic dynamics specific to the Turkish economy. Such a methodology imposes a non-linearity to the model and thus requires the use of EKF. However, it still remains to be checked whether the output gap estimates derived using the assumption of time-varying parameters significantly differs from that of time-invariant parameters, which is the task of this subsection. In order to do so, we estimate our baseline model with the parameters assumed to be constant over time by utilizing SKF and compare the results with those obtained from the EKF (Figure 5).

Figure 5. Comparison of EKF and SKF Results for the Output Gap



The alternative output gap figures exhibit a resemblance in terms of their turning points whereas significant level differences are observed especially for the two crisis periods–1994 and 2001–and the expansion period of 2000. Probably the most striking difference is related with the expansion in 2000: Contrary to EKF estimates; even high economic activity observed throughout the year 2000 could not push the output gap to positive levels according to SKF results. On the other hand, end-sample information revealed by two estimates is similar, with actual output approaching to its potential level.

V. Summary and Concluding Remarks

This paper presented a time-varying parameter methodology for constructing an estimate of output gap by exploiting the extended Kalman filter technique in a multivariate setting, incorporating economic content by the inclusion of inflation and output gap dynamics. Several results emerge out of our findings: First of all, we have shown that estimating the potential output and output gap in a multivariate setting has many advantages over univariate techniques, such as the HP filter. Our sensitivity analysis points out, for example, that using a purely statistical filter can lead to serious policy mistakes.

To give an explicit idea, suppose that the central bank had employed a typical Taylor rule for the conduct of monetary policy where output gap is one of the parameters against which the monetary authority reacts. Had the central bank measured the output gap by HP filter, *ceteris paribus*, monetary stance would have been tightened in Turkey right after the second quarter of 2002. On the contrary, had the central bank used extended Kalman filter to measure output gap, the Taylor rule would command a loosening in the monetary policy. Given that inflation has fallen drastically after 2002 with no explicit tightening in monetary policy, it is clear that in such a setting our multivariate setting would be superior to its statistical counterparts such as the HP filter.

Second, our output gap estimates confirm the historical boom-bust cycles and point out that business cycles (if it exists) of Turkey display sharp turning points rather than exhibiting smooth patterns. Sharp transitions between expansion and recession periods reflect several internal and external disturbances causing severe economic crises in the last ten years. Moreover, our empirical findings also point that the sizeable output gap of 2001 has been shrinking more gradually than the gaps of 1994 or 1998 crisis. This finding also suggests that, the contribution of the output gap to the rapid disinflation process in 2002-2004 has been considerable.

Third, historical inflation and output gap dynamics seem to have been largely determined by exchange rate movements and expectations, leaving little room for a conventional monetary transmission mechanism where the real interest rate is the main policy tool of the monetary authority. However, our findings bode well for the current and future effectiveness of the monetary policy. The evolution of the time varying parameters point that, the extent of the relation between real interest rates and the output gap has been subject to change in recent years. Specifically, a hike in the real interest rate seems to be associated with a decline in the output gap increasingly for the last couple of years. Moreover, the impact of output gap on inflation has been rising. Whether central bank can apply the 'lean against the wind' policy in fighting inflation, on the other hand, still remains to be tested.

Nevertheless, all these findings should not lead one to undermine the caution associated with output gap measures. Since output gap is unobservable by definition, its measures are not more reliable than the model they are based on. Therefore, establishing the best model representing the true structure of the economy is of great importance. Moreover, data revisions and lags in the announcement of data give rise to criticisms about real-time accuracy of the output gap estimates, since the information available to the policy maker at the time policy decisions are taken can be subject to significant changes.

