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Estimating Jamaica's Potential Output

Hubert G. Scarlett

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BOJ Working Paper

Research Unit

Estimating Jamaica's Potential Output

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Authorized for distribution by Prudence Serju-Thomas

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Abstract

This study estimates Jamaica's potential output using the production function (PF) approach. Previous studies, including those on Jamaica, assumed that capital and labour are the only factor inputs that determine the productive capacity of a country. This paper contributes to the literature on potential output by identifying and including human capital in the production function. Fourteen measures of potential output for Jamaica and, consequently, 14 measures of the output gap are estimated and evaluated. The findings indicate that the output gap, based on a PF augmented with human capital and, labour supply informed by time invariant NAIRU and the Christiano-Fitzgerald long-run trend components, provides the best forecast of inflation (without agriculture). At the beginning of 2021, Jamaica's estimated output gap was negative 2.9 per cent and is projected to gradually increase before closing after the December 2022 quarter. This measure of the output gap will be useful in forecasting inflation and informing monetary policy decisions by the Bank of Jamaica.

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1. Introduction, Motivation and Overview

This paper attempts to estimate Jamaica's potential output and, consequently the output gap, with the aim of contributing to the understanding of the factors that drive inflation in Jamaica. This framework is intended to complement other models currently in use at the central bank to forecast inflation and to inform monetary policy decisions.

Potential output is an estimate of the level of GDP attainable when the economy is operating at a high rate of resource use. It is not a technical ceiling on output that cannot be exceeded. Rather, it is a measure of maximum sustainable output—the level of real GDP in a given year that is consistent with a stable rate of inflation. If output rises above its potential level, then constraints on capacity begin to bind and inflationary pressures build; if output falls below potential, then resources are lying idle and inflationary pressures abate.

Bank of Jamaica has over the years attempted to measure potential output (Serju, 2007; Brown, 2017). The driving motivation behind these research was to assist the Bank in better understanding the monetary transmission mechanism over the so called "last mile". This is when the forces pushing aggregate demand, including monetary conditions, are supposed to stimulate inflationary pressures in the economy, either through factor or product markets. This type of assessment requires knowledge of the production frontier of the economy against which demand forces will induce inflation.

More recently, the central bank adopted a quarterly projection model (QPM) as its workhorse tool in forecasting inflation (Williams and Lee, 2019). The QPM is a reduced form, forward-looking, open economy gap, semi-structural model. It is heavily dependent on calibrated parameters, trends and the steady states for some macroeconomic variables which reflect BOJ's economists' views about the underlying structure of the Jamaican economy. In the Phillips curve equation, inflation is estimated as a function of the output gap, among other factors (including terms of trade shocks). Aggregate demand, in gap terms, is derived in the model from a Kalman filter. To validate the model's estimate of potential output, particularly in real time, there has emerged a need for the Bank to develop alternative methods to enrich its perspectives on the size, trajectory and projections for this variable. This paper attempts to fill this gap.

Jamaica has undergone a range of structural adjustments over the past seven years under two International Monetary Fund (IMF)–supported reform programmes. The promise of these programmes of structural adjustment is that Jamaica's output growth will rise. Questions have therefore arisen about how the long-run rate of growth, and the lowest level of unemployment consistent with this, can be achieved – an inquiry that this paper also seeks to address.

We contribute to the literature on Jamaica's potential output in the following two ways. First, relative to Brown (2017), this paper includes human capital as an additional factor in the production function.[2] Secondly, the paper's estimate of potential labour supply is based on three measures. Together, the first and second contributions give 14 measures of potential output and, consequently, the output gap from which the best structural model for Jamaica is chosen.

The results indicate that the output gap, based on the PF augmented with human capital and potential labour supply, for which the long-run unemployment rate (consistent with the time invariant inflation rate of unemployment), provides the best forecast of inflation. The preferred measure suggests a relatively large negative output gaps for Jamaica over a majority of the sample period, with the gap closing steadily over the 2014 to 2019 period. Further, using this measure, we estimate the output gap at the start of 2021 at negative 2.9 per cent. With projections for GDP growth to average approximately 5.4 per cent over eight quarters starting in the June 2021 quarter. The gap is projected to close after the December 2022 quarter, implying the absence of inflationary pressures in Jamaica.

The remainder of the paper is as follows: Section 2 outlines the structure of the production function and section 3 estimates the historical values of potential output. Section 4 provides a framework to select the preferred potential output measure. In sections 5 we forecast potential output and Section 6 concludes.

[2] Human capital encompasses the skill set of an individual acquired via educational attainment both on and off the job. The literature shows a positive link between income and human capital (Barro and Lee, 2013) as well as between income earnings and education in the labour market study by (Mincer, 1974). There is an added positive spillover effect of human capital in influencing technological progress, health outcome and poverty reduction (Wilson and Briscoe, 2004), all of which positively influence income and output of a country.

2. The Production Function

A vast body of literature has been built up around estimating the output gap and using it to predict inflation. These estimates of potential output are commonly derived from statistical, econometric or economic fundamentals methods. Havik et al. (2014) indicate that the preference for the economic fundamentals approach (which is based on the production function concept) is grounded in the fact that meaningful links can be established between policy initiatives and outcomes in the labour and capital markets that drive changes in potential output. The production function approach also enables an evaluation of the relationship between changes in potential output and changes in underlying structural economic factors.[3] Finally, forecasts of potential output growth are made possible by the explicit use of demographic, institutional and technological trends.

In relation to previous studies on Jamaica, Serju (2007)'s study used a structural vector autoregressive (SVAR) model, Hodrick-Prescott (HP), Band-Pass and Kalman filters to estimate potential output and output gap. The author found that the SVAR model was the best model for estimating and forecasting the output gap as well as for estimating inflation. Brown (2017) on the other hand used a production function approach to estimate Jamaica's potential output. The results of that paper indicated that the production function better captured resource under-utilization and over-utilization in Jamaica, relative to other techniques.

Following Brown (2017), we start with the standard Cobb-Douglas (CD) production function with constant returns to scale (CRS) of the form

$$Y_t = A_t \, L_t^{\alpha} K_t^{\beta} \qquad [1]$$

Where Y_t is output, A_t is total factor productivity (TFP), and L_t and K_t are labour supply and the capital stock, respectively. The output elasticities of labour and physical capital are represented by α and β, respectively. These parameters can be viewed as the contribution that the growth of each input makes to the growth of output. The CRS assumption implies that $\alpha, \beta < 1$ and $\alpha + \beta = 1$.

[3] These include changes in investment, demographic and labour market trends as well technological progress. Changes in the underlying factors gives an indication of the structural changes in Jamaica's economy over time.

The production function can, however, be augmented with a measure of human capital (H_t), a measure of the efficiency of the labour force to produce goods and services, which is a key factor of production that had not been included in previous studies on Jamaica.[4] The augmented growth model with human capital therefore is

$$Y_t = A\, H_t^{\varphi} L_t^{\alpha}\, K_t^{\beta} \quad [2]$$

The CRS assumption implies that $\varphi, \alpha, \beta < 1$ and $\varphi + \alpha + \beta = 1$. Through a logarithmic transformation, equation [2] becomes [3].

$$lnY_t = lnA_t + \varphi lnH_t + \alpha lnL_t + \beta lnK_t \quad [3]$$

3. Estimating Historical Values of Potential Output

To compute historical values of potential output for Jamaica (which we will denote as Y_t^*), we follow the Congressional Budget Office (CBO) (2001) by estimating potential, or cyclically adjusted, versions of the factor inputs (A_t, H_t, L_t, *and* K_t) and their associated parameters (φ, α & β) and then combining them using the CD production function. Cyclical adjustment removes the influence of the business cycle on a variable in order to estimate the variable's trend component. In this section, we therefore discuss the methodologies underpinning the estimate of the trend growth in each of the factor inputs in [3]. We also estimate and report the steady state levels for some of the factor inputs.

This study uses quarterly data for the period 1997:1 to 2020:4. Data on labour market variables, investment flows, GDP and the consumer price index (without agriculture) are from the Statistical Institute of Jamaica (STATIN). Data on the exchange rate is sourced from the Bank of Jamaica while data on oil price is based on the West Texas Intermediate index. Where relevant, all the data

[4] Mankiw et al. (1992) Laitner (1993) provided separate frameworks to analyze the role of human capital within a growth model. Mankiw et al. (1992) found that the augmented production function gives a good description of the cross-country data. Laitner (1993) analyzed long-run growth in a closed economy model with physical capital and human capital determined endogenously. After calibrating the model on data for the US, the author found that human capital accumulation contributes 16.0 per cent to 50.0 per cent to the long-run growth in per capita output.

are seasonally adjusted. Two frequency filters are used to derive long-run trend of all variables namely, the HP filter and Christiano-Fitzgerald (CF) full sample asymmetric statistical methods.[5]

3.1 Potential Physical and Human Capital Stock

Physical Capital

We begin by constructing the potential capital stock (K_t^*) through the use of the perpetual inventory method. The accumulation of the capital stock (K^*) is modelled as a function of current investment (I_t) and net depreciation of the capital stock (δ) as shown in [4].

$$K_{t+1}^* = I_t + (1-\delta)\, K_t^* \qquad [4]$$

The initial capital stock (K_0) can be computed as the initial investment (I_0) divided by the sum of the average growth in investment over the sample period (g) and the rate of depreciation (δ).[6] We use the estimated investment at the start of the sample period as a proxy for I_0. Following Brown (2017), a depreciation rate of 5.0 per cent per year is assumed. To estimate g^k, we follow Berlemann and Wessehoft (2014) and regress investment (in logs) on a constant (Ψ), time trend (*trend*) and a dummy variable to capture any structural breaks (*D*).

$$K_0 = \frac{I_o}{g^k + \delta} \qquad [5]$$

$$lnI_t = \Psi + g^k trend + \partial_1 D_t^{Break2019} + \partial_2 D_t^{Break2020} + \varepsilon_t \qquad [6]$$

---

[5] These are the two sets of filters used hereafter. The HP filter uses a smoothing parameter of 1600. For the CF filter, the cycle periods are low of four quarters and high of 32 quarters with assumption of a random walk and detrending done by removing the mean.

