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Estimation of Egypt's Potential Output and Output Gap

Heba Shahin[1]

Abstract

Potential output is an important tool for policy formulation, but no less important is the output gap which provides a benchmark for the policy control process in the short run. The paper employs univariate and multivariate methods to estimate Egypt's potential output and the output gap, in order to select a reliable technique capable of interpreting economic changes such as inflation and unemployment gap. The univariate methods include the HP filter, the Running Median Smoothing filter (RMS), and the de-noising wavelets filter. The production function approach is also adopted where a robust estimate of the potential labor is obtained by deriving Egypt's NAIRU. A medium term forecast for the output gap is also provided.

JEL Classification: C5, C6, E2, E3

Keywords: Potential Output, Output Gap, Production Function, NAIRU.

I. Introduction

Estimating potential output has become an issue of high importance since it represents one of the widely used tools for policy formulation. Potential output is the maximum output an economy can sustain, without generating a rise in inflation (Masi 1997). It is also defined as the level of output at which demand and supply are balanced. Following Cobb-Douglas production function, it is the level of output that an economy can produce, based on its available resources (factors), given the current technology (total factor productivity TFP). The potential output determines the pace

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of sustainable growth in the medium term, while its deviation from the actual results in the output gap which provides a benchmark against the dynamics of inflation and the policy control process in the short term. Their importance stems from the necessity of identifying the level of output that would be consistent with the objectives of the macroeconomic policy, especially price stability.

On the other hand, the output gap - defined here as potential output differenced from actual output - plays a key role in the inflation process. In detail, when the actual level of output is above the potential output, inflation tends to rise due to inflationary pressures and vice versa. Thus, it becomes important to estimate the future path of potential output in order to ascertain whether the projected path of output - which is the outcome of the current monetary policy - will cause the price level to be consistent with the monetary policy target.

Egypt is one of the small open economies that have gone through many structural changes and global shocks which created relatively large fluctuations in its output levels. For instance, Egypt's GDP growth rate increased from 4.2% in 2003/2004 (the year preceding large economic reforms) to 7.2% in 2007/2008.

In this paper, Egypt's potential output, output gap, and NAIRU are estimated. The estimates are used to investigate the effects of the global economic crisis on Egypt and to find out whether these effects are permanent or transitory.

Estimates of potential output may vary, depending on the estimation technique, giving possibly misleading indications, which poses the risk of formulating inappropriate macroeconomic policy decisions. Hence, it is highly recommended to employ several techniques to estimate the potential output and compare them, especially the extent to which they can interpret economic changes such as inflation and the unemployment gap.

To achieve its purpose, this paper implements multiple univariate and multivariate statistical methods to estimate the potential output; including the popular production function approach. The employed univariate techniques include: Hodrick-Prescott (HP) filter, the Running Median Smoothing filter (RMS), and the de-noising wavelets filter.

The paper is organized as follows: section II describes the data and briefly defines the respective estimation techniques. Section III is reserved for empirical results. Firstly, the potential output and the output gap of Egypt are derived on the basis of univariate de-trending techniques. Secondly, Egypt's production function is estimated and then the potential level of output is derived. Special emphasis is placed on deriving the NAIRU estimate as part of the process of deriving the potential output. In addition, the paper presents a medium term forecast for the output gap, based on each of the used approaches. Finally, section IV summarizes the main ideas and draws conclusions.

II. Estimation Techniques

In this section, some univariate de-trending methods are implemented to estimate potential output. In addition, the popular production function approach is employed to derive the potential output, with a special focus on deriving the potential employment via the NAIRU concept.

II.1. Data Description

The computations in this paper are based on quarterly data. The output data is the GDP at 2001/2002 prices starting from the third quarter of 2001 (the earliest quarterly observation published by the Egyptian Ministry of Economic Development). Output data are exponentially smoothed. Using the seasonal factor index for output series, the annual values of output two years earlier were decomposed into quarterly data to provide a minimum length for de-trending using the de-noising wavelets method. Otherwise, for other methods, the paper sticks only to the published series length.

For the production function, in order to calculate the NAIRU, the unemployment rate, labor force, and the number of employees are used starting from the first quarter of 2003 (the first data point available from the Central Agency for Public Mobilization and Statistics CAPMAS). In addition, data on the imported inflation are calculated using the whole price indices for Egypt's major trade partners which are available on the International Monetary Fund (IMF) website; IFS data.

II.2. Univariate Methods

The univariate methods identify the permanent component in the output to be a measure of potential output (Beveridge and Nelson 1981, Clark 1987). Univariate methods for estimating potential output depend on de-trending the output. They differ in the degree of smoothness they achieve, or equivalently the amount of economic changes they incorporate into the derived series.

Univariate time-series techniques are used to fit trend lines through the data and these trend lines provide measures of the underlying "equilibrium" values. Deviations of the trend lines from the actual define "gaps".

<u>The Hodrick Prescott (HP) Filter</u>

The HP filter is a very common technique used to derive the trend in an actual data series. It is famous for its simplicity and for being a univariate technique which allows for working on a relatively short time series. However, it is criticized for assuming stable conditions over an extended period of time and, in doing so, it does not account for structural changes.

Mathematically, the HP filter is a two-sided linear filter that computes the smoothed series Y^* of Y by minimizing the variance of Y around Y^*, subject to a penalty that constrains the second difference of Y^*. That is, the HP filter chooses Y^* to minimize the quantity:

$$\sum_{1}^{T}(Y_t - Y_t^*)^2 + \lambda\sum_{2}^{T-1}((Y_{t+1}^* - Y_t^*) - (Y_t^* - Y_{t-1}^*))^2 \qquad (1)$$

The penalty parameter λ controls the smoothness of the series Y^*. The larger λ, the smoother Y^*. T refers to the series length.

