Economics Group

Working Paper

Estimations of the Output Gap and Potential Output with Natural Disasters: Fiji Case Study

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1 This research is a collaboration between the IMF Resident Office for the Pacific, the Pacific Financial Technical Assistance Centre (PFTAC) and the RBF.
Abstract

Estimates of potential output and the output gap serve as useful indicators for the conduct of monetary and fiscal policy, but obtaining accurate measures is always a challenge. Our estimation for Fiji utilizes a multivariate Kalman filter, which is considered a more appropriate method for countries with relatively short time-series, structural changes and shocks, and characteristics relevant to Pacific countries. The method makes use of the information in macroeconomic variables (real output, inflation, and employment data) and interpreted through the relations among the variables implied by the Phillips Curve and Okun’s Law. A novel addition to our estimation is to include the effect of natural disasters, which have a material impact on Fiji (and other Pacific countries). Natural disasters can reduce both an economy’s supply capacity and can lead to a decline in aggregate demand. Our results reiterate, through empirical methods, the impact of natural disasters on the economy. The research suggests that policy response may be different if natural disasters are included in the calibration depending on the type and intensity of the natural disaster.
I. INTRODUCTION

Estimates of potential output and the output gap serve as useful indicators for the conduct of monetary and fiscal policy. A sustained positive output gap, i.e. actual output exceeding potential output, for instance, is a signal to the central bank that inflationary pressures are increasing and that a policy tightening may be required. To the Ministry of Finance, a positive (negative) output gap signals that the economy is operating above (below) capacity and that tax collection is above (below) ‘normal’ levels. When the government’s target is to have a balanced budget over the business cycle (i.e. a period of expansion followed by a downturn) revenues collected above normal levels during an economic expansion should be saved to offset lower revenues and budget deficits during an economic downturn.

This paper presents and compares estimates of Fiji’s potential output and output gap from two filtering and model-based techniques. The simplest measures presented in the paper employs statistical univariate filters of Hodrick-Prescott (HP) and Band-Pass filters, and the model-based approach is a multivariate Kalman filter encompassing the Phillips curve and Okun’s law. We then extend the multivariate filter to include the effect of natural disasters.

This topic is particularly interesting for Fiji because, apart from typical demand and supply side shocks, the economy has faced natural disasters (e.g. drought, hurricane, flooding) of varying magnitudes almost each year in the sample period 1993 to 2017, growing by an average 3.0 percent. This research tries to find out the impact of these factors on Fiji’s output gap and potential. Estimating potential output in Fiji also builds on the limited pool of domestic research into this matter. In the Pacific, natural disasters so far have not been incorporated into analysis of whether economic activity is below or above productive capacity.

The paper is organized as follows: Section II briefly describes the different methodologies used to estimate the output gap and potential output. Section III describes the methodology used and data, Section IV looks at some stylized facts on Fiji. Section V compares the estimation results and the final section provides concluding discussions.
II. A brief overview of estimation methods

The literature points to four broad approaches to estimate the output gap and potential output. The first approach, which this paper discusses and compares, are statistical filtering techniques (univariate and multivariate filters). Univariate filters commonly used are the Hodrick & Prescott (HP) and band-pass filters. The HP filter extracts a trend component by trying to balance a good fit to the actual series with a certain degree of smoothness in the trend. The band-pass filter, on the other hand, extracts frequencies corresponding to the length of the business cycle, normally two to eight years and does this by constituting a weighted moving average of past and future observations (Micallef, 2014). Univariate filters are simple, transparent and can be easily applied for any country where output or Gross Domestic Product (GDP) data exists, however, there are some limitations attached to them. Univariate filters are purely statistical approaches and estimates generated from these filters are often thought of as ‘trend’ (rather than potential) growth as these filters do not incorporate changes in the economic structure. Univariate filters also suffer from ‘end of sample’ problem.²

A second technique commonly used in estimating potential output is the production function approach. This approach combines factor inputs of labor and capital in a production function (generally Cobb-Douglas) to determine the level of potential output and construes total factor productivity as the residual from the production function equation.³ Difficulty in obtaining reliable capital data limits the use of this method for Fiji now. In addition, this technique typically requires univariate trend/cycle filters for the production function inputs.