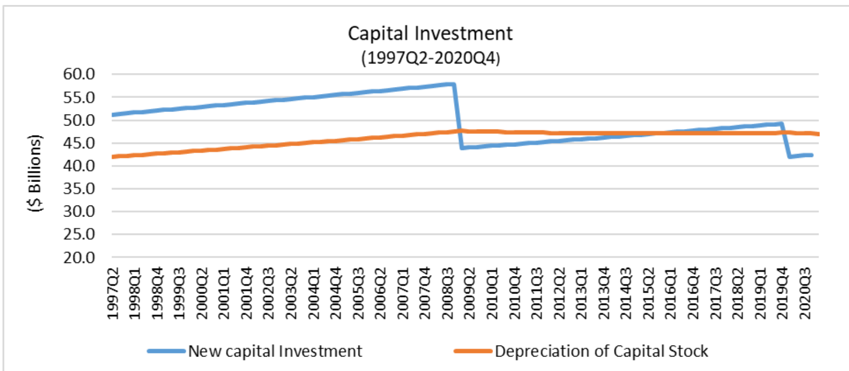
[6] The growth rate of physical capital stock can be expressed as g^k. Substituting for K_{t+1}^* from [4] into g^k, then simplifying and solving for K_t gives

$$g^k = \frac{K_{t+1} - K_t}{K_t}$$
$$K_t = \frac{I_t}{g^k + \delta}$$

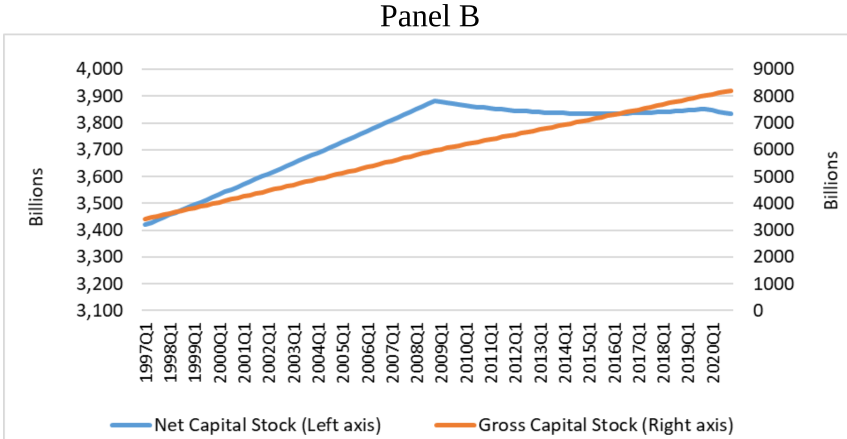
The results of the model indicate that a structural break occurred in 2009q1, shortly after the financial crisis. A second structural break is included to capture the effect of the SARS coronavirus (COVID-19) pandemic in 2020. [7,8] Over the sample period, investment grew by an average of 0.27 per cent (Figure 1 - Panel A). Fitted values of I_t (potential or trend investment) are calculated using the estimated parameters (Ψ, g^k and ∂).

Figure 1: Investment and Physical Capital Stock: 1997q1 to 2020q4

Panel A



Panel B



[7] See least squares breakpoint estimates in Table A1. The COVID-19 structural break was imposed because the breakpoint test was unable to capture the event by design.

[8] We use least squares breakpoint test to determine the structural break. The falloff in investment from 2009 to 2017 is largely attributed to downturn in the mining sector, as the global demand for metal fell significantly (Bank of Jamaica, 2010). In this regard, the capital stock would reflect a combination of decline in investments and depreciation of the capital stock. The rebound in the capital stock after 2017Q2 largely reflects rebound in investment, particularly in the mining sector, which was more than sufficient to offset the depreciation in the capital stock (Figure 1 - Panel B).

Human Capital

For the estimate of human capital, the literature generally points to primary school enrollment, literacy rates, years of schooling and university achievement as widely used proxies (Coulombe and Tremblay, 2006; Földváril and Bas van Leeuwen; 2009). This paper uses the average years of schooling by Jamaicans, sourced from STATIN and Barro and Lee (2013), as a proxy for human capital. Years of schooling data from STATIN is available for the period 2008q1 to 2019q4. Data for the prior and post quarters within the paper's sample period are computed using the implied growth rates from Barro and Lee (2013) average years of schooling information.[9]

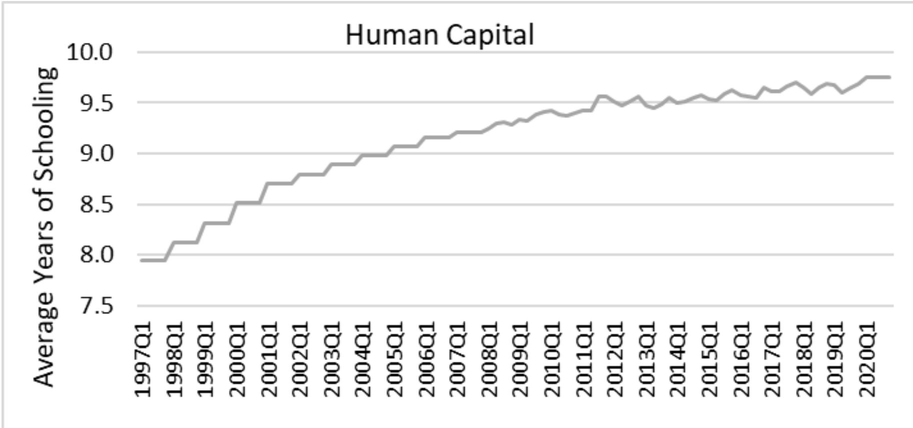
The evolution of the human capital measure for Jamaica is presented in Figure 2. In 1997, Jamaicans underwent an average of 7.9 years of schooling. Our estimates suggest that, in 2020, the average years of schooling in Jamaica was 9.7 years, reflecting an average growth rate of 1.0 per cent over the sample period.

[9] Barro and Lee (2013) data is available at 5-year intervals (that is, 1995, 2000, 2005, etc.). Information before 2008 and after 2019 are based on their projections. Using this information, we compute the annualized growth rate $(g_t^h)$for each 5-year period using the standard growth formula $H_{t+1} = (1 + g_t^h)H_t$ to generate yearly data. The average years of schooling for each quarter is interpolated using the following formula

$$g_t^h = \left(\left(\frac{H_{t+5}}{H_t}\right)^{\frac{1}{5}} - 1\right) * 100$$

Migration is one key factor that can have a negative effect on the stock of human capital in a country (Dinkelman and Mariotti, 2016). For Jamaica, net migration trended downwards to 5.6 per cent in 2016 from 7.5 per cent in 1997 (Planning Institute of Jamaica, 2018). This is an indication that any deterioration of the human capital stock to international migration would have been on the decline since 1997. In this regard, Jamaican immigrants admitted to the United States and to Canada (as permanent residents) within the '*Employment Based*' and '*Professionals, Senior Officials and Technicians*' classes is also likely to have trended downwards over the same period, respectively. The decline in the migration rate from Jamaica is consistent with a fall in brain drain and, as such, signals that the upward trend in the average years of schooling is an appropriate proxy for human capital.

Figure 2: Jamaica's Average Years of Schooling (1997q1 to 2020q4)



Compared to international benchmarks, Jamaica's human capital development is at a high level, although the quality of this schooling may be in question.[10] For North America (United States of America and Canada), the average years of schooling in 2019 was classified as very high at 13.4 years. Similarly, Europe and Central Asia enjoyed 10.4 years of schooling in 2019 while the most recent statistic for the regional average of Latin America and the Caribbean was 8.7 years. This implies some scope for Jamaica to improve its human capital over the next 5 years, if the required capital investment to bring this about can be achieved.[11]

3.2 Potential Labour Supply

The estimation of potential labour supply (in hours) is based on equation [7], a common feature in the literature (Shaheen et al., 2015; Lienert and Gillmore, 2015; Brown, 2017).

$$L^*_{s,t} = w_t P^*_t (1 - NAIRU_t) hper_t \quad [7]$$

[10] Based on the United Nations Development Programme (2020) categorization of human development based, a country's mean years of schooling is placed into one of four groups: very high, high, medium and low with average values of 12.2, 8.4, 6.3 and 4.9 years, respectively.

[11] We estimate that for Jamaica to attain the level of educational attainment and hence human capital development enjoyed by its more developed neighbours, years of schooling would have to rise at an annual average rate of 6.6 per cent over the next 5 years, relative to the decline of 0.4 per cent experienced over the past 10 years. .

L_t^* is potential labour hours, w_t is the working age population, P_t^* is the trend (or equilibrium) participation rate, $NAIRU_t$ is the unemployment rate that is consistent with non-accelerating inflation and $hper_t$ is hours worked per employed person.

Clearly, labour supply (in hours) is positively related to the size of the working age population (w_t) (which itself is dependent on population growth in the context of the natural net birth rate and the net immigration rate of the country), the participation rate of this working population (P_t), and the average number of hours worked by employed persons. Labour supply is however inversely related to the unemployment rate ($NAIRU_t$). It is also clear that changes in the factors that drive labour supply can offset or complement each other. For example, a rise in the working age population as a result of net inflow of immigrants may offset the effect on inflationary pressures of reductions in the unemployment rate. Deriving potential labour supply rests on our ability to estimate the potential (or trend) factors in [7]. The following section begins with a discussion of the NAIRU.

3.2.1 Estimating the NAIRU

Following Bryson (2008), the NAIRU is estimated using a Kalman filter where the augmented Phillips curve is modelled with change in inflation as the dependent variable and which incorporates independents variables: lags of changes in inflation, the unemployment gap, among other control variables.

For the Kalman filter, the unemployment rate is modelled as an unobservable trend component (the equilibrium unemployment rate) ($\overline{U}$) and an unobservable cyclical component (the unemployment gap) (G_t). $\overline{U}$ is assumed to be a random walk with drift (Epstein and Macchiarelli, 2010), while G_t is assumed to be a stationary ($\emptyset_1 + \emptyset_2 < 1$) second order autoregressive process. The error terms ($\aleph_t$ & $\mho_t$) are assumed to be independently and identically distributed.

$$U_t = \overline{U} + G_t$$

$$\overline{U} = \mu_t + \overline{U}_{t-1} + \aleph_t,$$

$$G_t = \emptyset_1 G_{t-1} + \emptyset_2 G_{t-2} + \mho_t$$

We employ an augmented Phillips curve [8] which, in addition to modelling the traditional unemployment gap $(U_t - \overline{U})$ and inflation expectations, include changes in the exchange rate $(Exrate_t)$ and changes in oil price (West Texas Intermediate) (wti_t).[12]

$$\Delta\pi_{t+1} = \alpha(L)\Delta\pi_t + \rho(L)(U_t - \overline{U}) + \beta(L)\Delta Exrate_t + \theta(L)\Delta wti_t + \varepsilon_t \qquad [8]$$

$\alpha(L), \rho(L), \beta(L)\ \theta(L)\ and\ \beta(L)$ are lag polynomials and ε_t is a non-serially correlated error term.

In the Phillips curve, the effect of changes in demand results in a negative relationship between inflation and unemployment in the short-run (Ball and Mankiw, 2002). This means that whenever the unemployment rate exceeds (fall below) the long-run unemployment rate, inflationary expectations in the economy tend to fall (rise). Otherwise, the inflation rate remains stable.

Long-run Trend in Unemployment Rate

As a robustness check, we estimate an alternative NAIRU that is associated with a time invariant NAIRU (NAIRU-LR). Following Epstein and Macchiarelli's (2010) approach, the NAIRU-LR is based on a time invariant (or long-run) rate of unemployment. The computation of the time invariant unemployment rate takes into consideration how the unemployment rate adjusts over the sample period and the resulting unemployment rate that would be independent of changes in the inflation rate. By assuming the long-run unemployment to be constant, the augmented Phillips curve in [8] can be reformulated as [9].

$$\Delta\pi_t = \gamma + \alpha(L)\Delta\pi_t + \rho(L)(U_t) + \beta(L)\Delta Exrate_t + \theta(L)\Delta wti_t + \varepsilon_t \qquad [9]$$

where $\gamma = -\rho(L)\overline{U} = -\overline{U}\sum_{i=1}\rho_i$, which gives the time invariant NAIRU as $\overline{U} = {}^{-\gamma}\!/_{\sum_{i=1}\rho_i}$.

