© *The Pakistan Development Review*
56:3 (Autumn 2017) pp. 193–219

The Unreliability of Output-Gap Estimates in Real Time

AHSAN UL HAQ SATTI and WASIM SHAHID MALIK

Most research on monetary policy assumes availability of information regarding the current state of economy, at the time of the policy decision. A key challenge for policy-makers is to find indicators that give a clear and precise signal of the state of the economy in real time—that is, when policy decisions are actually taken. One of the indicators used to asses the economic condition is the output gap; and the estimates of output gap from real time data misrepresents the true state of economy. So the policy decisions taken on the basis of real time noisy data are proved wrong when true data become available. Within this context we find evidence of wrong estimates of output gap in real time data. This is done by comparing estimates of output gap based on real time data with that in the revised data. The quasi real time data are also constructed such that the difference between estimates of output gap from real time data and that from quasi real time data reflects data revision and the difference between estimates of output gap from final data and that from quasi real time data portray other revisions including end sample bias. Moreover, output gap is estimated with the help of five methods namely the linear trend method, quadratic trend method, Hordrick-Prescott (HP) filter, production function method, and structural vector autoregressive method. Results indicate that the estimates of output gap in real time data are different from what have been found in final data but other revisions, compared to data revisions, are found more significant. Moreover, the output gap measured using all the methods, except the linear trend method, appropriately portray the state of economy in the historical context. It is also found that recessions can be better predicted by real time data instead of revised data, and final data show more intensity of recession compared with what has been shown in real time data.

JEL Classification: E320
Keywords: Data Uncertainty, Measurement Uncertainty, Output Gap, Business Cycle, Economic Activity

1. INTRODUCTION

The main limitation of the literature on monetary policy rules is that it ignores uncertainty. Monetary authorities are uncertain regarding transmission channels through which changes in monetary policy instruments affect target variables; about parameter values of structural equations; and regarding the current state of the economy, at the time when policy decisions are taken. These types of uncertainties may cause inappropriate policy actions which have unintended consequences *ex post* for economic activity. Policy-makers may find their decisions—that have been taken in an optimal way based

Ahsan ul Haq Satti <ahsansatti@pide.org.pk> is Assistant Professor at Pakistan Institute of Development Economics (PIDE), Islamabad. Wasim Shahid Malik <wsmalick@gmail.com> is Assistant Professor at Quaid-i-Azam University, Islamabad.

on the information available at that time—inappropriate in the future when policy effects are reflected in the economic variables.

The main indicator of current state of the economy is the output gap; positive values of the output gap reflect boom in economic activity while negative values portray recession. So it is considered an important input in the design of monetary policy, as it is evident from the Taylor rule. Despite its importance in the conduct of monetary policy, the true value of the current output gap is difficult to estimate at the time of policy decisions; and output gap estimated from real time data may portray a misleading picture of the economy. Assuming that output gap is autoregressive process, one period ahead forecast may be upward biased in recession and downward biased in boom. The discussion on output gap uncertainty and monetary policy formulation started with the pioneering work of Orphanides and Norden (2002) regarding the unreliability of estimates of the output gap in real time data.

Output gap, which proxies business cycle, is the difference between current level of output in the economy and the potential level that could be supplied without putting upward or downward pressure on inflation. The measurement of output gap goes back to the work of Mitchell (1927) and Burns and Mitchell (1946), which mainly focused on the timing of recessions—episodes which they interpreted to be deviations from full-employment level of output. In macroeconomic models output gap is considered a macroeconomic indicator just like the others but for practitioners the potential output is not directly observable. Therefore it has to be estimated from available information using certain assumptions about path of potential output.

There are at least three reasons why estimates of the current output gap may be inaccurate. First, data of GDP are subject to revisions so revised data may be quite different from what is available to policy-maker at the time of policy decisions. There are technical reasons why final data cannot be released at the end of each year. In Pakistan, for instance, data on GDP are released at the end of each fiscal year but at the time of release data for the last quarter are not available, so estimated figures are used for the last quarter. Second, there are different methods of estimating potential output which may give different estimates. Each method has its own merits and demerits. Some of the methods estimate output gap from data without considering economic theory, while those based on economic theory needs certain assumptions regarding the production technology in the country which may not be true. Some methods are flexible enough that they under-estimate the severity of business cycles while others are so trend dominated that their estimates are subject to end sample bias. Third, assuming that output gap is autoregressive process, one period ahead forecast may be upward biased in recession and downward biased in boom.

Despite importance of uncertainty in the estimates of output gap, researchers in the field have not yet focused on the issue with reference to Pakistan. There are few studies available, like Syed and Shah (2009) and Sherbaz, *et al.* (2010), that estimate output gap for Pakistan using different methodologies but they did not deal with the uncertainty issue. Within this context we will explore the evidence of over and/or under estimation of the output gap based on real time data with that in the revised data.

However, the difference between estimates from these two data sets does not reflect the only data revision. At the start of each period policy-makers have access to different vintages of data, therefore estimates based on these vintages of data are subject to end sample bias. Hence we constructed the quasi real time data in which the final or revised data are considered, but in the same vintages as that of real time data. Difference between estimates of output gap from real time data and that from quasi real time data reflects data revision and the difference between estimates of output gap from final data and that from quasi real time data portray the revisions other than the data revisions including end sample bias. Moreover, output gap is estimated with the help of five methods namely the linear trend method, quadratic trend method, HP filter, production function method, and vector autoregressive method. Furthermore, to analyse the revisions in the output gap, some indicators of revision are also discussed in the study. The list of these indicators include mean revision, mean absolute revision, root mean square error, signal to noise ratio, and autocorrelation function of the estimates.

Rest of the study proceeds as follows: Section 2 highlights the existing literature on the measurement of the output gap with a special focus on real time data; Section 3 explains the methods of estimating the output gap and construction of vintages of real time data and quasi real time data; Section 4 presents and explains detailed empirical results; and Section 5 concludes the study.

2. LITERATURE REVIEW

2.1. Output Gap: Definition and Measurement

Output gap is defined as the percentage difference between the actual output and its potential level. Different economists define potential level of output in different ways. One school of thought follows Okun's (1962) definition where potential output is the level of output that economy is capable of producing in the absence of shocks. Other economists, who base their macroeconomic models on micro foundations, define potential output as the output in the absence of nominal rigidities [Mankiw and Romer (1991)]. So the potential output can be defined as the output that can be produced in the absence of intervention or external shocks and nominal rigidities. This level of output is also called natural or normal level of output.

The gap between the actual level of output and the potential level can be used as an indicator of economic conditions of a country. If the actual level of output is above its potential, that is, the output gap is positive then there is boom in economic activity which most of the times leads to higher than average inflation rate. Negative output gap, a situation when actual output is below its potential, reflects slowdown of the economic activity and these recessionary phases are mostly associated with low inflation rate but high unemployment.

2.2. Measurement Uncertainty in Output Gap

There are different viewpoints regarding the definition and modelling of potential output and output gap. According to pure statistical perspective the potential output is simply the trend output and output gap is the deviation of actual output from this long run trend. According to theoretical viewpoint potential output is the supply side phenomenon and it is the output level where the factors of production are utilised at potential level with current available state of technology. This theoretical idea of potential output reveals that the output gap is due to demand side shocks and these gaps are transitory components of the output. Therefore, the potential output is the stable component of output linked with the long run aggregate supply curve in the absence of nominal rigidities.

There are several studies in the literature that have made an effort to estimate the potential level of output and output gap using different estimation methods. Some of them estimated the potential output using pure statistical approaches while others applied structural or theoretical approaches and attempted to model the output using production function. These different estimation methods of output gap give rise to differences in cyclical component in terms of amplitude, length of gap, range and autocorrelation.

The statistical approaches are based on the assertion that *"let the data speak"* rather than relying on economic theory [Cogley (1997)]. These methods separate the permanent component of output which is non-stationary from transitory component which is stationary and usually consists of cyclical and irregular component [Nelson and Plosser (1982)]. The simplest examples of this approach are linear trend method and quadratic trend method that assume trend output as potential level of output and residuals are a measure of the output gap. Other statistical approaches are Hodrick and Prescott (1997) filter, the Band-pass (BP) filter proposed by Baxter and King (1995), the BN filter proposed by Beveridge and Nelson (1981) and the unobservable-components (UC) time-series approach proposed by Watson (1986) and Clark (1987).

Structural approach makes use of economic theory to estimate the potential output. In this approach different economic variables related to the business cycles, like employment and inflation rate are used and the estimation relies on the particular production function with specific assumption regarding technology. So this approach separates structural and cyclical components of output using economic theory [Saxena and Cerra (2000)]. Another approach estimating the output gap is the mixed approach which combines both the statistical model with economic theory under certain assumptions. Kuttner (1994), for instance, applied unobserved components (UC) model using data on actual output and inflation to estimate the output gap in the USA under the assumption that relationship between these two variables is stable within the sample period. The advantage of structural approach over statistical approach is that the data are not mechanically linked to GDP; rather, this is done with strong theoretical linkages. But the disadvantage is that it requires long time series of key variables which are usually missing for emerging economies. Misspecification of structural model can also be a source of poor output gap estimate through structural approach.

