The natural interest rate in Latin America

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Abstract

The natural interest rate is a critical building block in the evaluation of a monetary policy stance. We estimate the natural interest rate for the five largest Latin American economies. We follow the method in Laubach and Williams (2003), complemented with rational and survey inflation expectations and adapted to Bayesian maximum likelihood estimation. The model is the standard neo-Keynesian model, complemented with equations for the natural interest rate in nominal terms and the rational inflation expectations. We find that in real terms the natural interest rate trends down and remains above zero in the larger economies (Brazil, Mexico and Colombia), while it remains without a noticeable trend although closer to zero in the smaller economies (Chile and Peru). We also find that in nominal terms, the natural rate trends down, in most economies a consequence of the drop in inflation and inflation expectations. Regarding the policy implications, the natural interest rate still does not pose a critical challenge for monetary policy in Latin America, as it does in advanced economies (Ball 2014). Nonetheless, in Chile and Peru the natural rate in nominal terms is just above 2 and 3 percent, respectively, offering narrow room for expansionary monetary policy.

Keywords: Natural interest rate; Semi-structural model; Inflation expectations; Expansionary monetary policy

JEL codes: E58; E37; E43

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La tasa de interés natural en América Latina

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Abstract

La tasa de interés natural es un elemento crítico en la evaluación de la postura de la política monetaria. El artículo presenta la estimación de la tasa de interés natural en las 5 economías más grandes de América Latina. Seguimos el método de Laubach y Williams (2003), complementado con expectativas racionales y de encuestas, y adaptado a la estimación de máxima verosimilitud bayesina. El modelo es el neo-keynesiano estándar, complementado con ecuaciones para la tasa de interés natural en términos nominales y para las expectativas de inflación racionales. Encontramos que en términos reales la tasa de interés natural muestra una tendencia decreciente y permanece por encima de cero en las economías más grandes (Brasil, México y Colombia), mientras que permanece sin tendencia discernible aunque más cerca de cero en las economías más pequeñas (Chile y Perú). También encontramos que en términos nominales la tasa natural muestra una tendencia decreciente, en la mayoría de las economías como consecuencia de la caída en la inflación y en las expectativas de inflación. En cuanto a las implicaciones de política, la tasa de interés natural aún no representa un desafío crítico para la política monetaria en América Latina, como es el caso en las economías avanzadas (Ball 2014). Sin embargo, en Chile y Perú la tasa de interés natural en términos nominales se encuentra apenas por encima de 2 y 3 por ciento, respectivamente, ofreciendo un margen estrecho para una política monetaria expansiva.

Palabras clave: Tasa de interés natural; Modelo semiestructural; Expectativas de inflación; Política monetaria expansiva

Clasificación JEL: E58; E37; E43

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1 Introduction

The natural interest rate is an important building block in the evaluation of a monetary policy stance. We estimate the natural interest rate for the five largest Latin American economies. We follow the method in Laubach and Williams (2003), complementing the arima-type inflation expectations with rational and survey inflation expectations. In the estimation, the semi-structural neo-Keynesian model is used. As is well-known, the semi-structural model contains some important elements of the New Neoclassical Synthesis (NNS), which is the standing paradigm in monetary policy. The estimated natural interest rate is endogenous to the transmission mechanisms in this model.

The natural interest rate can be defined as that which would hold should variables such as output, inflation, and the exchange rate be at their long-term equilibrium levels (Holtson et al. (2016), Laubach and Williams (2016), and Summers (2014)). This definition fits well the semi-structural model used here.[1]

The natural interest rate has recently become a topic of increasing relevance in advanced economies, owing to its downward trend and in particular to its collapse into negative numbers since the global financial crisis of 2008. With strongly negative natural interest rates, monetary policy hardly has any room to stimulate aggregate demand due to the effective lower bound on policy interest rates. In turn, in emerging economies the real interest rate showed a significant drop during the global financial crisis, but the natural interest rate did not drop to such extent as to become a stringent constraint on monetary policy. Nonetheless, should current trends continue in some merging economies, the natural interest rate could eventually become an important restriction in the future.

The article is divided into six sections including this introduction. In the second section, we present the model. Here we give emphasis to the stochastic process for the natural interest rate, the definition of the natural rate in nominal terms and the behavioral equation for the rational inflation expectations. In the third section, we present the data sources. In the fourth section, we present the calibration and estimation of the model parameters. In the fifth section, we present the estimation of the natural interest rate. This section also deals with uncertainty in the estimation of the natural interest rate. Finally, section sixth offers some conclusions.

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[1] Alternatively, in a definition more akin to the DGSE neo-Kensesian model, the natural rate is that which would hold were all prices flexible (Woodford, 2003b).

2 The model

The natural interest rate. Following Laubach and Williams (2003), Williams (2015) and (2016), and Holston et al. (2017), the natural interest rate is defined as the sum of a detrended and a trend component

$$\bar{r}_t = \bar{r}_t^{Det} + \bar{r}_t^{Trend}, \tag{1}$$

where the detrended component is a function of the growth of potential output plus an error term

$$\bar{r}_t^{Det} = c_{\bar{r}\gamma}\gamma_t + \varepsilon_t^{\bar{r}^{Det}}, \tag{2}$$

the trend component follows a random walk

$$\bar{r}_t^{Trend} = \bar{r}_{t-1}^{Trend} + \varepsilon_t^{\bar{r}^{Trend}} \tag{3}$$

and the bars denote latent values.

Potential growth γ_t enters equation (2) multiplied by coefficient $c_{\bar{r}\gamma}$, the inverse of the intertemporal elasticity of substitution in consumption. Coefficient $c_{\bar{r}\gamma}$ is among the estimated coefficients in this paper.[2]

The natural interest rate, nominal and real. Debate on the downward trend in the natural interest rate *vis a vis* the effective lower bound on the policy rate (see Blanchard 2010 and Ball 2014) usually considers on one hand the natural rate in real terms and on the other hand the policy rate in nominal terms. The analysis can be made more straightforward by defining a natural rate in nominal terms. We define the natural nominal interest rate as

$$\bar{\imath}_t \equiv \bar{r}_t + \pi_t^e, \tag{4}$$

where π_t^e denotes inflation expectations for the total CPI over the next four quarters.[3]

Define the real interest rate as

$$r_t \equiv i_t - \pi_t^e. \tag{5}$$

From equations (4) and (5), it follows that the interest rate gap is invariant to using the interest rate in real or nominal terms

$$\hat{r}_t = \hat{\imath}_t, \tag{6}$$

where a hat denotes the deviation from the natural rate, $\hat{r}_t = r_t - \bar{r}_t$ and $\hat{\imath}_t = i_t - \bar{\imath}_t$.

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[2]Note that the measure of potential growth γ_t, in equation (30), is different from the measure $\bar{y}_t^{\Delta} = 4(\bar{y}_t - \bar{y}_{t-1})$. We use the former definition to obtain lower volatility in the natural rate given that the detrended component adds considerable volatility to the natural rate, particularly in Chile and Peru.