Equation [9] can now be conveniently estimated using an autoregressive distributed lag (ARDL) model. Figure 3 compares the unemployment rate with the two measures of the NAIRU. The NAIRU tracks below the unemployment rate for majority of the sample period, with the

[12] Inflation rate is measured by the year-over year change in the consumer price index. Exchange rate is measured as the ratio of Jamaican Dollar to a United States dollar. Both exchange rate and WTI enters the model as year-over year changes.

unemployment rate only oscillating around the NAIRU prior to 2007. Towards the end of 2019, the unemployment rate converges with the NAIRU but remained, at the end of the sample, some distant away from the long-run measure. At December 2019, NAIRU was 6.6 per cent, while NAIRU-LR (the long-run measure of the NAIRU) was 5.8 per cent. It therefore appears that the NAIRU for Jamaica lies in the range 5.8 per cent to 6.6 per cent.[13] In 2020, the unemployment rate deviated significantly from the NAIRUs, with the deterioration in the labour market condition, stemming from the negative economic effects from COVID-19 pandemic. The employment gap at the end of the sample is an indication that there is room for further improvement in employment without necessarily precipitating an escalation in inflation.

Figure 4, which graphs inflation with two measures of the unemployment gap, shows sign of the expected negative relationship between the unemployment gaps and inflation rate.[14] However, the contemporaneous correlation coefficients between the unemployment gaps and inflation rate is only statistically significant for the unemployment gap based on the NAIRU, which has a value of -0.35 (see Table A3 in Appendix).

[13] See estimates in Table A2.

[14] Unemployment gap is the actual unemployment rate less the long-run unemployment rate proxy by the NAIRU. Inflation rate is calculated as year-over-year change in the consumer price index (without agriculture).

Figure 3: Unemployment Rate and NAIRUs

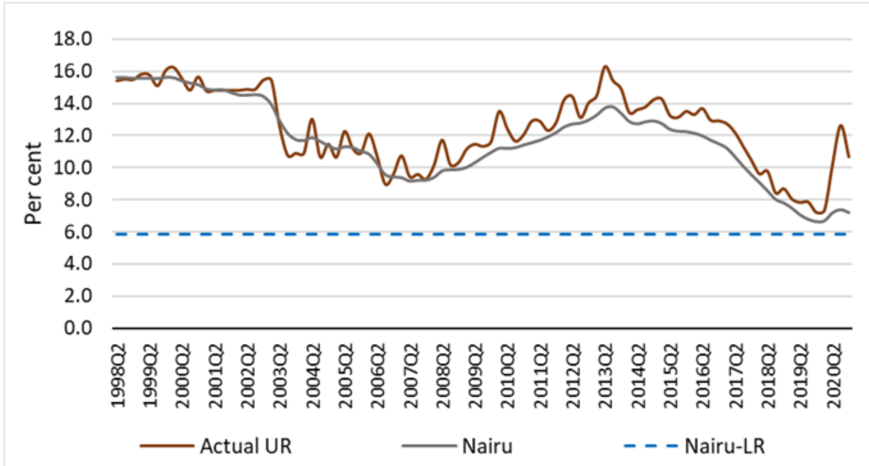
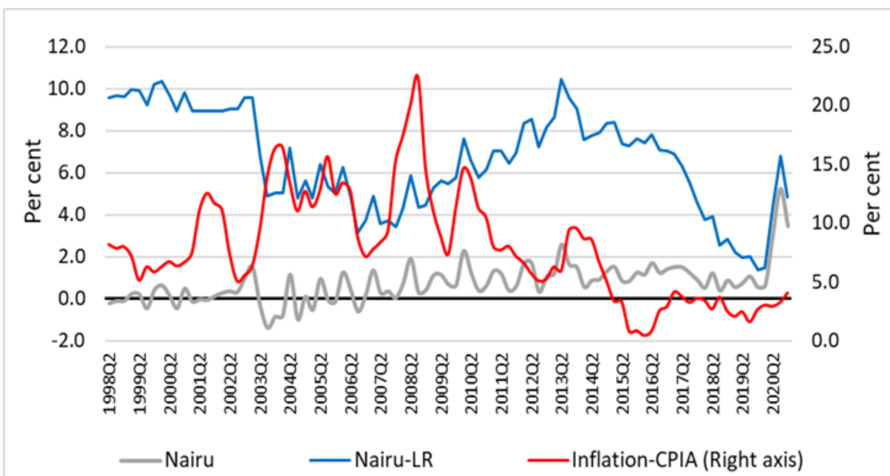


Figure 4: Unemployment Gaps and Inflation (year-over-year)



3.2.2 Potential Participation Rate

The potential participation rate is modelled by applying an appropriate filter to the actual participation rate to extract the trend component (see Figure A1 in Appendix). The actual labour force participation rate average 64.0 per cent over the sample period but oscillates over time and appears to be inversely related to the unemployment rate. As unemployment started to rise in the aftermath of the 2008 financial crisis, the participation rate began to fall, perhaps reflecting the extent to which persons in the working age population either became discouraged and stopped looking for jobs, or went back to school. In relation to the potential measure, the actual data suggest that, in 2020, the potential participation rate was 62.1 per cent.

3.2.3 Potential Hours Worked (hper)

The potential hours worked per person is computed by applying appropriate filters to the time series on average hours worked per employed person (see Figure 5). As a cross check, we include the assumption that all workers work a standard 40-hour work week as defined by Jamaica's labour law, which translates in 520 hours per person per quarter.

Figure 5: Average Hours Worked Per Worker

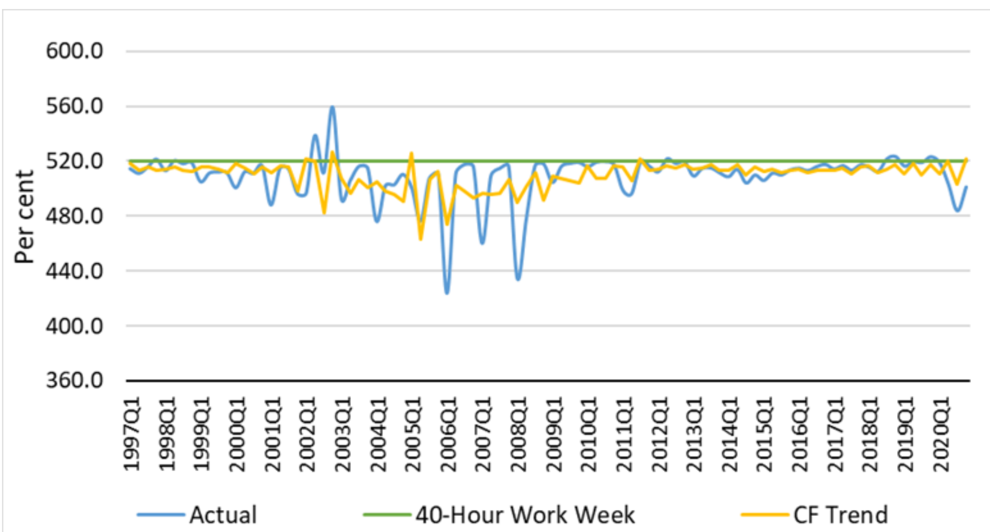
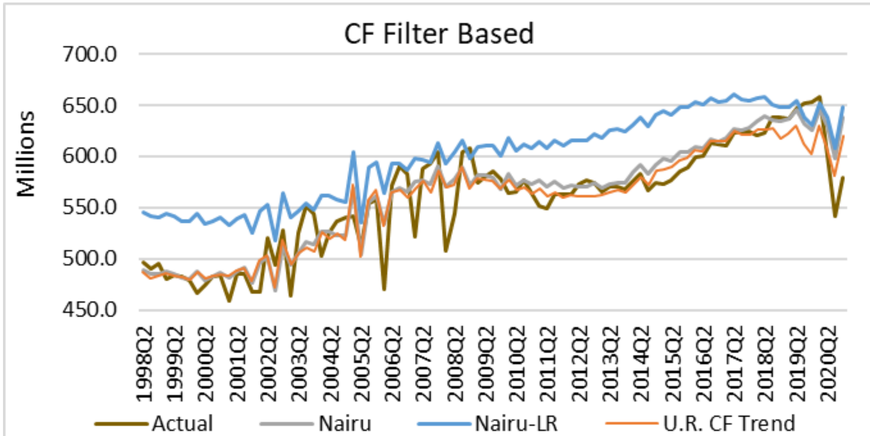


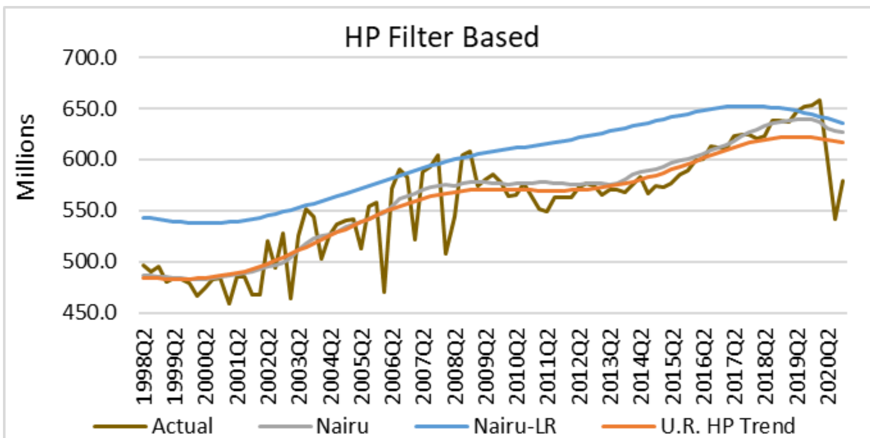
Figure 5 shows that the average hours worked per Jamaican worker increased at an average year-over-year rate per quarter of 0.1 per cent over the 1998 to 2019 period. In 1997q1, the average Jamaican worked 515 hours per quarter, which was broadly consistent with the stipulations of the law. Average hours worked however dipped significantly below the 520 hours for the 2004 to 2008 period before growing to 523 hours at the end of 2019, which implied that the average Jamaican worked the maximum hours as stipulated by the law. By end-2020, actual hours fell to 501 hours, reflecting the negative impact of the COVID-19 pandemic. The potential hours worked at the end of the sample period was broadly consistent with the actual.