These different measures of potential output and output gap are valued based on how well they present the true picture of economic state of a country. For estimating output gap with statistical approach the simplest model used is linear time trend under the assumption that potential output is a function of time and it grows at constant rate. The percentage deviation of GDP from its trend line is the output gap. The first criticism of the linear trend method is the assumption that potential output grows at a constant rate which implies that the time trend is only demand determined and supply shocks are ignored which may distort resulting cycles and trend [Claus (1999, 2000)]. Secondly, the use of OLS methodology is criticised because GDP contains unit root as Nelson and Plosser (1982) found. Moreover, it does not fulfil another time series property as cyclical output, which is de-trended series, may not be stationary and the property of mean reversion in output gap may not necessarily hold [Gibbs (1995); Diebold and Senhadji (1996); De Brouwer (1998); Billmeier (2004)].

This linear trend model was later replaced with the linear breaking trend model. Perron (1989, 1997) augmented the linear trend with the dummy of structural breaks of 1972 oil crisis and estimated using OLS. Breaking trend approach uses the time trend with restriction of discrete breaks in trend line to avoid the condition of constant potential output growth [Kenny (1995)]. This linear breaking trend is not restricted to only one break rather we can include more than one breaks by introducing dummies. Lots of mixed literature exists on whether the output gap follows a deterministic trend, possibly with breaks, or a stochastic trend [Diebold and Senhadji (1996)].

Another model which is estimated using ordinary least squares method is the one in which potential output is modelled as quadratic trend. The difference between the linear and quadratic trend is that in linear trend the GDP growth rate is assumed to be constant while in quadratic trend this assumption can be relaxed. The quadratic time trend method is more flexible as compared with linear time trend method and it performs better at the end points of data set. The quadratic time trend method may create problem, however, at the start of the sample period.

Other statistical approaches to measuring output gap are smoothing techniques. Despite improvement in structural modelling of the economy, these estimation methodologies are still popular in the macroeconomics literature. One of the smoothing approaches is Hodrick-Prescott (HP) filter [Hodrick and Prescott (1997)]. The HP method is commonly used to estimate potential output from actual output by fitting a smooth curve along a point. The HP filter divides the GDP into trend component and cyclical components. The trend component is the potential output while the cyclical component is the output gap. The HP method is flexible to attain fluctuation in potential output growth by setting different values of smoothing parameter [Correia, *et al.* (1992, 1995) and Cooley and Ohanian (1992)]. Another smoothing approach is the Band-pass filter. In Band-pass filter, as opposed to Hodrick and Prescott filter, we can make use of historical experience with regards to duration of the business cycle. Therefore, we can say that our business cycle has the length that has historically been observed for business cycles. The most important contribution of Baxter and King (1995) is the derivation of a band pass filter to estimate directly the cyclical component.

Although the statistical methods are easy to apply, there are some problems associated with this approach. Firstly, using the univariate approach it is not possible to decompose the output into its components affected by demand and supply shock [Quah (1992)]. Secondly, statistical approaches do not make use of information related to the state of the economy contained in variables related to potential output, while structural methods rely on economic theory [Chagny and Döpke (2001)].

In structural approach two methods which are commonly used for decomposing the output are the production function method and the structural vector autoregressive. In the production function method a specific production function is supposed to capture true production technology in the economy. Mostly the Cobb-Douglas production function is used with two factors of production [Giorno, *et al.* (1995) and Froyland and Nymoen (2000)]. The problem with the production function approach is the assumption about elasticity of substitution between labour and capital which is assumed to be one but it is found to be higher in empirical research. The second problem is that, the capital stock which is used in this method is not directly observed and its data needs to be constructed assuming a constant depreciation rate of capital. Thirdly, data for inputs (like capital, labour, a measure of productivity and sometimes intermediate inputs) are not available, poor in quality or difficult to estimate [Claus (2000)].

Another approach which combines the statistical smoothing along with economic theory is the structural autoregressive models (SVAR). SVAR models allow us to consider all interaction between endogenous variables considering for feedback effects [Sims (1980)]. The SVAR method based on Blanchard and Quah (1989) combines the economic theory with statistical technique to separate the permanent and temporary movements in output. They reconsidered the Beveridge and Nelson (1981) decomposition of Real GNP under the assumption that the demand side shocks have temporary while the supply side shocks have permanent effect on output.

2.3. Empirical Literature and the Choice of Method of Measuring Output Gap

Clark (1987) used the multivariate unobserved components model and estimated the output gap for US economy. He applied a bi-variate model using unemployment and real GDP based on Okun's law. Apel, *et al.* (1999) also applied multivariate unobserved components model and estimated the potential output for Canada, US and UK using three variables inflation unemployment and GDP. Scott (2003) used tri-variate model including capacity utilisation, inflation and GDP and projected the output gap for New Zealand. Runstler (2002) applied both multivariate and univariate models for Euro area and provided the real-time valuation of output gap reliability and usefulness of real time output gap for inflation forecasting. Laxton and Tetlow (1992) criticised the HP filter which is based on OLS method and highlighted importance of the theory based models of potential output.

On the same lines, Araujo, *et al.* (2004) used both trended and structural methods of potential output for Brazilian economy and found that all measures have strong short term co-movement. The results indicate that different models of potential output show low and high variance and Beverage-Nelson method performs better at the specific forecast horizons. Dupasquier, *et al.* (1997) estimated the output gap for United States using different estimation methods and show that the VAR based methodology of measuring transitory and long run component of output gap perform better. Saxena and Cerra (2000) used different methods of potential output to estimate the output gap for Sweden. Billmeier (2004) used the data from 1980-2002 for Finland and estimated the output gap using nine different measures. He found that measurement of output gap based on statistical measures may lead to errors as it is unable to capture the high volatility in output.

2.4. Output Gap with Real Time Data

There are some problems with the estimation of output gap. Firstly, the output gap estimated using real time data differs from that estimated using revised data, published later. Secondly, different estimation techniques for estimating output gap give different results using same available data. Thirdly, estimated coefficients' magnitude may change over time which leads to wrong estimates of the business cycle [Croushore and Stark (2003)].

Orphanides (2001, 2003) explained that the imperfect information about current state of the economy played a vital role in inflation process during 1970s. The productivity slowdown of that time was interpreted as negative output gap by Federal Reserve which led to expansionary monetary policy. After a long time, the monetary authority realised that the potential output growth rate was lower and eventually adjusted policy to bring inflation down. The author used the real-time estimates of the output gap and proved that the measurement error of the output gap leads to deterioration of the policy outcomes. How a policy-maker estimates current output gap on the basis of available information (real time estimate) is important, since the final information regarding output arrives with some time lags. Kuttner (1992, 1994) highlighted the importance of the output gap for real time and examined the difficulties associated with the real time output gap estimation.

Orphanides (2001) finds the estimates of output gap with official records of final data and compared these with most recent estimates of the output gaps. Orphanides and Van-Norden (2002) explained different phases of the output gap revisions and found that the deviations between the real time estimates of the output gap and final the output gap are on average about 2.6 percent. He also decomposed the output gap revisions into two parts. First, data revision, which is due to the measurement error of GDP series and secondly other revisions which are due to different measures of the output gap named filtering error. This mis-measurement of GDP series explains the extent of revisions in GDP series.

Orphanides (2003) reconstructed the real time GDP series from 1951 and estimated the output gap with this real time series. He compared the output gap of real time series with the final series of GDP and showed persistent underestimation of output gap till 1980s. Nelson and Nikolov (2003) rebuilt a series of output gap in real time for UK, dating from 1965. They found that, in 1970s, the perception about real time output gap which was 7 percent less than what could be quantified at this time and this was the main cause of slowdown as monetary policy was wrongly tightened on the basis of incorrect estimates of the output gap. Kozicki (2004) using U.S. data and Kamada (2005) by using same for Japan show that if policy-makers do not take into account the possibility of data revision at all then the policy actions may be more aggressive. Cayen and Van-Norden (2005) used the data vintages from 1972 for Canada and applied different univariate and multivariate techniques to find out the output gap. They found that revisions in output gap are important and data revision role is not as harmless as it was earlier believed. Bernhardsen, *et al.* (2004) found that total revisions in output gap are greatly influenced by the measurement uncertainty while data revision uncertainty is small in magnitude. Contrary to most of the empirical findings, Crushore and Evans (2006) concluded that the data revision is insignificant for measure of monetary policy shocks, but in simultaneous equation system it is difficult to identify in the presence of data revision. Based on a simulated multivariate filtered real-time output gap series for Australia, Gruen, *et al.* (2002) report revisions below four percentage points of GDP. Moreover, drawing on ex-post data for the Euro area Rünstler (2002) finds revisions to various real-time output gap estimates that do not exceed two percentage points of GDP.

