Pontifícia Universidade Católica
do Rio de Janeiro

Beatriz Leão Braga Nogueira

The COVID-19 Pandemic's Effect on the Brazilian Natural Interest Rate

Monografia de Final de Curso

Orientador: Márcio Gomes Pinto Garcia

Coorientador: Francisco Luna

Rio de Janeiro, junho de 2024

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Declaro que o presente trabalho é de minha autoria e que não recorri para realizá-lo, a nenhuma forma de ajuda externa, exceto quando autorizado pelo professor tutor.

I declare that this work is my own and that I did not use any form of external help to carry it out, except when authorized by the advisor.

Abstract

The COVID-19 pandemic had an enormous impact on the economy of nations. One of its most visible and enduring effects was a rise on prices, through shocks on both supply and demand. However, due to the resilience of this episode of global inflation it is unclear whether there has been a change to the trajectory of natural interest rates across the globe. The aim of this thesis is to estimate the Brazilian natural rate during the COVID-19 pandemic and study possible drivers behind its trajectory. To that end, the Brazilian natural interest rate was estimated from 2003 to 2023, using the Laubach-Williams method. The results were slightly lower than those of most peers for the entire estimation period and indicate that the natural interest rate was higher in 2022 and 2023 than in pre-pandemic years.

Keywords

Pandemic; Natural Interest Rate; COVID-19; Monetary Policy; Laubach-Williams.

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1 Introduction

With the arrival of the COVID-19 pandemic and subsequent lockdown policies set in place across the globe, many countries adopted emergency responsive measures, such as support packages (including food, health care, or income support), tax deferrals or instalment payment deferrals.

In the Brazilian case, according to a report on policy responses by the International Monetary Fund (IMF, 2021), Congress declared a state of emergency and exempted the government from meeting the primary balance target in 2020. Fiscal measures established by the government included expanded healthcare spending and financial aid for vulnerable households, while, in terms of monetary policy, the policy rate was set to its historical low of 2 percent by the Brazilian Central Bank (Banco Central do Brasil - BCB).

Nevertheless, by the time the acute phase of contamination and transmission in most countries had passed, central banks were left to face yet another hurdle: inflation. The inflationary process that took place during the COVID-19 pandemic was unique in its making: lockdowns, combined with stimulus packages and the spread of remote work practices, caused a shift in consumption from services to durable goods. However, the very nature of lockdowns severely disrupted the supply chain of many durable goods, as these have, in the past decades, tended to rely more on global value chain participation. Therefore, the reduced supply of goods, combined with expanded demand, resulted in a rise of the level of prices. (LaBelle and Santacreu, 2022)

Simultaneously, the pandemic generated not only a challenging fiscal perspective for governments, but also affected individual aspects of economies. It caused part of the population to exit the labour force, resulting in a reduced participation rate and therefore a tighter labour market (Monteiro, 2023). Meanwhile, disproportionate income losses increased inequality within and across countries, seeing as youth, women, the self-employed, and casual workers with lower levels of formal education suffered greater losses. (The World Bank, 2022)

Thus, as central banks progressively restricted their monetary policy, but economies and labour markets remained tight, the question arose as to whether this was a sign that the rates were not high enough, or rather that the benchmark for a “high” or “low” interest rate had changed.

This "benchmark" in question is the natural interest rate (r^*), meaning the interest rate that neither stimulates nor contracts the economy (IMF, 2023). Hence, it is a crucial variable for central banks' decision-making, because if the policy interest rate of an economy is set below its natural interest rate, an expansionary effect on the economy is created, and vice versa. (Holston, Laubach, and Williams, 2017).

There are several structural factors that impact the natural interest rate of a country. The IMF (2023) categorizes as macroeconomic drivers productivity growth, demographics, fiscal policy, market power, and labour share, and as financial drivers international capital flows, the scarcity of safe assets, risk aversion, and leverage cycles. While BCB (2023a) also enumerates as drivers potential output growth rate; preferences of economic agents in terms of consumption, savings and investment; financial system efficiency; and the economy wide risk premium.

