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CANADA

# PBO's Approach to Measuring Potential GDP

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The Parliamentary Budget Officer (PBO) supports Parliament by providing economic and financial analysis for the purposes of raising the quality of parliamentary debate and promoting greater budget transparency and accountability.

This report describes PBO's approach to measuring potential GDP.

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# Executive Summary

Potential GDP is a measure of the sustainable productive capacity of an economy. It is typically defined as the level of output that can be achieved with available resources (e.g., labour, capital and technology) without creating inflationary pressures. As such, potential GDP provides a natural benchmark for assessing economic performance at a macro level.

Both the level and growth rate of potential GDP can be influenced by actual economic conditions as well as government policies. Ultimately, an economy's capacity to generate increases in living standards and to support government programs is tied to potential GDP.

Potential GDP is not directly observable and therefore must be estimated. PBO uses a standard "production-function" approach to construct estimates of potential GDP over history and projection horizons. This approach measures the amount of output an economy can produce when labour, capital and technology are at their respective trends.

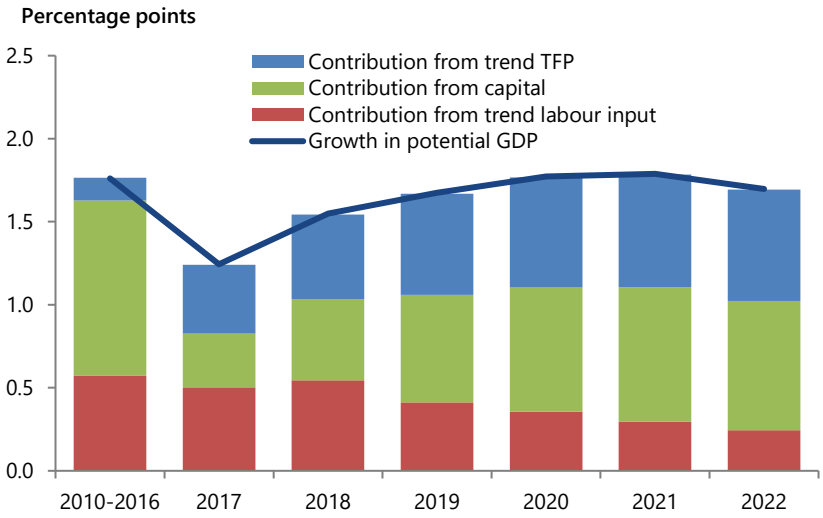
To calculate potential GDP, we incorporate our estimates of trend labour, capital and trend total factor productivity—a measure of technological progress—into a conventional production function.

Based on our April 2018 Economic and Fiscal Outlook, we estimate that real GDP rose above potential GDP in the second quarter of 2017 and stood at 0.7 per cent above potential at the end of 2017.

Looking ahead, we project growth in potential GDP to rebound from 1.2 per cent in 2017 to reach 1.8 per cent in 2020 and 2021. This projected rebound is due to an acceleration in capital accumulation and faster growth in trend total factor productivity (Summary Figure 1).

Summary Figure 1

## Projected growth in potential GDP, 2018 to 2022




Source: Parliamentary Budget Officer.

Compared to other institutions that produce estimates of potential GDP, PBO's estimate of potential growth in 2017 is at the lower end, likely reflecting both weaker growth in trend labour productivity and trend labour input. However, over the medium term, our projected growth in potential GDP is in line with the Bank of Canada's projection.

# 1. Introduction

Potential GDP is a measure of the sustainable productive capacity of an economy. As noted by the Congressional Budget Office (CBO) and the Bank of Canada, it is not a technical limit on production: it is the level of output that can be achieved with available resources (labour, capital and technology) without creating inflationary pressures.[1]

Potential GDP provides a natural benchmark for assessing economic performance at a macro level.

Comparing the level of observed, or actual, real GDP to potential GDP provides an estimate of excess demand or excess supply in the overall economy, which can be useful to gauge inflationary pressures.

Comparing growth in real GDP to growth in potential GDP gives a sense of how far observed growth is from underlying or "normal" growth.

Furthermore, the duration in which the level of real GDP deviates from potential GDP provides an estimate of the length of an economic boom, bust or recovery.

Both the level and growth rate of potential GDP can be influenced by actual economic conditions as well as government policies. Ultimately, an economy's capacity to generate increases in living standards and to support government programs is tied to potential GDP.

Potential GDP is not directly observable and therefore must be estimated. PBO uses a standard "production-function" approach to construct estimates of potential GDP over history and projection horizons. This approach measures the amount of output an economy can produce when labour, capital and technology are at their respective trends.[2]

The remainder of this report details PBO's approach to estimating the potential GDP of the Canadian economy. Section 2 presents the production function. Sections 3 through 5 describe, respectively, the trend labour, capital and total factor productivity (TFP) inputs. Section 6 presents our current estimates of potential GDP over history and over our medium-term projection horizon, including a comparison of potential estimates prepared by other organizations.

The estimates and projections presented in this report are based on PBO's April 2018 Economic and Fiscal Outlook.

# 2. The production function

PBO's estimate of potential GDP is based on the widely used Cobb-Douglas production function, which transforms labour (L) and physical capital (K), along with total factor productivity (A), into output (Y) for the Canadian economy as a whole.