3.2.3 Measures of Potential Labour Supply

Given the two estimates of potential NAIRUs and the long-run unemployment rate derived from either of the two appropriate filters, we compute six measures of potential labour supply from equation [7] by combining them (the potential NAIRUs and unemployment rate trends) with the estimates of the potential hours worked, the potential participation rate and potential working age population based on the filters. The six measures of potential labour supply are shown in Figure 6, along with the actual labour supply. The supply of labour has only fully trended below the measures of potential supply of labour based on NAIRU-LR (with the exception of a few quarters). In this vein, for the December 2020 quarter, the potential labour supply gap for Jamaica ranged between 37.7 million hours per quarter (or 6.5 %) and 68.1 million hours per quarter (or 11.7 %).

Figure 6: Actual and Potential Labour Supply based on all Filtering Methods (Hours Worked)





3.3 Potential Total Factor Productivity

We derive potential TFP from the Solow residual in the empirical version of [3] using an appropriate filter. This therefore dictates that we first identify capital (human and physical) and labour's shares of output (the elasticities) to get actual TFP and then apply the appropriate filter to the actual TFP. Expressing [3] in terms of the TFP (lnA_t) gives [11].

$$lnA_t = \; lnY_t - (\varphi lnH_t + \alpha lnL_t + \beta lnK_t) \qquad [11]$$

There are several methods to estimate the elasticities. For this study we will use two approaches: that used by the CBO and econometric estimates. The CBO estimates the parameters (α and β) from the production function in [1] by computing the shares of labour compensation and capital income in the value of output, respectively.[15] Once the share of labour is computed, the CRS assumption can be imposed to get the capital share.

For us to apply the CBO's approach to the augmented production function in [2], we also need to estimate the share of human capital income in the value of output.[16] We do this by estimating the capital elasticity (β) and the labour elasticity (α) and then imposing the CRS assumption to compute the human capital share (φ) in income.

An output elasticity of labour (α) of 0.45 was calculated as the ratio of compensation to employees to gross domestic product over a selected period.[17] By definition, the output elasticity of overall capital is therefore 0.55. An output elasticity of capital (β) of 0.28 was also calculated as the ratio of compensation of capital to gross domestic product over the same selected period, which implies, by imposing the CRS assumption, that the elasticity of human capital is 0.27. Equation [12] and [13] summarises for convenience the various estimates of the elasticities for the simple and the expanded CD production function.

$$Residual_{t,1} = lnA_{t,1} = lnY_t - 0.45lnL_t - 0.28lnK_t - 0.27lnH_t \quad [12]$$

$$Residual_{t,2} = lnA_{t,2} = lnY_t - 0.55lnK_t - 0.45lnL_t \quad [13]$$

Using the econometric approach to compute the elasticities of the factor inputs, we estimate equations [1] and [2] using ordinary least squares, with the input variables entering the model in logarithm forms. The input estimates are then used to compute the Solow residuals as shown in

[15] This latter estimate is supported by Mankiw et al. (1992) who indicated that the elasticity of physical capital is not substantially different from capital's share in income. The CBO (2001) estimates that, for the United States, the shares of labour compensation and capital income in the value of output are 0.7 and 0.3, respectively.

[16] Finding a reasonable estimate can be challenging. Mankiw et al. (1992) suggest that an estimate of the return of human capital is the earnings of the work force's (excluding those earning minimum wage) share of the value of output. This computation would not be possible for Jamaica, given the paucity of employees' compensation data.

[17] Data for compensation to employees was taken from STATIN's National Income and Product reports (1997 – 2017).

[14] and [15]. All elasticity estimates are provided in Table A4 in the appendix. For [1], the output elasticities for labour and physical capital are 0.37 and 0.73, respectively, with greater contribution from capital as shown in the results from the CBO approach. On the other hand, for the augmented production function, [2], the output elasticities for labour, physical capital and human capital are 0.36, 0.47 and 0.22, respectively. These elasticity estimates are varied with the respective annual averages using the CBO's approach in [12] and [13]. [18]

$$Residual_{t,3} = lnA_{t,3} = lnY_t - 0.36lnL_t - 0.47lnK_t - 0.22lnH_t - structural\ breaks \quad [14]$$

$$Residual_{t,4} = lnA_{t,4} = lnY_t - 0.73lnK_t - 0.37lnL_t - structural\ breaks \quad [15]$$

Figure 7 presents the plot of the growth of the appropriate filtered TFP. The figure shows that TFP growth for all the measures was fairly balanced between positive and negative. The fall in TFP over the period 2006q4 to 2012q1 was consistent with the advent of the global financial crisis, which saw domestic production, induced by the crunch in external demand, falling faster than employed factor inputs. TFP generally rebounded after 2012 at an annual average rate each quarter of 0.2 per cent, a period which coincided with an intensification of structural reforms under the country's economic reform programme) (Table 1).

[18] The production function is tested to determine if it exhibits constant returns to scale. That is, if the summation of the factor input coefficients sum to one ($\varphi + \alpha + \beta = 1$). Using the standard Wald or F-statistics, it was determined that the production function exhibits constant returns to scale at the 1 per cent level of significance. In the standard economic growth literature, capital share of income in the Cobb-Douglas PF is assumed to be a-third and the remaining two-third allocated to labour's share (Romer, 2012). The coefficients on all three factor inputs are also not statistically different from the equal, one-third, input shares in Mankiw et al. (1992)'s production function framework that is consistent with their empirical findings that best explains the differences in per capita income across countries.

In order to get a deeper understanding of human capital share of income, we estimate the augmented PF, [2], separately with the average years of schooling for each of the three educational level instead of the total average years of schooling. The results from the three regressions indicate that the elasticity estimates of human capital based on primary, secondary and tertiary average years of schooling are 0.25, 0.10 and -0.02, respectively. These input shares suggest that educational attainment in Jamaica above the secondary does not contribute positively to income or may not be useful for estimating potential output for Jamaica. Further research is, however, warranted.

Figure 7: Growth of TFP Trend using the CF Filter (Selected Measures)

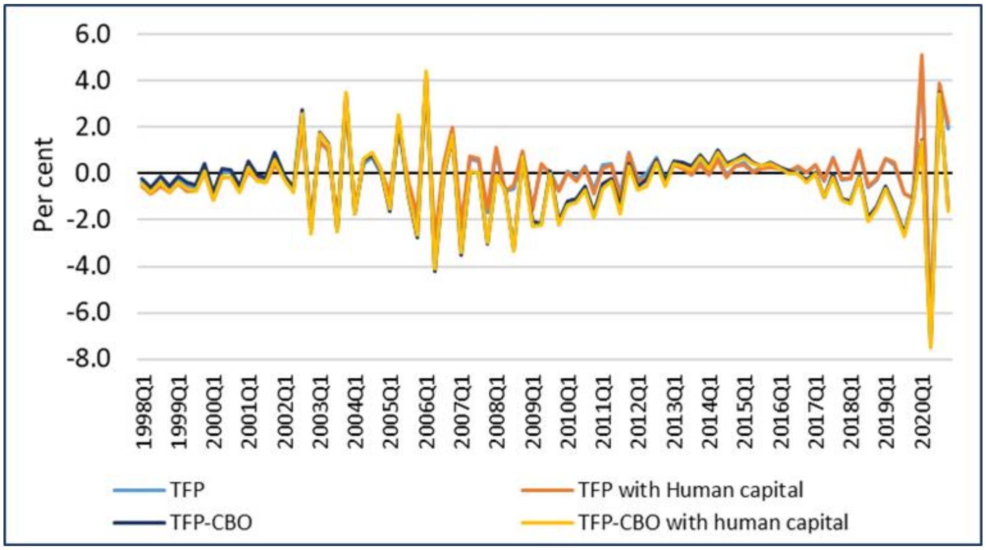


Table 1: TFP Growth – CF Filtered

	2011 – 2015	2016 – 2020
ΔTFP (human capital)	0.1	0.2

3.4 Estimating Potential Output

The estimate for potential output is the summation of all the potential inputs calculated above. Overall, we develop 14 measures of potential output as shown in Table A5 in the Appendix, that is, seven per filter used. Four of the nine measures, from each filter, are based on the production functions in equations [1] and [2], augmented with the two measures of potential labour supply. The other measures of potential output are based simply on the long-run trends of actual real GDP and the factor inputs.

4. Selection of Potential Output

To identify the best candidate measure of potential output, we estimate different versions of our by-now standard Phillips curve in which inflation is regressed on various measures of the output gap ($Gap_{i,t}$) (calculated as shown in Table A5 in the Appendix) and two control variables (exchange rate and *wti*).

$$\pi_{t+1} = \gamma + \alpha(L)\pi_t + \rho(L)Gap_{i,t} + \beta(L)Exrate_t + \theta(L)wti_t + \varepsilon_t \qquad [16]$$

The best measure of potential output is that which best explains inflation. The estimation is done with an ARDL model. Root mean squared errors (RSME) is used to provide a measure of the distance of the true form of inflation rate from the forecasted values. The lower the RSME value, the better is the model forecast and hence the better is the estimate of potential output. Table A7 in the appendix presents the RSME values used to evaluate the in-sample forecasts. From this assessment, Model 2 based on the CF filter (CF-M2) was selected as the preferred model for the in-sample forecast from 14 candidates (see Figure 8). For this model, the potential output measure is based on the PF framework augmented with human capital and labour supply computed as a function of the time invariant NAIRU (NAIRU-LR). This potential output measure was constructed with the elasticity estimates from OLS (1) in Table A4 in the appendix.[19] The result from the preferred ARDL model is presented in Table A6 in the appendix.

5. Potential Output – Stylised Facts

Over the 2001:1 to 2020:4 period, potential output for Jamaica, as indicated by the successful candidate, grew by 0.2 per cent, virtually in line with real GDP growth.[20] Our model also indicates that, over the past ten years, potential output declined at an annual average rate of -0.3 per cent, marginally higher than the -0.2 per cent growth in real GDP over the same period (see Table A8 in the appendix). The decline in potential labour supply and TFP were moderate at around 0.2 per cent and 0.1 per cent, respectively over the same period. The physical capital stock was flat while human capital grew.

For the last five years (2016 to 2020), while labour supply (0.8 per cent) and TFP (0.2 per cent) continued to decline in Jamaica, human capital grew by 0.1 per cent while the capital stock remained flat. In the context of these estimated influences, potential output fell by 1.0 per cent, virtually in line with the growth in real GDP. The output gap was estimated to be negative for the

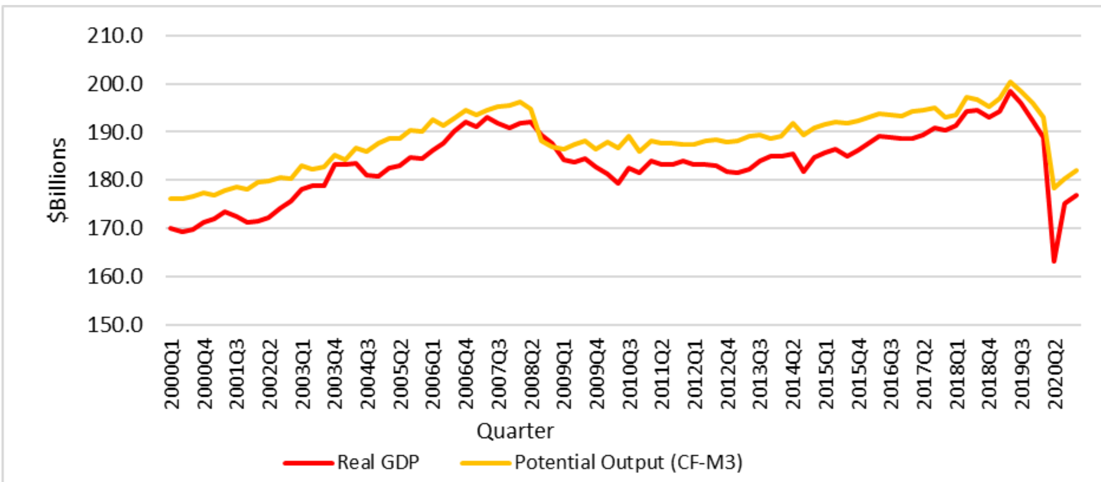
[19] Specifically, using the Christiano-Fitzgerald derived long-run trend from the Solow residual from equation [14], we compute the potential output as $Y_t^* = A\ H_t^{0.22} L_t^{0.36}\ K_t^{0.47}$.

