Box 3:
NATURAL RATE OF INTEREST ESTIMATES FOR COLOMBIA

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Through its benchmark interest rate, *Banco de la República* is able to influence the behavior of the Colombian economy, and that of variables such as inflation, GDP growth, among others. A significant portion of the impact of monetary policy depends on the distance between the policy rate and its natural (or neutral) level.

Thus, the "natural" or "neutral" rate of interest gains special importance. There are several alternative interpretations of this concept, based on Wicksell's definition (1898) of the natural rate of interest as the interest rate level that equals savings to investment and, in the absence of financial frictions, is equal to the marginal product of capital. The most commonly modern definition used is the one proposed by Laubach and Williams (2003), who specify it as the interest rate level that keeps the output gap closed and inflation stable in the medium term.

Consequently, natural rate of interest estimates are part of the diverse set of indicators and analysis employed to determine the monetary policy stance.

Despite its usefulness, the concept of the natural rate of interest has important limitations. Being a theoretical notion, it is not observable, nor is there a consensus on its most appropriate estimation method. Moreover, the high degree of uncertainty involved must be considered, not only that inherent of the statistical estimators, but also the that due to model specification and choice.

In this section, the natural rate of interest is estimated using eleven different methods, and their evolution in time is discussed. Hereinafter, we refer to the natural rate and the neutral rate, indistinctly. While some of the estimates are closer to one classification or the other, there is no consensus on the most appropriate one. So, we chose to analyze both.

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Methods [1]

The Solow-Swan growth model with Harrod-neutral technological progress

The Solow-Swan model explains long-term economic growth through capital accumulation, the rate of savings, labor force growth and exogenous increases in productivity (Solow, 1956 and Swan, 1956). Assuming the production function of the Colombian economy follows a Cobb-Douglas with technological enhancing labor (Acemoglu, 2003),[2] it is possible to obtain an expression for the real equilibrium interest rate (the natural rate of interest) based on the marginal productivity of capital (Chetwin and Wood, 2013). The procedure described in Cobo (2005) is modified to accomplish this objective. By employing non-inflationary levels of utilization of production factors, the results can be considered close to both the definition of the natural rate of interest and that of the neutral rate of interest.

Consumption-smoothing models

This method corresponds to a closed economy without market friction in which a representative agent optimizes its consumption-saving program. The interest rate is obtained through Euler's equation, using a plausible set of parameter values (Sources and Gredig, 2007; Magud and Tsounta, 2012). In this case, we compute the natural rate of interest using specifications with and without consumption habits, according to Cochrane (2001) and Campbell and Cochcrane (2001). The results are consistent with *Banco de la República*'s non-inflationary potential GDP estimates.

Uncovered interest rate parity

Interest rate parity is a no-arbitrage condition[3], under which investors are indifferent in equilibrium to interest rates on

1 The details of the estimates are presented in Amador & Beltrán (2016, unpublished).

2 According to Acemoglu (2003), there is evidence that this type of technological change is a stronger assumption. Preliminary exercises with neutral technological change in the sense of Hicks resulted in unrealistic estimates.

3 This is a situation in which all assets are appropriately priced and there is no way earnings can be increased through arbitrage.

the assets of two countries. This suggests that the return on local assets will be equal to the expected return, adjusted for risk and exchange rate, on foreign assets. To obtain this estimate we employ the emerging markets bond index (EMBI), as a measure of Colombia's risk premium, to which the natural rate of the United States, published by the Federal Reserve Bank of San Francisco is added, along the 12 months depreciation expectations in the *Monthly Survey of Analysts' Expectations*, and the difference between the inflation targets in the United States and Colombia. The resulting series is filtered by the Hodrick-Prescott method to obtain trend values. Unlike the previous methods, this one merely reflects the effect of external financing conditions on the domestic rate of interest.

Hodrick-Prescott Filter (HP)

The HP filter is one most commonly used time series trend extraction tools. It assumes that permanent changes in the level of the observed interest rate correspond to changes in the level of the natural rate of interest. Thus, the component that reflects only changes in the lowest frequencies (the trend component) pertains to the natural rate.[4]

Dynamic Taylor's rule

The Taylor rule (1993) indicates how a central bank should change the policy interest rate in response to changes in inflation, GDP, and possibly other economic variables. To obtain a natural rate consistent with this method, we estimate the Taylor rule by means of the Kalman filter, assuming the natural rate of interest follows a random walk.