2.5. Literature Review Related to Pakistan Economy

A limited number of researchers focused on the measurement of the output gap for Pakistan but they did not estimate the gap using real time data. Sherbaz, *et al.*

(2010) used time series data from 1963–2005 and estimated the output gap by applying production function approach. They determine the factors which cause movement in the output gap. According to their results imports and money supply cause to increase the output gap, while public sector investment and exports lessen the output gap. Syed and Shah (2009) estimated the output gap for Pakistan economy using annual data from 1951 to 2007. They applied different measures of output gap to identify the different spans of excess supply and excess demand. They also show that the economy is facing inflationary pressure since 2005. Haider and Khan (2008) estimated output gap using six different methods. They found that measures of output gap were not identical but they showed some degree of co-movement. Therefore, they constructed a composite index of output gap series measured through all six methods.

3. METHODOLOGY

We have used five different methodologies to estimate the output gap using real time data, quasi real time data and revised data. This section presents brief discussion of each method of estimation and explains the method of constructing the series of real time and quasi real time data.

3.1. Methodologies for Estimation of Output Gap

3.1.1. *Linear Trend Method*

The simplest way of estimating the potential output is through linear time trend under the assumption that potential output grows at a constant rate and output gap is a percentage deviation of actual output from the fitted trend line. The trend (potential) output is represented by: $\overset{*}{y} = \beta_0 + \beta_1 t + \varepsilon_t$; and the cyclical component is given as: $C = y - \overset{*}{y}$ which is a measure of output gap.

3.1.2. *Quadratic Trend Method*

In the quadratic trend method the log of GDP is regressed on time and square of time with constant included which can be written as:

$$y_t = \beta_0 + \beta_1 t + \beta_2 t^2 + \varepsilon_t$$

The cyclical component is again estimated as the difference between actual values of log of the output and the fitted values.

3.1.3. *Hodrick-Prescott Filter*

The Hodrick and Prescott (1997) filter methodology is used under the assumption that the GDP growth, though not constant, is smooth over time. H-P filter divides the GDP into two parts GDP* (potential or trend component) and C (Cyclical component).

GDP=GDP*+C

Where GDP* is the sum of squares of its second difference which can be found by minimising the following loss function:

$$MinL = \left\{ \sum_{t=1}^{t} C_t^{\,2} + \lambda \sum_{t=2}^{t} (\Delta GDP_t^{*} - \Delta GDP_{t-1}^{\ *})^2 \right\}$$

$$= \left\{ \sum_{t=1}^{t} (GDP_t - GDP_t^{*})^2 + \lambda \sum_{t=2}^{t} [(GDP_t^{*} - GDP_{t-1}^{\ *}) - ((GDP_{t-1}^{\ *} - GDP_{t-2}^{\ *})]^2 \right\}$$

The lambda is smoothing parameter which is set equal to 1600 for quarterly data, as used by Hodrick and Prescott (1997) and 400 or 100 is used for annual data.

3.1.4. *Production Function Method*

Production function method of estimating output gap is mostly associated with the basic structure of the economy which relates the growth of GDP to the growth of factors of production including labour, capital and total factor productivity. This can be captured by Cobb-Douglas production function, where we consider capital and labour (employment) as inputs. Production function of this type can be written as:

$$Y_t = A_t N_t^{\alpha} K_t^{1-\alpha}$$

Here Y_t is actual output (GDP), A_t is total factor productivity, N_t is employment and K_t is capital, α is the labour share and $1-\alpha$ is the capital share in total output. Here total factor productivity (A_t) is un-observable which is usually computed as the Solow residual i.e. by subtracting contribution of capital and labour to GDP from actual GDP. Above equation can be converted into log form as:

$$y_t = A_t + \alpha l_t + (1-\alpha) k_t$$

Now all the variables are in log form and we have information regarding GDP and employment level, while capital stock is constructed using Nehru and Dhareshwar (1993) methodology, explained in data section. Furthermore, we need to know the share of the labour α and share of capital $1-\alpha$. We set value of labour and capital share as 0.56 and 0.44 respectively, used by Khan (2006).

$$y_t^{*} = A_t^{*} + 0.56 l_t^{*} + 0.44 k_t^{*}$$

The resulting residual from this equation is smoothed using HP filter to get potential level of total factor productivity. After getting all required information and setting the potential capital stock equal to actual capital stock and potential employment equal to labour force we can use above equation to find the potential level of output, deviation of actual output from which is the measure of output gap.

3.1.5. Structural Vector Autoregressive (SVAR) Approach

The VAR models allow us to consider all interactions between endogenous variables considering feedback effects [Sims (1980)]. The SVAR method based on Blanchard and Quah (1989) combines the economic theory with statistical technique to separate the permanent and temporary components of output. The BQ method reconsiders the Beveridge and Nelson (1981) decomposition of Real GNP under the assumption that the demand side shocks have temporary while supply side shocks have permanent effects. In order to use BQ technique at least one of the variables must be non-stationary as a stationary variable does not have a permanent component. Here, we want to decompose the real GDP $\{y_t\}$, which is integrated of order 1, into temporary and permanent components and we have another variable, unemployment (U_t), which is stationary. The bivariate moving average (BMA) representation of these two variables is:

$$\Delta y_t = \sum_{k=0}^{\infty} c_{11}(k)\varepsilon_{1t-k} + \sum_{k=0}^{\infty} c_{12}(k)\varepsilon_{2t-k}$$

$$U_t = \sum_{k=0}^{\infty} c_{21}(k)\varepsilon_{1t-k} + \sum_{k=0}^{\infty} c_{22}(k)\varepsilon_{2t-k}$$

Here ε_{1t} and ε_{2t} are exogenous variables; ε_{1t} is the aggregate demand shock and ε_{2t} is the aggregate supply shock.

The demand and supply shocks are not directly observed. Given the variables in the system are stationary, the VAR representation of the variables is given as:

$$X_t = A(L)X_{t-1} + e_t$$

Where

The VAR residuals e_{1t}, e_{2t} can be defined as forecast errors and they are composites terms of demand and supply shocks, ε_{1t} and ε_{2t} as:

$$e_{1t} = c_{11}(0)\varepsilon_{1t} + c_{12}(0)\varepsilon_{2t} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \text{(i)}$$

$$e_{2t} = c_{21}(0)\varepsilon_{1t} + c_{22}(0)\varepsilon_{2t} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \text{(ii)}$$

If the coefficient matrix of the above system is known we can estimate the structural shocks from estimated forecast errors. These coefficients are, however, unknown and need to be estimated from data. Blanchard and Quah provide the following restrictions to find these four coefficients.

Restriction 1

Considering Equation (i) and given that $E\,\varepsilon_{1t}\varepsilon_{2t} = 0$, the normalisation var($\varepsilon_1$) = var ($\varepsilon_2$) = 1 means that the variance of e_{1t} is var(e_1) = $c_{11}(0)^2 + c_{12}(0)^2$.

Restriction 2

Considering Equation (ii) and given that $E\,\varepsilon_{1t}\varepsilon_{2t} = 0$, the normalisation var($\varepsilon_1$) = var ($\varepsilon_2$) = 1, means that the variance of e_{2t} is var(e_2) = $c_{21}(0)^2 + c_{22}(0)^2$.

Restriction 3

$$Ee_{1t}e_{2t} = c_{11}(0)c_{21}(0) + c_{12}(0)c_{22}(0),$$

The restriction that ε_{1t} sequence has no long-run effect on y_t can be written as:

$$\left[1-\sum_{k=0}^{\infty}a_{22}(k)L^{k+1}\right]c_{11}(0)\varepsilon_{1t}+\sum_{k=0}^{\infty}a_{12}(k)L^{k+1}c_{21}(0)\varepsilon_{1t}=0$$

Restriction 4

For all realisations of ε_{1t} sequence, ε_{1t} shocks will have only temporary effects on Δy_t sequence if

$$\left[1-\sum_{k=0}^{\infty}a_{22}(k)\right]c_{11}(0)+\sum_{k=0}^{\infty}a_{12}(k)c_{21}(0)=0$$

Potential output is estimated using only supply side shocks while demand side shocks are ignored. The difference between actual output and the estimated output series is the measure of the output gap.

Each method of estimating the output gap has its own merits and demerits. None of the methods is the one that can solely be relied upon for research or for policy-making. It is therefore better to estimate the output gap with the help of different methods so that results from these methods can be compared.

3.2. The Revision Indicator Formulae

The indicators of revisions, used to analyse the magnitude, predictive power and persistence in the output gap are presented in Table 1.

