Box 1
New Estimates for Colombia's Potential (Trend) GDP and Output Gap

Leonardo Bonilla Mejía
José David Pulido*

One of the most important variables to consider when making monetary policy decisions is potential (trend) GDP, which measures the maximum level of goods and services an economy can produce without experiencing inflationary pressures. An economy's output gap, defined as the percentage difference between potential and observed GDP, allows policymakers to diagnose the existence of such pressures[1]. A negative output gap, where aggregate demand is below production capacity, should lead to slack in the labor market and low inflation. When that gap is positive, by contrast, policymakers anticipate tighter labor markets and higher rates of inflation.

One difficulty lies in the fact that potential GDP is not an observable metric; inferring its size and trajectory requires policymakers to use statistical and economic modeling. Each modeling methodology makes its own assumptions and includes its own restrictions and degree of uncertainty, meaning that estimates of potential GDP include some margin of error. Moreover, as there is no single criterion with which to select between the available modeling methods, in practice potential GDP is projected using several different methodologies.

This issue of the Monetary Policy Report updates and expands on the methodologies previously used by the Central Bank of Colombia to calculate potential GDP and the economy's output gap. It also incorporates new data from the most recent population census, takes into account the effects of recent migration to Colombia from Venezuela, and assesses the impact of the Financial Act of 2018 (Ley de Financiamiento) on the factors of production.

The new set of models is based on six methodologies that are widely used in specialized economic literature. These include a growth accounting model (production function), a statistical model (univariate Hodrick-Prescott filter) and four semi-structural models that account for different aspects of the economy, the goods market and the labor market. A brief description of each can be found at the end of this supplement.

There are two main innovations incorporated in this update. The first is the inclusion of two new semi-structural models, the Okun's Law model and the free 4G model, each of which accounts for key aspects of the Colombian economy. The first considers the direct relationship between the labor market and the goods market by accounting for the explicit relationship between economic activity and the unemployment rate (known as Okun's Law). This model simultaneously estimates potential GDP and the non-accelerating inflation rate of unemployment (NAIRU). For its part, the free 4G model, which is used in baseline forecast models for monetary policy (see Central Bank of Colombia, 2019a), includes a disaggregation of the four sub-baskets of the consumer price index (CPI): food, regulated items, tradables and non-tradables. This model considers the sub-baskets' corresponding relationship with the output gap and the real exchange rate, providing a more detailed understanding of the transmission mechanisms of monetary policy.

The second innovation is related to updates to the production function model. First, the population information was updated using results from national census data from 2018 and migration information included in the General Integrated Household Survey, both of which were produced by Colombia's national statistics agency, DANE. Graph B1.1 compares the previous size and annual growth of the working-age population (WAP) with the new, updated series. Panel A shows that the updated figures measure lower WAP growth prior to a recent influx of migration, followed by expansion related to subsequent growth in incoming migration flows. In Panel B, both the previous series and the updated series are seen to coincide at the end of 2018 and the beginning of 2019. This suggests that the effect on population calculations resulting from new census and migration data have offset each other in such a way that the 2019 WAP level remains very similar to previous estimates.

The NAIRU estimate was also updated, based on the Okun's Law model (see the second section of this supplement for more details) and a further battery of five models, the results of which are included in the Central Bank of Colombia's Labor Market Report. Graph B1.2 shows the result of the estimate in this variable together with the urban unemployment rate[2], and shows a slight upward trend in the NAIRU rate over the last two years. The unemployment rate remains higher than the NAIRU rate, suggesting the presence of low inflationary pressures originating in the labor

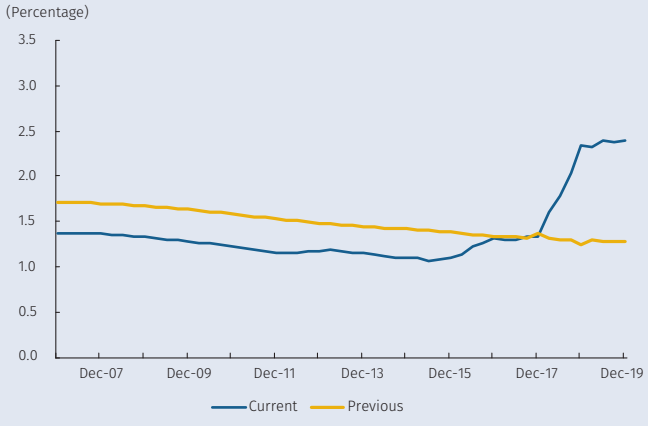
* The authors are economist and senior economist at the Office for Monetary Policy and Economic Information's Labor Market Analysis Group, respectively.