[20] Abstracting for the fallout in output due to COVID-19, potential output grew by 0.5 per cent, marginally below real GDP growth of 0.7 per cent for the comparable period.

sample period but, for 2016 to 2019, closed gradually, then widened thereafter due to the effect of the COVID-19 pandemic.

The decline in the potential labour supply, TFP, and potential capital stock at the end of the sample period (the December 2020 quarter) was estimated at 2.2 per cent, 1.2 per cent and 0.1 per cent, respectively. The growth in average years of schooling at the end of 2020 was estimated at 0.1 per cent. At the end of the sample, the output gap was negative 2.9 per cent.[21]

Figure 8: Actual Real GDP and Potential Output (CF Model 2)



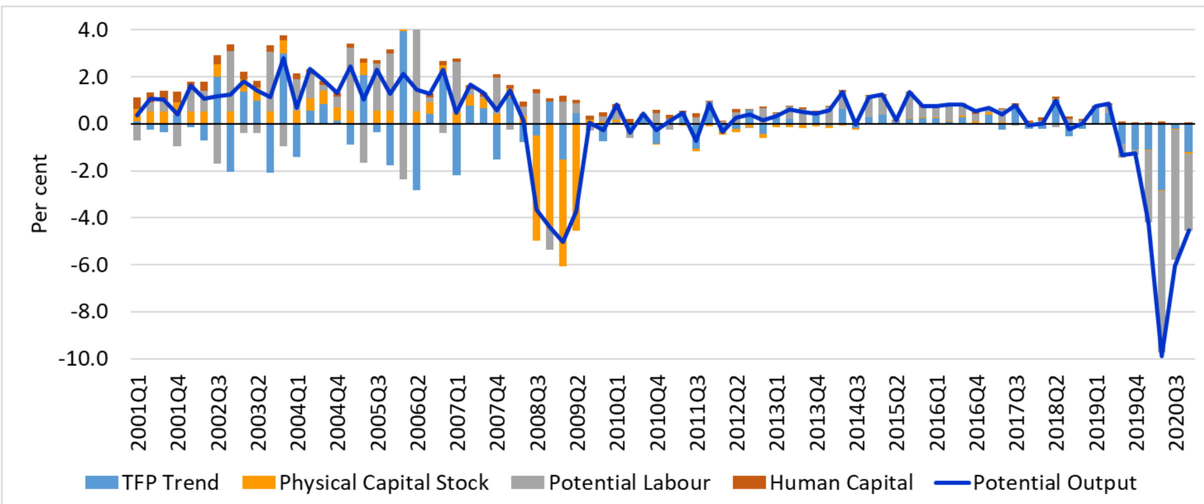
Notes: CF Model 3 (CF-M3) potential output is computed from the production function framework augmented with human capital and the potential labour supply as a function of the time invariant NAIRU.

Figure 9 presents labour, physical capital and human capital's contributions to potential output growth. The contribution of the growth in potential labour supply to potential output growth was strong over the sample period and was particularly evident for the period 2002 to 2009. This performance principally reflected growth in the working age population (see Figure 10). The contribution of potential TFP also rose steadily between 2013 and 2019, while the contribution of the potential capital stock to potential output growth was negligible after the 2008 financial crisis.

[21] See all potential output and output gap measures in Figures A2 and A3, respectively. This study historically estimate of Jamaica's output gap shows Jamaica's economy operating close to full capacity for majority of the sample period. Brown (2017) estimates indicated that Jamaica was around full capacity after 2008.

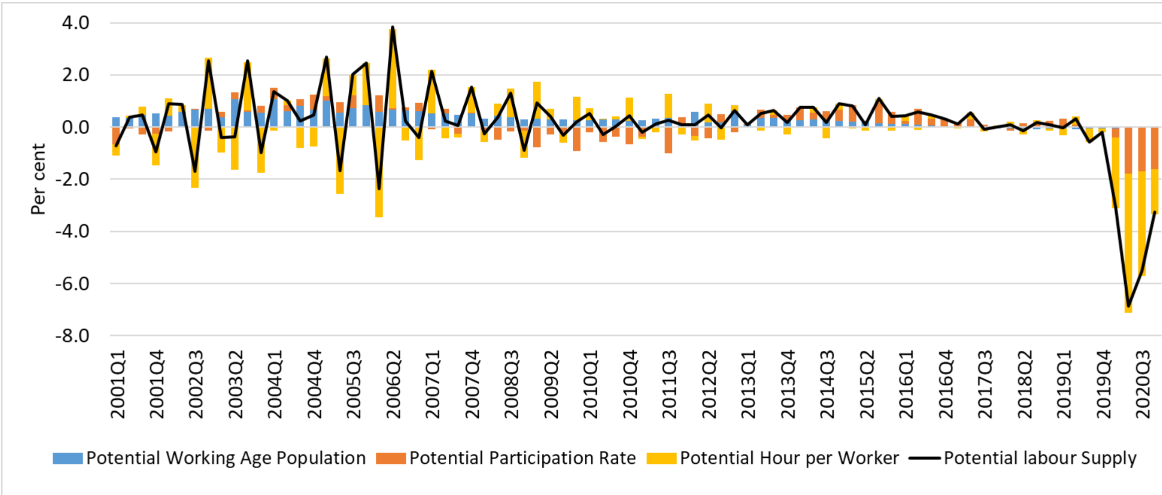
Human capital did not have a strong influence on potential output growth between 2012 and 2019. This may reflect the impact on access to - and the desire to access - schooling of the financial crisis and the advent of structural adjustments and fiscal consolidation, which saw a rise in poverty in Jamaica. With the progressive closing of the output gap since 2015 into 2019, inflation, although relatively low, began firming over the period 2015 to 2019 (Figure 11).

Figure 9: Contributions to Potential Output Growth



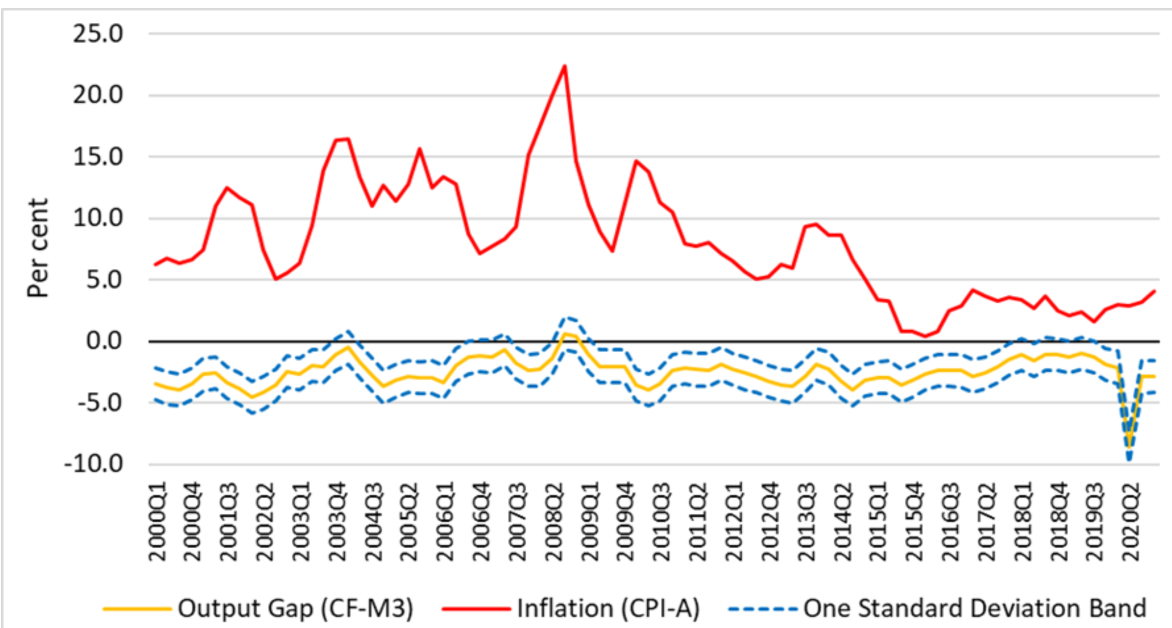
Notes: Contributions are computed as year-over-year weighted changes. Labour, capital stock, human capital and TFP contributions sum up to the potential output growth rates.

Figure 10: Contributions to Potential Labour Supply Growth



Notes: Contributions are computed as year-over-year weighted changes. Hours per worker, participation rate and working age population contributions sum up to the potential labour growth rates.

Figure 11: Output Gap and Inflation Rate



To put the estimated output gap for Jamaica in context, we compare it with the output gaps for selected countries (Table 2). Abstracting for the different methods used to compute the output gap, the trend and level of the output gap across the selected countries are relatively consistent.

Table 2: Output Gap Comparisons for Jamaica with Selected Countries

Countries	2006	2010	2014	2018	2020
Jamaica (CF-M3)	-0.7	-4.0	-2.8	-1.1	-4.1
Barbados[a]	4.2	-1.0	-1.7	NA	NA
United States[b]	0.8	-4.0	-2.4	0.6	-4.5
Global[c]	1.4	-1.6	-0.4	0.1	NA

Notes: Jamaica's gap represents the average for the year.
[a] Data sourced from the Inter-American Development Bank at https://mydata.iadb.org/idb/dataset/3itg-avtz
[b]U.S. Bureau of Economic Analysis, Real Gross Domestic Product [GDPC1], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/GDPC1, April 15, 2021. The figure represents the average of the quarterly output gap for the respective years.

[c] World Bank (2018). Calculated using multivariate filter. Aggregated output gaps are calculated using constant 2010 U.S. dollar GDP weights. The sample includes 15 advanced economies and 23 EMDEs
NA means not available.

5. Forecasting: Potential Output

To project potential output over the five-year period to 2025, we extrapolate the cyclically adjusted factor inputs in the best candidate model and substitute them back into the production function.[22] All projected variables are in Figure A4 in the appendix.[23]

[22] The cyclically adjusted variables are constructed to follow linear time trends over history, so they have constant growth rates and are easy to extrapolate.