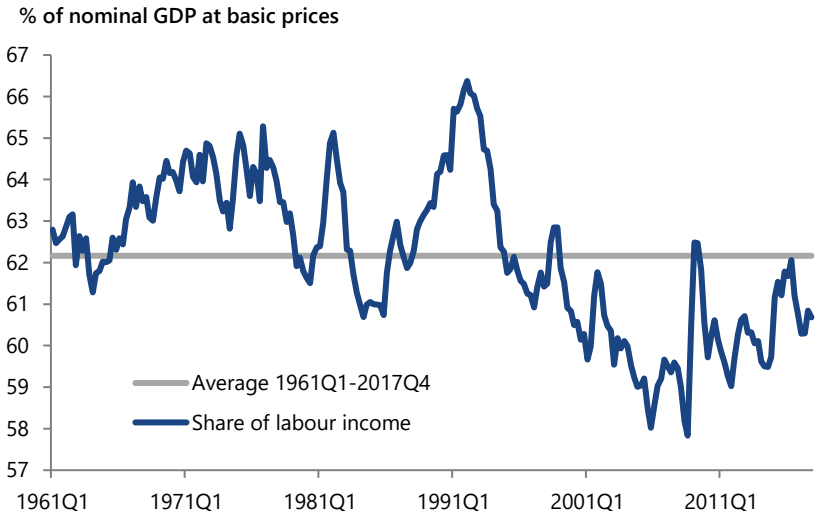
$$Y_t = A_t \cdot L_t^{\alpha} \cdot K_t^{1-\alpha}$$

The parameters α and (1 – α) represent the output elasticities of labour and capital, respectively. Under certain conditions, these parameters will be equivalent to the shares of income accruing to labour and capital from production.[3]

Total factor productivity (TFP), as CBO notes, is typically characterized as a measure of technological progress. However, because it is measured residually given output, labour and capital inputs, and income shares, it therefore captures other important phenomena (e.g., factor quality, labour effort and measurement error).

To calculate potential GDP, we incorporate our estimates of trend labour, capital and trend TFP into the Cobb-Douglas production structure. We estimate the parameter α based on the long-term average of labour income expressed as a share of nominal GDP measured at basic prices (Figure 2-1).[4]

**Figure 2-1 Labour's share of income, 1961Q1 to 2017Q4**




Sources: Statistics Canada and Parliamentary Budget Officer.

At first glance, it might appear that the value of the output-labour elasticity or labour income share ($\alpha$) would play a key role in determining the level of potential GDP. However, given that trend TFP is typically estimated by filtering, or smoothing, the residually-determined "raw" TFP series, the level of potential GDP constructed under the Cobb-Douglas structure is essentially invariant to the value of the labour share parameter.

# 3. Labour trends

In our framework, labour input (L) is measured as total hours worked, which is determined by the size of the population 15 years of age and older (LFPOP) (i.e., the "source population"), the aggregate employment rate (LFER) and the average number of hours worked (LFAH) by an employed individual in a given week.[5]

$$L_t = LFPOP_t \cdot LFER_t \cdot LFAH_t \cdot 52$$

To construct our measure of trend labour input (L_T), we combine the source population with our estimates of the trend (aggregate) employment rate (LFER_T) and trend average weekly hours worked (LFAH_T).

$$L\_T_t = LFPOP_t \cdot LFER\_T_t \cdot LFAH\_T_t \cdot 52$$

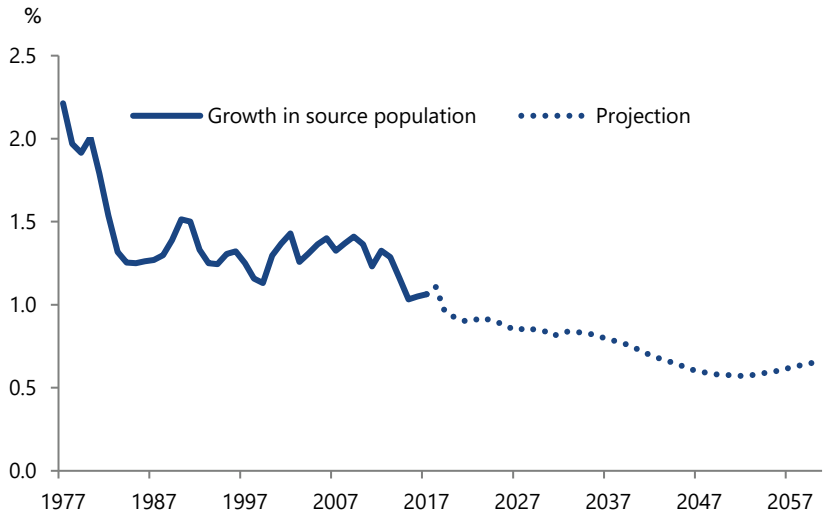
The following details each component of our measure of trend labour input.

**Source population**

The source population corresponds to Statistics Canada's Labour Force Survey (LFS) target population, which includes "all persons aged 15 years and over residing in the provinces of Canada, with the exception of the following: persons living on Indian reserves, full-time members of the regular Armed Forces and persons living in institutions (for example, inmates of penal institutions and patients in hospitals or nursing homes)".[6]

To produce estimates of the source population over our medium- and long-term projection horizons, we extrapolate from the most recent levels of the source population by single-year age and sex groups using their corresponding growth rates taken from Statistics Canada's M1 population projection.[7] Figure 3-1 presents the annual growth in the source population over history and projection.

Figure 3-1 Growth in the source population




Sources: Statistics Canada and Parliamentary Budget Officer.

Note: The projection period covers 2018 to 2060.

Growth in the source population has trended lower over the last 40 years, falling from 2.2 per cent in 1977 to 1.1 per cent in 2017. Based on Statistics Canada's M1 scenario, growth in the source population is projected to continue to slow over the medium term, falling to 0.9 per cent in 2022 and then to 0.6 per cent in 2052.