Table 1

The Revision Indicator

1. Mean Revision (Mean) $=\frac{1}{n}\sum(y_t{}^F-y_t{}^R)$	Indicator of revision bias but it does not indicate magnitude of the revision
2. Mean Absolute Revision (MAR) = $\frac{1}{n}\sum\left\|y_t{}^F-y_t{}^R\right\|$	Measures the magnitude of revision. And represents the average deviation between the output gap with final data and output gap with real time.
3. Root Mean Square Residual (RMS) = $\sqrt{\frac{1}{n}\sum(Y_t{}^F-Y_t{}^R)^2}$	
4. Noise Signal Ratio (NS) = $\frac{RMS}{SD(Y_t{}^F)}$	Ratio between the signal (meaningful information) and noise (not meaningful). High NS indicate significant difference between the real time and final output gap.
5. Correlation Coefficient (COR) = $\frac{COV(Y_t{}^F,Y_t{}^R)}{SD(Y_t{}^F)SD(Y_t{}^R)}$	COR is the correlation between the final and real time estimates of output gap. The low COR value implies the significance of revision in size and high COR value indicates the low association between both series.
6. First Order Autocorrelation (AR) $(y_t{}^F-y_t{}^R)=\gamma(y_{t-1}{}^F-y_{t-1}{}^R)$ Where γ shows the degree of persistence	Measure the degree of persistence in the revision. High AR shows persistence in revision which leads the policymaker and other economic agents to make persistent errors about estimation of business cycle movements.
7. Opposite Signs (OPSIGN) = $\frac{1}{n}\sum O_t$,Such that $O_t=\begin{cases}1 & if \quad Sign(Y_t{}^F)\neq Sign(Y_t{}^R)\\ 0 & otherwise\end{cases}$	Positive sign of output gap shows inflationary gap while negative signs show deflationary gap. The OPSIGN gives the number of time periods, as ratio of total sample period, when estimates from both types of data have same sign.

3.3. The Components of Output Gap Revision

To analyse the total revisions in output gap and to decompose it into data revision and other revisions we followed Orphanides and van Norden (2002). The output gap is estimated using three types of data sets namely the real time data, quasi real time data and final data. Further, the output gap is estimated using five well known de-trending techniques including linear trend, quadratic trend, HP filter, production function, and vector autoregressive model.

For estimating the output gap in real time we estimated all the five models for every vintage of data available up to a particular year and then constructed a new series of output gap. From each of these series we have taken only the last value and then a new series is constructed that contains all these last values; this new series represents the timeliest estimates of output gap that policy-maker could have accessed in each time period. The output gap from final data is estimated using last vintage of data (taken from POS of 2012) by applying all five de-trending methods. The estimated output gap from final data is the one that is usually used in the research on monetary policy. However, these estimates were not available to policy-maker when (s)he was actually taking the policy decisions.

The difference between final estimates and the real time estimates of the output gap represents the total revision in the output gap. This total revision in the output gap is because of two reasons; first it might be due to the GDP data revision, that is, data revision and secondly it might be due to other reasons, that is, other revisions. These other revisions are due to both end sample bias and parameter instability problem. To decompose the total revision into these two components we have also estimated the output gap in quasi real time data. Quasi-real time estimates of the output gap are constructed using the same approach as that in real time data but using rolling regression in final data. Rolling regression in final data is the same as estimating models in the quasi real time data. Again from estimates of output gap from each of these vintages we have taken only the last value and then the series constructed with these last values represents quasi-real-time estimates of output gap. The difference between quasi-real time and real time estimates of output gap is due to data revision over the sample period and the difference between final and quasi real estimates represents the other revisions that may be due to the end sample bias. So we have three types of revisions:

Total revision in output gap = final series of output gap—real time estimates of output gap.

Data revision = quasi real time estimates of output gap—real time estimates of output gap.

Other revision = final estimates of output gap—quasi real time estimates of output gap.

3.4. Data Related Issues

As we are estimating the output gap both from real and revised data the first stage is to develop the real-time data set for those variables which are subject to revision over time. The real time data set is a snapshot of available data that existed prior to subsequent revisions. Following Croushore and Stark (2001, 2003) we designate the last available information set with the most recent revisions, up to specific time as "Vintage" and the collection of these vintages is called "the real time data set".

Data on Real GDP, Labour Force, Real Gross Fixed Capital Formation, Consumer Price Index and Unemployment, over the period 1960 to 2010, have been taken from various issues of *Pakistan Economic Survey* (POS), published by Ministry of Finance, Government of Pakistan. The reason for not taking the data beyond 2010 is the non-availability of revised data after this period. The variables labour force, unemployment and inflation rate are not subject to revision so the annual data, on these variables, from 1960 to 2010 is taken from POS 2012 issue.

The data set for GDP and the fixed capital formation which is further used for construction of the capital stock is subject to revision so real time data set for these two variables is constructed. For the construction of real time data set of these variables we just dig through old sources of data going back to start of that sample period and note down what data sets were available at that point of time. We used different issues of POS from 1974 to 2010 for construction of the real time data series for GDP and gross fixed capital formation. So the first vintage of data, 1960 to 1974, has been taken from the POS published in 1974.

Table 2

Generic Real-time Data Set for GDP

Date to Which	Data Release Date									
Data Pertain	i=1974	i=1975	i=1976		i=t	i=t+1	i=t+2		i=2009	i=2010
j=1960	y_i (j)	y_i (j)	y_i (j)	…….	y_i (j)	y_i (j)	y_i (j)	……	y_i (j)	y_i (j)
:	y_i (j)	y_i (j)	y_i (j)	…….	y_i (j)	y_i (j)	y_i (j)	……	y_i (j)	y_i (j)
j=1974	y_i (j)	y_i (j)	y_i (j)	…….	y_i (j)	y_i (j)	y_i (j)	……	y_i (j)	y_i (j)
j=1975		y_i (j)	y_i (j)	…….	y_i (j)	y_i (j)	y_i (j)	……	y_i (j)	y_i (j)
j=1976			y_i (j)	…….	y_i (j)	y_i (j)	y_i (j)	……	y_i (j)	y_i (j)
:					y_i (j)	y_i (j)	y_i (j)	……	y_i (j)	y_i (j)
j=t					y_i (j)	y_i (j)	y_i (j)	……	y_i (j)	y_i (j)
j=t+1						y_i (j)	y_i (j)	……	y_i (j)	y_i (j)
j=t+2							y_i (j)	……	y_i (j)	y_i (j)
:									y_i (j)	y_i (j)
j=2009									y_i (j)	y_i (j)
j=2010										y_i (j)

Table 2 explains the procedure of taking different vintages of data from different issues of POS. First of all we present the table of generic real-time data for GDP. The entries in Table 2 are represented by $y_i(j)$, where the subscript i represents the time or year at which data was released and (j) in parentheses refers to the data pertaining to period j. The diagonal elements at the end of each column represent the provisional data or first release or preliminary data. While the element just above the diagonal of each column represents the revised data and the element above that is the final data of the corresponding year.[1]

[1]In Pakistan data on National Income Accounts are revised twice: first time data are released at the end of fiscal year, after one year data are published again as *Revised Data* and in the third year data are published as *Final Data*.

In Pakistan, the method of measuring GDP has been revised three times in history, so the data on GDP over the period 1960–2010 are available with breaks; three sub-samples are based on three different methodologies. First time, methodology is changed in 1988-89, so the data prior to that period are available with old methodology. Second time the methodology is changed in 1999–2000, so the data on GDP over the period 1989–2003 is based on the second methodology and after that GDP is measured with the third methodology. Before estimating the output gap we have converted all the vintages according to the methodology of 1999-2000 so that a consistent series of output gap can be obtained.

Similarly the GDP data sets are available at three different prices with respect to base year; data for 1960-88 are available at prices of 1959-60, for 1989-2003 it is available at prices of 1980-81 and from 2004-2010 it is on constant prices of 1999-2000. Therefore we converted revised data on GDP and all the vintages of real time GDP on the base price of 1999-2000. Similar procedure has been adopted for the variable, *Gross Fixed Capital Formation*.

The data on *gross fixed capital formation*, however, are not available. Therefore, this variable has been estimated for use in the estimation of the output gap using production function method. Capital stock series is constructed using *Perpetual Inventory Method* which takes capital stock as the accumulation of the stream of past investments or gross fixed capital formation, that is, $K_t = GFCF_t + (1-\sigma)K_{t-1}$ where σ is the depreciation rate. For this purpose we used the Nehru and Dhareshwar (1993) methodology according to which the equation generating capital stock is given as:

$$K_t = (1-\sigma)^t K_0 + \sum_{i=0}^{t-1} GFCF_{t-i}(1-\sigma)^i$$

Where *GFCF* is gross fixed capital formation and K_0 is initial capital stock which is calculated by method introduced by Harberger (1978) and is modified further by Nehru and Dhareshwar (1993). To get the initial value of capital stock, log of *GFCF* is regressed on time and the fitted value of *GFCF* is used to calculate initial capital stock using the following equation $K_{t-1} = \frac{GFCF_t}{(g+\sigma)}$, where *g* is the growth rate of GDP for the period *t* and depreciation rate is considered as 4 percent. By applying above mentioned methodology to each vintage of data on gross fixed capital formation we constructed the real time data series for the capital stock.