[23] See Table A9 in the appendix for summary of key formulas.

Investments

The forecast for investments uses information about planned investments financed by domestic and foreign sources [17]. The domestic portion comprises government projects, identifiable private sector projects and a trend component.

$$I = I_d + I_f \qquad [17]$$

$$I_d = I_d^G + I_d^P = Identifiable\ projects + Others$$

Where I_d represents domestic (public and private) investments, I_f represents foreign investments, I_d^G represents planned government investments, I_d^P represents identifiable private sector projects and unexpected investments.

A key assumption is made regarding the time the projected investments affects Jamaica's productive capacity and, by extension, potential output. It is expected that it will take two years on average for investments to affect productive capacity in Jamaica. Within the context of this study, investments breaking ground in 2020q1 are assumed to affect potential output in 2022q1.[24] That is, the forecasted capital stock from 2022q2 and beyond therefore evolves according to the projection for investment minus the rate of depreciation as shown in [4]. In order to ensure a smooth transition in the evolution of the capital stock, the stock for the period 2021q1 to 2022q4 is projected to decline by 0.04 per cent, which is the average rate of growth of the net capital stock over the period 2019q1 to 2020q4.[25]

[24] Over the period 1997 to 2019, the time it takes for investments to impact potential output varies across sectors. It takes between one to one and a half, two to three and two years for Mining & Quarrying, Hotels & Restaurants and Manufacture industries to impact Jamaica's productive capacity, respectively.

[25] As a robustness check, we estimated an investment function using real private sector credit and trend to generate a forecast for investment. The thinking is that a bottom-up approach such as the one adopted by this paper, may miss potential projects that are being incentivize by monetary conditions. This simulation supported the projections using the bottom-up approach.

Human Capital

The projection for human capital is generated using the annualized growth from Barro and Lee. In this regard, average years of schooling is projected at 9.7 years for 2020 and is expected to increase to 10.0 years by the end of the projection period.

Labour Supply

To project the NAIRU-LR to the end of 2025, we maintain the estimated time invariant of 5.8 per cent.

The forecasts for working age population is based on the ten-quarter moving-average growth rate of the variables. [26] For hours worked per person, we project a gradual rise to a 40-hour work week into the June 2023 quarter, after the fallout due to the COVID-19 pandemic where domestic movements were constrained due to restricted movements. The projection for the participation rate also reflects a rebound to its long run level of 65.0 per cent after the temporary fall-off stemming from the COVID-19 pandemic.[27] Together, these projections are used to compute the forecast for potential labour hours using [8].

Over the projection horizon, real GDP is assumed to grow by an average of 2.4 per cent, which is higher than the average potential output growth of 1.7 per cent, given the expected rebounds in the context of the end of the pandemic (see Table A8 in the appendix). With this projected growth rate, Jamaica's real GDP is projected to converge with potential output after the December 2022 quarter (see Figure 12 and 13). The near and subsequent closure of the output gap in the March 2023 quarter and beyond suggests full capacity utilization and the expectation of some inflationary pressures.

[26] Population projections by STATIN indicates that the working age population will decline in the future. This decline has become evident in the 2019 statistics. In this context, an assumption that the working age population will remain flat is fairly optimistic.

[27]The long run labour force participation rate of 65% is consistent with the output gap closing over the medium term, where there is not extended period of slack in the labour market and the demographic make-up of the economy remains relatively constant. Of the remaining 35 percentage points (pp), 25 pp captures those persons either at school or has retired. The remaining 10 pp may capture those persons who are ill or choose to remain outside of the labour force because of factors such as remittances.

Figure 12: Real GDP and Potential Output Projections

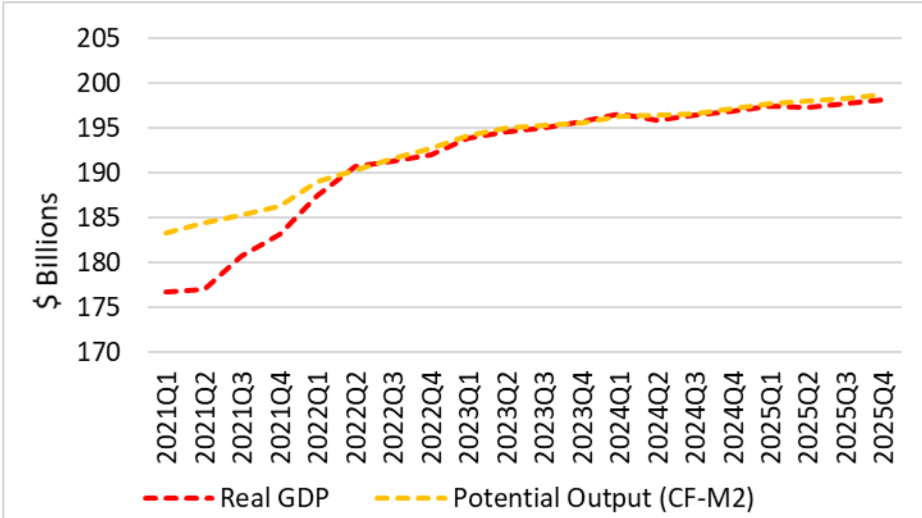
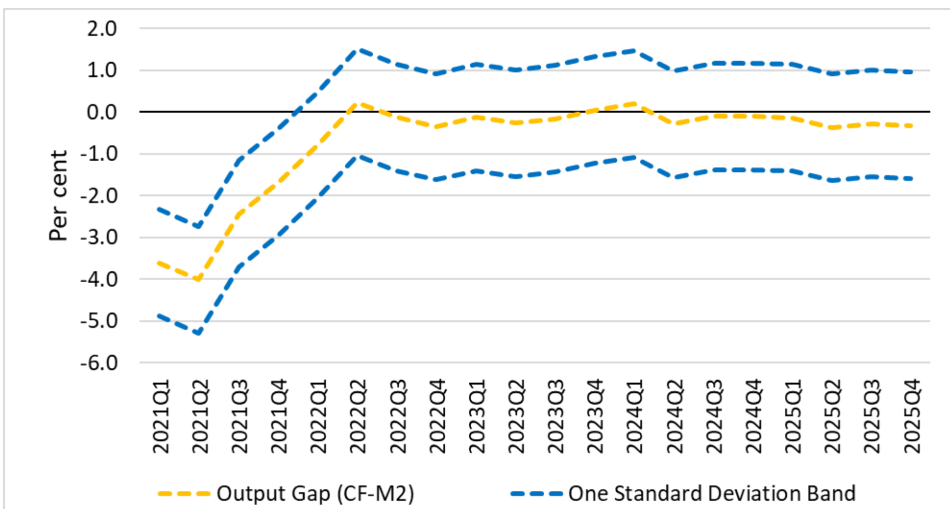


Figure 13: Output Gap (CF Model 2) Projections



The projection for potential output growth assumes that potential labour supply will grow at an annual average rate of 1.2 per cent, relative to the historical average decline. Growth in potential labour is projected to be largely driven by expected increases in hours work and to a lesser extent growth in the labour force participation rate. The path for human capital assumes an average growth of 0.1 per cent, which is relatively in line with the average growth of the past five and ten years. In the context of the investments flows projected by the central bank, the potential capital stock is projected to remain flat, in line with the past 5 years. We assume that if the impact of structural reforms materialize, TFP growth will accelerate to an average of 0.5 percent over the next five years.[28]

6. Conclusion

The output gap plays an important role in informing BOJ's monetary policy. This paper estimates Jamaica's potential output and, consequently, the output gap using a production function framework augmented with human capital as an additional factor input. The aim of this paper is to augment the information set available to Bank of Jamaica in estimating and projecting potential output growth and inflation.

The results of this study indicate that the output gap, based on the PF framework augmented with human capital and potential labour supply as a function of long-run unemployment rate (NAIRU), is the preferred measure to forecast Jamaica's inflation. At the start of 2021, Jamaica's negative gap was estimated at approximately 2.9 per cent. This compares to the lowest negative gaps of 8.6 per cent for 2020q2 and 5.3 per cent for 1998q1. The estimate suggests that over the period of study, Jamaica's resources were largely under-utilized. Over the last two years of the sample period, in the context of general firming of inflation at low levels, the economy showed signs of falloff in capacity utilization. For the near term, the economy is expected to operate for the most part below capacity which signals no inflationary pressures over this horizon. This has broader implications for wage setting, inflation expectations and monetary policy decisions in Jamaica.

[28] If potential output growth is expected to surpass that of real GDP, and grow at approximately 2.4 per cent per year over the next five years, increased growth can emanate from the capital stock. For potential growth of 2.4 per cent to materialize, the capital stock would have to grow by 1.5 per cent per year (=0.7/0.47), to contribute the additional 0.7 per cent to potential output growth, all things being equal.

7. References

Ball, L. and N.G. Mankiw. 2002. "The NAIRU in Theory and Practice." *Journal of Economic Perspectives* 16 (4): 115-136.

Bank of Jamaica. 2010. "Annual Report 2009." http://www.boj.org.jm/publications/ (accessed June 20, 2019).

Barro, R. and J. Lee. 2013. "A New Data Set of Educational Attainment in the World, 1950-2010." *Journal of Development Economics* 104: 184-198.

Berlemann, M. and J.E. Wesselhoft. 2014. "Estimating Aggregate Capital Stocks Using the Perpetual Inventory Method." *The Review of Economic Studies* 65: 1-34.

Brown, D. 2017. "Estimating Potential Output for Jamaica: A Production Function Approach." Bank of Jamaica Working Paper.

Bryson, T. 2008. "NAIRU: Is it Useful for Monetary Policy?" Bank of Jamaica Working Paper. http://boj.org.jm/uploads/pdf/papers_pamphlets/papers_pamphlets_NAIRU__Is_it_Useful_for_Monetary_Policy_.pdf (accessed March 1, 2019).

Coulombe and Tremblay. 2006. "Human Capital and Canadian Provincial Standards of Living." Statistics Canada.

Congressional Budget Office. 2001. "CBO's Method for Estimating Potential Output: An Update. Congressional Budget Office." https://www.cbo.gov/sites/default/files/107th-congress-2001-2002/reports/potentialoutput.pdf (accessed May 15, 2019).

Dinkelman, T. and M. Mariotti. 2016. "The Long run Effects of Labor Migration on Human Capital Formation in Communities of Origin." National Bureau of Economic Research Working Paper 22049 http://www.nber.org/papers/w22049 (accessed May 15, 2019).

Epstein, N. and C. Macchiarelli. 2010. "Estimating Poland's Potential Output: A Production Function Approach." IMF Working Paper –WP/10/15. https://www.imf.org/external/pubs/ft/wp/2010/wp1015.pdf (accessed: April 1, 2019).

Planning Institute of Jamaica. 2018. "Economic and Social Survey Jamaica 2017." Kingston: Pear Tree Press.

Földvári1, Péter and Bas van Leeuwen. 2009. "An Alternative Interpretation of Average Years of Education in Growth Regressions." http://www.iisg.nl/indonesianeconomy/humancapital/workingpapers/av_years.pdf (accessed March 2, 2019).