**Trend employment rate**

The aggregate employment rate is defined as the share of the source population that is employed. It can be calculated as a weighted average of age- and sex-specific employment rates, where the weights are the respective shares of each group in the source population. Our estimate of the trend employment rate is constructed by weighting trend estimates of age- and sex-specific employment rates by their source population shares.

Age- and sex-specific employment rate trends are estimated using a hybrid method, which combines a model-based projection and statistical filtering. We use a birth cohort model based on Barnett (2007), where each cohort's employment rate is modeled as a function of cyclical, structural and cohort-specific factors, to project the employment rate beyond the historical period using assumed paths for each of the explanatory variables.

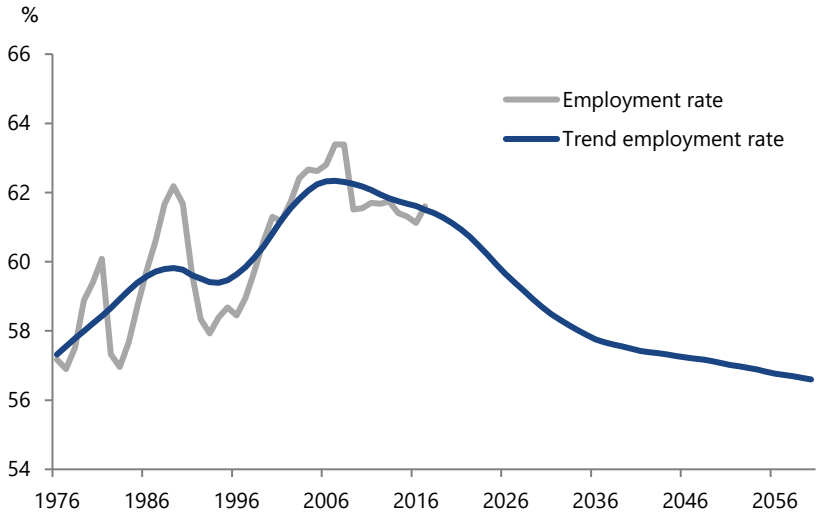
Specifically, each cohort's employment rate is a function of a cyclical labour demand variable and several structural variables including: age-related dummy variables, net household worth (relative to GDP), a real after-tax interest rate, a measure of Employment Insurance disincentives, the lagged employment rate and for women, a birth-year cohort effect is included. Except for the cohort effect and lagged employment rate, all explanatory

variables interact with an age dummy variable to allow for impacts to vary over an individual's lifecycle. The model is estimated as a system of equations from 1977 to the most recent year available (2017 in the current case). See Barnett (2007) and Barnett et al. (2004) for additional detail.

Projected cohort employment rates are then converted into employment rates by age and sex groups (e.g., males 35 to 39 and females 35 to 39) and then merged with their respective historical series. Each employment rate series, including both historical and projected data, is then filtered using the Hodrick-Prescott (H-P) filter to separate out cyclical and trend movements.[8] This approach helps to alleviate the end-of-sample problem associated with this filter and it ensures greater consistency between our historical and projected trends.

Next, we aggregate the trend employment rates by age and sex using their source population shares to construct the trend aggregate employment rate (Figure 3-2). Because employment rates follow an inverted U shape over the course of an individual's lifetime, shifts in the age distribution of the population can have important impacts on the aggregate employment rate. The lifecycle path of employment rates becomes particularly important over the projection horizon as the share of the source population 55 years of age and over increases. Since individuals over 55 years of age typically have lower labour force participation than their younger counterparts, the population shift toward older age groups puts downward pressure on the aggregate employment rate.

**Figure 3-2 Trend employment rate**




Sources: Statistics Canada and Parliamentary Budget Officer.

Note: The projection period covers 2018 to 2060.

Consequently, the trend employment rate is projected to continue its decline over the projection horizon, falling from 61.5 per cent in 2017 to 56.6 per cent by 2060. To put this decline in perspective, a 1-percentage point reduction in the aggregate employment rate in 2017 would translate into approximately 299,000 fewer Canadians working.

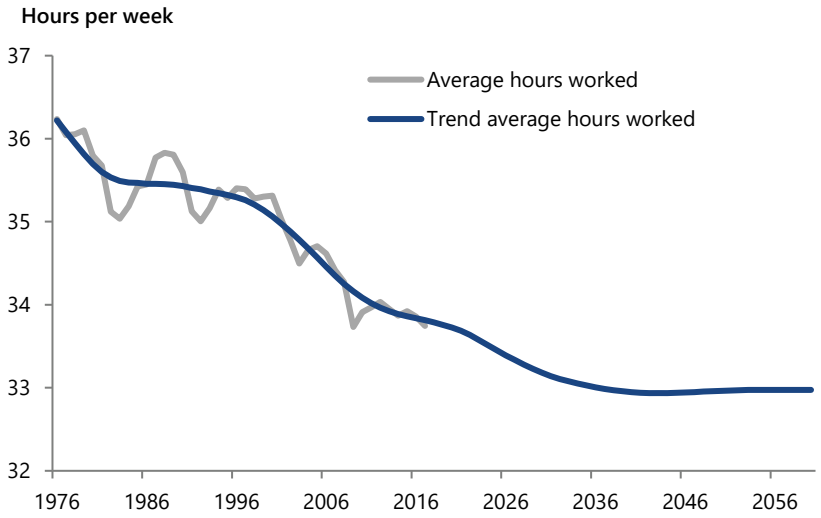
**Trend average hours worked**

While the source population and the employment rate determine the number of employees in the labour market, average (weekly) hours worked is a measure of labour intensity. Average hours worked, for the entire labour market, can be calculated as a weighted series of age- and sex-specific average hours worked, where the weights are each group's respective share in total employment. Our estimate of trend average hours worked is constructing by weighting trend estimates of age- and sex-specific average hours worked by their (trend) employment shares.