The issue of the degree of smoothing emerges in the HP filter as with similar de-trending techniques. One has to assign a smoothing degree in the filtering process, depending on the nature of the shocks to the economy. If the shocks to the economy are primarily shocks to aggregate demand, with supply conditions largely unaffected, then potential output does not move closely with the data, and it is appropriate to use a high level of smoothing in the filter. If, on the other hand, there is a high proportion of supply shocks, then potential output is indeed moving with the data, and a lower degree of smoothing is appropriate (Benes and N'Diaye 2004).

The Running Median Smoothing (RMS) Filter

RMS filter is another univariate statistical technique with an advantage over the HP filter, as it adapts to structural changes, and thus, results in less smoothed estimates. It separates transitory from permanent movements in the data and excludes outliers from the permanent so that it can extract the business cycle dynamics rather than noisy fluctuations.

Within this paper, an algorithm for Tukey (1977) is used, where the non-linear RMS of the input vector is computed. The used technique of the 4(3RSR)2H type[2], smoothes the data (Y^s), computes the residuals (E), smoothes the residuals (E^s), and adds this back to the first smooth (Y^s) to finally get the RMS filter (Y^*):

$$\left.\begin{aligned} Y &= Y^s + E \\ E &= E^s + e \end{aligned}\right\} \Rightarrow Y^* = Y^s + E^s$$

This technique is maintained, using the MATLAB environment.

The Wavelets Filter

The wavelets filter is a middle ground of sorts between the previous two filters in the sense that it is less adaptive to structural changes than the RMS, but it does not suffer from the HP problems, especially the way the HP deals with shocks experienced by the economy. It has an advantage of letting potential output include time-varying dynamics.

The filter used in this study is known as the wavelets de-noising filter or wavelets shrinkage developed by Donoho et al (1995). The de-noising methods, based on wavelets decomposition, were mainly initiated by Donoho and Johnstone in the USA, and Kerkyacharian and Picard in France. Meyer (1993) considers that this topic is one of the most significant applications of wavelets.

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[2] The used code is written by Huy Le, Massachusetts Institute of Technology, 1997. (http://www.mathworks.com/ matlabcentral/fileexchange/274-smooth)

The idea is to extract a filtered series from the original noisy series by decomposing the actual one into the de-noised series – potential output in this paper – and an error component which denotes transitory movements as in the following equation:

$$Y = Y^* + E \tag{2}$$

where Y denotes the actual output, Y^* potential output, and finally E denotes the transitory movements or equivalently the output gap. It is worth noting that extraction of Y^* is implemented via the MATLAB software using the wavelets toolbox facility[3].

It is worth mentioning that univariate filtering techniques may be preferably chosen over other more complicated approaches because considerably less data are required, and implementation is easier. However, they suffer from a number of problems, such as lacking an economic basis, in addition to becoming imprecise at the end of the sample.

Estimation of the potential output using structural approaches, such as the production function, is a common classical technique which is credited for being useful in identifying the factors contributing to changes in the growth rate of potential output. Its importance is even higher within the emerging and developing countries, where growth is generally higher than advanced countries, making short-term fluctuations less clear.

II.3. Production Function Approach

The classic Cobb-Douglas specification for the production function is adopted, assuming constant returns to scale. This technique is largely common in literature (Epstein and Macchiarelli 2010 and Konuki 2008).

[3] The wavelets toolbox facility provides an interactive interface that allowed for using the soft thresholding method for extracting the de-noised series, assuming a wavelet following the DB family with level 3. A minimum number of 40 observations is required to run this software which is 5 observations larger than the available. To overcome this obstacle, the annual output levels in the two years preceding the available quarterly data on output are decomposed, using the seasonal factors index, to obtain extra observations.

According to the Cobb-Douglas specification, the output is considered a function of labor and capital inputs, as well as of Total Factor Productivity (TFP):

$$Y_t = A_t\ L_t^{\alpha}\ K_t^{1-\alpha} \tag{3}$$

where Y_t is output, L_t and K_t are labor and capital, respectively, and A_t denotes TFP. The assumption of constant returns to scale adds the restriction that the output elasticities sum up to one as can be inferred from the previous form of the production function.

The labor input is defined as the number of employees in the economy. The capital input is the capital stock constructed from total investment using perpetual inventory method, which takes the stock of capital as the accumulation of the stream of past investments:

$$K_t = I_t + (1-\phi)K_{t-1} \tag{4}$$

where ϕ is the rate of geometric decay, K_t refers to capital stock in period *t*, and I_t refers to investment flow in period *t*. Following Nehru and Dhareshwar (1993), the concept of initial capital stock $K(0)$ is used in the construction of the capital stock series:

$$K_t = (1-\phi)^t K(0) + \sum_{i=0}^{t-1} I_{t-i}(1-\phi)^i \tag{5}$$

where $K(0)$ is the initial capital stock. Following Nehru and Dhareshwar (1993), the initial investment value is re-estimated through a linear regression of log investment against time. The fitted value of initial investment $\hat{I}(1)$ is used to calculate the initial capital stock using the following equation:

$$K(0) = \hat{I}(1) \big/ (g+\phi) \tag{6}$$

where g is the average rate of quarterly output growth and ϕ is the quarterly depreciation rate of capital where it is assumed to equal 0.01.

It is worth mentioning that the output, labor, and investment stock variables were exponentially smoothed before proceeding to the analysis process.

TFP is calculated as *Solow* residual from the Cobb-Douglas production function, although it is preferable to be improved by allowing for quality changes in factor inputs by using indices that reflect changes in composition of capital and labor force. However, the non-availability of such readymade indices in Egypt makes it difficult to make such a refinement. The TFP component can then be derived as a *Solow residual* from (3):

$$A_t = \frac{Y_t}{L_t^{\alpha}\ K_t^{1-\alpha}}. \tag{7}$$

To estimate potential output, there is a need to obtain potential inputs. As for potential utilization of capital stock, and in consistency with literature, *full* utilization of the existing stock of capital is assumed, since the capital stock can be regarded as an indicator for the overall capacity of the economy (Denis *et al*. 2000). On the other hand, potential TFP is obtained as an HP trend for the TFP obtained in (7).