The third approach is to use models including the dynamic stochastic general equilibrium (DSGE) model.⁴ This approach is theoretically rigorous with microeconomic foundations and appeals to academics. However, it is demanding to implement, requiring extensive modelling expertise, and the results are dependent on the particular model specified (and data).

² HP is a “moving-average” type of filter that observes both t-i observations and t+i observations. At the end of the sample with actual observations, t+i observations are missing and the last point of the series has an exaggerated impact on the trend at the end of the series. The usual way to solve this end-point bias problem is to extend the series (for example with ARIMA or other forecasts). Thus the last actual point is no longer at the end of the series. The usefulness of this approach is limited, however, by the quality of the forecast.

³ Referenced research on production function: Lienert & Gillmore (2015), and Blagrave, Garcia-Santos, Laxton, & Zhang (2015).

The fourth approach which we use, is multivariate filters. Multivariate filters tend to extract the trend and cycle components using the information in variables, considering empirical relationships such as the Philips Curve and the Okun’s Law. Thus, the advantage of using multivariate filters is that they are flexible and can allow the estimations of output gap and potential to vary with an array of recent information, while at the same time considering the more stable trends evident in long-run time series. In essence, this method lies between methods 1 and 3; it is not purely statistical, because it contains economic structure, and it specifies key macroeconomic relationships rather than requiring detailed micro foundations.

III. Overview

The multivariate Kalman filter approach is utilized in this research and tries to estimate the output gap and potential output (unobserved variables) using information from observed variables: output, inflation, and unemployment. The economic relationships specified between output, inflation and unemployment are the Phillips Curve and Okun’s Law. The relationships are written in state space form, which is a general way of representing dynamic systems such that the observed variables are specified as a function of the unobserved variables in the measurement (or observation, signal) equation, and a separate transition (or state) equation which specifies the autoregressive process for the unobserved variables.

Once a dynamic time series model is written in a state-space form, the unobserved state vector (and parameters) may be estimated from the data using the standard Kalman filter recursive algorithm (Hamilton, 1994). In the remainder of the section, we first present the data, then define the unobserved variables and how they relate to the observed variables.

Data

The estimation sample period is 1993 to 2017, the period for which annual data is available for all three variables – output, inflation and the unemployment. We measure the data at annual frequency to help deal with the noise in higher frequency data.

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Figure 1, Panel 1, show that output, GDP, grew on average by 2.3 percent during the sample period and remained positive for nine consecutive years since 2009 (LOG(GDP) is GDP in logarithms and the year-on-year change in LOG(GDP) is DOT_GDP). For the inflation or consumer price index (CPI) variables in Figure 1, Panel 2, the trimmed mean inflation (DOT_CORETRIM) and headline inflation (DOT_CPI) moved more in line with each other, compared to the CPI excluding volatile items (DOT_CORECPI).

Figure 1: Snapshot of the Key Indicators - Output, Inflation and Unemployment

6 GDP hereon refers to GDP measured as the value-added production expressed in 2014 base year prices.
7 The CPI trimmed mean removes 15 percent of the largest and 15 percent smallest monthly movements in the basket before calculating a re-weighted mean.
8 The overall or headline CPI is an index that measures changes in the prices of a fixed representative basket of goods and services that households purchase with a 2014 base year.
9 CPI excluding volatile items is the headline CPI excluding basket items such as fuel and food prices.
In the absence of unemployment data for the full sample period, the net Fiji National Provident Fund (FNPF) compulsory registered superannuation members (i.e. registered compulsory members minus compulsory members that have left the Fund) was used as a proxy for unemployment ($U_t$).\textsuperscript{10} The FNPF is Fiji’s only superannuation fund which is mandated by law to collect compulsory contributions from employees and employers. The deviation of compulsory registered superannuation members (LPENSION) from a HP filter constructed long term trend (LPENSION_EQ_HP) is used as a proxy for the employment gap, $U_{\text{GAP}}$ (Figure 1, Panel 3). In this case, a fall in the net number of registered compulsory employees implies that there are less people employed in the economy (an increase in unemployment) and vice versa. In other words, it is assumed that being registered is a proof of being employed.\textsuperscript{11}