Similar to our approach for estimating the trend employment rate, we filter historical data combined with a model-based projection for age- and sex-specific average hours worked.[9] Because there are no discernable cohort effects in average hours worked, we used an age-specific fixed-effects model. Following Barnett (2007), average weekly hours worked (by age and sex group) are modelled as a function of a cyclical labour demand variable, the real after-tax interest rate, the share of services in total employment[10], the LFS seasonal adjustment factor and lagged average hours worked. All explanatory variables interact with age-group dummy variables. See Barnett (2007) for additional detail.

Over the last 40 years the average length of the Canadian workweek has trended downward, falling from approximately 36.2 hours per week in 1976 to 33.7 hours per week in 2017 (Figure 3-3). Based on PBO's model, this reflects the growing importance of the service sector in the labour market Since service sector employees work fewer hours per week, on average, compared to employees in the goods sector, the rising share of service sector employment has pulled economy-wide average weekly hours worked down. In addition, because females typically work fewer paid hours than males, the rising share of females in employment over this period has put downward pressure on economy-wide average weekly hours worked.

Figure 3-3 Trend average hours worked




Sources: Statistics Canada and Parliamentary Budget Officer.

Note: The projection period covers 2018 to 2060.

We project the decline in trend average hours worked to continue through 2035. Thereafter, however, as the share of service sector employment and the share of females in employment stabilise, this decline is halted and trend average hours worked stabilises around 33.0 hours per week, which is 9 per cent lower than the average work week in 1976.

**Trend labour input**

PBO's measure of trend labour input (TLI) combines the source population with our estimates of the trend (aggregate) employment rate and trend average weekly hours worked.

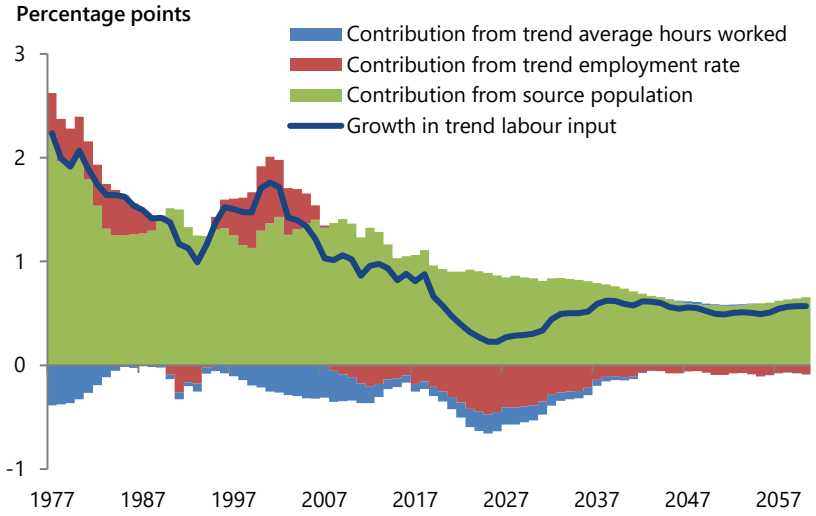
Over the historical period 1977 to 2017, growth in TLI averaged 1.4 per cent annually, due almost exclusively to growth in the source population (Figure 3-4). On balance over this period, positive contributions from a higher trend employment rate were offset by negative contributions from falling trend average hours worked.

Over 2011 to 2018, our estimates indicate that growth in TLI was relatively stable, averaging 0.9 per cent annually. However, we project that growth in TLI will begin to decline in 2019, falling to 0.2 per cent annual growth by 2026. The decline in TLI growth over this period reflects reduced contributions from all factors—lower growth in the source population and declines in the trend employment rate and trend average hours worked.

Growth in TLI is projected to pick up after 2026 through 2038 even as growth in the source population continues to fall. This reflects a moderation in the declines in the trend employment rate and trend hours worked that reduces

their negative contributions to TLI growth over this period. Thereafter, as trend average hours worked stabilizes and the trend employment rate gradually edges lower, growth in trend labour input falls only slightly short of matching growth in the source population.

Figure 3-4 Growth in trend labour input




Sources: Statistics Canada and Parliamentary Budget Officer.

Note: The projection period covers 2018 to 2060.

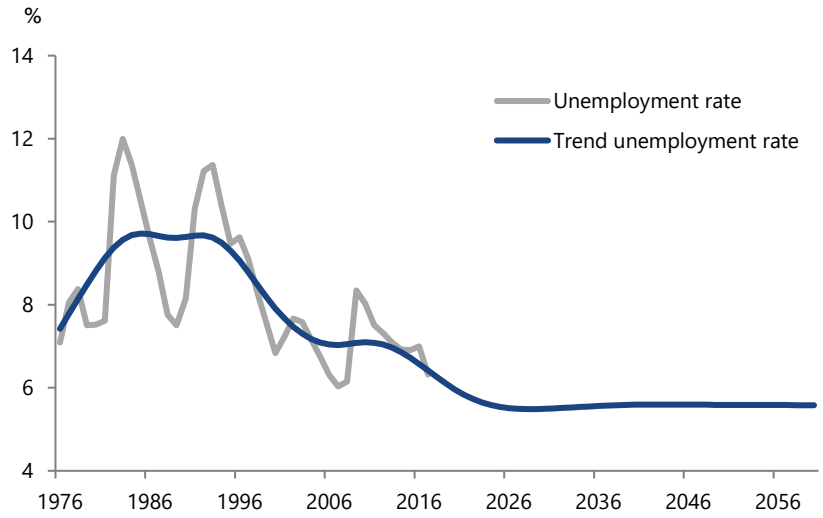
**Trend unemployment rate**

PBO's measure of trend labour input does not require an estimate of the trend unemployment rate. However, we do construct an estimate of the trend unemployment rate and use it to project unemployment over the medium-term horizon. Our estimate of the trend unemployment rate is constructed by first applying our cohort methodology and specification to the labour force participation rate (by the same age and sex groupings) to estimate its trend.[11] The trend unemployment rate (LFUR_T) is then determined residually given the trend employment (LFER_T) and trend labour force participation rates (LFPR_T).