For GDP and capital stock three types of data sets have been used. First, the final data from 1960 to 2010, which are currently available in POS, published in 2012. Second type of data are the real time data that existed prior to subsequent revisions. Finally, quasi-real time data have been constructed using the same data span as for the real-time but using the rolling final data. This last type of data set is used for comparison of estimated output gap from real time and final data without facing the problems of end sample bias. The commonality between real time data and quasi real time data is that both have same vintage of data in terms of time period. But the difference is that the former contains real time data while the later contains final data. Data on all variables other than

GDP and capital stock are taken from the latest issue of POS as all other variables are not subject to revision overt time.

4. EMPIRICAL RESULTS

4.1. Output Gap Estimates

Figures 4.1 and 4.2 show the visual comparison between the business cycles measured with five different methods mentioned above, for real-time and final data respectively. From Figures it is clear that the estimates from all the five methods have strong short-term co-movement. The turning points of the output gap, estimated from all methods, are almost the same. However, the estimates generated from Quadratic Trend, HP filter, Production Function method and SVAR are consistent with the historical facts while the estimates generated using linear trend method contradict historical facts. Furthermore, different measures give rise to a wide range of the output gap. The range of estimates from real time data is much wider than that found in the final or revised data. With four measures, Quadratic Trend, HP filter, Production Function method and SVAR, the recessions and booms in real time estimates seem to be more prominent than those found in final data. The linear trend method under-estimates output gap in real time data and over estimates the final data.

The final estimates of the output gap shown in Figure 4.2 are consistent with the economic history of Pakistan. During the time period 1974-1977, the results show that the economy is in recession and reached the trough in 1977. The main cause of this recession is the disintegration of Bangladesh from Pakistan after a civil war. The country was faced with the challenges of recovery from the effects of war, increase in petroleum prices and recession in overall world market. To overcome these problems the government of Pakistan took steps to restructure the economy like land reforms, labour reforms, nationalisation of industries, banks and insurance companies. These reforms were introduced to improve efficiency of manufacturing and agricultural sector but the control of government over the key decisions was proved as the major setback to the economy. The overall economy faced a decline of GDP growth of about 3.6 percent per annum because of decline in share of two major sectors, manufacturing and agriculture.

Significant differences can be found among estimates of the output gaps estimated in two types of data sets. For instance, the real-time estimates of the output gap show that the recovery of economic activity started after 1977 but the final estimates show that the economy remained in recession till 1979 and recovery started after that period.

If we look at final estimates of the output gap the economy is in recovery phase from 1978 to 1992 and the speed of recovery is different with different measures of output gap. When the economy reached its peak in 1992 the output gap value with LT, QT, HP filter, VAR and PF are 9.458 percent, 2.934 percent, 2.798, 1.009 and 3.394 respectively. If we compare these final estimates of output gap with the real-time estimates of the output gap for 1992, the values of real time estimates of the output gap are above those from final estimates. The real time estimates of the output gap show different results. The recovery process started after 1979 and reached the peak point in 1987 with gap values 2.73 percent, 4.05 percent, 3.56 percent, 5.77 percent, and 1.42 for LT, QT, HP, VAR and PF respectively. This recovery phase is consistent with the history of Pakistan. The recovery phase is not due to some fundamental policy changes or reforms rather it was due to large financial assistance, as a result of the Afghan War that improved the balance of payments position and the output that came on stream from large

Fig. 4.1. Estimates of Output Gap in Real Time Data

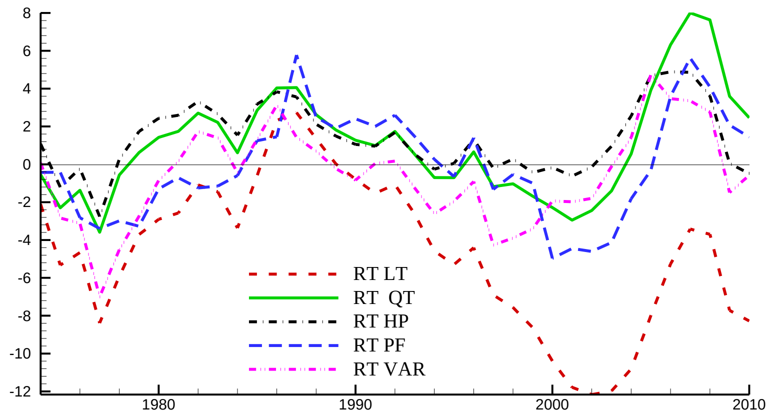
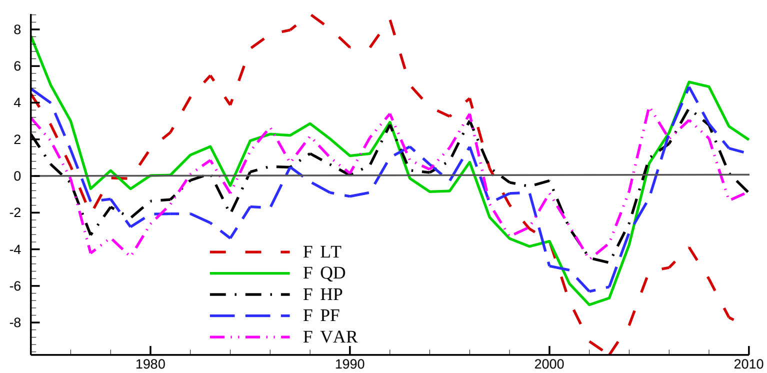


Fig. 4.2. Estimates of Output Gap in Final Data



public sector investment made in 1970s. For instance, the *Tarbela Dam* that added significantly to irrigation water availability and hydel power capacity.

The economic performance of Pakistan declined during the 1990s, as the average GDP growth rate was 4.4 percent per annum during this time period. Although different reforms were started in the form of denationalisation, reducing the role of the public sector and introduction of measures to provide better business environment to attract foreign businesses. But due to political instability, frequent changes of government, withdrawl of US aid after the end of Afghan war and sanctions after the nuclear test, the GDP growth rate remained low. The final estimates show that recession in the economy started in 1992 and continued till 2002, with the output gap estimates at a trough in 2002 at –9.02, –7.03, –4.46, –6.30 and –4.55 with LT, QT, HP, VAR and PF methods. Real time estimates of the output gap show the start of recession from 1988, reaching the trough in 2002 with the output gap values of –12.16, –2.439, –0.1323,–4.60, and –1.794 with LT, QT, HP, VAR and PF methods, respectively. With the four measures QT, HP, VAR and PF it is apparent that real time estimates overstate the trough in this period as the gap values are higher in magnitude with real time estimates of the output gap. These output gap values are also different with different measures of the output gap.

After the recession of 1990s the recovery period started in 2002 and continued till 2007. Both real time and final estimates of output show the recovery of economy started in 2002 and reached its peak in 2007. These results are consistent with the actual position of Pakistan economy as the average growth rate of GDP remains 7 percent in this period. This recovery of economy is due to more liberal strategies for enhancing the share of Pakistani exports; privatisation of banking, telecommunication, oil and gas and energy sectors; alliance with coalition forces in the fight against terrorism; and more remittances from abroad after 9/11 event.

At its peak in 2007 the output gap value using real time estimates is –3.41 percent, 8.00 percent, 4.858 percent, 5.61 percent, and 3.35 percent with LT, QT, HP, VAR and PF methods, respectively while the corresponding output gap values of final estimates are 3.89 percent, 5.132 percent, 3.692 percent, 4.86 percent, and 3.05 percent. At its peak, these output gap values vary across different measures of the output gap but, contrary to findings at the trough, less difference is found between real time estimates and final estimates.

The recovery of Pakistan economy that started in 2002 did not last long and the economic activity started to decline in 2008. Both the real time and final estimates of output gap indicate that slowdown started in 2008 and continued till the end of the sample period. However, the intensity of recession is different within each measure of the output gap. The cause of this recession is adverse security condition, large exogenous price shocks, and global financial recession.

It can be concluded from above discussion that the slowdown in the economic activity is indicated first by the real time data and then by the final data. Moreover, the real time estimates of the output gap are higher than those found in final data, both in boom and recession periods. Hence the real time estimates, compared with the final estimates, show a lesser intensity of recession, but greater intensity of boom. Moreover, all the methods except linear time trend model give similar results in both types of data sets.

4.2. Output Gap Revision: Size and Persistence

Total revision, which is the difference between the final output gap estimates and the real time estimates of the output gap, is presented in Figure 4.3. The magnitude of the revision with different output gap measures is different. These revisions are relatively high with positive sign in linear time trend based output gap, while the difference is negative, most of the time, in HP filter based output gap. The difference between final estimates and real time estimates is almost zero when output gap is estimated through the production function approach.

Table 3 presents descriptive statistics about various series of output gaps.[2] It can be seen from the first four columns of this table that the output gap series based on the

[2]Although table contains results from final data, real time data, and quasi real time data, the estimates from first two types of data are explained in this section. Estimates of output gap from quasi real time data are given in this table but these estimates are used to decompose total revisions into data revisions and other revisions, which are explained below.

linear time trend has greater amplitude and standard deviation when compared with other output gap methods.