To proxy natural disasters, an index series (NDINT) on intensity of the natural disasters based on either damage to GDP or population affected to total population ratios and ranked by percentile was used (Dongyeol et. al, 2018) shown on Figure 1 Panel 4. The data used was sourced from the Emergency Events Database (EM-DAT).\textsuperscript{12}

\begin{itemize}
\item\textsuperscript{10} Available unemployment data was obtained from the Fiji Bureau of Statistics. When the available unemployment data series was tested, it yielded similar results as the superannuation data. Superannuation data was used to encourage and show research applicability to the rest of the Pacific Island Countries.
\item\textsuperscript{11} Compulsory superannuation withdrawal grounds include retirement, medical incapacity, migration or low balance (less than FJS2,000).
\item\textsuperscript{12} Website: https://www.emdat.be/
\end{itemize}
Looking at the correlation among the indicators, the natural disasters variable is positively correlated with inflation but negatively correlated with GDP (DOT_GDP and the LGDP_GAP_HP which is the generated gap between actual GDP and trend GDP using the HP filter) and employment gap (Table 1). While correlation cannot be seen as causation, the signs of the relationships are in line with prior expectations. Natural disasters are expected to raise inflation, lower economic output in the period of the event and reduce the employment gap.

**Figure 2: First Check of the Phillips Curve and Okun’s Law Theories**
After testing possible annual proxies for GDP, inflation and unemployment, the following indicators were settled on: trimmed mean core measure (CORETRIM) as a proxy for inflation ($\pi_t$), to also take out supply side and one-off effects on inflation; a real GDP ($Y_t$) series was used for actual output; the FNPF compulsory registrations gap as a proxy for unemployment ($U_t$); and NDINT, the natural disaster index series produced by Dongyeol et. al, 2018 (Figure 2, Panel 1 and Panel 2).

**Defining model variables**

There are two gaps in the model: the output gap ($\bar{Y}_t$) and unemployment gap. The output gap is the difference between actual real GDP ($Y_t$) and potential ($\bar{Y}$) output.

Potential output ($\bar{Y}$) is obtained after applying the HP filter to real GDP. The end-sample bias is treated with Central Bank forecasts for up to $t+3$.

\[
\bar{Y}_t = Y_t - \bar{Y}_t
\]  

(1)

The employment gap ($\bar{U}_t$) is the equilibrium employment rate ($\bar{U}_t$), minus the actual employment rate ($U_t$), superannuation proxy series. $\bar{U}_t$ is obtained by using the HP filter on $U_t$.

\[
\bar{U}_t = \bar{U}_t - U_t
\]  

(2)
Inclusion of a natural disaster proxy

The natural disaster proxy was then added into the measurement and transition equations (Equations 3, 4, and 5) for the Philips Curve and Okun’s Law.

The natural disaster intensity measure captures the distribution of economic damage and population affected during/after the event (Lee et al (2018)). Based on past data and Post Disaster Needs Assessment (PDNA) Reports on Fiji for 2013 and 2016, the coefficient assumed for this variable is 30 percent.

The impact of natural disasters can be viewed through the following channels – 1) a long-term or short-term impact on aggregate supply; and 2) a short-term impact on income and prices. Depending on country conditions, for example, level of resilience, size of country, administrative capacity, fiscal space, disasters can have a long-term adverse effect on aggregate supply. In addition, the type and intensity of a natural disaster could determine whether the impact would be long or short term.

Natural disasters can also have a short-term impact on aggregate demand via both the income and price channels. During periods of disasters, consumers and producers are likely to limit spending in preparation for the worst possible outcomes or divert funds toward rehabilitation post-disaster. For goods and services affected by a disaster, lower supply leads to higher prices. For example, the supply of agricultural produce are affected in most cases after a hurricane, leading to an increase in prices of these items, eventually also leading to lower demand. This was addressed implicitly by having a larger variance of the error term in the Phillips curve.

Identifying Relationships

a) Inflation Equation

Measurement (observation, signal) equation:

\[ \pi_t = \pi_{st_t} \]  \hspace{1cm} (3)

\[ \log(d_t) = \log(d_{gap}) + \log(d_{eq}) \]  \hspace{1cm} (4)
Equation (3) ensures that the choice of inflation measure, $\pi_t$, is a state variable, $\pi_{st_t}$.