In order to obtain potential employment, an estimate of the Non-Accelerating Inflation Rate of Unemployment (NAIRU) is derived. It is defined as the unemployment rate at which inflation will have no tendency to move up or down. A natural rate of output (potential output) corresponds to NAIRU.

NAIRU is obtained through decomposing the unemployment rate, using Kalman filter (see appendix 1), into a trend component representing a benchmark for the equilibrium unemployment rate and a cyclical component representing a reference for the unemployment gap (Epstein and Macchiarelli 2010). The derived cyclical component is then modeled through a standard Philips curve relationship. Thus, NAIRU can be derived directly from estimates of the Phillips curve and then an estimate of potential output can be obtained (Adamu 2009).

III. Empirical Results

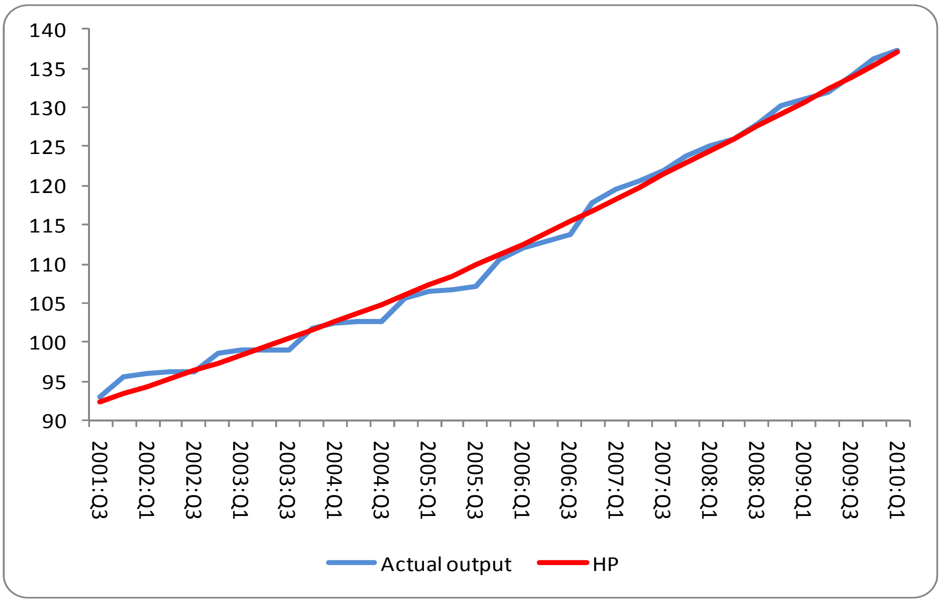
This section presents the outcomes of applying the univariate methods; HP, RMS, and wavelets, and the production function approach for estimating the potential output and the output gap. It is noteworthy that the term “actual output” is used as a shortcut for the exponentially smoothed real output series.

III.1. Univariate Methods

Figure (1) shows actual output against its potential measured with the HP filter which clearly gives a very smooth line as expected. According to the HP filter, the period starting the 2nd quarter of 2004 and ending the 3rd quarter of 2006 witnessed negative output gaps, while the following period – that witnessed high growth rates in real output – showed better performance, where the actual was very much close to, or even higher than, the potential.

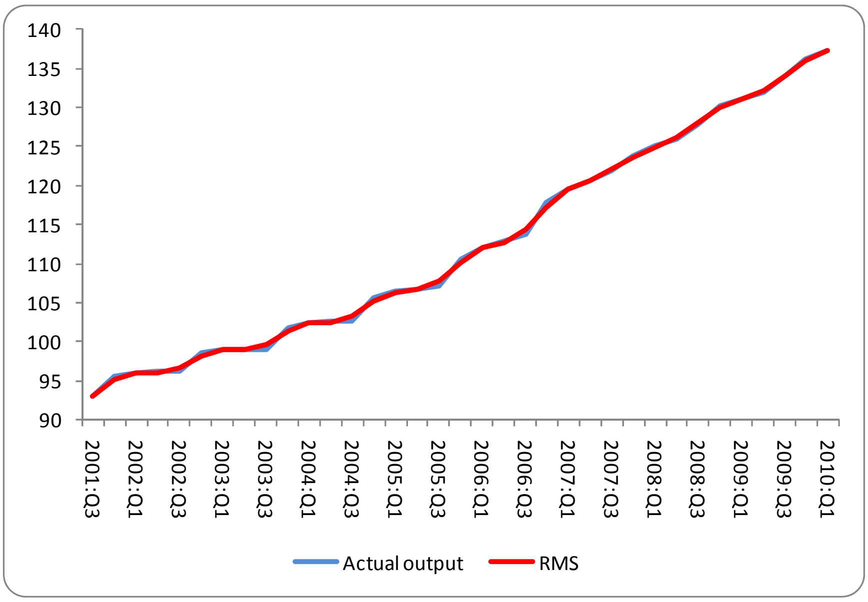
It is worthy to mention that the effect of the financial crisis was not clear according to the HP filter. This may be due to its nature, since it is a univariate filter and is known to suffer from end of sample biases.