[3]Henceforth, we use the terms natural real interest rate and natural nominal interest rate rate to denote the two natural rates under study.

The policy rule. We use the policy rule in Taylor (1993, p. 202) that with some changes in notation may be written as

$$i_t = \bar{r} + \pi_t^4 + 0.5(\pi_t^4 - \bar{\pi}) + 0.5\hat{y}_t, \tag{7}$$

where $\bar{r}$ is the (constant) natural real interest rate, π_t^4 is annual inflation, and $\bar{\pi}$ is the inflation target. Note that in rule (7) the natural real interest rate and the inflation target are both time invariant, as stated in Taylor (1993, p. 202).

But we use a variable natural real interest rate instead of a constant, "perhaps the most important suggested change in policy rules in recent years" Taylor (2017, p. 15). We then write the policy rule as

$$i_t = \bar{r}_t + \pi_t^4 + 0.5(\pi_t^4 - \bar{\pi}_t) + 0.5\hat{y}_t, \tag{8}$$

where a time subscript in the natural rate $\bar{r}_t$ indicates that the natural rate is time-varying. Note that the inflation target is also time-varying. Here we measure the inflation target with the Hodrick-Prescott filter of CPI inflation–an implicit inflation target.

Adding and subtracting inflation expectations π_t^e at the right hand side of equation (8) and using $\pi_t^e \simeq \bar{\pi}_t$, the following Taylor rule obtains

$$i_t = \bar{\imath}_t + 1.5(\pi_t^4 - \bar{\pi}_t) + 0.5\hat{y}_t + \varepsilon_t^i. \tag{9}$$

This form of the policy rule appears in Svensson (1993, p. 614). In addition we have added a monetary policy shock or stance ε_t^i.

Given definitions (5) and (4) for the real interest rate and the natural nominal interest rate, policy rule (9) may be read either as a reaction function for the real interest rate gap $\hat{r}_t = 1.5\hat{\pi}_{C,t} + 0.5\hat{y}_t + \varepsilon_t^i$ or as a reaction function for the nominal interest rate gap $\hat{\imath}_t = 1.5\hat{\pi}_{C,t} + 0.5\hat{y}_t + \varepsilon_t^i$, indistinctly.

To improve the estimation of the natural rate, we write the rule in the slightly more general form

$$i_t = \bar{\imath}_t + c_{i\pi}\hat{\pi}_{C,t} + c_{iy}\hat{y}_t + \varepsilon_t^i, \tag{10}$$

where coefficients $c_{i\pi}$ and c_{iy} are among the coefficients to be estimated.

The uncertainty in the estimation of the natural interest rate. According to Fiorentini et al (2018), the standard error of the natural interest rate can be improved by using a stationary real interest rate gap. Adding a smoothing term at the right hand side of the policy rule, the real interest rate gap follows the process

$$\hat{r}_t = c_{rr}\hat{r}_{t-1} + 0.5\hat{\pi}_{C,t} + 0.5\hat{y}_t + \varepsilon_t^i, \tag{11}$$

which is a stationary process for $c_{rr} < 1$, given that the inflation and output gaps are stationary. Defining the quasidifference of the interest rate as $i_t^\Delta \equiv i_t - c_{ii}i_{t-1}$, policy rule (11) can be formulated in nominal terms as

$$i_t^\Delta = \bar{\imath}_t^\Delta + 1.5\hat{\pi}_{C,t} + 0.5\hat{y}_t + \varepsilon_t^i. \tag{12}$$

This rule is similar to that in Svensson (1999, p. 614) but defined in the quasidifference of the nominal interest rate.

Hereafter we use $c_{rr} = 0$ so that condition $c_{rr} < 1$ is satisfied, the real interest rate gap is stationary and the policy rule is (10).

Okun's law. As stated in equations (1) and (2), the growth of potential output is important in the estimation of the natural rate. To improve the estimation of the growth of potential output we incorporate Okun's Law into the model. Unemployment is broken down as $u_t = \hat{u}_t + \bar{u}_t$, where cyclical unemployment $\hat{u}_t$ follows

$$\hat{u}_t = c_{uu}\hat{u}_{t-1} - c_{uy}\hat{y}_t + \varepsilon_t^{\hat{u}}, \tag{13}$$

and the NAIRU $\bar{u}_t$ follows the stochastic process

$$\bar{u}_t = \bar{u}_{t-1} + \gamma_t^{\bar{u}} + \varepsilon_t^{\bar{u}}, \tag{14}$$

$$\gamma_t^{\bar{u}} = \gamma_{t-1}^{\bar{u}} + \varepsilon_t^{\gamma^{\bar{u}}}. \tag{15}$$

The Phillips curve. Inflation π_t is the aggregate of core $\pi_{C,t}$ and non-core $\pi_{NC,t}$ components

$$\pi_t = c_{\pi c}\pi_{C,t} + (1 - c_{\pi c})\pi_{NC,t}. \tag{16}$$

Two Phillips curves are set up for each component

$$\pi_{C,t} = c_{\pi e}\pi_{C,t}^e + (1 - c_{\pi e})\pi_{C,t-1}^4 + c_{\pi y}\hat{y}_t + c_{\pi q}\hat{q}_{t-1} + \varepsilon_t^{\pi_C} \tag{17}$$

and

$$\pi_{NC,t} = c_{\pi e}\pi_{NC,t}^e + (1 - c_{\pi e})\pi_{NC,t-1}^4 + c_{\pi y}\hat{y}_t + c_{\pi q}\hat{q}_t \tag{18}$$
$$- c_{\pi\Delta q}(\pi_{NC,t-1} - \pi_{C,t-1}) + \varepsilon_t^{\pi_{NC}},$$

where $\pi_{C,t}$ is quarterly core inflation and $\pi_{C,t}^4$ is annual core inflation; similar definitions apply for non-core inflation.

The term $\pi_{NC,t} - \pi_{C,t}$ at the right hand side of equation (18) can be shown to be equal to the change in the relative price of non-core goods. The feedback in this term, $-c_{\pi\Delta q}$, helps anchor non-core inflation to core inflation.

It may be argued that non-core inflation is a pure supply shock and that hence it does not follow the output and exchange-rate gaps (or in other terms, that in equation (18) $c_{\pi y} = c_{\pi q} = 0$). Nonetheless, food and energy inflation can follow supply shocks $\varepsilon_t^{\pi NC}$ as well as marginal cost pressure given by the output and exchange-rate gaps.[4] Hence, we maintain here that $c_{\pi y}$ and $c_{\pi q}$ can both be different from zero.