Equation (4) is the identity that ensures that output gap, $lgdp\_gap_t$, is the deviation of actual GDP, $lgdp_t$, from potential GDP, $lgdp\_eq_t$.

**Transition (state) equation:**

\[
\pi_{st_t} = 0.5\pi_{st_{t-1}} + (1 - 0.5)\pi_{tar_t} + 0.2lgdp\_gap_{t-1} + 30ndint_t + [var = 3] \tag{5}
\]

\[
lgdp\_gap_t = 0.3lgdp\_gap_{t-1} + [var = 2] \tag{6}
\]

\[
lgdp\_eq_t = lgdp\_eq_{t-1} + 3 - 2*ndint_t + [var = 1] \tag{7}
\]

Where $\pi_{tar_t}$ is the long term trend of the choice of inflation measure (2 percent), $ndint_t$, refers to the natural disasters index as in (Lee et al (2018)), discussed in the earlier section. Based on past data and Post Disaster Needs Assessment (PDNA) Reports on Fiji for 2013 and 2016, the magnitude assumed for this variable is 30 percent (Eq 5) and 2 percent (Eq 7). In Equation 7, the steady-state rate of growth (3 percent) of the potential GDP is the data sample average excluding all negative rates of growth.

**b) Dynamic Okun’s Law**

Okun’s Law is defined as a simple relationship between unemployment (unemployment gap ($\tilde{U}_t$)) and the output gap ($\tilde{Y}_t$).

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13 There is a risk of double counting by adding the natural disaster dummy both to the Phillips curve and potential output equations. However, anecdotal evidence of natural disasters in Fiji so far affected both supply and demand and we decided to leave the natural disaster variable in both equations. We noted that unless there is immediate Government assistance or family support through remittances, demand is lower because most may not have funds to stock up on necessities before the cyclone/disaster. Post-disaster, apart from rebuilding items, demand for other products is lower. There is also substitution between fruits and vegetable/food products that become more expensive (no price controls) for cheaper processed food (especially price controlled items). Income is mostly spent on rebuilding.
\[ U_t = -\delta \hat{Y}_{t-1} + \epsilon_t^Y \]  

Apart from the repetition of (3) to (7) above in this model, an additional signal equation (Equation 2) is introduced to act as a proxy for unemployment gap in Fiji, \( \hat{U}_t \).

\[ u_{gap_t} = 0.3 l_{gdp\_gap_{t-1}} + [var = 2] \]  

IV. Fiji: Briefly

The Fiji economy has come through different stages of development. The Fiji economy relied heavily on primary industries, particularly, cane and sugar production, up to the mid-1990’s. A structural change followed, due to a shift in development policy focus to tourism and manufacturing. The economy has now transitioned to a stage whereby the services sectors are now the key driver of activity. Apart from sectoral developments, Fiji’s macroeconomic history has also been shaped by natural disasters, discussed briefly later in this section; global events which in some cases resulted in the need to devalue the Fijian currency; political events; and monetary and fiscal policies. These factors have caused volatility in Fiji’s real GDP rate (Chart 1).

**Chart 1: Real GDP rate between 1993 and 2017**

**Real GDP rate**

(Percent)

<table>
<thead>
<tr>
<th>Year</th>
<th>Average 1993-2005</th>
<th>Average 2006-2017</th>
<th>Past 8 years consecutive growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td></td>
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Source: Fiji Bureau of Statistics and author’s averages
In terms of natural disasters, in the last 24 years (1993-2016), Table 1 and Chart 2, the Fiji economy has experienced 16. When the full sample is compared in 12-year blocks (1993-2004 vs 2005-2016), natural disasters have increased in intensity. Its impact is estimated via the index calculated in Lee et al (2018) which focuses on economic impact and proportion of population affected. While the frequency on average remains stable, the frequency and intensity of natural disasters have increased (2007 to 2010 and 2015-2016) (Chart 2).

Natural disaster intensity in the period 1993-2016 averaged 0.4 (on a scale of 0 to 1) in the years of the event. As expected, the intensity measure shows that some natural disasters are more severe than others.