1 Not to be confused with steady-state economic growth, with which it converges in the long term. All models are calibrated based on a steady-state growth rate of 3.3%.

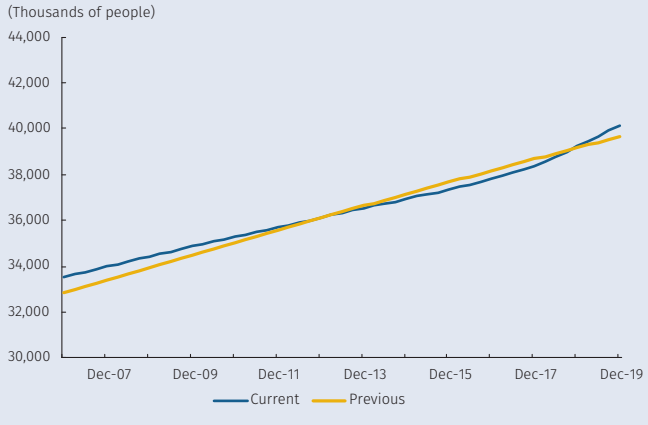
2 Due to greater availability of historic data, the NAIRU estimate bases its unemployment rate on Colombia's seven largest cities.

Graph B1.1
Update to the Population Series for Working-age Adults in the Production Function Model

A. Annual Growth

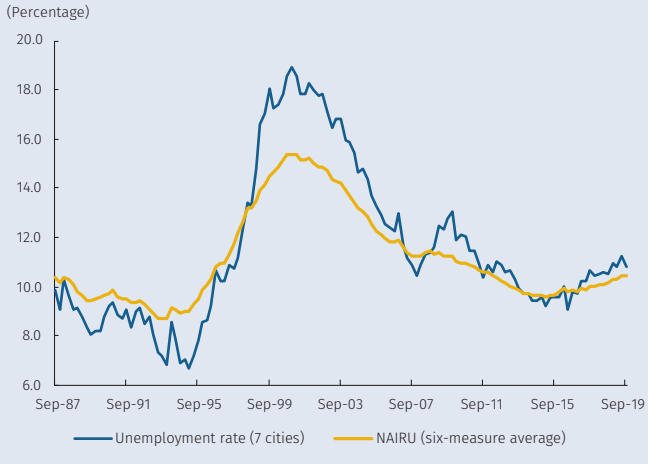


B. Levels



Note: Current WAP calculations are consistent with overall national census data, while the previous WAP series came directly from DANE's General Integrated Household Survey, which is not representative of the entire country. This produced a lower level in the previous series until 2012.
Source: calculations by *Banco de la República*.

Graph B1.2
Urban Unemployment Rate (7 cities) and NAIRU Estimate (six-model average)
(seasonally adjusted quarters)



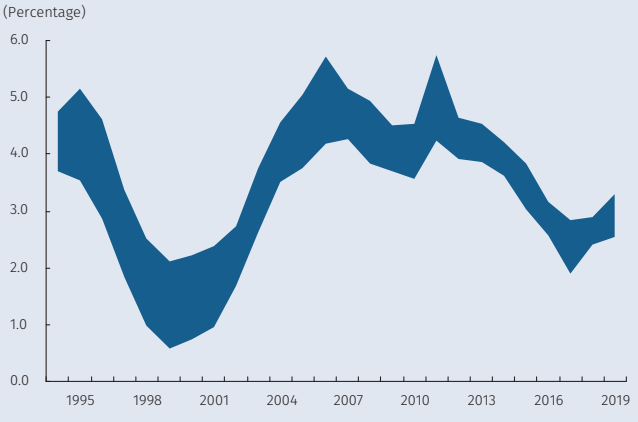
Source: DANE (GIHS); calculations by *Banco de la República*.

market[3]. Finally, the model specification was changed to incorporate changes in workforce composition based on education levels, expanding the number of workers measured as human capital.