Notwithstanding these shortcomings and practical problems, output gap still continue to appear in inflation reports of many central banks. On the other hand, being aware of numerous shortcomings of the output gap measures, most central banks acknowledge that output gap is just one variable in the information set of the policy maker among many indicators for forecasting future inflationary pressures, and thus, interpretation of the output gap measures along with the information provided by other indicators will improve the overall quality of assessing inflationary pressures. This is, to some extent, equivalent to utilizing other relevant information that is not captured by the multivariate filter. For instance, labor market dynamics is not represented explicitly in our model. Considering the non-inflationary, albeit high-rated, growth performance of the Turkish economy in the last three years, one should not undervalue the role of labor market developments characterized with high unemployment rates and declining real wages. In other words, rigidities in the labor market, which have been contributing to recent disinflationary process in Turkey, should also be taken into account in policy analysis. This observation suggests that, the joint estimation of output gap and unemployment gap is one extension to be explored.

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APPENDIX

1.A Extended Kalman Filter Algorithm[±]

Following algorithm presents the results when the extended Kalman filter is applied to the estimation of the parameter vector of $\theta = (\alpha_1, \alpha_3, \rho, \gamma_1, \alpha_2, \alpha_4, \gamma_2, \gamma_3, \gamma_4)$. In addition to the usual Kalman filter algorithm, in here we have also random parameters, which are assumed to be evolving according to the random walk process. Simply, in the EKF case, because of the non-linear relationship, we linearize the process and measurement functions at the current state estimate by using the partial derivatives and then apply the usual Kalman filter algorithm.

The unobserved state vector X can be seen as partitioned into two parts: one is the usual unobserved state variables and other is the unknown parameter vector:

$$X(t) = \begin{pmatrix} x(t) \\ \theta(t-1) \end{pmatrix}, \ \bar{K}(t) = \begin{pmatrix} K(t) \\ L(t) \end{pmatrix}, \ \bar{P}(t) = \begin{pmatrix} P_1(t) & P_2(t) \\ P_2^T(t) & P_3(t) \end{pmatrix} \qquad \textbf{1.A.1}$$

where $\bar{K}$ and $\bar{P}$ are the Kalman gain and covariance matrix for the extended state. Then the general algorithm:

$$S_t = H_t P_1(t) H_t^T + H_t P_2(t) D_t^T + D_t P_2^T(t) H_t^T + D_t P_3(t) D_t^T + R_2 \qquad \textbf{1.A.2}$$

$$L(t) = \left[P_2^T(t) H_{t-1}^T + P_3(t) D_t^T \right] S_t^{-1} \qquad \textbf{1.A.3}$$

$$K(t) = \left[F_t P_1(t) H_t^T + M_t P_2^T(t) H_t^T + F_t P_2(t) D_t^T + M_t P_2(t) D_t^T + R_{12} \right] S_t^{-1} \qquad \textbf{1.A.4}$$

$$P_1(t+1) = F_t P_1(t) F_t^T + F_t P_2(t) M_t^T + M_t P_2^T(t) F_t^T + M_t P_3(t) M_t^T - K(t) S_t K^T(t) + R_1 \qquad \textbf{1.A.5}$$

$$P_2(t+1) = F_t P_2(t) + M_t P_3(t) - K(t) S_t L^T(t) \qquad \textbf{1.A.6}$$

$$P_3(t+1) = P_3(t) - L(t) S_t L^T(t) + Q \qquad \textbf{1.A.7}$$

$$\hat{x}(t+1) = F_t \hat{x}(t) + G_t u(t) + K(t) \left[z(t) - H_t \hat{x}(t) \right] \qquad \textbf{1.A.8}$$

[±] The algorithm is discussed in details in "Theory and practice of recursive identification" by Ljung and Soderstrom (1983).

$$\hat{\theta}(t) = \hat{\theta}(t-1) + L(t)\left[z(t) - H_{t-1}\hat{x}(t)\right] \quad \textbf{1.A.9}$$

Here, $F_t = F(\hat{\theta}(t))$, $G_t = G(\hat{\theta}(t))$, $H_t = H(\hat{\theta}(t))$ **1.A.10**