$$LFUR\_T_t = 1 - ( LFER\_T_t / LFPR\_T_t )$$

Based on our estimate, the unemployment rate in 2017 (6.3 per cent) was close to its trend level of 6.4 per cent (Figure 3-5). Over the medium term, we project the trend unemployment rate to decline further, reaching 5.7 per cent in 2022. This decline is due to a somewhat sharper decrease in the trend participation rate relative to the trend employment rate, reflecting, in part, greater sensitivity to interest rates for males.[12] Thereafter, the trend unemployment rate remains relatively stable around 5.6 per cent.

**Figure 3-5** Trend unemployment rate




Sources: Statistics Canada and Parliamentary Budget Officer.

Note: The projection period covers 2018 to 2060.

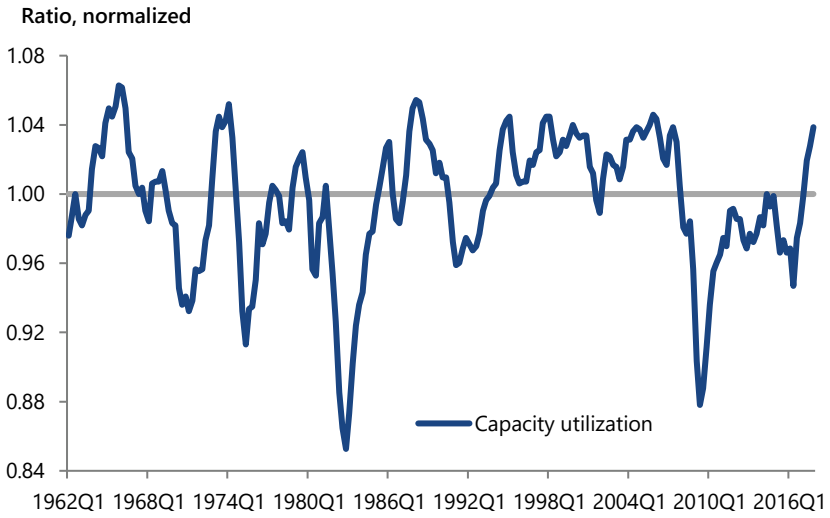
# 4. Capital stock

Consistent with the aggregate production function for the economy, we use the total non-residential capital stock, which includes business, government and non-profit sectors. This stock consists of buildings (e.g., factories and offices) and engineering construction (e.g., bridges and pipelines), machinery and equipment (e.g., computers and office equipment), as well as intellectual property products (e.g., software, research and development).

The stock of capital evolves over time as new capital expenditures add to the stock while depreciation (the reduction in the value of the capital stock from use) subtracts from the stock. We use Statistics Canada's estimate of the (net) non-residential capital stock at the end of year, with geometric depreciation. Given historical investment flows by type of asset, we calculate implicit depreciation rates and then use these rates, along with current investment flows, to extend Statistics Canada's capital stock series to the current period.[13]

Over the course of a business cycle, firms utilize their existing capital stock to varying degrees. For example, in expansionary periods, firms will typically use their capital more intensively. In our framework, we use Statistics Canada's measure of capacity utilization as a proxy of the intensity with which firms utilize their capital stock.[14] Further, we normalize Statistics Canada's measure to have a median value of 1 over the historical period (Figure 4-1). In this way, the actual value of the capital stock represents utilization of the non-residential capital stock under "normal" conditions.

Figure 4-1 Capacity utilization (non-farm goods-producing industries)




Sources: Statistics Canada and Parliamentary Budget Officer.

Note: The rate of capacity utilization (in per cent) is normalized by dividing the quarterly series by the median rate of capacity utilization over the historical period. The historical period covers 1962Q1 to 2017Q4.

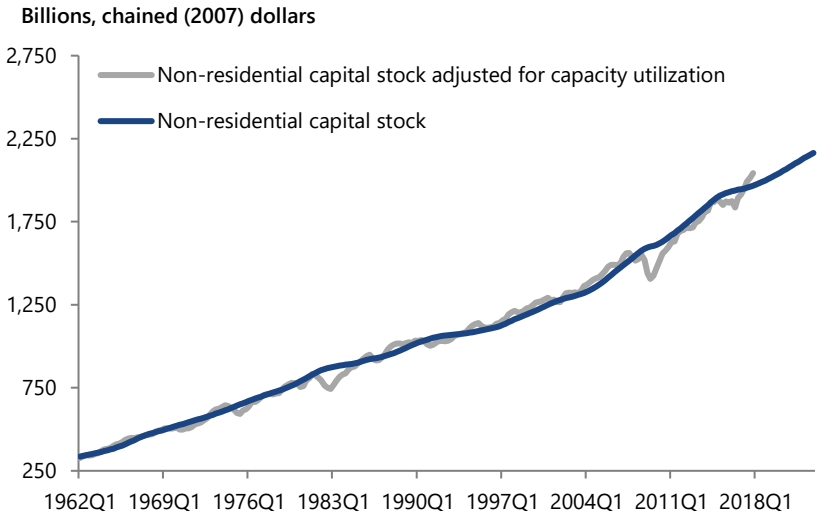
Combining the normalized rate of capacity utilization and the actual capital stock produces an estimate of the effective capital input into current production (Figure 4-2).