Implicit common stochastic trend model It is reasonable to think that, disregarding possible financial frictions, long-term rates reflect market expectations about the future behavior of short-term rates (Sources and Gredig, 2007). By exploiting this relationship, we obtain natural rates through the state-space representation of three different models. The first one only follows the dynamics between short-term and long-term rates. The second controls for inflation expectations. In the third, the relationships between short- and long-term rates in the United States and Colombia are modeled, assuming the natural rate of the second country depends on that of the first, plus a spread that follows a random walk.

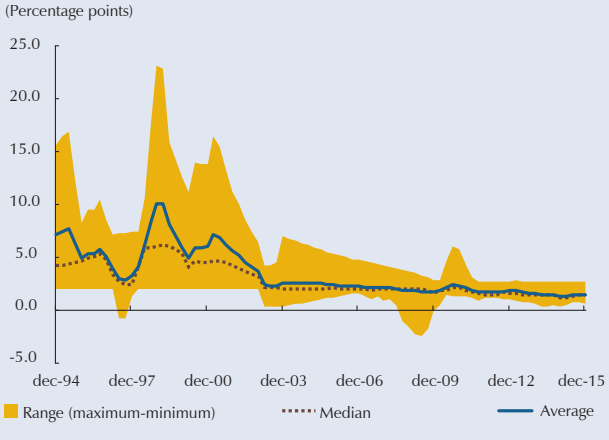
New Keynesian adaptive and rational expectations models

Although the natural rate is unobservable, economic theory suggests ways in which it can be related to variables that are observable. Following Gonzalez et al. (2012), we estimate two versions of a model that includes a Taylor rule, an investment-savings curve (IS), a Phillips curve and equations that describe the behavior of the real interest rate and the real exchange rate. The difference between the two versions of the model resides in the fact that they have different processes for forming inflation expectations: in one, these processes are adaptive; in the other, rational.

Results and Several Considerations

Graph B3.1 shows the historical evolution of the median, average and range between the maximum and minimum values of the eleven methods for each quarter. Estimates cover the period 1994-2016. It is worth noting that both point estimates and their associated uncertainty[5] change over time. While it is possible to obtain the average or median to summarize the various estimates, these central trend statistics are not necessarily informative, since they ignore the confidence intervals related to each one and the lack of consensus on a preferred method. However, both offer an idea of the evolution of the set of measures over time.

Graph B3.1
Estimates of the Natural Rate of Interest



Note: The methods are explained in detail in Amador and Beltran (2016, unpublished). Only the range between the minimum and maximum estimates is presented; therefore, the uncertainty could be higher than this graph suggests. Also, given the uncertainty and the absence of a preferred method based on consensus, the average and median are not necessarily informative.
Source: Amador & Beltran (2016, unpublished).

4 Interbank interest rate(IIR) forecasts are included to prevent the results from being overly sensitive to the last data point in the time series.

5 Measured by the range between the minimum and maximum at each point in time.

As noted, there is a high degree of dispersion among the different estimates. Judging by the average and the median, it is very likely the natural rate has declined during the period in question. Magud and Tsounta (2012) estimate a real natural rate of 2.3% for Colombia, with information up to May 2012. The estimates presented in this section result in an average of 1.41%, up to 2015 (Table B3.1).

Table B3.1
Estimates of the Natural Rate of Interest

Model	Year 2015
Solow-Swan model	0.74
Consumption smoothing	2.00
Consumption smoothing with habits	2.68
Uncovered interest rate parity	0.74
HP filter	0.81
Dynamic Taylor rule	1.44
Latent factor	2.18
Latent factor with expectations	1.41
Latent Factor US-Colombia	1.20
NK adaptive model	1.40
NK rational model	0.87
Maximum	2.68
Minimum	0.74
Average	1.41
Median	1.40

Note: The methods are explained in detail in Amador and Beltran (2016, unpublished). Only the range between the minimum and maximum estimates is presented; therefore, the uncertainty could be higher than this graph suggests. Also, given the uncertainty and the absence of a preferred method based on consensus, the average and median are not necessarily informative.
Source: Amador & Beltran (2016, unpublished).

The observed downward trend that can be explained by several factors. Among the external ones are the persistently low international interest rates. Models that include external funding components show the possible effect this would have on the Colombian real natural rate of interest for Colombia. Changes in certain local variables, such as the savings rate increase and the lower population growth, also help to explain the downturn in the natural rate. This trend might be offset in the future by changes in sovereign risk premiums associated with scarcer global liquidity and the fiscal effects of a permanent reduction in international prices for oil.

It is important to bear in mind that, according to the methods suggested here, the natural rate of interest can vary significantly over time, which adds even more uncertainty to the exercise. Estimates of the natural rate of interest, as well as its variability in time and uncertainty are included in the broad array of information *Banco de la República* uses to define its monetary policy stance.

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