Fig. 4.3. Total Revision in Output Gap

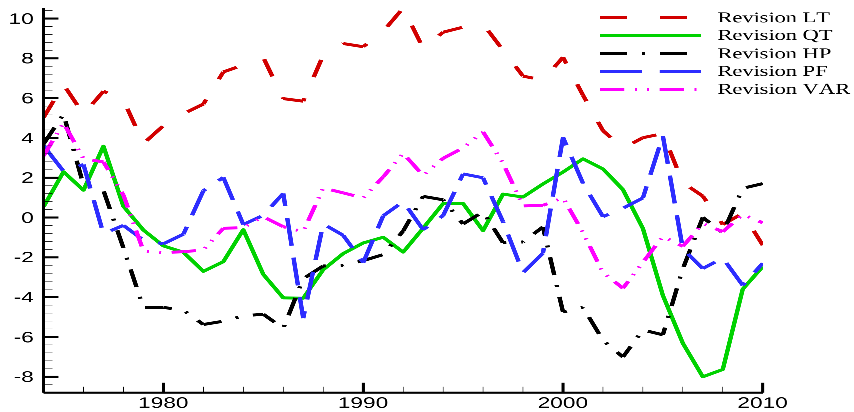


Table 3

Output-Gap Summary Statistics

Method	MEAN	SD	MIN	MAX	COR
Linear Trend					
Final	1.27	5.63	–9.67	9.51	1
Quasi-real	–4.66	3.99	–12.17	2.73	0.87
Real-time	–4.15	4.05	–12.3	1.43	0.87
Quadratic Trend					
Final	0.37	3.27	–7.03	7.65	1
Quasi-real	1.24	2.47	–2.67	7.31	0.62
Real-time	1.07	2.78	–3.59	8	0.58
Hodrick-Prescott Filter					
Final	–0.15	1.94	–4.73	3.69	1
Quasi-real	1.58	1.68	–0.93	5.31	0.38
Real-time	1.37	1.82	–2.76	4.89	0.42
Vector Autoregressive					
Final	–0.71	2.7	–6.3	4.86	1
Quasi-real	0.16	2.41	–4.65	5.15	0.68
Real-time	–0.06	2.74	–4.97	5.78	0.68
Production Function					
Final	–0.08	2.46	–4.56	3.79	1
Quasi-real	–0.33	2.3	–4.66	5.34	0.65
Real-time	–0.62	2.52	–7	4.73	0.65

The last column of the Table 3 gives the correlation coefficient of the final estimates of the output gap with other measures to portray the information about the output gap revision. The low correlation value implies the significance of revision. It is shown that the positive and high correlation coefficient between the final and real time gaps is found in linear time trend method, while there is a positive and relatively low correlation for all other estimation methods QT, HP, VAR and PF. Correlation between the real and final estimates is less than 70 percent in four out of five models which suggest that the revision is important in size.

4.2.1. *Revision Statistics*

To analyse the significance of revision, several indicators are used and their values are presented in Table 4. The mean of total revision varies across different measures of the output gap. According to the estimates found in case of quadratic trend, vector autoregressive model, and production function method, revision is quite small while that with the other two methods is quite large. The reason behind this result is that both linear trend method and HP filter give biased estimates at the end of samples. The mean revision is a useful indicator of revision bias but cannot be used for the magnitude of revisions, as the positive revisions offset the negative revisions.

Table 4

Summery Revision Statistics (Final Minus Real-Time Estimates)

Method	MEAN	SD	RMS	MIN	MAX	AR
Linear Trend	5.94	2.95	6.61	–1.39	10.53	0.91
Quadratic trend	–0.7	2.8	2.85	–5.26	8.19	0.92
Hodrick-Prescott Filter	–1.52	2.02	2.51	–5.69	1.84	0.84
Vector Autoregressive	–0.65	2.17	2.23	–5.29	5.2	0.90
Production Function	0.53	2.07	2.11	–3.55	4.75	0.84

Root mean square (RMS) which is a suitable indicator for capturing the magnitude of total revision in the output gap indicates that total revisions are substantial as RMS values are quite high. Moreover, the RMS obtained from the output gap estimated from linear time trend is way above those found from other methods. The last column of Table 3 reports the estimated first-order autocorrelation coefficients for revision. The results indicate that all revision series are highly persistent, though it differs across different methods. The coefficient ranges from 0.84 for HP and PF model to 0.92 for QT model. The high degree of persistence in the total revision series indicates that real-time output gap estimates may lead policy-makers and other economic agents to make persistent mistakes about the business cycles state.

4.2.2. *Indicators of Reliability*

The statistics given in Table 4 shed some light on the total revision but all these statistics are biased indicators of revision. Therefore, in order to compare the difference between measures of the output gap in different types of data some reliability indicators, which are independent of the size of the gap, are calculated and results are presented in Table 4. The statistics are the indicators of reliability in the sense that they show how real-time estimates of the output gap are different from those found in the final data.

These are not the reliability indicators, however, between different models of the output gap estimation.

First column of the Table 5 presents the correlation between the final and real-time series for each method, which ranges from the lowest value of 0.42 for HP filter method to 0.87 for linear time trend method. As discussed above the low correlation value implies the significance of revision in size but this may understate the relative importance of the revision. This is because the correlation ignores the differences in means of the two series. From Figure 4.1 it is apparent that the linear trend model produces remarkable revision in the output gap but still there is the highest correlation between real time and final gap estimates.

Table 5

Reliability Indicators

Method	COR	NS	NSR	OPSIGN
Linear Trend	0.87	0.52	1.18	0.49
Quadratic trend	0.58	0.85	0.87	0.22
Hodrick-Prescott Filter	0.42	1.04	1.30	0.32
Vector Autoregressive	0.68	0.80	0.83	0.24
Production Function	0.65	0.84	0.86	0.24

The alternative measure to identify the importance of revision and measure of association between the real time and final estimates is OPSIGN (frequency with which the real time and the final estimates have opposite signs). This OPSIGN estimates is of specific importance because the signs of output gap reflects the inflationary or deflationary pressure in the economy, which leads to either loose or tight monetary policy. The results in the last column of Table 4 confirm the unreliability of correlation results because real time estimates from all models give the opposite signs ranging from 22 percent for QT model to 49 percent with linear trend model.

The RMS value given in Table 3 indicates that there is a substantial revision in the output gap, but these indicators do not take account of the variability of the output gaps. Low or high value of RMS may be due to low or high variability in the series rather than the size of revision. Hence, to control this problem another measure of the relative importance of the output gap revision is the Noise to Signal Ratio which is defined as the ratio between the RMS of revision over the standard deviation of revision. This measure captures the effect of downward and upward revisions. The value of NSR ranges from 0.83 for VAR method to 1.30 for HP filter and exceeds 1 for linear time trend and HP filter method. This shows relatively high degree of noise in real time output gap.

4.3. Decomposition of the Output Gap Revision

For each model total revision in the output gap can be further decomposed into different factors that account for revision. We decomposed these revisions into data revision (difference between quasi real time and real time estimates) and other revision (difference between final and quasi real time estimates). The data revision is associated with revision in GDP series, while other revisions are related to the inclusion of new observations in the sample, end sample bias etc. In Figure 4.4 panel (a) to (e), we plot the real time estimates of the output gap together with the data revision and total revision. The summary statistics related to this decomposition are presented in Table 4.

As results from the quadratic trend method are more consistent with the historical facts, therefore, we explain the decomposition based on the output gap estimates found with quadratic trend in more detail. Figure 4.4 panel (b) shows the results from quadratic trend. By comparing the real time estimates with total revision it is found that both the series are almost equal in 1979, 1994, and 2001, which indicate that final estimates of the output gap are roughly zero. In 2001, real time estimates indicate extreme recession but final or *ex post* estimates indicate the economy was operating at potential level. The graph also shows the data revision, the difference between the real time estimates of out gap and quasi real time estimates. These data revisions are approximately equal to total revisions for the period year 1987 to 1994, which indicate that nearly all of the revision in our estimated output gap for those years was due to subsequent revisions in the published data. However, considering the whole sample period from 1974 to 2010 the data revision variability tends to be small compared with that of the total revision, so most of these revisions are due to the addition of new sample points in our data or due to the end sample bias. Figure 4.4 panels (a), (c), (d) and (e) show the results for linear trend, HP filter, vector autoregressive and production function methods respectively, which indicate that data revisions seem to play a secondary role in explaining the total revisions.

Although the data revisions are relatively small in magnitude as compared with other revisions even so these revision are significant. The significance of data revision can be confirmed by looking at the results in Table 5 which presents the summary statistics for total revisions, data revisions and other revisions in the output gap estimated using different methods. Total revision in the output gap is negative in QT, HP and VAR models which indicates the downward revision in the gap while it is positive in LT and PF models. The average data revisions, however, are positive in all five models which indicates that final estimates are, in general, above real time estimates. The standard deviation is almost the same in all models which indicate more or less the same spread in revisions.