Over the period 1962 to 1981, the non-residential capital stock (adjusted for inflation) expanded by 4.8 per cent annually, on average, somewhat faster than average annual growth in real GDP of 4.6 per cent. Thereafter, through 2016, annual growth in the capital stock fluctuated around 2.4 per cent, matching average annual growth in real GDP.

Over the medium term, we project non-residential investment for the business, government and non-profit sectors. Given the existing capital stocks, assumptions for depreciation rates and future investment flows, the non-residential capital stock evolves according to the perpetual inventory method.[15] That is, investment adds to the capital stock while depreciation subtracts from it.[16] Consequently, the outlook for potential GDP is determined endogenously over our projection horizon.

Based on our medium-term projection, we project growth in the capital stock to slow to 1.8 per cent annually, on average, over 2017 to 2022, which is slightly lower than our projected average growth in real GDP of 1.9 per cent over the same period.

## Figure 4-2 Non-residential capital stock




Sources: Statistics Canada and Parliamentary Budget Officer.

Note: The historical period covers 1962Q1 to 2016Q4. The projection period covers 2017Q1 to 2022Q4.

# 5. Trend total factor productivity

As mentioned previously, total factor productivity (A) is measured residually given GDP (Y), labour (L) and (capacity utilization (u) adjusted) capital (K) inputs, and income shares ($\alpha$ and $(1 - \alpha)$).

$$A_t = Y_t / [L_t^{\alpha} \cdot (u_t \cdot K_t)^{1-\alpha}]$$

This calculation yields a "raw" measure of TFP on a quarterly basis. The adjustment of the capital stock for capacity utilization helps to remove cyclical fluctuations in TFP that are unrelated to technical progress.[17]

To estimate trend TFP, we first extrapolate the raw TFP series over the medium-term projection horizon based on its long-term historical average growth (1981Q2-2017Q4), and then filter the combined historical and projected level series.[18]

According to our estimates, quarterly trend TFP advanced by 0.64 per cent at an annual rate (period to period) over 1981Q2 to 2017Q4 (Figure 5-1). This average growth rate, however, masks an uneven performance over the historical period.

**Figure 5-1 Trend total factor productivity**


Source: Parliamentary Budget Officer.

Note: The historical period covers 1981Q1 to 2017Q4. The projection period covers 2018Q1 to 2022Q4.

From 1981Q2 to 1990Q4, at annual rates (period to period), trend TFP advanced by 0.47 per cent, on average, and then surged to average 1.25 per cent over 1991Q1 to 2002Q4, broadly coinciding with high-tech boom. Trend TFP growth subsequently moderated during the commodity price boom; it

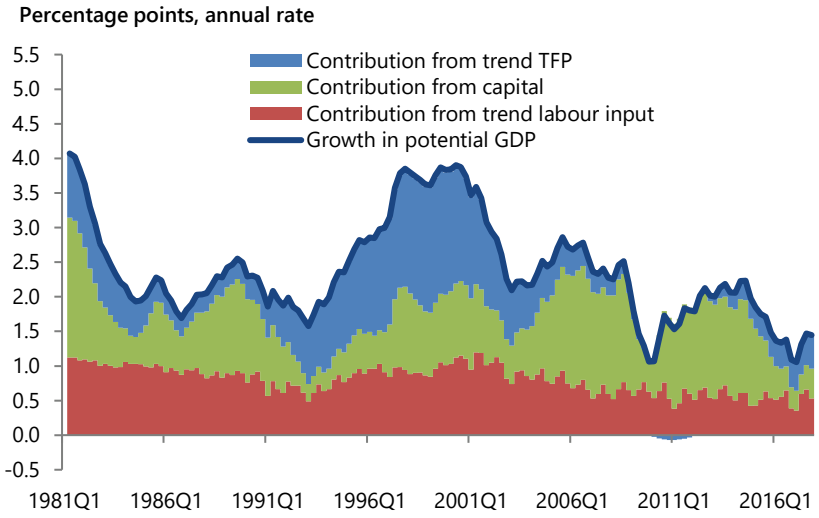
then stalled during the global financial crisis and its aftermath, and has since remained below its long-term historical average. We have assumed that trend TFP growth will continue to improve, averaging 0.64 per cent over the medium term 2018Q1 to 2022Q4.

# 6. Potential GDP estimates

To calculate potential GDP on a quarterly basis, we incorporate our estimates of trend labour, capital and trend TFP into the Cobb-Douglas production structure described in Section 2.[19]

Growth in potential GDP has slowed considerably since the early 2000s (Figure 6-1). This slowdown is due primarily to slower growth in trend TFP and, to a lesser extent, growth in trend labour input. While potential GDP growth initially rebounded from its weakness during the global financial crisis, our estimates indicate that it decelerated sharply in late 2014 through early 2017 in the wake of the collapse in oil prices. Growth in potential GDP has improved over the course of 2017, averaging 1.5 per cent at an annual rate (period to period) in the second half of the year.