In addition, to help improve the estimation of the Phillips curve, the observed core inflation $\pi_{C,t}^{NS}$ is split into signal $\pi_{C,t}$ and noise ε_t^N components

$$\pi_{C,t}^{NS} = \pi_{C,t} + \varepsilon_{C,t}^N. \tag{19}$$

Likewise, the breakdown applies to non-core inflation as follows:

$$\pi_{NC,t}^{NS} = \pi_{NC,t} + \varepsilon_{NC,t}^N. \tag{20}$$

Inflation expectations.   CPI inflation expectations π_t^e are the weighted sum of core $\pi_{C,t}^e$ and non-core $\pi_{NC,t}^e$ components

$$\pi_t^e = c_{\pi c}\pi_{C,t}^e + (1 - c_{\pi c})\pi_{NC,t}^e. \tag{21}$$

Core inflation expectations are unobserved and estimated as a forward- and backward-looking convulusion of core inflation

$$\pi_{C,t}^e = c_{ee}\pi_{C,t+4|t}^4 + (1 - c_{ee})\pi_{C,t-1}^e + \varepsilon_t^{\pi_C^e}. \tag{22}$$

Non-core inflation expectations are also unobserved and likewise estimated as follows:

$$\pi_{NC,t}^e = c_{ee}\pi_{NC,t+4|t}^4 + (1 - c_{ee})\pi_{NC,t-1}^e + \varepsilon_t^{\pi_{NC}^e}. \tag{23}$$

While core and non-core inflation expectations $\pi_{C,t}^e$ and $\pi_{NC,t}^e$ at the right-hand side of equation (21) are unobserved, CPI inflation expectations π_t^e at the right-hand side of this equation can be either unobserved or observed. We study three measures of inflation expectations. The first one is the rational or model-consistent inflation expectations where CPI inflation expectations are estimated as unobserved. The second and third measures are the survey and arima inflation expectations.

The exchange rate.   The real multilateral exchange rate $q_{CO|WO,t}$ is defined as a trade-weighted average of the real bilateral exchange rates against I trade partners $q_{CO|i} \equiv s_{CO|i} + p_{i,t} - p_{CO,t}$, $i = 1...I$, where, for expositional purposes, Colombia, with subindex CO, is the base country, $s_{CO|i}$ is the (log) nominal interest rate against trade partner i, $p_{i,t}$ is the (log) price level of trade partner i, and $p_{CO,t}$ is the (log) price level of Colombia.

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[4]Coefficients $c_{\pi y}$ and $c_{\pi q}$ appear identical in Phillips curves (17) and (18) merely for notational simplicity.

We then turn to the theory of the real exchange rate, it is the uncovered interest rate parity condition (UIP), formulated for convenience in real terms as

$$q_{CO|WO,t} = q_{CO|WO,t+1|t} - \frac{1}{4}(r_{CO,t}^{Det} - r_{WO,t}^{Det}) + \chi_{CO|WO,t}, \tag{24}$$

where the UIP residual is the sum of detrended and trend components

$$\chi_{CO|WO,t} = \hat{\chi}_{CO|WO,t} + \bar{\chi}_{CO|WO,t}, \tag{25}$$

the trend component is

$$\bar{\chi}_{CO|WO,t} \equiv \bar{q}_{CO|WO,t} - \bar{q}_{CO|WO,t+1|t} + \frac{1}{4}\left[\bar{r}_{CO,t}^{Det} - \bar{r}_{WO,t}^{Det}\right], \tag{26}$$

the detrended real interest rate is

$$r_{CO,t}^{Det} = r_{CO,t} - \bar{r}_{CO,t}^{Trend} \tag{27}$$

and $r_{WO,t}^{Det}$ is a trade-weighted average of the real interest rates of the trade partners.[5]

Note that plugging equations (25) to (27) into the UIP condition (24), a UIP condition holds for the real multilateral exchange rate and the real interest rates, both in deviation form. This modification of the UIP condition helps estimate the latent real exchange rate $\bar{q}_{CO|WO,t}$ in a context where the natural real interest rate in each economy can have trend components that differ.

The output gap. Lastly, output is the sum of the output gap and potential output

$$y_t = \hat{y}_t + \bar{y}_t, \tag{28}$$

where the output gap is given by a standard aggregate demand equation

$$\hat{y}_t = c_{yf}\hat{y}_{t+1|t} + c_{yy}\hat{y}_{t-1} - c_{yr}\hat{r}_t + c_{yq}\hat{q}_{t-1} + c_{yw}\hat{y}_{WO,t} + \varepsilon_t^{\hat{y}}, \tag{29}$$

and potential output follows the process given by equations

$$\bar{y}_t = \bar{y}_{t-1} + \frac{1}{4}\gamma_t + \varepsilon_t^{\bar{y}} \tag{30}$$

and

$$\gamma_t = \gamma_{t-1} + \varepsilon_t^{\gamma}, \tag{31}$$

where, in equation (29), variable $\hat{y}_{WO,t}$ is the world output gap.

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[5]The UIP condition for a given country *vis a vis* the world economy can be derived as a trade-weighted average of the UIP condition of the bilateral real exchange rates against the trade partners.

The rest of the world. The block for the rest of the world is set up as a world economy model. It consists of two Phillips curves, one each for core and non-core inflation; two expectations equations, also for core and non-core inflation; and an output gap equation and a Taylor rule. The equations are similar to those presented above for the open economy, but without foreign variables. Details of the model appear in Gómez (2018), while the list of countries and data sources is shown in Gómez (2017).

The world economy model helps provide estimates of the world output gap, the real interest rate and natural real interest rate; the former is an input in the output gap equation (29) while the later is an input in equations (24) and (26).

3   The data

Data are quarterly for the period 1996Q1−2017Q4. The study period covers the latin american end-of-the-century crisis and a subsequent inflation-targeting period, starting at the beginning of 2000 in most countries. Although the study period has the drawback of including two regimes, the pre and post inflation-targeting periods, it has the important advantage that it includes a major recession, a valuable input for estimating the Phillips curves.

Interest-rate data is end-of-period, not seasonally adjusted. Owing to changes in monetary policy regimes, central bank policy rates were spliced with data for comparable interest rates. For Brazil, the interest rate is the central bank base rate (from source Banco Central do Brazil), spliced in 1999Q3 with the central bank policy rate (from source IMF International Financial Statistics). For Mexico, the interest rate is the 28-days interbank rate (from source Banco de Mexico), spliced in 2008Q1 with the central bank policy rate (from source Banco de Mexico). For Colombia, the interest rate is the central bank policy rate (from source Banco de la República). For Chile, the interest rate is the central bank policy rate (from source IMF IFS). For Peru, the interest rate is the interbank rate (from source Reserve Bank of Peru), spliced in 2003Q3 with the central bank policy rate (from source Reserve Bank of Peru).

Data for consumer and core price indices are end-of-period and seasonally adjusted. For Brazil, the source is the country statistics department. For Mexico and Colombia, the source is DANE. For Chile and Peru, the sources are the countries central banks.

As explained above, we use two measures of observed inflation expectations. Survey expectations are available since about 2000 for all countries. The sources for data for survey expectations are the countries central banks. Survey expectations before 2000 are obtained as unobserved. Arima expectations can be constructed for the entire sample; however, the arima process tends to produce systematic forecast errors before 2000 as a consequence of the down-

ward trend in inflation in all countries. Therefore, arima expectations before 2000 were also obtained as unobserved.[6]

Real GDP data for Brazil and Colombia was obtained from the countries statistics departments. For Mexico, Chile, and Peru, the source is the countries central banks. Real GDP was seasonally adjusted.