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Number of natural disasters:</td>
<td>8</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>Sum of intensity of natural disasters:</td>
<td>2.90</td>
<td>3.89</td>
<td>6.80</td>
</tr>
<tr>
<td>Average intensity of natural disasters:</td>
<td>0.36</td>
<td>0.48</td>
<td>0.42</td>
</tr>
</tbody>
</table>

Source: EMDAT

![Chart 2: Intensity of Natural Disasters between 1993 and 2016](Sources: EM-DAT and Dongyeol et. al, 2018)

V. Estimation results

For comparison purposes, the filter estimations of both the Philips Curve and Okun’s Law including and excluding the proxy for natural disasters was conducted. As expected, estimations of all filters used show that natural disasters tend to create economic slack – that is a negative output gap.
With the inclusion of the natural disaster proxy in the Philips Curve filter, the output gap is larger capturing the negative demand shock and shows more persistence (from 2004) when compared to the HP filter results. Inflation in most years was driven by the factors mentioned in Section IV rather than excessive demand.

**Chart 2: Results of the Philips Curve Relationship**

![Graphs showing results of the Philips Curve Relationship](image)

Source: Authors estimates

The Okun’s law filter which was included as an attempt to capture supply-side shocks showed similar results to that of the Philips Curve filter – a larger negative gap with the natural disaster proxy. The results were in line with economic theory, and although slightly lagged, there was a negative employment gap (less employed/unemployment) during periods of economic slack or natural disasters.
Between the Philips Curve and Okun’s Law filters, the latter seem to provide better estimations in line with economic theory. The diversion of results (with the inclusion of the natural disaster proxy) between the two filters are noticeable from 2009 onwards with the Okun’s Law negative output gap being smaller in magnitude and notably less persistent. The persistence of the negative output gap is in line with the higher average intensity of natural disasters (Table 1) in recent years compared to 20 years ago – more damage to the economy and longer recovery time required.
It was also observed that the magnitude and persistence of the output gap depended on the intensity and type of natural disaster. For example, the turnaround in gap for 1997 after experiencing a drought was faster than a hurricane in other years. This observation was reinforced when a test was conducted on the year 2004 which despite a natural disaster had a positive output gap. The output gap becomes negative when the intensity of the natural disaster is artificially increased.

Nonetheless, the research findings highlight that a different set of policies will be required when dealing with natural disasters. For example, the no natural disaster scenario (Chart 4) suggest higher demand than supply in the economy – a positive output gap – and therefore the need to tighten monetary and fiscal policy. In contrast, with natural disasters included, the gap is negative, highlighting the need for easing policies. Various literature covers other possible policy recommendations such as accounting for natural disasters in medium-to-long term planning, building fiscal buffers, improving disaster preparedness and considering resilient infrastructure. These policies will improve an economy’s resilience to natural disasters.

Looking ahead, this paper provides a base for similar exercises to be carried out for other Pacific Island Countries (PICs). PICs that do not have reliable unemployment data can instead make use of available superannuation data. The current method is restrictive in that it does not allow for the decomposition of output into sources of growth, research focusing on developing a production approach can capture this. In addition, this research is limited as it cannot adequately capture the rehabilitation

Source: Authors estimates
efforts post disaster or “good weather” and the results are mostly assumption dependent – especially those made on natural disasters.

VI. Conclusion

The estimations of the multivariate filters based on the Philips Curve and Okun’s Law provided an opportunity to build on the limited research and literature on this topic as well as to include a key demand and supply shock in the Pacific, natural disasters.

The results of the research reiterate expectations of the effect of natural disasters, and the magnitude of impact on an economy is dependent on the intensity and frequency of a natural disaster. Inclusion of natural disasters in the calibrations show that the output gap can be larger and persistent compared with results based on the without natural disasters scenario - suggesting policy responses outside what is normally indicated by the output gap and potential output estimations particularly around increasing an economy’s resilience to natural disasters.

There are limitations to this research and therefore room for further development on this topic. This paper provides a supporting base to build on including other methods of estimating the output gap and potential output.
VII. References


Krippner L, 2018, “A Non-Technical Overview of the Kalman Filter.”