Figure (1): Actual Output and the HP Filter



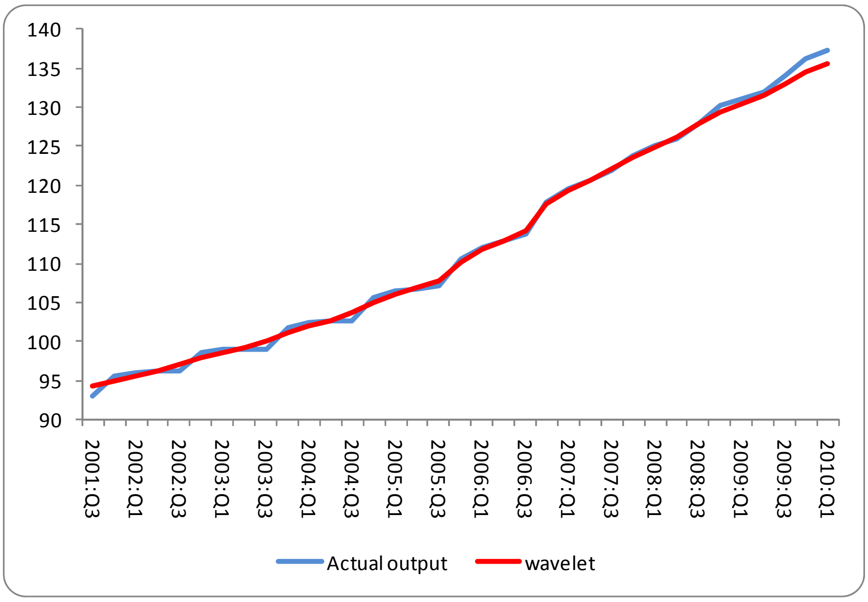
On the other hand, figure (2) shows the actual output against its potential measured with the RMS filter of the (R3RSR)2H type. While this filter is very adaptive to changes in the actual level of output, it considers the peaks of ups and downs as transitory effects and, hence, removes them from the potential. According to the said filter, there were no significant output gaps.

Figure (2): Actual Output and the RMS Filter



Finally, figure (3) shows the actual output against its potential measured with the de-noising wavelets filter. According to the wavelets filter trend, it recently seems that the economy is showing output levels higher than its potential and the gap is gradually increasing. The recent increase in actual output growth could have driven that trend.

Figure (3): Actual Output and the Wavelets Filter



Although Egypt exhibited low growth rates in the wake of the crisis, the positive output gap - according to the wavelets filter - started by the end of 2008, implying that the crisis had larger effect on the potential output than it had on the actual. However, the early positive gap may simply be due to the end of sample biases that univariate methods could entail.

III.2. Production Function Approach

To estimate the production function, the involved variables are first tested for stationarity to avoid spurious regression. It is noteworthy that the used software for analysis and estimation is Eviews. Table (1) below shows the results of Philips-Perron unit root tests for the natural logarithm of the actual output (Y), capital stock (K), and labor (L). It is found that all variables are non-stationary in terms of their levels, yet they are stationary in terms of their first-differences.

Table (1)
Philips-Perron Unit Root Tests for Variables' Stationarity

Variable	Bandwidth (Newey-West using Bartlett kernel)	Adj. t-statistic
Y	12	1.53
ΔY	26	-8.34*
K	3	2.59
ΔK	1	-4.07*
L	1	-0.64
ΔL	0	-4.12*

(*) Denotes rejection of the hypothesis at the 1% level.

Standard Johansen's co-integration test - based on an unrestricted VAR model with 1 lag and no constant term - suggests the existence of one long-run co-integrating relationship among the three variables (Table 2).

Table (2): Johansen's Co-Integration Test

Hypothesized No. of co-integrating vectors	Eigen value	Trace Statistic	5% Critical Value	1% Critical Value
None *	0.58	30.91	29.68	35.65
At most 1	0.24	7.41	15.41	20.04
At most 2	0.01	0.16	3.76	6.65

* Denotes rejection of the hypothesis at the 5% level.
Trace test indicates 1 co-integrating equation at the 5%.

Thus, by reformulating equation (3) to its logarithmic form and estimating it (under the constant returns to scale assumption), we get the following result:

$$Y = -3.82 + 0.44\,K + 0.56\,L \tag{8}$$

S.E.: (0.13) (0.04) (0.04)

P-value: (0.000) (0.000) (0.000)

Adj. $R^2 = 0.987$

The model parameters are highly significant and give the expected sign. These results show that 98.7% of Egypt's production is explained by capital and labor, while the remaining 1.3% is due to TFP. The estimated elasticities of both capital and labor are highly significant and their values are consistent with many empirical studies on the developing countries.

Thus, the TFP is easily computed as *Solow* residuals mentioned earlier by equation (7). The HP trend of the resulting series can then be considered as the potential TFP.

Potential output is achieved when all factors of production are fully utilized. As previously mentioned, we assume *full* utilization of the existing stock of capital and the potential TFP is taken as the HP filter for the derived TFP, and finally comes the estimation of the potential employment. To estimate the potential employment, NAIRU is estimated, accordingly the derivation of the potential employment is straightforward.

To estimate the NAIRU, we follow a similar algorithm to that of Epstein and Macchiarelli (2010), the unemployment rate U_t is first decomposed - using the Kalman filter approach - into a trend $\overline{U}_t$ and a cyclical component G_t:

$$U_t = \overline{U}_t + G_t \tag{9}$$

where the trend component follows a local linear trend model; specifically:

$$\overline{U}_t = \mu_{t-1} + \overline{U}_{t-1} + \eta_t \tag{10}$$

where the trend unemployment is described by a random walk plus drift process, and where the drift is allowed to be stochastic, i.e. $\mu_t = \mu_{t-1} + \xi_t$. η_t is assumed to be iid following $N(0,\ 0.01)$. This choice for the variance of η_t allows the long-run unemployment rate to display the desirable property of shifting smoothly (Gordon 1996). The cyclical component is modeled as a stationary autoregressive process:

$$G_t = \phi_1 G_{t-1} + \phi_2 G_{t-2} + \phi_3 G_{t-3} + \phi_4 G_{t-4} + \psi_t\,. \tag{11}$$

The Philips relation can be represented as follows:

$$\pi_t - \pi_t^* = \beta\,(U_t - \overline{U}_t) + \delta\, Z_t + v_t \tag{12}$$

where π_t is an estimate of the actual inflation rate, π_t^* is the expected inflation rate, Z_t is the imported inflation to represent the supply shocks, and v_t is an error term. It is assumed that the economic agents are building their expectations for inflation in a naive way; based on the last observed inflation rate. Hence $\pi_t^* = \pi_{t-1}$, so that $\pi_t - \pi_t^* = \Delta\pi_t$. The model becomes:

$$\Delta\pi_t = \beta\,(U_t - \overline{U}_t) + \delta\, Z_t + v_t \tag{13}$$

Equation (13) neglects the possibility of serial correlation in the error term. Therefore, an autoregressive specification is used:

$$\Delta\pi_t = \beta\,(L)(U_t - \overline{U}_t) + \gamma(L)\Delta\pi_{t-1} + \delta(L)\, Z_t + \varepsilon_t \tag{14}$$

where L is the lag operator (e.g. $B(L)X = B_1 X_{t-1} + B_2 X_{t-2} + \ldots$), $\beta\,(L)$, $\gamma(L)$, and $\delta(L)$ are lag polynomials and ε_t is a serially uncorrelated error term.