Exchange rate data was not seasonally adjusted. The source is Bloomberg Financial Services.

4 Calibration and estimation of the model coefficients

A set of coefficients was calibrated, and another was estimated. The calibrated coefficients were, first, those that define real persistence, c_{yy}, c_{yf}, c_{uu} and nominal persistence, $c_{\pi e}$, c_{ee} (Table 1). Real persistence was calibrated to fit the length of the business cycle while nominal persistence to obtain reasonable impulse responses. With the calibrated levels of real and nominal persistence we proceeded to obtain the slopes of the aggregate demand and Phillips curve equations by estimation, as explained below. Other calibrated coefficients were fixed parameters (the share of core inflation in CPI inflation $c_{\pi c}$) and coefficients that were not critical for the estimation of the natural interest rate.

The standard deviation of the shocks was also calibrated. The standard deviation of $\varepsilon_t^{\bar{r}^{Det}}$ was set at zero for simplicity. Two standard deviations were also calibrated so as to obtain reasonable estimates of the natural interest rates and output gaps. The first relative standard deviation is that of $\varepsilon_t^{\bar{r}^{Trend}}$ relative to the standard deviation of ε_t^i. The second relative standard deviation is that of ε_t^y plus ε_t^γ relative to the standard deviation of $\varepsilon_t^{\hat{y}}$ (Table 1).

The estimated coefficients were the slope of the behavioral equations, in the Phillips curve, $c_{\pi y}$ and $c_{\pi q}$; in the aggregate demand equation, c_{yr} and c_{yq}; and in Okun's Law, c_{uy}. The coefficients in the policy rule, $c_{i\pi}$, c_{iy}, were also estimated. The process was carried out by Bayesian maximum likelihood estimation.

The estimated coefficients were estimated with model-consistent inflation expectations; they appear in Table 2. The prior for coefficient $c_{\bar{r}\gamma}$ was set at 0.8. This prior was obtained as the estimated coefficient for Colombia and Peru during a first round of estimation.[7]

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[6]We also experimented with one-year ahead break-even expectations. We do not present the results for break-even inflation expectations because the sample perior was short. The sources for break-even inflation expectations are as follows: for Brazil and Mexico, data are available for both countries since 2012 from source Bloomberg. For Colombia, Chile, and Peru, data are for the return on nominal and real bonds. The source for this data for Colombia is Banco de la República, available since 2003Q1; for Chile is Bloomberg, since 2006Q2; for Peru is Bloomberg, starting in 2007Q3.

[7]For the remaining economies, the data was not informative, meaning that the Bayesian posterior was equal to the prior. Although the estimated value for the world economy was $c_{r\gamma} = 0.96$, we decided to use $c_{r\gamma} = 0.8$,

Priors for coefficients $c_{\pi y}$ were set at 0.12 to reflect relatively flat Phillips curves. Nonetheless, most estimated coefficients increased to the range (0.156, 0.194). Likewise, priors for coefficients c_{yr} were also set at 0.12 to reflect relatively flat aggregate demanda equations. The estimated coefficients also increased to the range (0.128, 0.171).

5   Results for the natural interest rate

Figures 1 to 5 and Table 3 present the natural interest rate in the five largest economies in Latin America. These results correspond to the case where the real interest rate is calculated using model consistent inflation expectations. The advantages of this measure of inflation expectations are, first, that it can be estimated or made available for the entire study period and, second, that it gives the smallest standard erros in the esimation of the natural interest rate.

Panels A in Figures 1 to 5 show the natural real interest rate. Following Holston, Laubach and Williams (2017), the estimates are one-sided; that is, they are based only on current and past information. The credible intervals show two standard deviations from the mean. The natural real interest rate experiences a downward trend in the larger economies, Brazil, Mexico, and Colombia (Panels A in Figures 1 to 3). In comparison, it experiences virtually no trend in the smaller economies, Chile and Peru (Panels A in Figures 4 and 5). Naturally, the trend or trendless feature of the natural real interest rate is explained by the trend component of the natural real interest rate (Panel D in Figure 6).

Panels B in Figures 1 to 5 show the results of the estimation of the unobserved natural nominal interest rate. The natural nominal interest rate experiences a downward trend in all economies. In the case of Brazil, the natural nominal interest rate trends down due to the downward trend in the natural real interest rate, meaning that inflation and inflation expectations virtually show no trend during the study period. In the remaining economies, the natural nominal interest rate trends down due to both the trend in the natural real interest rate and the downward trend in inflation and inflation expectations.[8]

At the end of the sample, the room for expansionary monetary policy is still generous in the larger economies, where the natural real interest rate still trends down. In contrast, the room for expansionary monetary policy is not as generous in the smaller economies, where the natural real rate does not show a trend. In the smaller economies, the natural real interest rate is close to zero, while the natural nominal interest rate is just above 2 percent.

The results of the estimation uncertainty appear in Table 4. The table shows two-standard-

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owing to the presumably larger volatility in the emerging economies in the study.

[8]Note that the results for the natural nominal interest rate, the natural real interest rate and the model-consistent inflation expectations are all estimation results for unobserved variables.

deviation credible intervals for the natural real and natural nominal interest rates and for the detrended and trend components of the natural real interest rate. Estimation uncertainty is larger in the larger economies, where the trend component of the natural rate trends down, while smaller in the smaller economies where no trend is discernible. The credible intervals are also indicated in Figures 1 to 5.

Estimation uncertainty improves using model-consistent inflation expectations. The larger estimated credible intervals using survey (observed) and arima inflation expectations are also reported in Table 4.

While model-consistent inflation expectations help improve estimation of uncertainty, this measure of inflation expectations is comparable to other available measures. Table 5 compares model-consistent expectations with survey, arima, and break-even inflation expectations. The statistic reported is the RMSE between observed inflation and the measure of inflation expectations, $\pi_t - \pi_{t|t-4}$, where $\pi_{t|t-4}$ are four-quarter ahead inflation expectations. The comparison was carried out for two sample periods according to data availability. The shorter period, starting in 2013Q2, covers all countries while the longer period, starting in 2008Q3, excludes Mexico.[9] The table shows that the model-consistent inflation expectations are similar to other available measures.[10]

6   Conclusions

We have estimated the natural interest rate in the 5 largest economies in Latin America. We used the standard neo-Keynesian model and the Laubach Williams (2003) method, complemented with a definition of the natural interest rate in nominal terms and a behavioral equations for the rational or model-consistent inflation expectations.

In the results we find that in the larger economies, Brazil, Mexico, and Colombia, the estimated natural real interest real rate features a downward trend. Nonetheless, the estimated natural nominal interest rate still remains above zero, allowing ample room for expansionary monetary policy. In the smaller economies, Chile and Peru, the estimated natural real rate has hovered closer to zero. In these economies, the room for expansionary policy does not appear as extensive, as the estimated natural nominal interest rate is just above 2 and 3 percent, respectively.

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[9]Still another period, starting in 2004Q1 and not reported, uses data for break-even inflation expectations only for Colombia. The conclusions are mantained.