$M_t = M(\hat{\theta}(t), \hat{x}(t), u(t))$, with $M(\hat{\theta}, x, u) = \frac{\partial}{\partial \theta}\left[F(\theta)x + G(\theta)u\right]\Big|_{\theta=\hat{\theta}}$ **1.A.11**

and $D_t = D(\hat{\theta}(t-1), \hat{x}(t))$ with $D(\hat{\theta}, x) = \frac{\partial}{\partial \theta}\left[H(\theta)x\right]\Big|_{\theta=\hat{\theta}}$ **1.A.12**

Finally, regarding the initial values:

$$P_1(0) = P_{1,0},\ P_2(0) = 0,\ P_3(0) = P_{3,0},\ \hat{x}(0) = x_0,\ \hat{\theta}(0) = \theta_0 \quad \textbf{1.A.13}$$

1.B The Smoothing Algorithm

The potential output can be estimated in two different ways depending on what information is used. The filtered estimate at time t is one-sided and it uses information up to time t ($y^*_{t|t}$). Therefore, Kalman filter, used as a real-time or online algorithm, estimates the state vectors exploiting the current and past information. On the other hand, a smoothed value is two-sided and uses information from the whole sample, up to time T ($y^*_{t|T}$ where 0≤ t ≤ T). In this way, the smoothing algorithm allows for considering future information as well, in the estimation of potential output. Unless there is some immediate real-time constraint, state estimates can be improved by using the smoothing algorithms. Referring to the fixed interval-smoothing (Rauch-Tung-Striebel Two-Pass Smoother) algorithm, the smoothed estimator can be defined as:

$$X(t-1 \mid T) = X(t-1 \mid t-1) + B(t)[X(t \mid T) - X(t \mid t-1)] \quad \textbf{1.B.1}$$

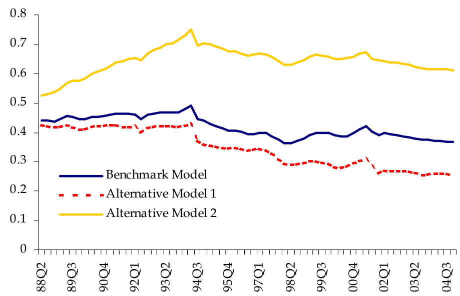
with its corresponding covariance matrix,

$$\overline{P}(t-1 \mid T) = \overline{P}(t-1 \mid t-1) + B(t)[\overline{P}(t \mid T) - \overline{P}(t \mid t-1)]B(t)' \quad \textbf{1.B.2}$$

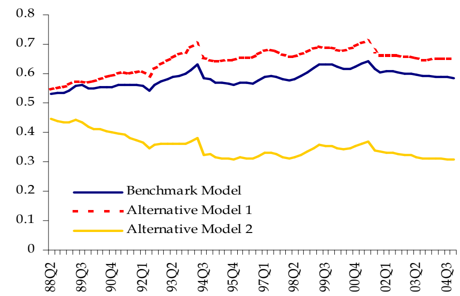
where $B(t) = \overline{P}(t-1 \mid t-1) f(t)' \overline{P}^{-1}(t \mid t-1)$ for t=T…1 and $f(t) = \begin{bmatrix} F_t & 0 \\ 0 & I_{k \times k} \end{bmatrix}$ with k representing the number of the time-varying parameters. Since the smoother is based on more information than the filtered estimator, it will have an MSE that is smaller than that of the filtered estimator.

2. Time-Varying Parameter Estimates Under Alternative Models

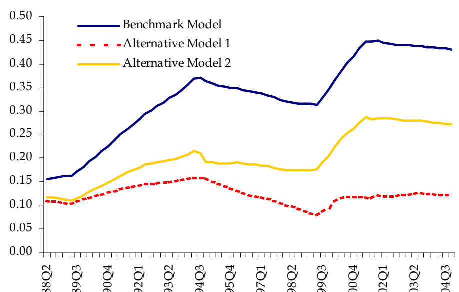
α_1 (Coefficient of π_{t-1})