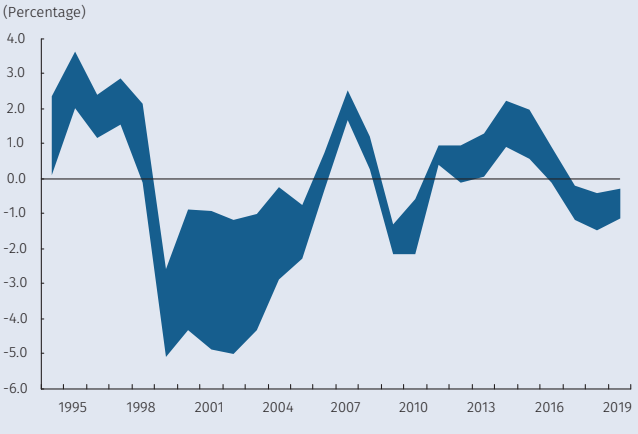
Graph B1.3 shows the evolution over time of the minimum and maximum estimated values from a set of six potential GDP growth models, as well as the output gap between 1994 and 2019. Estimates have shown a negative output gap since 2017, but that has tended to tighten over the last two years. Table B1.1 shows the value of these estimates for 2019, which suggest potential GDP growth in a range between 2.53% and 3.29%, with an output gap then between -1.11% and -0.26%.

Graph B1.3
Change Over Time of Various Potential GDP and Output Gap Estimates

A. Potential GDP Growth: Maximum and Minimum Estimated Values



B. Output Gap (median estimates)



Source: calculations by *Banco de la República*.

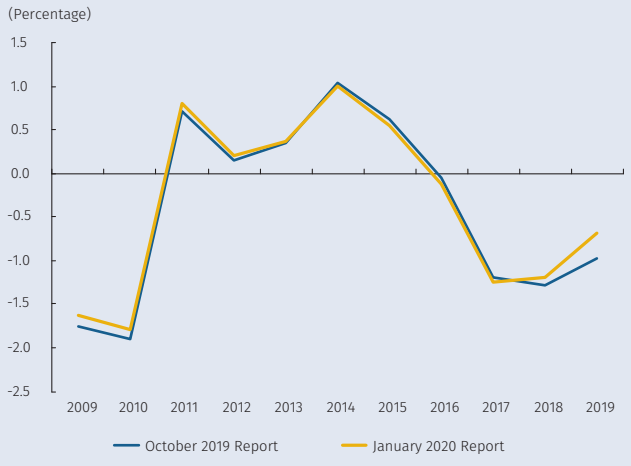
3 Models estimate a NAIRU range between 9.3% and 11.4% for the third quarter of 2019. Various available NAIRU measurements were evaluated in terms of the goodness of fit and their predictive power on Phillips curves for salaries and inflation in non-tradable items. The results of the exercise were not conclusive in favor of a single measurement, and as a result the average of these measurements was used.

Table B1.1
Potential GDP and Output Gap Estimates for 2019

	Potential GDP	Output Gap
Focus 1: growth accounting		
Production function (updated)	2.86	-0.84
Focus 2: statistical filters		
Hodrick and Prescott with forecasts	2.80	-0.44
Focus 3: semi-structural models		
Adaptive expectations	3.11	-0.44
Rational expectations	3.29	-0.52
Okun's Law (new)	2.88	-1.11
4G-Free (new)	2.53	-0.26
Minimum	2.53	-1.11
Maximum	3.29	-0.26

Source: calculations by *Banco de la República*.

Graph B1.4
Output Gap Estimate used in the Macroeconomic Forecast



Source: calculations by *Banco de la República*.