[10]Model-consistent inflation expectations are estimated with high precision. The confidence intervals are smaller than those of the natural interest rates and also smaller in the smaller countries. A two-standard-deviation confidence interval for model-consistent inflation expectations for Brazil is 1.3; Mexico, 1.1; Colombia, 0.8; Chile, 0.7; and Peru, 0.6.

Estimation uncertainty is larger in countries where the real natural rate trends down, Brazil, Mexico, and Colombia, and smaller in those countries with a more stable long-term natural real interest rate. Estimation uncertainty is sharply reduced by using model-consistent inflation expectations.

As to the policy implications, the natural interest rate still does not pose a critical challenge for monetary policy in Latin America, as it does in advanced economies. Nonetheless, the natural nominal interest rate offers a narrow room for expansionary monetary policy in Chile and Peru.

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Table 1. Calibrated coefficients

Coefficient	Calibrated value					
	All countries	Brazil	Mexico	Colombia	Chile	Peru
c_{yy}	0.770					
c_{yf}	0.030					
c_{uu}	0.770					
$c_{\pi e}$	0.200					
c_{ee}	0.500					
$c_{\pi \Delta q}$	0.050					
$c_{\pi c}$		0.675	0.724	0.732	0.722	0.594
$c_{\pi q}$		0.020	0.100	0.075	0.050	0.025
c_{yq}		0.020	0.070	0.030	0.040	0.060
c_{yw}		0.030	0.080	0.040	0.070	0.050
$\sigma_{\varepsilon^{\bar{r} Trend}}/\sigma_{\varepsilon^i}$		0.225	0.150	0.225	0.100	0.050
$\left(\sigma_{\varepsilon^{\bar{y}}} + \sigma_{\varepsilon^{\gamma}}\right)/\sigma_{\varepsilon^{\hat{y}}}$		0.300	0.500	0.300	0.300	0.300

Table 2. Estimation results: estimated coefficients

Coefficient	Prior	Posterior				
		Brazil	Mexico	Colombia	Chile	Peru
$c_{r\gamma}$	0.800	0.807	0.819	0.795	0.814	0.812
$c_{i\pi}$	1.500	1.317	1.411	1.446	1.277	1.289
c_{iy}	0.500	0.513	0.507	0.528	0.458	0.425
$c_{\pi y}$	0.120	0.194	0.155	0.165	0.171	0.156
c_{yr}	0.120	0.169	0.131	0.128	0.170	0.171
c_{uy}	0.200	0.171	0.199	0.196	0.199	0.186

Table 3. Estimation results: the natural interest rate

	Natural real interest rate					Natural nominal interest rate				
	Brazil	Mexico	Colombia	Chile	Peru	Brazil	Mexico	Colombia	Chile	Peru
2014Q1	4.1	0.1	1.3	2.1	1.5	10.0	3.3	4.2	4.7	4.2
14Q2	3.9	0.3	1.2	1.6	1.2	10.0	3.5	4.3	4.5	4.0
14Q3	4.1	0.4	1.5	1.3	1.3	10.3	3.5	4.7	4.4	4.1
14Q4	4.7	0.6	1.9	0.9	1.2	10.9	3.8	5.3	4.2	4.0
15Q1	3.9	0.9	2.0	0.6	0.9	10.3	3.9	5.8	4.0	3.6
15Q2	4.2	1.1	1.7	0.2	0.6	11.0	4.1	6.0	3.8	3.5
15Q3	5.2	1.4	2.0	0.0	0.3	12.2	4.4	6.7	3.7	3.3
15Q4	5.6	1.5	1.8	0.0	0.4	12.8	4.4	6.9	3.8	3.6
16Q1	6.5	1.6	1.4	-0.2	0.7	13.7	4.6	7.0	3.6	3.9
16Q2	6.0	2.1	1.1	-0.3	0.7	13.2	5.2	7.0	3.5	3.9
16Q3	6.1	2.6	1.0	-0.2	0.7	13.3	5.7	6.9	3.5	3.9
16Q4	6.5	3.0	1.6	-0.2	0.5	13.5	6.1	7.0	3.3	3.6
17Q1	6.8	2.2	1.1	-0.2	0.4	13.5	5.6	6.3	3.1	3.6
17Q2	6.9	1.8	1.1	-0.2	0.7	13.1	5.5	6.3	3.0	3.8
17Q3	5.9	2.0	1.4	0.0	0.5	11.6	5.9	6.4	3.0	3.5
17Q4	5.1	2.4	1.6	-0.2	0.5	10.5	6.4	6.2	2.6	3.4

Table 4. Estimation uncertainty

(Two-standard-deviation credible interval)

	Brazil	Mexico	Colombia	Chile	Peru
Model-consistent expectations					
Natural nominal interest rate	5.6	4.4	4.0	2.3	1.8
Natural real interest rate	5.9	4.6	4.3	2.4	1.9
Detrended natural real interest rate	4.8	4.5	3.4	21	1.8
Trend natural real interest rate	5.4	3.7	3.8	1.9	1.2
Survey expectations					
Natural nominal interest rate	11.0	5.0	5.7	3.2	2.4
Natural real interest rate	11.1	5.0	5.7	3.2	2.4
Detrended natural real interest rate	9.4	5.0	4.7	3.0	2.3
Trend natural real interest rate	10.2	4.1	5.2	2.6	1.5
Arima expectations					
Natural nominal interest rate	9.6	7.5	6.2	5.1	3.4
Natural real interest rate	9.7	7.5	6.2	5.1	3.4
Detrended natural real interest rate	8.3	7.5	5.2	4.7	3.3
Trend natural real interest rate	8.9	6.1	5.7	4.0	2.1