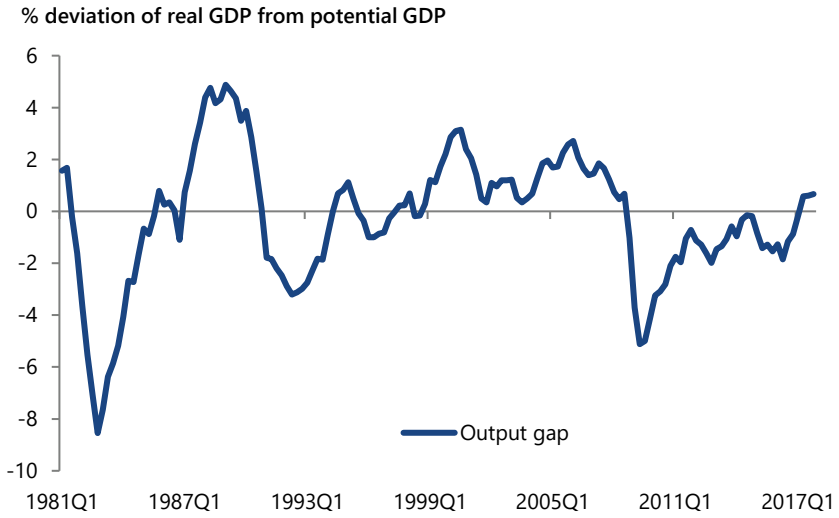
**Figure 6-1 Growth in potential GDP, 1981Q2 to 2017Q4**




Source: Parliamentary Budget Officer.

Comparing the level of observed, or actual, real GDP to potential GDP provides an estimate of excess demand or excess supply in the overall economy. Specifically, the "output gap" represents the percentage deviation of real GDP from potential GDP (Figure 6-2).

Figure 6-2 Output gap, 1981Q1 to 2017Q4



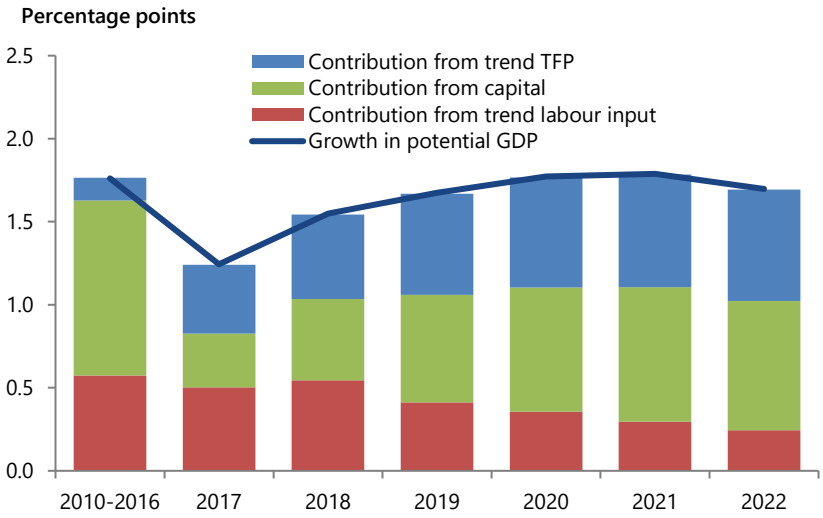

Sources: Statistics Canada and Parliamentary Budget Officer.

Based on our estimates, the Canadian economy was operating above its potential from 1998Q4 to 2008Q3. With the sharp declines in real GDP observed in late 2008 and the first half of 2009 during the global financial crisis, the Canadian economy fell to 5 per cent below its level of potential GDP. The economy's performance (relative to potential) then improved steadily through 2011 but suffered setbacks in 2012 (from a slowdown in global economic activity, disruptions in the energy sector and weak government spending) and then again in 2015 with the collapse in global oil prices.

With the sharp declines in business investment following the weakness in oil prices in 2015 and 2016, growth in the capital stock and potential GDP slowed markedly through the first quarter of 2017. At the same time, growth in real GDP rebounded in the second half of 2016 and surged in the first half of 2017. Consequently, real GDP rose above potential GDP in the second quarter of 2017 and, based on our estimate, stood at 0.7 per cent above potential at the end of 2017. This positive output gap primarily reflects above-normal capacity utilization that more than offsets below-trend total factor productivity.

Looking ahead, based on our April 2018 Economic and Fiscal Outlook, we project growth in potential GDP to rebound from its current growth of 1.2 per cent to reach 1.8 per cent in 2020 and 2021 (Figure 6-3). This projected rebound is due to an acceleration in capital accumulation and faster growth in trend total factor productivity growth. The contribution from trend labour input is projected to dissipate over the medium term as the trend employment rate and trend average hours worked decline and growth in the source population moderates.

Figure 6-3 Projected growth in potential GDP, 2018 to 2022




Source: Parliamentary Budget Officer.

Compared to other institutions that produce estimates of potential GDP, PBO's estimate of potential growth in 2017 is at the lower end, likely reflecting both weaker growth in trend labour productivity and trend labour input.[20] However, over the medium term, our projected growth in potential GDP is in line with the Bank of Canada's projection.

Table 6-1 Comparison of potential GDP growth projections

| % | PBO (April 2018) | Bank of Canada (April 2018) | IMF (April 2018) | OECD (June 2018) |
|---|---|---|---|---|
| **2017** | 1.2 | 1.7 | 2.0 | 1.6 |
| **2018** | 1.5 | 1.8 | 2.0 | 1.5 |
| **2019** | 1.7 | 1.8 | 2.0 | 1.5 |
| **2020** | 1.8 | 1.8 | 1.9 | |
| **2021** | 1.8 | 1.9 | 1.9 | |
| **2022** | 1.7 | | 1.8 | |

Sources: Bank of Canada; International Monetary Fund; Organisation for Economic Co-operation and Development; and Parliamentary Budget Officer.