Havik, K., K. McMorrow, F. Orlandi, C. Planas, R. Raciborski, W. Roger, A. Rossi, A. Thum-Thysen, A. and V. Vandermeulen. 2014. "The Production Function Methodology for

Calculating Potential Growth Rates & Output Gaps. European Commission, Directorate General for Economic and Financial Affairs." Economic Papers 535. http://ec.europa.eu/economy_finance/publications/economic_paper/2014/pdf/ecp535_en.pdf (accessed March 2, 2019).

Laitner, J. 1993. "Long-run Growth and Human Capital." *The Canadian Journal of Economics* 26 (4): 796-814.

Lienert, A. and D. Gillmore. 2015. "The Reserve Bank's Method of Estimating Potential Output." Reserve Bank of New Zealand Analytical Notes 2015/01. http://www.rbnz.govt.nz/research_and_publications/analytical_notes/2015/an2015_01.pdf (accessed March 2, 2019).

Mankiw, G., D. Romer and D. Weil. 1992. "A Contribution to the Empirics of Economic Growth." *Quarterly Journal of Economics* 107(2): 407-437.

Mincer, J. 1974. "Schooling, Experience and Earnings". Cambridge: NBER Book.

Organization for Economic Cooperation and development. 2001. "Measurement of Capital Stocks, Consumption of Fixed Capital and Capital Services." https://doi.org/10.1787/9789264193260-en (accessed May 2, 2019).

Romer, D. 2012. "Advanced Macroeconomics." 4th ed. New York: Mcgraw-Hill.

Serju, P. 2007. "Estimating Potential Output for Jamaica: A Structural VAR Approach." *Money Affairs* XX (I):1-22.

Shaheen, F., Haider, A., Jabeen, S. and M. Iftikhar ul Husanain. 2015. "Estimating Potential Output for Pakistan: A Production Function Approach." *British Journal of Economics, Management & Trade* 9(4): 1-13.

The Economist. 2014. "Output Gaps in Developing Countries." https://www.economist.com/economic-and-financial-indicators/2014/01/18/output-gaps-in-developing-countries (accessed June 01, 2019).

United Nations Development Programme. 2018. "Human Development Indices and Indicators: 2018 Statistical Update." http://hdr.undp.org/en/2018-update/download (accessed May 20, 2019).

Williams, C. and A. Lee. 2019. "Assessing the Usefulness of the Neutral Rate of Interest to Monetary Policy in Jamaica." Bank of Jamaica Working Paper.

Wilson, R. and G. Briscoe. 2004. "The impact of human capital on economic growth: A Review." https://www.cedefop.europa.eu/files/BgR3_Wilson.pdf (accessed May 1, 2019).

World Bank. 2018. "Global Economic Prospects: Broad-Based Upturn, but for How Long?" www.worldbank.org (accessed May 15, 2019).

8. Appendix

Figure A1: Labour Force Participation Rate (1997Q1 to 2020Q4)

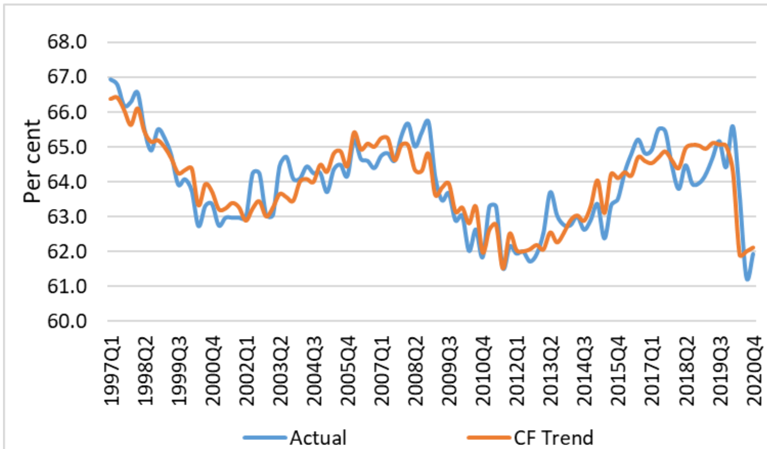


Figure A2: Actual Real GDP and Potential Output Measures

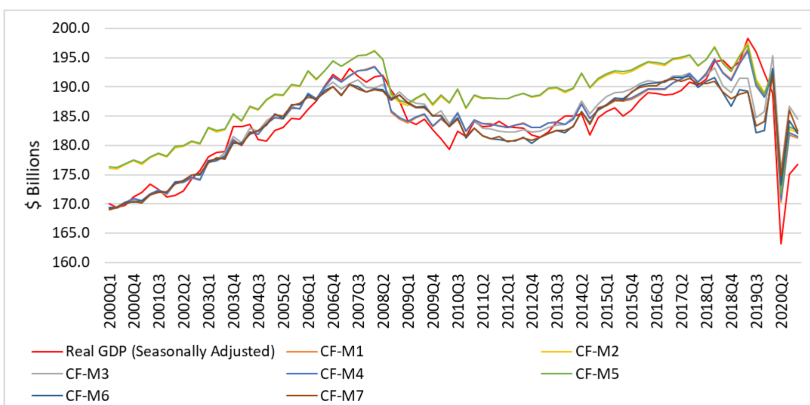
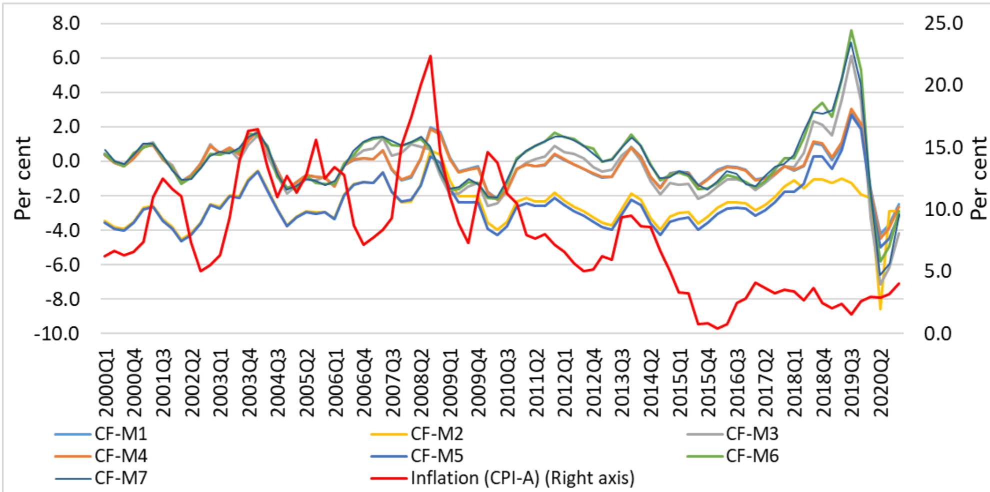


Figure A3: Output Gaps and Inflation Rate



Note: Output gap is computed as $(Y_t - Y^*)/Y^*$, where * represents the potential level.

Figure A4: Potential and Projected Variables

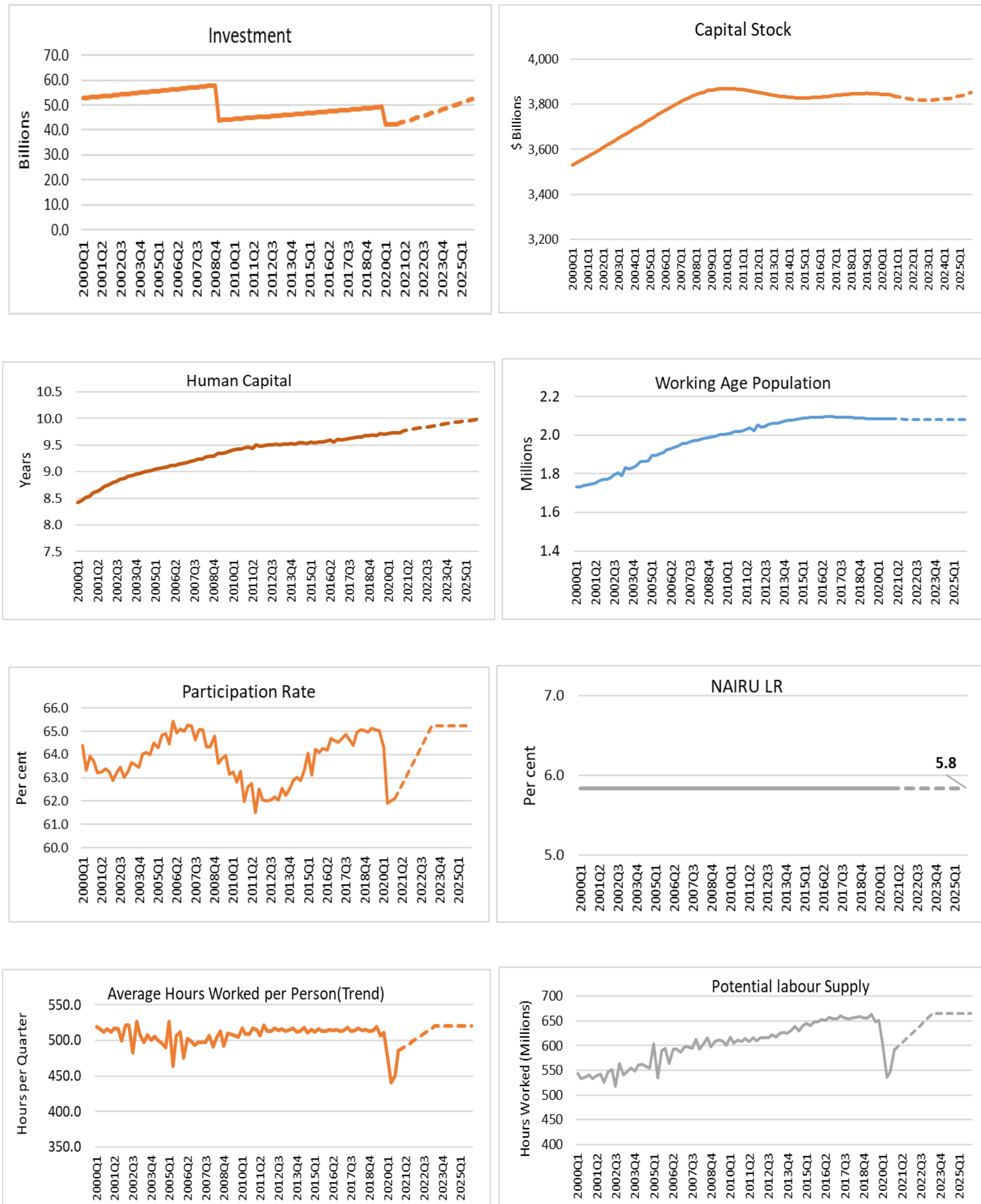


Figure A4: Potential and Projected Variables (Continued)