Table 5. Comparison of different measures of inflation expectations with observed inflation
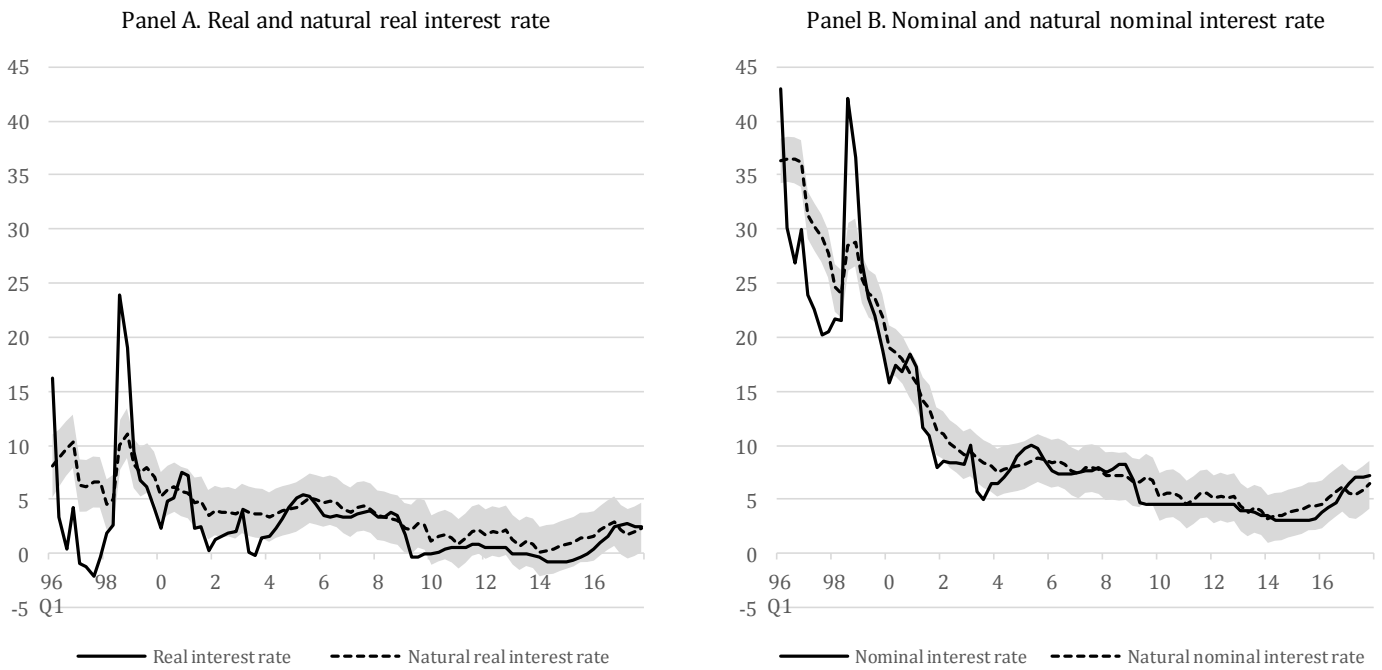(Root-mean-squared error)

	Brazil	Mexico	Colombia	Chile	Peru
Sample 2002Q2−2017Q4					
Model-consistent expectations	2.9	1.4	1.9	2.6	1.7
Survey expectations	2.9	1.0	1.6	2.0	1.5
Arima	3.4	2.9	2.5	2.8	1.8
Break-even inflation expectations	n.a	n.a	1.7	2.0	1.5
Sample 2013Q2−2017Q4					
Model-consistent expectations	2.9	1.2	2.0	1.2	0.8
Survey expectations	2.4	1.4	2.2	1.4	0.7
Arima	2.6	1.4	2.1	1.1	0.7
Break-even inflation expectations	3.4	1.4	2.0	1.2	0.8