The variables involved in the estimation relationship are tested and found stationary. In the estimated model, the change in the quarterly inflation rate (4 quarters change) with one lead $\Delta\pi_{t+1}$ is regressed on the cyclical component G_t under the specification in (11), the contemporaneous change in inflation $\Delta\pi_t$ and its lagged value $\Delta\pi_{t-1}$, and finally the lead and contemporaneous values of imported inflation; Z_{t+1} and Z_t:

$$\Delta\pi_{t+1} = 0.04\,G_t + 0.58\,\Delta\pi_t - 0.20\,\Delta\pi_{t-1} + 0.41\,Z_{t+1} - 0.37 \quad (15)$$

S.E.:	(0.03)	(0.21)	(0.25)	(0.22)	(0.23)
P-value:	(0.108)	(0.014)	(0.421)	(0.076)	(0.123)

Adj. R^2 = 0.50

The estimated Philips model gives the expected sign with explanatory variables that are significant. The relatively low value of the Adj.R^2 is accepted with models depending on differenced series.

Figure (4): Unemployment (Actual, Equilibrium, and NAIRU)

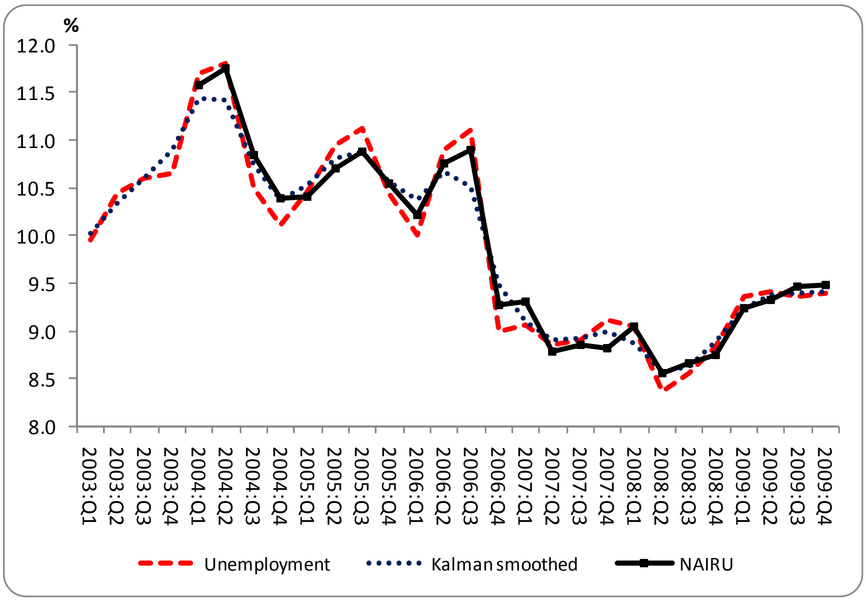
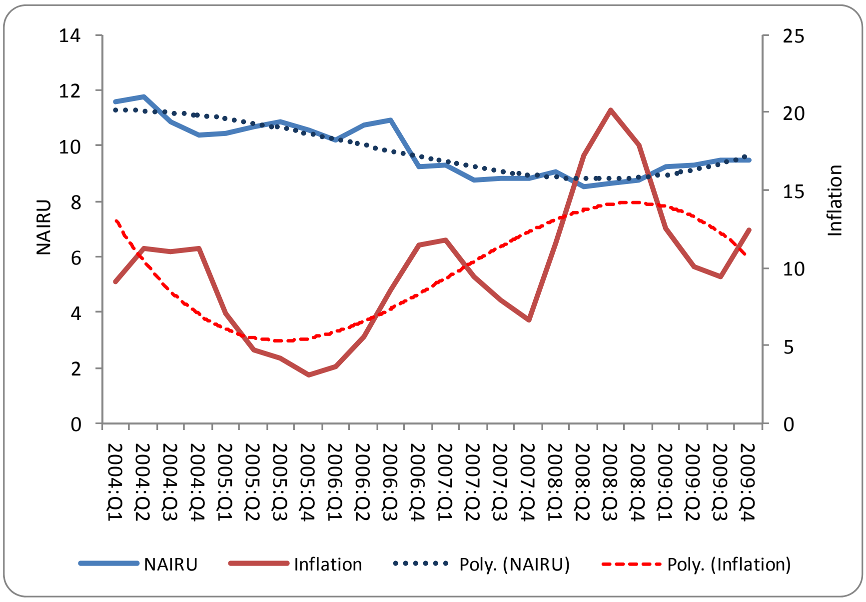


Figure 4 reports the actual unemployment rate, NAIRU, and the equilibrium unemployment rate (obtained by the Kalman filter; $\overline{U}$). It can be noted that all the trends for unemployment rate show increases by the end of 2008 affected by the global crisis.

The relationship between NAIRU and the rate of inflation is shown in figure 5 where the NAIRU series is plotted against the annual inflation rate. Polynomial trends of the 3rd order for each of the two series are also plotted for better observance.

Figure (5): Unemployment and Inflation Rates



As well documented in literature, there exists an inverse relationship between the natural rate of unemployment and inflation which is clearly noticed in figure (5). It is noticed that from the last quarter of 2008 (when the global financial crisis began to hit the world), the NAIRU decreasing trend has slowed down and a new increasing trend began to show, which is consistent with the decreasing trend of inflation.