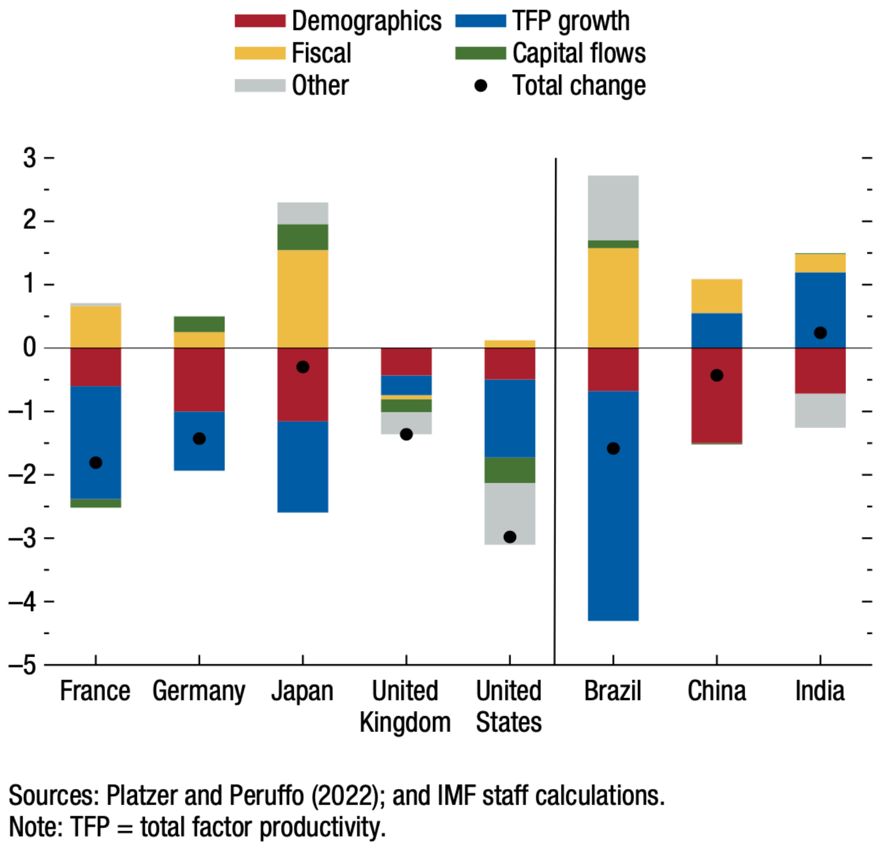
Although central to monetary policy-making, the natural interest rate of an economy is not an observable variable and needs to be estimated (Dahlberg, 2023). There are a number of models available in literature, which combine statistical filters and economic theory on various levels, therefore ranging from purely statistical approaches to structural models. (BCB, 2023a)

According to the IMF (2023), in most advanced economies r^* has been in a steady decline for the last forty years, while in emerging economies natural rates have on average remained stable for the past twenty years. Figure 1 shows the effects that different drivers have had on r^* in advanced (left) and emerging (right) economies in the aforementioned period, as estimated by the Platzer and Peruffo (2022) model. A positive impact from fiscal policy and a negative one from population aging is widespread in all economies, while Total Factor Productivity (TFP) growth had a negative role in advanced economies and Brazil, and a positive one in China and India. In Brazil there is a particularly strong effect of a slowdown in TFP growth and of fiscal policy, mostly due to an increase in public spending and public debt. (IMF, 2023)

In regards to the future, international evidence indicates that there's no reason to believe that the natural interest rate should diverge from its pre-pandemic downward trajectory. (BCB, 2023b)

As for the Brazilian natural interest rate, according to the June 2023 Inflation Report by BCB (2023a), which estimates the Brazilian natural rate using many different approaches (ranging from statistical to structural ones), in general there is

Figure 1 – Drivers of Natural Rate Changes from 1975–79 to 2015–19 for Selected Economies (in percentage points)



Source: IMF (2023)

a downward trend until early 2020, when the rate starts an upward trajectory.

In countries where, due to its history, inflation is a particularly daunting prospect, such as Brazil, monetary policy is crucial, and the natural interest rate is essential to guide monetary policy. Therefore, especially in the context of monetary policy tightening (such as 2022 and 2023), there is value in understanding the trajectory of the natural rate, if it has changed and whether these changes are permanent. Additionally, there is an equal value in understanding the drivers behind the natural interest rate, as these are important aspects of our economy and could help clarify the economical impacts of the pandemic.

The aim of this thesis is to estimate the trajectory of the Brazilian interest rate during the COVID-19 pandemic and to conduct a qualitative study on drivers that may have affected this variable on the aforementioned period. This introduction is followed by a literature review of the natural interest rate, its presumed drivers and different methods of estimating it, in Chapter 2. Chapters 3 and 4 detail the model and data used in the estimation of the natural interest rate. Finally, Chapter 5 analyzes the results of the estimation and Chapter 6 contains final remarks which bring this thesis to a close.