These estimates are used by the technical staff to complement the baseline forecast models used to describe the current state of the Colombian economy, and they allow for two important conclusions. First, a revision in the growth trajectory in the unemployment rate allows for an expected NAIRU rate higher than previously estimated, which suggests less excess capacity in the labor market with respect to previous estimates. This conclusion is also borne out in the Okun's Law model estimates, which take into account the relationship between inflation and the output gap as well as the relationship between the output gap and the unemployment gap. By using the production function to account for this information, we can also infer lower excess total capacity compared to previous estimates, even while taking into account the positive effects of the Financial Act of 2018 (Ley de Financiamiento) in the accumulation of capital, and the fact that revised demographic data had only a slight effect on 2019 estimates (Graph B1.1). Secondly, inflation performance, and the change in prices in CPI sub-baskets and their determinants, suggests the existence of a tighter output gap (free 4G model).

Graph B1.4 compares the output gap used for the current macroeconomic projection, incorporating all of the considerations above, with the estimate from the previous quarter. As mentioned throughout the Monetary Policy Report, the output gap for 2019 is expected to be slightly tighter (29 bp on average) compared to estimates from October, which is consistent with a downward revision in potential growth projections.

Brief Methodological Description

Production function

This estimate is based on the growth accounting framework. It represents the production capacity of the economy based on the Cobb-Douglas production function aggregate of value added, in which each factor of production is adjusted according to effective use levels:

$$Y_t = A_t \times (UCI_t \times K_t)^{\alpha} \times (WAP_t \times TGP_t \times (1-U_t) \times H_t)^{1-\alpha};\ \alpha = 0.4$$

Where Y_t corresponds to GDP; UCI_t is a measure of the utilization of installed capacity in the economy[4]; K_t represents aggregated capital inventory[5]; WAP_t is the working age population; TGP_t is the overall labor participation rate; U_t is the unemployment rate; and H_t is a non-linear function of average years of schooling, following the specification proposed by Inklaar and Timmer (2013). Potential GDP is obtained as using this equation:

$$Y_t^* = A_t^* \times (UCI_t^* \times K_t)^{\alpha} \times (WAP \times TGP_t^* \times (1-Nairu_t) \times H_t)^{1-\alpha}$$

The variables with an asterisk represent the trend components of the respective series (obtained using Hodrick and Prescott filters with projections and various smoothing parameter values) and the NAIRU rate corresponding to the average of the six different methodologies, five of

4 This measure corresponds to the measure for industrial manufacturing published by Fedesarrollo.

5 This figure is obtained by the perpetual inventory method using observed interest rates and an assumed depreciation rate.

which are used in the Labor Market Report[6], with the sixth derived from the Okun's Law model described below.

On a medium-term forecast horizon (up to 2 years), the model uses projections based on the growth and investment forecasts from baseline models, projections for participation and unemployment rates based on combinations of forecast models for worker flows (see Central Bank of Colombia, 2019b) and econometric models forecasting the utilization rate of installed capacity and schooling.

Semi-structural Models

This type of modeling depicts the primary relationships between variables of interest using simultaneous macroeconomic equations, the microfoundations of which can be obtained through neo-Keynesian models. The set of parameters for these models, which in some cases is relatively large, is estimated using Bayesian techniques. The Bank uses four models under this rubric, all of which take into account different aspects of the structure of the economy.

The first two commonly used models are described in Gonzalez et al (2013) and are labeled in Table B1.1 as rational expectation models and adaptive expectation models. Both represent a small and open economy excluding the labor market, and differ in the way that the actors in the model form expectations. Both are represented by an IS curve, a Philips Curve, a policy rule, an uncovered interest rate parity equation, and definitions for the output gap, potential GDP, inflation expectations and equilibrium levels for real domestic and foreign interest rates and the real exchange rate. Differences in the formation of expectations by actors in each model lead to differences in the functional forms for various equations made by the system[7].

The third model, labeled here as the Okun's Law model, was recently incorporated into the Central Bank of Colombia's battery of models and represents a closed economy based on a specification proposed by Blagrave et al (2015). The principal characteristic of this model is the inclusion of an equation that explicitly relates the output level with the unemployment rate, a relationship known in the literature as Okun's Law. This model is complemented with a Phillps curve, permanent and temporary shocks in the goods and labor markets, and definitions for the output and unemployment gaps together with their corresponding potential and non-inflationary levels (NAIRU)[8].