Figure 1. Brazil: the natural interest rate

Panel A. Real and natural real interest rate

— Real interest rate   ----- Natural real interest rate

Panel B. Nominal and natural nominal interest rate

— Nominal interest rate   ----- Natural nominal interest rate
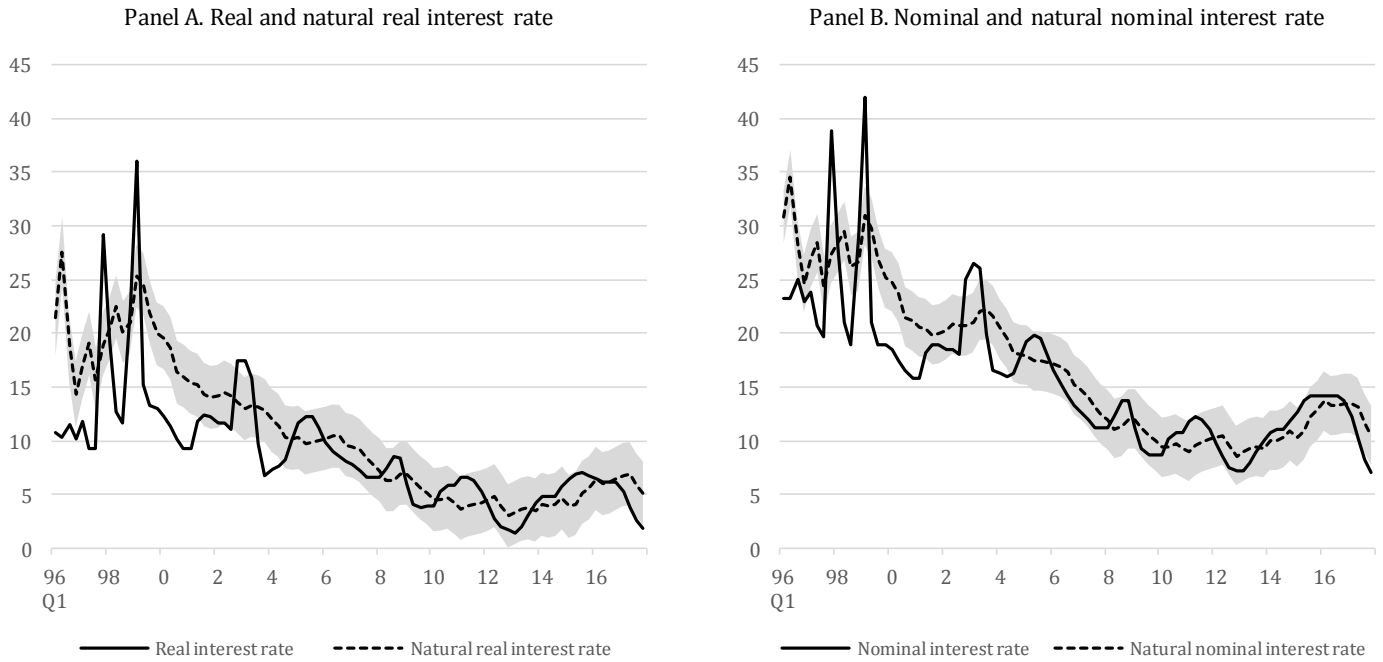
Source: author's estimations based on the model in the text.
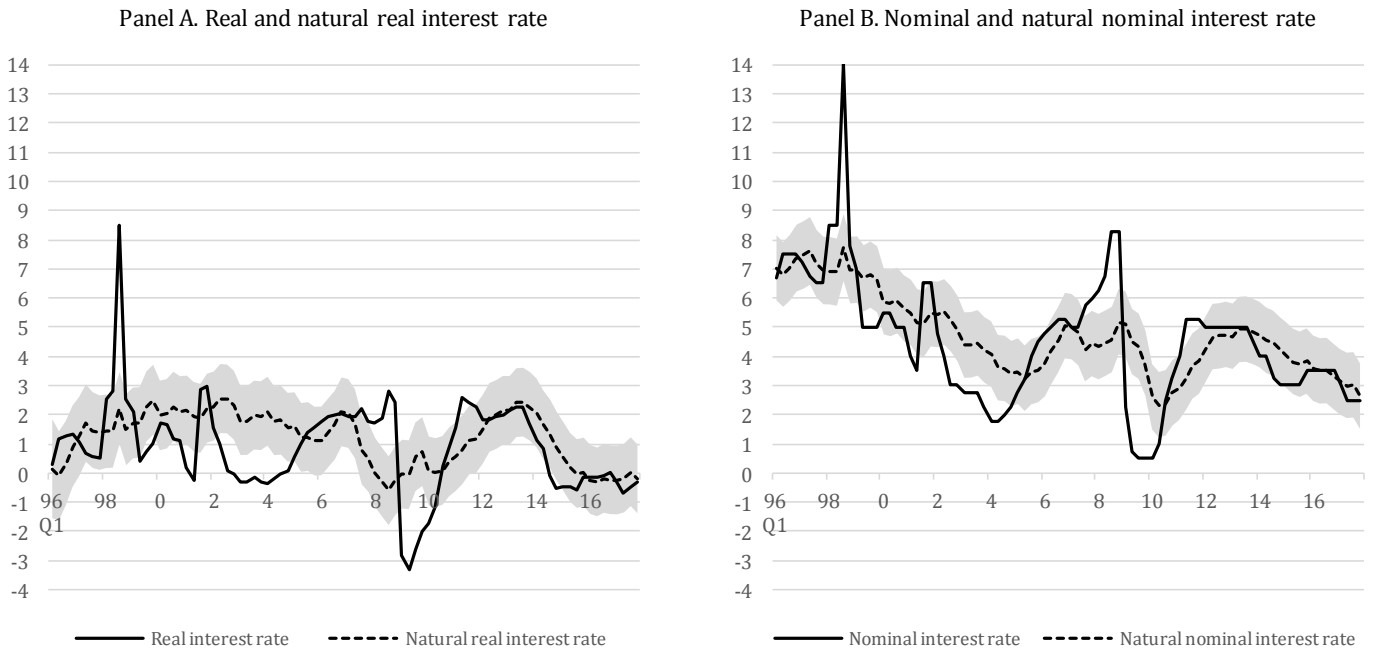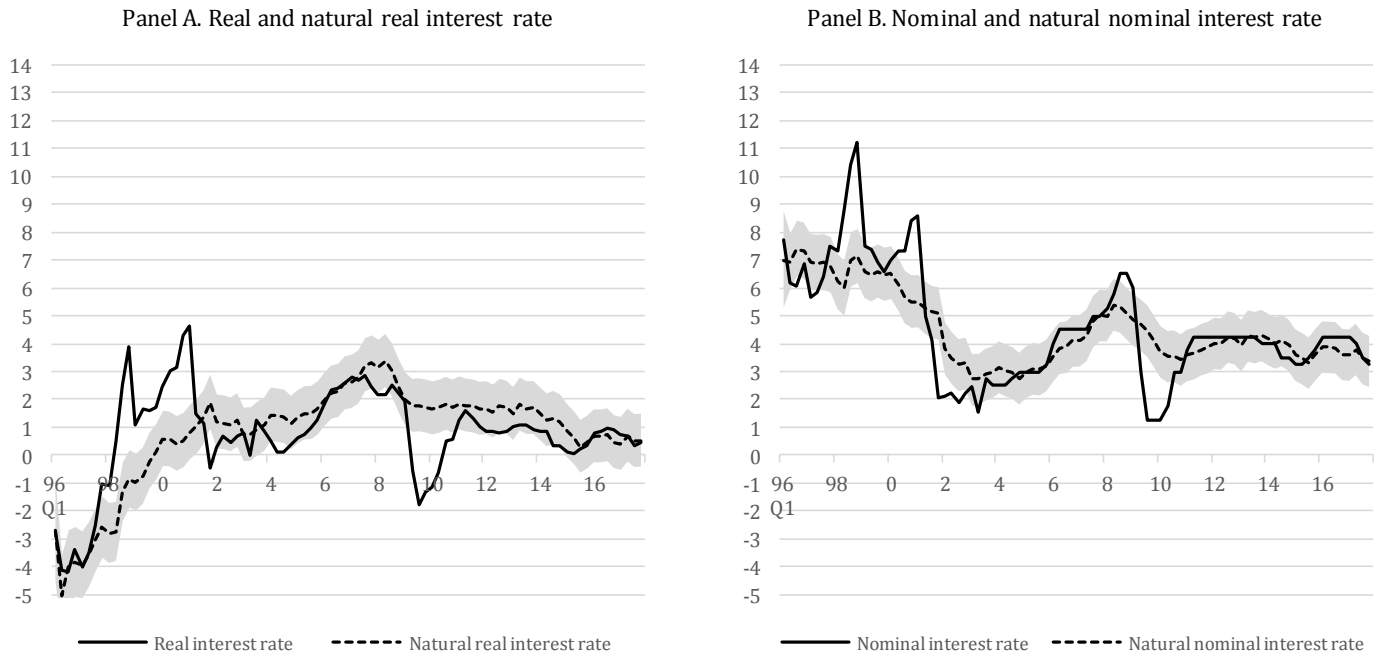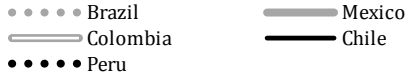
Figure 2. Mexico: the natural interest rate

Panel A. Real and natural real interest rate

— Real interest rate   ----- Natural real interest rate

Panel B. Nominal and natural nominal interest rate

— Nominal interest rate   ----- Natural nominal interest rate

Source: author's estimations based on the model in the text.

Figure 3. Colombia: the natural interest rate

Panel A. Real and natural real interest rate

Panel B. Nominal and natural nominal interest rate
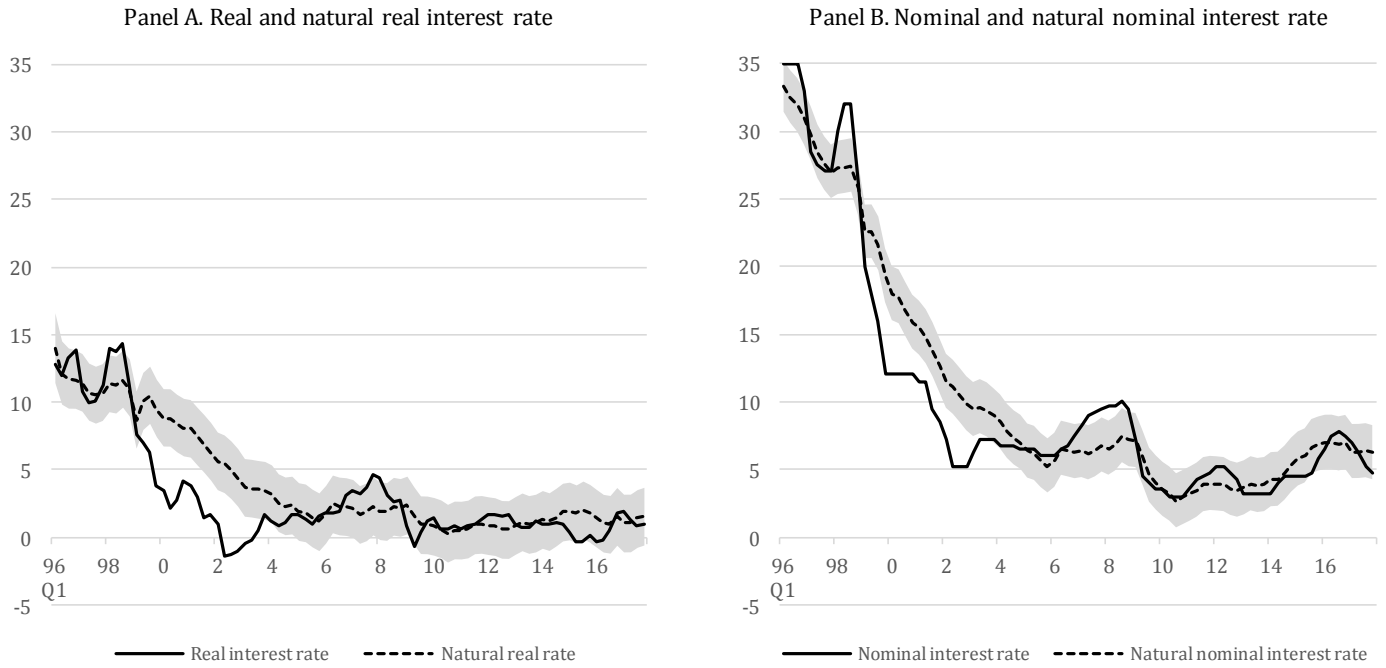
Source: author's estimations based on the model in the text.