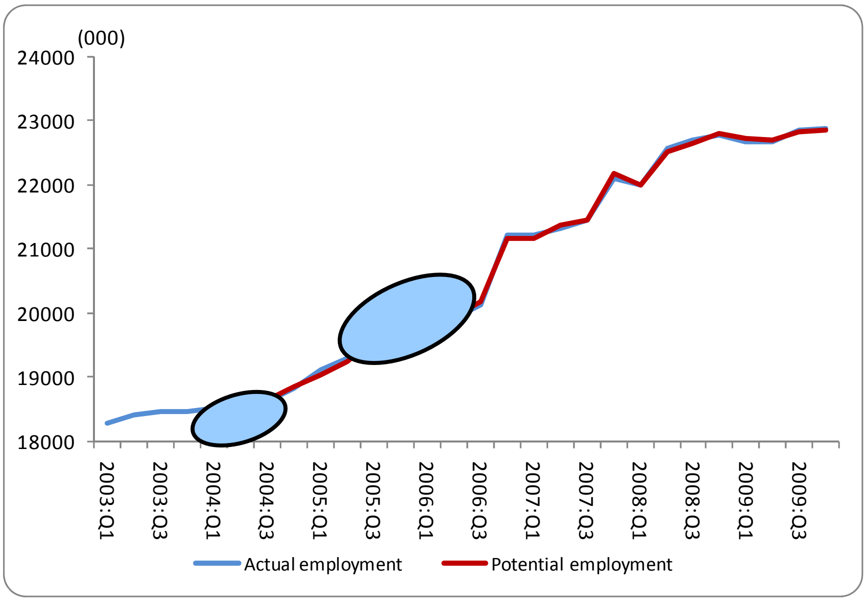
The estimated NAIRU from the Philips relationship is considered to be the potential level of unemployment. Thus, the derivation of potential employment is straightforward as shown by the following relation:

$L^p = L * (1 - NAIRU)$, where L denotes labor force. (16)

It is worth mentioning that the potential employment level can be modified by the participation ratio or other factors, such as the hours of work. However, these methods will not be followed due to data limitations.

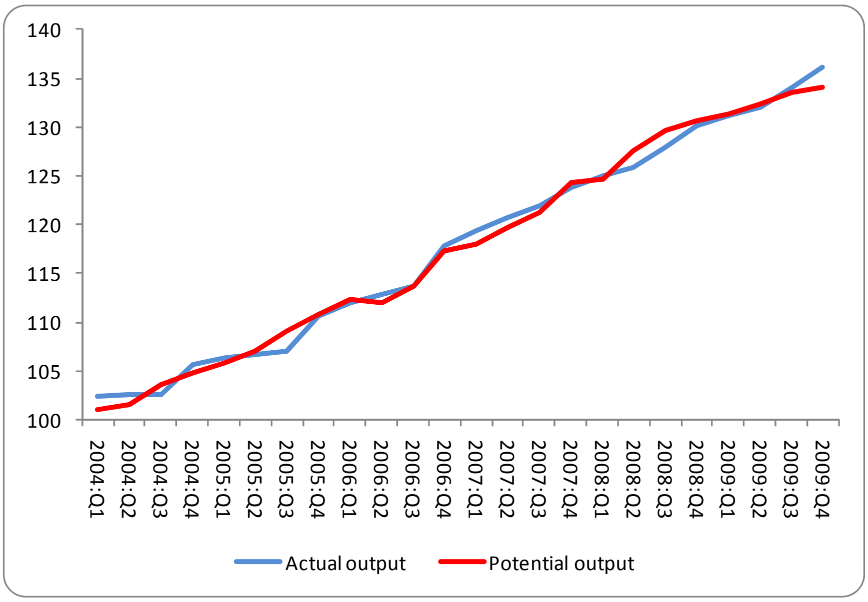
Figure (6) shows the actual employment level versus the potential level derived from NAIRU. From this figure, one can notice the negative gap in employment in the fiscal year 2005/2006. The reason behind the gap can be inferred from relating figure (5) to figure (6), where the former indicates the very low inflation rates in this period; therefore the potential employment would lead to a higher inflation rate that is closer to its normal track; i.e. the employment should be higher. The positive employment gap at the beginning of 2004 can be interpreted similarly.

Figure (6): Actual and Potential Employment



By applying the estimated Cobb-Douglas function, using the potential inputs, potential output is obtained. Potential output is plotted against the actual in the next figure which shows a positive gap that started in the 2nd quarter of 2006 and lasted for 6 quarters. However, the period from 2008 to mid 2009 exhibited negative gaps. By the end of 2008, the potential output decelerated compared to its previous trend and this behavior resulted in tightening the output gap. A positive gap started to appear by the end of 2009 which is consistent with the late increases in actual output growth rates.