Figure 4.4(a). Estimated Output Gap-Linear Trend

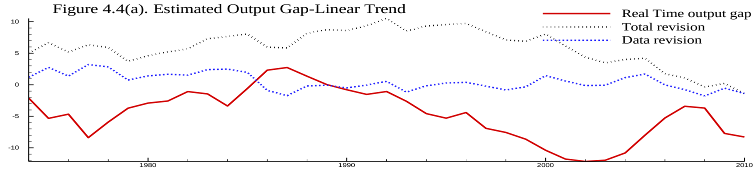


Figure 4.4(b). Estimated Output Gap-QT

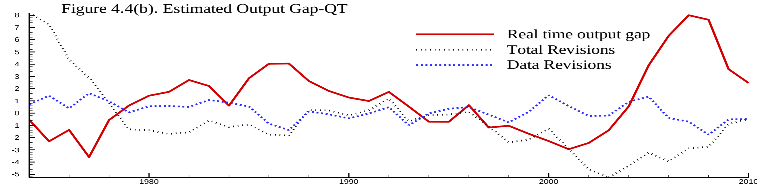


Figure 4.4(c). Estimated Output Gap-HP

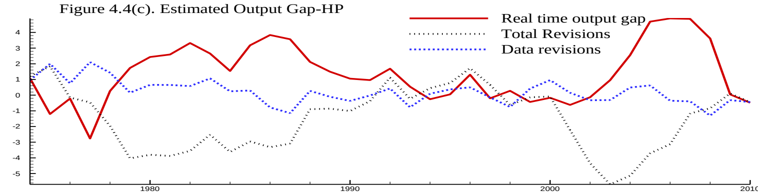


Figure 4.4(d): Output Gap Estimates - VAR Model

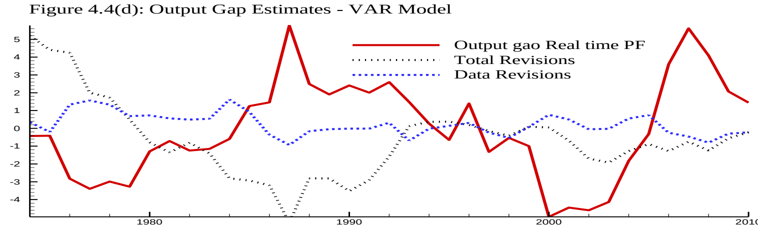
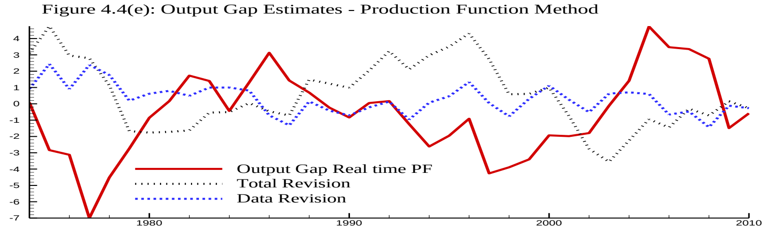


Figure 4.4(e): Output Gap Estimates - Production Function Method



In Table 5 first order autocorrelation coefficient, which measures the degree of persistence, is quite high for total revision series and ranges from 0.84 for HP filter and production function approach to 0.92 for quadratic trend measure. The persistence for other revisions is much higher than the total revision. It ranges from 0.87 for vector autoregressive measures to 0.98 for linear trend method. So the predictability of other revisions is better than total revisions. In the data revision, persistence is very low as compared with total revisions and other revisions. Only in the linear trend model, the data revision of the output gap has the persistence coefficient of 0.64, while in all other measures this coefficient is less than 0.50. This implies the lack of predictability of future data revisions.

Table 6

Decomposition of Total Revision into Data Revision and Other Revisions

Method	MEAN	SD	RMS	MIN	MAX	AR
Linear Trend						
Total Revision= F-RT	5.94	2.95	6.61	–1.39	10.53	0.91
Other Revisions=F-QR	5.43	2.94	6.15	0.00	9.98	0.98
Data Revision= QR-RT	0.51	1.32	1.40	–1.77	3.22	0.64
Quadratic trend						
Total Revision= F-RT	–0.70	2.80	2.84	–5.26	8.19	0.92
Other Revisions=F-QR	–0.87	2.61	2.79	–5.22	7.47	0.95
Data Revision= QR-RT	0.17	0.80	0.80	–1.76	1.62	0.43
Hodrick-Prescott Filter						
Total Revision= F-RT	–1.52	2.02	2.51	–5.69	1.84	0.84
Other Revisions=F-QR	–1.73	2.03	2.65	–5.62	1.22	0.91
Data Revision= QR-RT	0.21	0.76	0.78	–1.30	2.11	0.50
Vector autoregressive						
Total Revision= F-RT	–0.65	2.17	2.23	–5.29	5.20	0.90
Other Revisions=F-QR	–0.87	2.07	2.22	–4.43	4.85	0.87
Data Revision= QR-RT	0.22	0.63	0.67	–0.93	1.62	0.57
Production Function						
Total Revision= F-RT	0.54	2.07	2.11	–3.55	4.75	0.84
Other Revisions=F-QR	0.25	1.98	1.97	–4.18	3.09	0.91
Data Revision= QR-RT	0.29	0.91	0.94	–1.43	2.44	0.49

5. CONCLUSION

The objective of this paper is to find evidence of over and/or under estimation of the output gap. This is done by comparing estimates of the output gap based on real time data with that in the revised data. The quasi real time data is also constructed such that the difference between estimates of the output gap from real time data and that from quasi real time data reflects data revision and the difference between estimates of the output gap from final data and that from quasi real time data portray the revisions other than the data revisions including end sample bias. Moreover, the output gap is estimated with the help of five methods namely the linear time trend method, quadratic time trend method, HP filter, production function method, and vector autoregressive method.

The study used data on real GDP, inflation rate, interest rate, gross fixed capital formation, unemployment rate, and the labour force of Pakistan over the period 1960 to 2010 to fulfil the above stated objectives. Results can be summarised as follows.

- Estimates of the output gap in real time data are different from what has been found in the final data. Data revisions, though less than other revisions, are found to be significant. Hence output gap estimated from final or revised data is a poor proxy of the output gap estimate that was actually available to policy-makers at the time of policy decision.
- Output gap measured with linear trend method is a poor proxy of business cycle as it overestimates the intensity of the business cycle and is severely subject to the end sample bias.
- Estimates of the output gap from other four methods portray well the state of the economy. However, results based on quadratic time trend method and

production function method are more consistent with the business cycle facts for Pakistan economy.

- Contrary to the evidence in empirical literature for other countries, it is found that recessions are well predicted by real time data instead of revised data. Slowdown in economic activity is indicated first by real time data and then by final data.
- Despite the predicting power of real time data for recessions, final data shows more intensity of recession compared to what is shown in real time data. Opposite results are found in case of boom periods where real time data shows greater intensity.
- Correlation coefficient between different estimates of the output gap from final data and those from real time data is less than 0.7 which shows that the revision is significant in size.
- All the revision series are highly persistent. However, the persistence differs across different methods. The coefficient ranges from 0.84 for HP filter and PF model to 0.92 for QT model. The high degree of persistence in the total revision series indicates that the real-time output gap estimates may lead policy-makers and other economic agents to persist with false perceptions about the state of business cycles.

Policy Implications

The main policy implication of this paper is that the policy-makers in Pakistan should treat estimates of the output gap cautiously. The output gap estimates are a poor proxy for the business cycle and different measures of the output gap give different estimates. As revisions other than data revisions are larger in size, it is suggested that the policy-makers should rely on the methods of estimating the output gap that are less sensitive to end sample observations.

REFERENCES

Apel, Mikael and Per Jansson (1999) A Theory-consistent System Approach for Estimating Potential Output and the NAIRU. *Economics Letters, Elsevier* 64:3, 271–275.

Araujo, C. H. V., M. B. M. Areosa, and O. T. C. Guillén (2004) Estimating Potential Output and the Output Gap for Brazil. Banco Central do Brazil Working Paper Series.

Baxter, M. and R. G. King (1995) Measuring Business Cycles: Approximate Band-pass Filters for Economic Series. Massachusetts: NBER. (NBER Working Paper No. 5022).

Bernhardsen, T., Ø. Eitrheim, A. S. Jore, and Ø. Røisland (2004) Real-time Data for Norway: Challenges for Monetary Policy. Deutsche Bundesbank. (Discussion Papers 26/2004).

Beveridge, S. and C. R. Nelson (1981) A New Approach to the Decomposition of Economic Time Series into Permanent and Transient Components with Particular Attention to Measurement of the Business Cycle. *Journal of Monetary Economics* 7, 151–174.