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# Notes

1. See CBO's *Estimating and Projecting Potential Output Using CBO's Forecasting Growth Model*. Retrieved from: https://www.cbo.gov/system/files/115th-congress-2017-2018/workingpaper/53558-cbosforecastinggrowthmodel-workingpaper.pdf. See A. Côté's *The Promise of Potential*. Retrieved from: https://www.bankofcanada.ca/wp-content/uploads/2013/10/remarks-291013.pdf.

2. Organizations such as Finance Canada, the International Monetary Fund (IMF) and the Organisation for Economic Co-operation and Development (OECD) have used such an approach.

   https://www.fin.gc.ca/pub/pdfs/wp98-05e.pdf

   http://www.imf.org/en/publications/wp/issues/2016/12/31/canada-s-potential-growth-another-victim-of-the-crisis-23531

   http://www.oecd-ilibrary.org/economics/new-oecd-methods-for-supply-side-and-medium-term-assessments_628752675863

3. Under the Cobb-Douglas production structure, with constant returns to scale (that is, doubling labour and capital inputs would double output), if labour and capital are paid their marginal products (that is, the increase in output generated from an increase of one unit of labour or capital), then the total amount of payments made to labour and capital will equal the total output of the economy.

4. Labour income is calculated as compensation of employees plus two-thirds of net mixed income. Since there is no unique way to determine the amount of net mixed income accruing to labour and capital individually, we assume two-thirds goes to labour and one-third to capital.

   Ideally, one would use nominal GDP measured at factor cost to calculate labour's share of income. Since Statistics Canada no longer computes this measure, we use nominal GDP measured at basic prices as a proxy.

5. Some of the material in Section 3 has been described previously in PBO's 2010 report, *Estimating Potential GDP and the Government's Structural Budget Balance*: http://www.pbo-dpb.gc.ca/web/default/files/files/files/Publications/Potential_CABB_EN.pdf.

6. See *Guide to the Labour Force Survey 2017*: http://www.statcan.gc.ca/pub/71-543-g/71-543-g2017001-eng.htm.

7. See *Population Projections for Canada (2013 to 2063), Provinces and Territories (2013 to 2038)*: http://www.statcan.gc.ca/pub/91-520-x/91-520-x2014001-eng.htm.

8. The annual employment rate series by age and sex groups are filtered using an H-P smoothing parameter of 100.

9. The annual average weekly hours worked series by age and sex groups are filtered using an H-P smoothing parameter of 100.

10. Barnett (2007) uses sex-specific full-time school enrolment rates.

11. According to Statistics Canada, "[u]nemployed persons are those who, during reference week, were without work, were available for work and were either on temporary layoff, had looked for work in the past four weeks or had a job to start within the next four weeks."

    The labour force represents the sum of employed and unemployed persons.

    The labour force participation rate is defined as the labour force divided by the source population.

12. On balance, for male age groups, interest rate coefficient estimates are larger in absolute terms (i.e., more negative) for participation rates compared to employment rates. With the projected rise in real after-tax interest rates over the medium term, this puts greater downward pressure on the trend male participation rate. The discrepancies for female age groups are much less pronounced. Consequently, the trend female participation rate more closely follows the decline in the trend female employment rate, which results in a relatively stable trend female unemployment rate over the medium term.

13. To produce quarterly estimates of the non-residential capital stock, we use a cubic spline to match the last value of the (year-end) net capital stock. Implicit depreciation rates are calculated by asset type and simple models are used to project depreciation rates to the current period and over the medium-term projection horizon.

14. A drawback of this approach is that Statistics Canada's measure of capacity utilization applies only to (non-farm) goods-producing industries. Thus, in our framework, we implicitly assume that the capacity utilization rate in the service sector is perfectly correlated with the goods-producing sector.

15. Over the projection horizon, the non-residential capital stocks of the business, government and non-profit sectors (in chained 2007 dollars) are added together. A revaluation term is also included to reconcile the aggregation of chained series.

16. In PBO's Fiscal Sustainability Reports, the long-term GDP projection is determined by potential GDP. To project potential GDP beyond the medium-term horizon, we first extrapolate trend labour productivity such that its growth rate converges to the steady-state value that is consistent with the production function used to estimate potential GDP over history and the medium term. Based on our Cobb-Douglas specification, steady-state trend labour productivity growth is determined by growth in trend total factor productivity and the output-labour elasticity from the production function. Over the long term, trend labour productivity is then combined with trend labour input, which determines potential GDP.

17. Given that labour effort is unobserved, we assume that the intensity with which labour is used in production is adequately captured in the measure of actual hours worked.

    See Gu and Wang (2013) for a discussion of the bias in estimates of multifactor productivity (MFP). The authors examine approaches to adjusting MFP for capacity utilization and develop a non-parametric method.

18. The quarterly raw TFP series is filtered using an H-P smoothing parameter of 1600.

19. Quarterly estimates of the trend employment rate and trend average hours worked are calculated using a quadratic interpolation such that the average of the quarterly values matches the annual estimate.

20. That said, the Bank of Canada's Integrated Framework (IF) estimate of potential GDP growth in 2017 of 1.4 per cent is closer to PBO's estimate of 1.2 per cent. The Bank of Canada's IF estimate of potential GDP is also based on a production function approach. As Agopsowicz et al. (2018) note, the Bank of Canada's estimates of potential GDP growth (which we show in Table 6-1) are based on several sources, of which the IF estimate is one.