Figure (7): Production Function: Actual and Potential Output

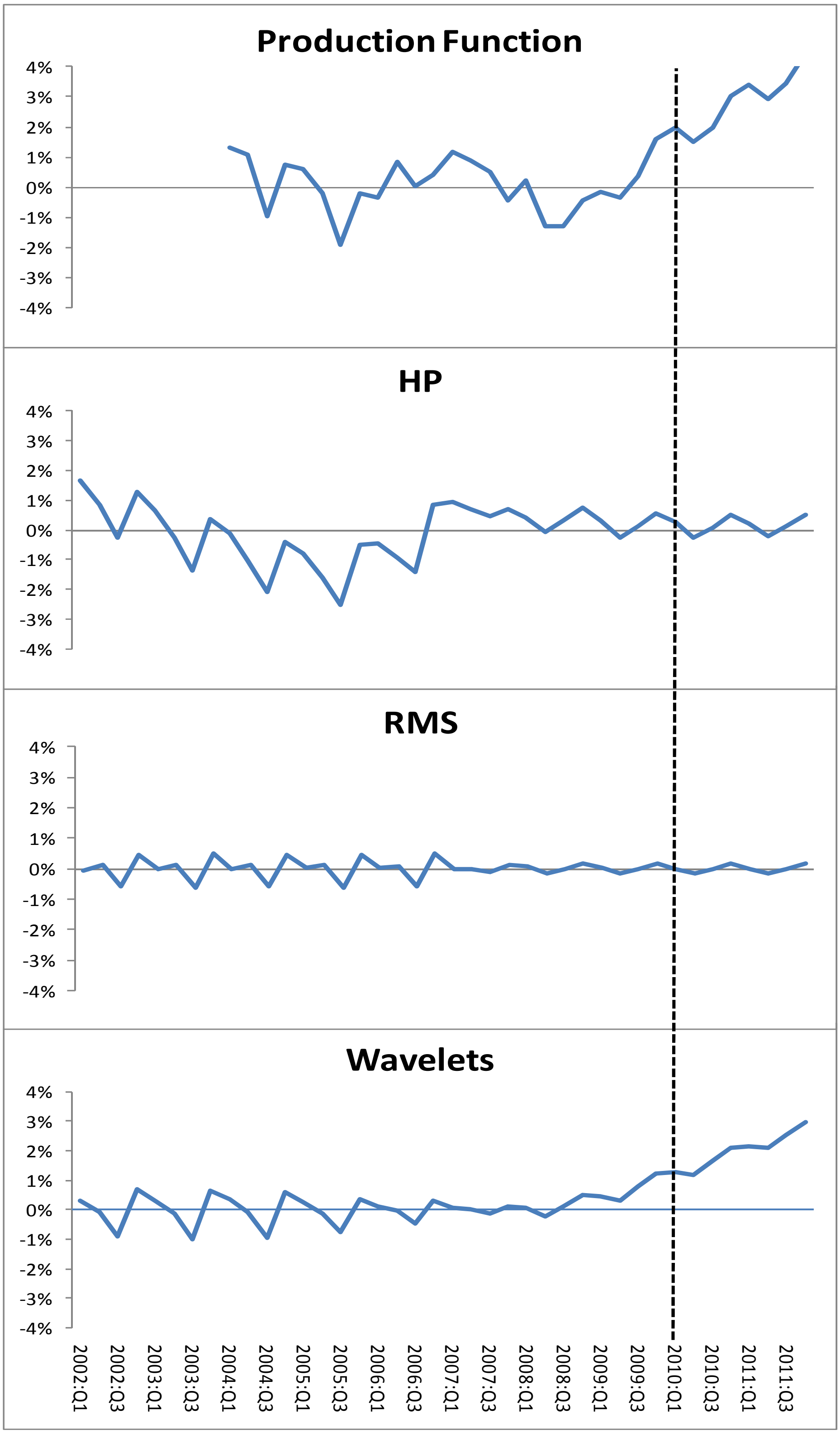


Estimating potential output using the production function approach may entail some problems, as Cerra and Saxena (2000) point out: "problems in obtaining potential estimates of the production function inputs are simply shifted to the estimated potential output". On the other hand, the merit of this approach over the univariate ones is that it focuses on the factors that drive growth in potential output, rather than simply on the historical behavior of output. These factors are useful for interpreting the structural changes that an economy may face.

Forecasting Egypt's output gap for the two years 2010 and 2011 is conducted, using the appropriate SARIMA models for each of the four gaps derived throughout this paper[4]. The forecast is shown in figure 8. It is worth mentioning that data were first adjusted for outliers and forecasted, using TRAMO/SEATS within the Eviews environment.

[4] The production function gap was fitted as a SARIMA model of order (0,1,1)(0,1,1), the HP followed SARIMA(1,0,0)(1,0,0) model, the RMS gap followed SARIMA(2,0,0)(0,1,0) model, and finally the wavelets gap followed SARIMA(0,1,0)(1,1,0) model.

Figure (8): Forecasting the Output Gap[5]



[5] Output gap here is calculated as the actual output minus potential output divided by potential output.

It is noticed that, according to the production function approach, the output gap is expected to widen further, implying that the economy would exhibit instable high output levels. This is relatively similar to the wavelets forecast. However, the latter shows positive gaps, starting with the end of 2008 which is illogical. The RMS and the HP filters show that the output level is expected to stay close to its potential, with tiny fluctuations.

The effect of the world's post-financial crisis has started to surface in the second quarter of 2008/2009, when the output growth registered a record low of 4.1%, compared to the 7% average registered over the past three years. However, a gradual increase continued to show in the following periods to reach 5.8% in the first quarter of 2010. The crisis also led to a temporary increase in the unemployment rate and a decrease in total investments. These facts suggest the following pattern of output gap: small, or even negative output gaps rather than positive gaps were expected at the end of 2008. Afterwards, as gradual improvements started to show in the economy, positive output gaps are expected. This pattern is maintained by the production function approach.

In fact, all of the measures provided for the output gap do not imply a major structural change in the Egyptian economy, in the wake of the global financial crisis. It can be explained by the fact that the damages of the global crisis were extremely limited because of the nature of the Egyptian economy which is not very open to the global financial markets. This is especially true after implementing a package of reforms in the Egyptian financial sector. It is worth mentioning that the banking sector was strong and was holding a considerable amount of liquidity by the beginning of the crisis. In addition, the Central Bank of Egypt held a large amount of NIRs (as the annual growth rate reached 17.1% in September 2008).

IV. Summary and Conclusion

This paper employs a number of univariate and multivariate methods in estimating Egypt's potential output and the output gap in order to reach a reliable technique which is capable of interpreting the economic changes. Univariate methods include the Hodrick-Prescott (HP), the Running Median Smoothing filter (RMS), and the de-noising wavelets filter. The production function approach is also adopted, where a robust estimate of labor input is obtained by deriving the Non-Accelerating Inflation Rate of Unemployment (NAIRU). The latter is derived by using Kalman filter which is augmented with a standard Philips curve to ultimately derive the potential employment. A medium term forecast of output gap is also provided by fitting the appropriate SARIMA model for each of the derived gaps.