Billmeier, A. (2004) Measuring a Roller Coaster: Evidence on the Finish Output Gap. Washington, DC; International Monetary Fund. (IMF Working Paper 04/57).

Blanchard, O. J. and D. Quah (1989) The Dynamic Effect of Aggregate Demand and Supply Disturbances. *American Economic Review* 79:4, 655–673.

Burns, Arthur F. and Wesley C. Mitchell (1946) Measuring Business Cycles. NBER Books.

Cayen, Jean-Philippe and Simon van Norden (2005) The Reliability of Canadian Output-gap Estimates. *The North American Journal of Economics and Finance, Elsevier* 16:3, 373–393.

Chagny, O. and J. Döpke (2001) Measures of the Output Gap in the Euro-Zone: An Empirical Assessment of Selected Methods. Kiel Institute of World Economics. (Kiel Working Paper, 1053).

Clark, P. K. (1987) The Cyclical Components of US Economic Activity. *Quarterly Journal of Economics* 102:4, 797–814.

Claus, Iris (2000) Is the Output Gap a Useful Indicator of Inflation? Reserve Bank of New Zealand. (Discussion Paper Series: DP2000/05).

Claus, Iris (1999) Estimating Potential Output in New Zealand: A Structural Var Approach. Reserve Bank of New Zealand. (Discussion Paper Series: DP2000/03).

Cogley, Timothy (1997) Evaluating Non-structural Measures of the Business Cycle. *Economic Review, Federal Reserve Bank of San Francisco,* 3–21.

Cooley, Thomas J. and Lee E. Ohanian (1992) The Cyclical Behaviour of Prices. *Journal of Monetary Economics* 28, 25–60.

Correia, I., J. C. Neves, and S. Rebelo (1995) Business Cycles in Small Open Economies. *European Economic Review* 39, 1089–1113.

Correia, I., J. C. Neves, and S. Rebelo (1992) Business Cycles from 1850–1950—New Facts about Old Data. *European Economic Review* 36:2, 459–467.

Dean, Croushore and Tom Stark (2000) A Real-Time Data Set for Macroeconomists: Does Data Vintage Matter for Forecasting? Federal Reserve Bank of Philadelphia. (Working Paper 00-6).

Croushore, Dean, and Tom Stark (2001) A Real-Time Data Set for Macroeconomists. *Journal of Econometrics* 105: (November), 111–130.

Croushore, D. and T. Stark (2003) A Real-Time Data Set for Macroeconomists: Does the Data Vintage Matter? *Review of Economics and Statistics* 85, 605–617.

Croushore, Dean and Charles L. Evans (2006) Data Revisions and the Identification of Monetary Policy Shocks. *Journal of Monetary Economics, Elsevier* 53:6, 1135–1160.

De Brouwer, G. (1998) Estimating Output Gaps. Reserve Bank of Australia. (Research Discussion Paper No: 9809).

Diebold, F. X. and A. S. Senhadji (1996) The Uncertain Unit Root on GNP: Comment. *American Economic Review* 86:5, 1291–8.

Dupasquier, Chantal, Alain Guay, and Pierre St-Amant (1997) A Comparison of Alternative Methodologies for Estimating Potential Output and the Output Gap. Bank of Canada. (Working Papers 97-5).

Froyland, E. and R. Nymoen (2000) Output Gap in the Norwegian Economy. Norges Bank. *Economic Bulletin* 71:2, 46–52.

Gibbs, D. (1995) Potential Output: Concepts and Measurements. Labour Market. *Bulletin of New Zealand Department of Labour* 1, 72–115.

Giorno, C., *et al.* (1995) Estimating Potential Output, Output Gaps and Structural Budget Balances. OECD Publishing. (OECD Economics Department Working Papers, No. 152).

Gruen, D., T. Robinson, and A. Stone (2002) Output Gaps in Real Time: Are They Reliable Enough to Use for Monetary Policy? (Reserve Bank of Australia Research Discussion Paper 2002-06).

Harberger, A. (1978) Perspectives on Capital and Technology in Less Developed Countries. In M. J. Artis and A. R. Nobay (eds.) *Contemporary Economic Analysis.*

Haider, Adnan and Sadar Ullah Khan (2008) Estimating Output Gap for Pakistan Economy: Structural and Statistical Approaches. *SBP Research Bulletin* 4:1, 31–60.

Hodrick, R. and E. C. Prescott (1997) Post-War US Business Cycles: An Empirical Investigation. *Journal of Money, Credit and Banking* 29, 1–16.

Kamada, Koichiro (2005) Real-time Estimation of the Output Gap in Japan and its Usefulness for Inflation Forecasting and Policy-making. *The North American Journal of Economics and Finance, Elsevier* 16:3, 309–332.

Kenny, G. (1995) Some Estimates of Potential Output and the Output Gap for Ireland. (Central Bank of Ireland Technical Paper, 5/RT/95).

Khan (2006) Macro Determinants of Total Factor Productivity in Pakistan. *SBP Research Bulletin* 2.

Kozicki, S. (2004) How Do Data Revisions Affect the Evaluation and Conduct of Monetary Policy? *Federal Reserve Bank of Kansas City, Economic Review* (Second Quarter), 5–38.

Kozicki, Sharon and P. A. Tinsley (2005) Permanent and Transitory Policy Shocks in an Empirical Macro Model with Asymmetric Information. *Journal of Economic Dynamics and Control, Elsevier* 29:11, 1985–2015.

Kuttner, K. N. (1994) Estimating Potential Output as a Latent Variable. *Journal of Business and Economic Statistics* 12, 361–368.

Kuttner, K. N. (1992) Monetary Policy with Uncertain Estimates of Potential Output. *Federal Reserve Bank of Chicago Economic Perspectives* 16, 2–15.

Laxton, D. and R. Tetlow (1992) A Simple Multivariate Filter for the Measurement of Potential Output. Bank of Canada. (Technical Report, No. 59).

Mankiw, N. Gregory, and David Romer (1991) *New Keynesian Economics: Coordination Failures and Real Rigidities.* Vol. 2. MIT Press.

Mitchell, Wesley C. (1927) Business Cycles: The Problem and its Setting.

Nehru, V. and A. Dhareshwar (1993) A New Database on Physical Capital Stock: Sources, Methodology and Results. *Revista de Analisis Economico* 8:1, 37–59.

Nelson, C. R. and C. I. Plosser (1982) Trends and Random Walks in Macroeconomic Time Series: Some Evidence and Implications. *Journal of Monetary Economics* 10, 139–62.

Nelson, Edward and Kalin Nikolov (2003) UK Inflation in the 1970s and 1980s: The Role of Output Gap Mismeasurement. *Journal of Economics and Business, Elsevier* 55:4, 353–370.

Okun, Arthur M. (1962) Potential GNP: Its Measurement and Significance. (Reprinted as Cowles Foundation Paper 190).

Orphanides, A. (2001) Monetary Policy Rules Based on Real-Time Data. *American Economic Review* 91:4, 964–985.

Orphanides, A. (2003) Historical Monetary Policy Analysis and the Taylor Rule. *Journal of Monetary Economics* 50, 983–1022.

Orphanides, A. and S. van Norden (2002) The Unreliability of Real Time Estimates of the Output Gap. *Review of Economics and Statistics* 84: 4, 569–83.

Perron, P. (1997) Further Evidence on Breaking Trend Functions in Macroeconomic Variables. *Journal of Econometrics* 80:2, 355–385.

Perron, P. (1989) The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis. *Econometrica* 57, 1361–1401.

Quah, Danny (1992) The Relative Importance of Permanent and Transitory Components: Identification and Some Theoretical Bounds. *Econometrica* 60:1, 107–118.

Rünstler, G. (2002) Are Real-time Estimates of the Output Gap Reliable? Computing in Economics and Finance 2002 300, Society for Computational Economics.

Saxena, S. Chaman and V. Cerra (2000) Alternative Methods of Estimating Potential Output and the Output Gap—An Application to Sweden. International Monetary Fund. (IMF Working Papers 00/59).

Sherbaz, Sadia, Fatima, Amjad, and Naheed Zia Khan (2010) Output Gap and its Determinants: Evidence from Pakistan. *Journal of Economic Cooperation and Development* 30: 3, 75–82.

Sims, C. A. (1980) Macroeconomics and Reality. *Econometrica* 48, 1–48.

Scott, A. (2000) Stylized Facts from Output Gap Measures. Wellington. (Reserve Bank of New Zealand Discussion Paper No. 2000/07).

Scott, A. (2003) A Multivariate Unobserved Components Model of Cyclical Activity. Reserve Bank of New Zealand.

Syed, Sarfaraz and Ali Shah (2009) Output Gap Measures for Pakistan: Methodologies and Challenges for the Monetary Policy. *Journal of Applied Research in Finance* 1: 2, 206–227.

Watson, M. W. (1986) Univariate Detrending Methods with Stochastic Trends. *Journal of Monetary Economics* 18, 49–75.