Finally, the free 4G model, summarized in Guarín and Romero (2019) and described in full in González et al (2020), is currently one of the baseline forecasting models used for monetary policy. It represents a small and open oil-exporting economy, in its current iteration excluding a labor market though this is in the process of being incorporated. The system of equations used is similar to those of the first two semi-structural models described above, but using a detailed characterization in the origin of inflationary pressures that disaggregates the four sub-baskets of the CPI (food, regulated items, tradables and non-tradables) and considers the overall change of relative prices. Estimates based on this model incorporate the set of satellite models without depending on the short-term projections that usually condition the model for generating macro forecasts.

6 The five methodologies used are: 1) the structural unemployment rate on a search model, based on Shimer (2012); 2) The non-accelerationg inflation rate of unemployment on a Phillips curve with adaptive expectations, according to Ball and Mankiw (2002); 3) the equilibrium unemployment rate obtained from an S-VAR with growth, inflation and the unemployment rate (King and Morely, 2007); 4) a statistical filter in which the NAIRU rate changes in accordance with a cubic spline, base July (2001); and 5) the non-accelerating unemployment rate for inflation on a Phillips curve with demographic changes, based on Arango et al (2013). For the implementation of the first three methodologies in the Colombian case, see Arango and Flórez (2018).

7 For a detailed description of the equations used in both models, see Gonzales et al (2013).

8 For a detailed description of the equations used in the model, see Blagrave et al (2015).

References

Arango, L. E.; Flórez, L. A. (2018) "Determinants of Structural Unemployment in Colombia: A Search Approach," *Empirical Economics*, pp. 1-34.

Arango, L. E.; García, A.; Posada, C. E. (2013) "Inflación y desempleo en Colombia: Nairu y tasa de desempleo compatible con la meta de inflación (1984-2010)", en Arango, L. E y F. Hamann (eds.), *El mercado de trabajo en Colombia: hechos, tendencias e instituciones*, Central Bank of Colombia, Bogotá.

Ball, L.; Mankiw, N. G. (2002) "The Nairu in Theory and Practice," *Journal of Economic Perspectives*, vol. 16 (Fall), pp. 115-136.

Blagrave, P.; García-Saltos, R.; Laxton, D.; Zhang, F. (2015). "A Simple Multivariate Filter for Estimating Potential Output," IMF Working Papers, no. WP/15/79, Fondo Monetario Internacional.

Central Bank of Colombia (2019a). *Informe de Política Monetaria*, octubre, Bogotá.

Central Bank of Colombia (2019b). "Tendencia a la baja de la demanda laboral: pausa en las ciudades y continúa en las áreas rurales", *Reporte del Mercado Laboral*, no. 12, October, Bogotá.

González, A.; Guarín, A.; Rodríguez, D.; Vargas, H. (2020). "4G: A New Model for the Monetary Policy Analysis in Colombia," Borradores de Economía (forthcoming), Central Bank of Colombia.

Guarín, A.; Romero, J. V. (2019). "Recuadro 2: El modelo 4G", *Monetary Policy Report*, Central Bank of Colombia, October.

González, A.; Ocampo, S.; Pérez, J.; Rodríguez, D. (2013). "Brecha del producto y medidas de la tasa de interés neutral para Colombia", *Monetaria*, vol. 35, no. 2, pp. 251-310.

Inklaar, R.; Timmer, M. P. (2013). "Capital, Labor and TFP in PWT 8.0" (mimeo), Groningen Growth and Development Centre, University of Groningen.

Julio, J. M. (2001). "How Uncertain Are Nairu Estimates in Colombia," *Borradores de Economía*, No. 184, Central Bank of Colombia.

King, T.; Morley, J. (2007) "In Search of the Natural Rate of Unemployment," *Journal of Monetary Economics*, no. 54, pp. 550-564.

Shimer, R. (2012) "Reassessing the Ins and Outs of Unemployment," *Review of Economic Dynamics*, vol. 15, no. 2, pp. 127-148.