The paper comes up with the following findings:

- As an input for potential output, NAIRU reflects well the inflation changes in the estimated potential unemployment, and hence shows the effect of these changes in the estimated potential output.

- The production function approach adapts well to structural changes, since it accurately describes the structural changes that the economy has gone through. According to this approach, the effect of the financial crisis is reflected by a negative gap, while the period of improvement is reflected by a positive gap.

- Given the production function approach, the output gap is expected to widen, showing increasing positive values till the end of 2011. In other words, the economy is expected to experience increasing output levels.

- Unexpectedly, the wavelets filter shows a positive output gap, following the global financial crisis, which may be due to the end of sample biases.

- The HP filter and the RMS filter behave similar to each other when comes to forecasting the gap. The RMS gap does not reflect any structural changes that the economy has gone through. On the other hand, the HP filter does not manage to reflect the effect of the global crisis.

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Appendix 1

The Kalman Filter[6]

A state-space model consists of a measurement equation linking actual observations with latent variables. We denote this state vector by α_t.

$$\alpha_t = T_t \alpha_{t-1} + c_t + R_t \eta_t; \qquad t = 1, 2 \ldots \tau,$$

where α_t is the m dimensional state vector, T_t is a $m \times m$ matrix, c_t is an $m \times 1$ vector, and R_t is $m \times g$.

The measurement equation is given by:

$$y_t = Z_t \alpha_t + d_t + \varepsilon_t; \qquad t = 1, 2 \ldots \tau,$$

where y_t is a given time-series with $N \times 1$ elements. Z_t is an $n \times m$ matrix, d_t an $N \times 1$ vector. η_t and ε_t are supposed to be normally distributed with 0 correlation. The first 2 moments are given as follows:

$$E[\eta_t] = 0,\ V[\eta_t] = Q_t,\ \mathrm{E}\ [\varepsilon_t] = 0, \text{ and } V[\varepsilon_t] = H_t\ .$$

We also assume that the state vector initially follows a Gaussian distribution with:

$$\mathrm{E}\ [\alpha_0] = a_0 \text{ and } V[\alpha_0] = P_0.$$

Consider a_t the best estimate of α_t given all available information up to time t, meaning that, $a_t = E_t[\alpha_t]$ and the variance-covariance matrix associated to α_t is given by $P_t = E_t\left[(a_t - \alpha_t)(a_{t\_}\alpha_t)'\right]$.

The Kalman Filter is given by the following recursive equations:

$$a_{t|t-1} = T_t a_{t-1} + c_t,$$

$$P_{t|t-1} = T_t P_{t-1} T_t' + R_t Q_t R_t',$$

$$\tilde{y}_{t|t-1} = Z_t a_{t|t-1} + d_t,$$

$$v_t = y_t - \tilde{y}_{t|t-1},$$

[6] For more detail, refer to the full paper published on: http://www.hec.unil.ch/matlabcodes/matlabcodes/Econometrics/KalmanFilter.pdf

$$F_t = Z_t P_{t|t-1} Z_t' + H_t,$$

$$a_t = a_{t|t-1} + P_{t|t-1} Z_t' F_t^{-1} v_t,$$

$$P_t = (I_m - P_{t|t-1} Z_t' F_t^{-1} Z_t) P_{t|t-1}.$$

where $a_{t|t-1}$ and $P_{t|t-1}$ are the best estimates of α_t and P_t conditionally on all the information available at time t-1. The innovation v_t is the difference between the actual observation and its best predictor.

The log-likelihood of the observation at time t corresponds to

$$l_t = -N/2\ln(2\pi) - 1/2\ln \mid F_t \mid -1/2 v_t' F_t^{-1} v_t$$

where $|F_t|$ is the determinant of F_t.

In this study, the (Local Linear Trend) model is used, being written as:

$$y_t = \mu_t + \varepsilon_t, \qquad E[\varepsilon_t] = 0, \qquad V[\varepsilon_t] = \sigma^2_{\varepsilon}$$

$$\mu_t = \mu_{t-1} + \beta_{t-1} + \xi_{t-1}, \qquad E[\xi_{1t}] = 0, \qquad V[\xi_{1t}] = \sigma^2_{\xi 1}$$

$$\beta_t = \beta_{t-1} + \xi_{2t} \qquad E[\xi_{2t}] = 0, \qquad V[\xi_{2t}] = \sigma^2_{\xi_{2t}}$$

All the sources of uncertainty ε_t, ξ_{1t} and ξ_{2t} are assumed to be independent. Now, we may cast the model in the state-space representation. This gives:

$$y_t = \begin{pmatrix} 1 & 0 \end{pmatrix} \begin{pmatrix} \mu_t \\ \beta_t \end{pmatrix} + 0 + \varepsilon_t,$$

$$\begin{pmatrix} \mu_t \\ \beta_t \end{pmatrix} = \begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} \mu_{t-1} \\ \beta_{t-1} \end{pmatrix} + 0 + \eta_t.$$

Hence,

$$\mathrm{Y}_t = y_t$$

$$Z_t = \begin{pmatrix} 1 & 0 \end{pmatrix}$$

$$d_t = 0$$

$$H_t = \left(\sigma_\varepsilon^2\right)$$

$$\alpha_t = \left(\mu_t \quad \beta_t\right)'$$

$$T_t = \begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix}$$

$$c_t = \begin{pmatrix} 0 \\ 0 \end{pmatrix}$$

$$R_t = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$$

$$Q_t = \begin{pmatrix} \sigma_{\xi_1}^2 & 0 \\ 0 & \sigma_{\xi_2}^2 \end{pmatrix}$$

The parameters to be estimated are σ_ε^2, $\sigma_{\xi_1}^2$, and $\sigma_{\xi_2}^2$.

Again the estimation may be easily made with maximum likelihood. As initial values, the following may be used:

$a_0 = \begin{pmatrix} y(1) \\ 0 \end{pmatrix}$ and $P_0 = \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}$.