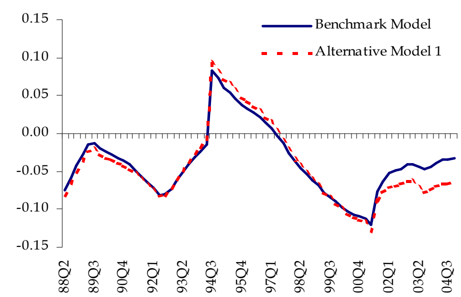
α_2 (Coefficient of π_{t-2})



α_3 (Coefficient of gap_{t-1})

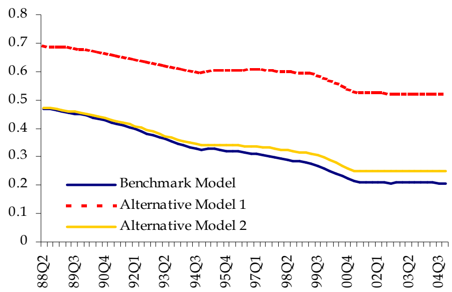


α_4 (Coefficient of $reer_t$)

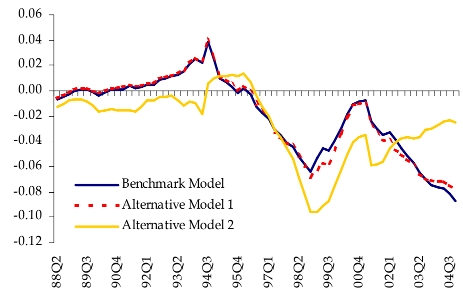


2. Time-Varying Parameter Estimates Under Alternative Models (continued)

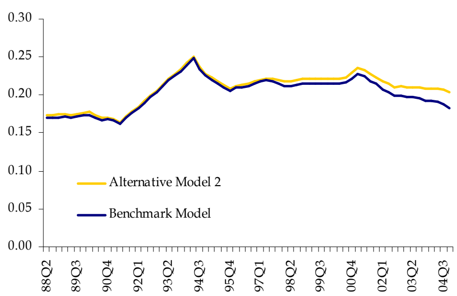
γ_1 (Coefficient of gap_{t-1})



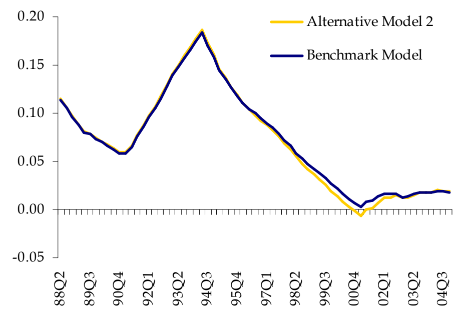
γ_2 (Coefficient of r_t)



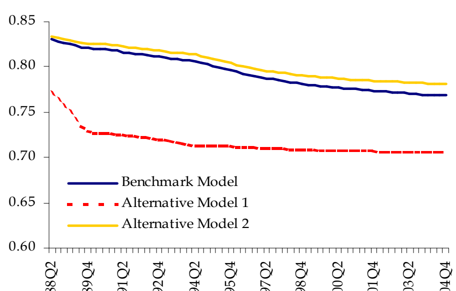
γ_3 (Coefficient of DI_t)



γ_4 (Coefficient of $reer_t$)



ρ (Persistence in Potential Growth)



3. Data Description

Sample period covers quarterly data between 1988:Q2 and 2004:Q2. The issue of seasonality is handled with the commonly used program named TRAMO/SEATS (Gomez and Maravall, 1998).

y_t : Logarithmic seasonally adjusted gross domestic product at 1987 constant prices

π_t : Log difference of quarterly seasonally adjusted consumer price index (1994=100)

$reer_t$: Log difference of CPI-based real effective exchange rate, (1995=100)

r_t : Ex-post real interest rate on 3-month average discounted Treasury action rates

DI_t : Demand index constructed from the Business Tendency Survey (BTS) of CBRT. Components of the index: BTS question 9 (total amounts of orders received this month), question 16 ((trend of next three months) volume of goods sold in domestic market), and question 18 ((Trend of next three months) volume of raw-material stocks).

Figure: Actual GDP Growth and Seasonal Adjusted GDP