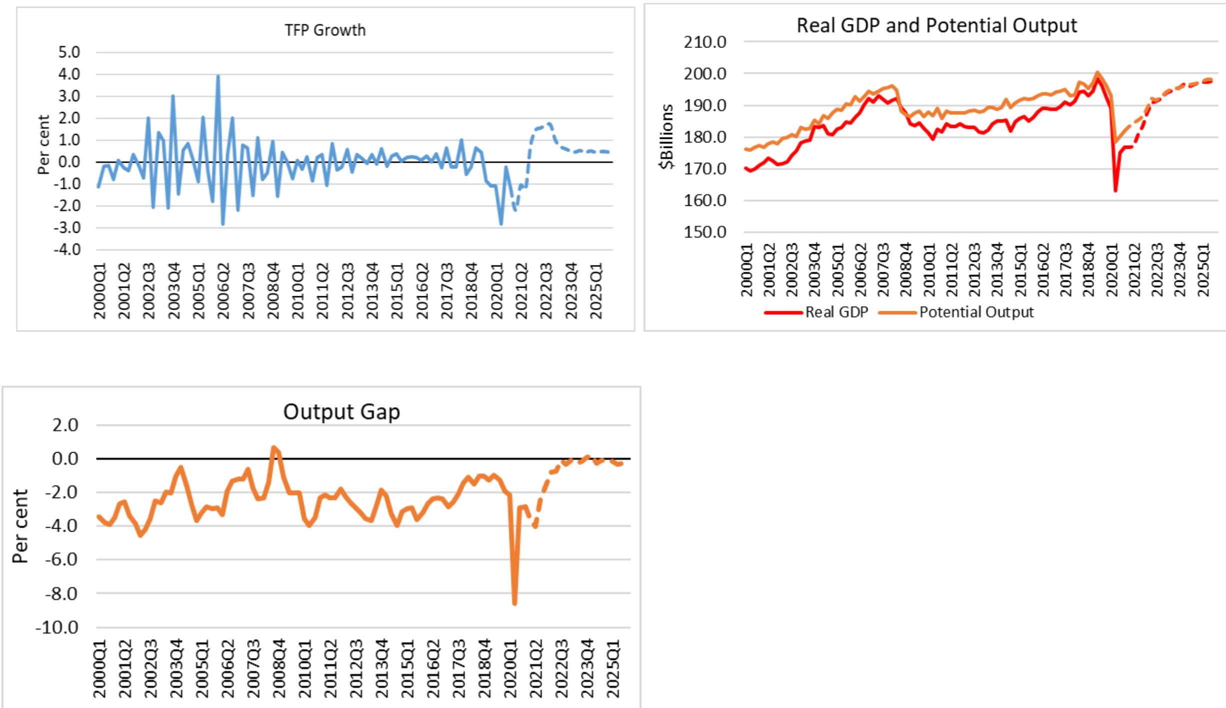


Table A1: Structural Break Test for Investment

Sequential F-statistic determined breaks:			1
Break Test	F-statistic	Scaled F-statistic	Critical Value**
0 vs. 1 *	21.10323	42.20646	11.47

* Significant at the 0.05 level.
** Bai-Perron critical values.

Break dates:

	Sequential	Repartition
1	2009Q1	2009Q1

Multiple breakpoint tests using Bai-Perron tests of L+1 vs. L sequentially determined breaks. Sample 1997Q1-2021Q4. Break test options: Trimming 0.15, Max. breaks 1, Sig. level 0.05. Breaking variables: C @TREND. Test statistics employ HAC covariances (Bartlett kernel, Newey-West fixed bandwidth) assuming common data distribution.

Table A 2: Estimates used to Compute NAIRU-LR2

Variable	Coefficient
D_Inflation(-1)	0.210***
	(0.075)
D_Inflation (-2)	-0.013
	(0.069)
D_Inflation (-3)	0.106
	(0.064)
D_Inflation (-4)	-0.520***
	(0.102)
UR	-0.001
	(0.001)
D_Growth EXRATE	0.074***
	(0.021)
D_Growth WTI	0.029***
	(0.009)
D_Growth WTI(-1)	-0.017**
	(0.007)
Constant	0.005
	(0.007)
R-squared	0.59
Adjusted R-squared	0.54
S.E. of regression	0.0096
Sum squared resid	0.005
Log likelihood	271.757
F-statistic	12.0528
Prob(F-statistic)	0

Notes: Dependent variable is the change in the inflation rate (without agriculture). 'D_' indicates variable is in first difference. Heteroskedasticity and autocorrelation consistent standard errors & covariance (Bartlett kernel, Newey-West fixed) are in brackets.

Table A3: Correlation between Inflation Rate and Unemployment Gaps

	NAIRU	NAIRU-LR
Inflation	-0.35***	-0.05

Notes: *** indicates significance of the correlation coefficient at the 1 per cent level. The correlation test was conducted on quarterly data from 19982:1 to 2020:4. The correlation coefficient should give an indication of the unemployment gap capability to predict or signal inflationary pressure (rise or fall).

Table A4: Dependent Variable is Log Real GDP

	OLS (1)	OLS (2)
constant	4.620	-2.686
	(4.762)	(2.346)
Capital	0.473**	0.735
	(0.183)	(0.105)***
Labour hours	0.355***	0.365***
	(0.044)	(0.048)
Years of Schooling	0.217	
	(0.143)	
Dummy_1	-0.047***	-0.045***
	(0.006)	(0.005)
Dummy_2	-0.114***	-0.106***
	(0.012)	(0.010)
Adjusted-Rsquared	0.89	0.89
Hypothesis: CRS (probability value)	0.56	0.17

Notes: Robust standard errors are in parentheses. *, ** and *** indicate significance at the 10 per cent, 5 per cent and 1 per cent, respectively. The test for constant returns to scale (CRS) tests if the sum of the coefficients of capital, labour and human capital is equal to one. Dummy_1 and Dummy_2 capture structural breaks in the real GDP series at 2008Q3 and 2020Q1, respectively.

Table A5: Measures of Potential Output by Potential Factor Input

Models (M)	Short Name	TFP	K	K (Filter)	H	H (Filter)	L	L (Filter)	NAIRU	NAIRU-LR1	NAIRU-LR2	UR (Filter)	Wpop (Filter)	P (Filter)	PLR-1 (Filter)	Hper	F_hour
M1	Pot.Output_PF(Hum)	√	√		√		√		√				√	√		√	
M2	Pot. Output_PF_LR(Hum	√	√		√		√				√		√	√		√	
M3	Pot. Output_PF_CBO_(Hum_lab+)	√		√		√		√				√	√	√		√	
M4	Pot. Output_PF	√	√				√		√				√	√		√	
M5	Pot. Output_PF_LR	√	√				√				√		√	√		√	
M6	Pot. Output_PF_CBO_(lab+)	√		√				√				√	√	√		√	
M7[a]	Pot. Output Filtered																

Note: [a] Potential output is derived using an appropriate filter to extract the long-run trend component from real GDP.

Table A6: Inflation Rate Forecast Evaluation using the 14 Output Gaps

Models	RSME Value	Rank
CF-M2	0.012891	1
CF-M5	0.012903	2
HP-M3	0.013188	3
HP-M6	0.013188	3
HP-M7	0.013188	3
HP-M5	0.013331	4
HP-M2	0.013343	5
HP-M1	0.013405	6
HP-M4	0.013407	7
CF-M1	0.013424	8
CF-M4	0.013429	9
CF-M3	0.013469	10
CF-M6	0.013472	11
CF-M7	0.013472	12

Note: The root squared mean error values are based on the in-sample static forecast.

Table A7: Inflation Rate Regression Results using Output Gap from CF Model 2

Variables	Estimates
Inflation (t-1)	1.219***
	(0.104)
Inflation (t-2)	-0.369***
	(0.099)
Gap(t)	0.096
	(0.245)
Gap(t-1)	0.521
	(0.444)
Gap(t-2)	0.851*
	(0.494)
Gap(t-3)	-0.823**
	(0.389)
Gap(t-4)	0.538***
	(0.200)
Growth Exrate(t)	0.088***
	(0.029)
Growth WTI(t)	0.040***
	(0.010)
Growth WTI(t-1)	-0.032***
	(0.011)
Growth WTI(t-2)	0.015*
	(0.008)
Constant	0.009**
	(0.004)
Adjusted R-squared	0.89
Normality (probability value)	0.92
Breusch-Godfrey Serial Correlation LM Test: (probability value)	0.38

Notes: Sample 1998q3 to 2020q4. Robust standard errors in brackets. *, ** and *** indicate significance at the 10 per cent, 5 per cent and 1 per cent, respectively.

Table A8: Average Growth of Real GDP, Potential Output and Factor Inputs

	2011 – 2020 (Past 10 Years)	2016 – 2020 (Past 5 Years)	2021 - 2025 (Proj 5 Years)
ΔY	-0.2	-1.0	2.4
ΔY^*	-0.3	-1.0	1.7
ΔL^*	-0.2	-0.8	1.2
ΔK^*	0.0	0.0	0.0
ΔH^*	0.1	0.1	0.1
ΔTFP^*	-0.1	-0.2	0.5

Notes:* Potential GDP, Y = GDP, L= potential labour supply, K = potential physical capital stock, H=potential human capital. Potential output growth is based on the production function augmented with human capital (Model CF_M2). Any discrepancy between the numbers is due to rounding.

Table A9: Table of Formulas

Variables	Formulas	Equation Number
Augmented production function	$Y_t = A\, H_t^{\varphi} L_t^{\alpha}\, K_t^{\beta}$	[2]
Physical capital stock	$K_{t+1}^{*} = I_t + (1-\delta)\, K_t^{*}$	[4]
Human capital annualized growth rate	$g_t^h = \left(\left(\frac{H_{t+5}}{H_t}\right)^{\frac{1}{5}} - 1\right) * 100$	
Initial physical capital stock	$K_0 = \frac{I_o}{g^k + \delta}$	[5]
Trend investment	$lnI_t = \varphi + g^k t + \partial D_t^{Break} + \varepsilon_t$	[6]
Potential labour supply (in hours)	$L_{s,t}^{*} = w_t P_t^{*}(1 - NAIRU_t) hper_t$	[7]
Augmented Phillips curve	$\Delta\pi_{t+1} = \alpha(L)\Delta\pi_t + \rho(L)(U_t - \overline{U}) + \beta(L)Exrate_t + \theta(L)wti_t + \varepsilon_t$	[8]
Time invariant NAIRU	$\Delta\pi_t = \gamma + \alpha(L)\Delta\pi_t + \rho(L)(U_t) + \beta(L)Exrate_t + \theta(L)wti_t + \varepsilon_t$ $\overline{U} = {}^{-\gamma}\!/_{\sum_{i=1}\rho_i}$	[10]
Solow residuals (in log form)	$lnA_t = lnY_t - (\varphi lnH_t + \alpha lnL_t + \beta lnK_t)$	[11]
Inflation forecast	$\pi_{t+1} = \gamma + \alpha(L)\pi_t + \rho(L)Gap_{i,t} + \beta(L)Exrate_t + \theta(L)wti_t + \varepsilon_t$	[16]
Investment forecast	$I = I_d + I_f$	[17]