Figure 4. Chile: the natural interest rate

Panel A. Real and natural real interest rate

Panel B. Nominal and natural nominal interest rate

Source: author's estimations based on the model in the text.

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Figure 5. Peru: the natural interest rate

Panel A. Real and natural real interest rate

Panel B. Nominal and natural nominal interest rate

Source: author's estimations based on the model in the text.

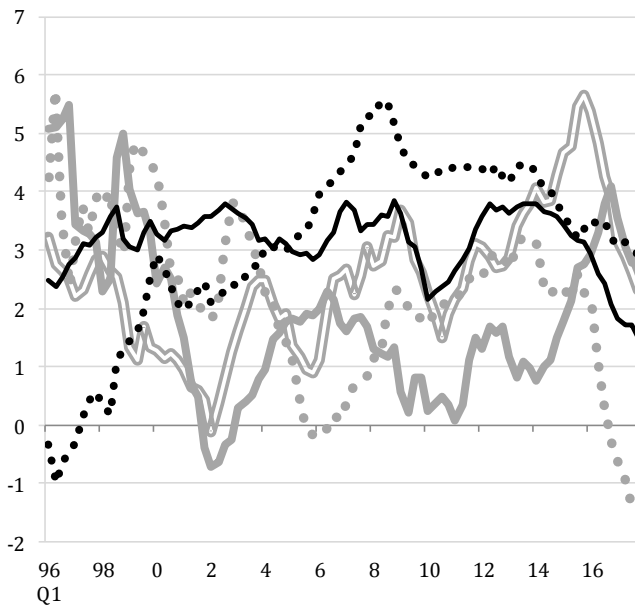# Figure 6. The natural interest rate: nominal and real; detrended and trend

Legend: Brazil, Colombia, Peru, Mexico, Chile
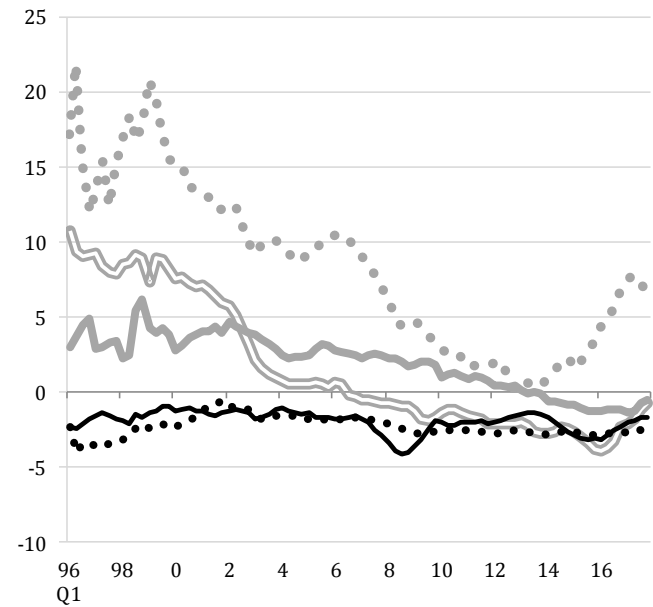
Panel A. Natural real interest rate
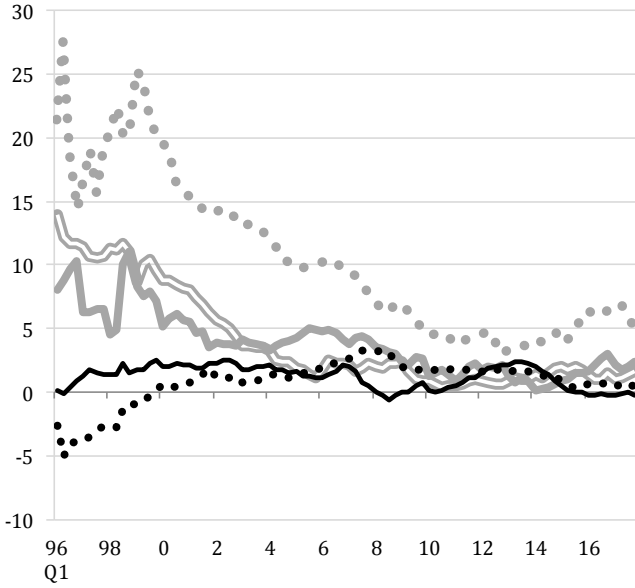
Panel B. Natural nominal interest rate
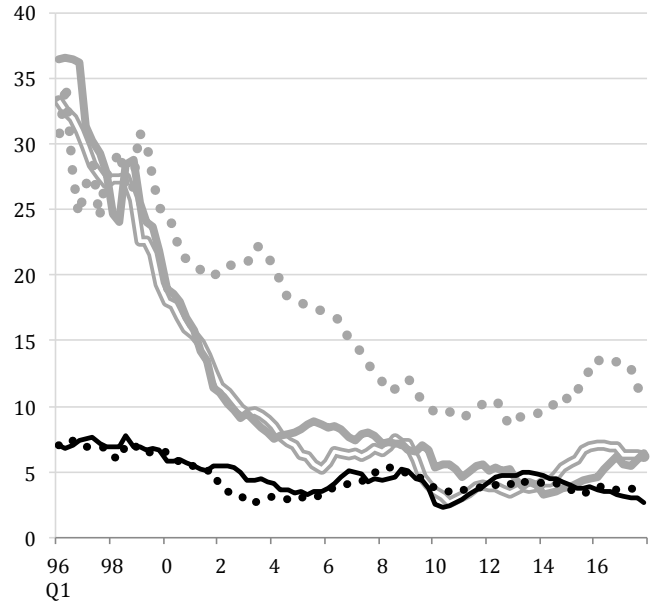
Panel C. Detrended natural real interest rate

Panel D. Trend natural real interest rate

Source: author's estimations based on the model in the text.

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