2 Literature Review

2.1 The natural interest rate

The natural interest rate is the real short-term interest rate in which output converges to its potential level, consistent with stable inflation (Laubach and Williams, 2003). In countries where the short-term interest rate is the primary policy instrument - such as Brazil - this is a crucial variable, as it is the interest rate that neither stimulates nor contracts the economy (IMF, 2023). Del Negro et al. (2017) go as far as stating that the natural interest rate (r*) represents the hypothetical rate that would be observed in the absence of monetary policy, and therefore encapsulates the forces guiding interest rate fluctuations.

The natural interest rate can vary due to changes in preferences and growth rate of output (Laubach and Williams, 2003), among other determinants, as detailed in the following section.

2.2 Drivers behind the natural interest rate

This section offers an overview of the most frequently mentioned and researched drivers for r^* in literature.

- **Productivity growth:** Higher productivity growth drives up the marginal product of capital and savers' opportunity cost, therefore a higher interest rate is needed to attract lending (IMF, 2023). Alternatively, a slowdown in productivity can tighten the borrowing constraints of the young - reducing the demand for loans - and prompt the middle-aged generation to increase retirement savings - expanding savings supply (Eggertsson, Mehrotra, and Robbins, 2019). Ultimately, a slowdown in productivity growth would lead to a decline in r^* and vice versa.
- **Demographics:** Changes in the demographic distribution may impact r^* as, due to differences in savings preferences along the life-cycle, they can impact the aggregate savings of the economy and therefore alter the supply of capital. For example, shifting demographics due to the aging of the baby boom generation in the United States is an explanation addressed in literature for the decline in

r^* in the past decades (Mian, Straub, and Sufi, 2021). In addition to that, a rise in the working-age population could lead to an increase in the natural interest rate, as there would be more demand for investments to equip it (ECB, 2004).

- **Inequality:** There is evidence in literature to suggest that saving rates are significantly higher in richer households. Therefore an increase in inequality could result in greater aggregate savings and, consequently, depress the natural rate (Platzer and Peruffo, 2022). Mian, Straub, and Sufi (2021) investigate the impact of demographic shifts versus increasing income inequality on saving behavior in the United States from 1950 to 2019, and their findings indicate that rising income inequality is the primary factor driving the decline in r^* in that period.

- **Government policy**: Higher government borrowing financed by debt issuance increases the demand for savings, driving up the natural interest rate. Also, rising social security transfers have been linked to a higher natural interest rate, as households tend to save less in preparation for their retirement (IMF, 2023; ECB, 2004).

- **Scarcity of safe assets:** In the context of global capital markets, there is an excess demand for safe and liquid assets from emerging economies, particularly for US government bonds, which drives down their return. In the case of a financial fragmentation, due to a rise in geopolitical tensions, surplus countries would repatriate excess savings, and this would bring down the natural interest rate (IMF, 2023). Del Negro et al. (2017) explore this relationship more thoroughly in their paper, in which their findings indicate that a rise in the premium for safety and liquidity is the main cause for the decline in r^* in the US.

- **Preferences of economic agents in terms of consumption:** According to Goldfajn (2011), the real equilibrium interest rate, which must be equal to $r*$, will be higher the less individuals prefer future consumption relative to present consumption and the lower the elasticity of substitution of consumption between two time periods.

- **Financial System efficiency & inflation and economy wide risk premium:** An improvement in the financial market structure could broaden the range of asset options in terms of return, risk, and liquidity available to savers, and therefore serve as an incentive for saving, lowering the natural interest rate. Alternatively, the costs of borrowing could be increased by uncertainties regarding inflation and the credibility of a currency. (ECB, 2004)

- **Market power and labour share**: On the one hand, an expectation that market power will increase implies reduced competition in labour and goods markets, akin to a decline in productivity, which drives down consumption and investment spending, consequently lowering the natural interest rate. This is inverted in the case of an increase in expected competition, where the natural interest rate rises, with the difference that perfect competition is the limit for this process (Natal and Stoffels, 2019).

2.3 Estimating the natural interest rate

Laubach and Williams (2003) (henceforth LW 2003) became a reference for estimating the natural interest rate with their 2003 paper, in which they apply the Kalman filter to jointly estimate the natural interest rate, the potential output, and its trend growth rate.

Holston, Laubach, and Williams (2017) (henceforth HLW 2017) applied the 2003 model, which was originally designed for U.S. data, on four advanced economies: the U.S., Canada, the Euro Area, and the United Kingdom. They found evidence of comovement between the natural interest rates across the economies, as well as a common downward trend over the previous 25 years, in part due to a declining trend in growth rate.

Lastly, Holston, Laubach, and Williams (2023) (henceforth HLW 2023) adjusted this model to encompass the volatility that marked the COVID-19 pandemic. Applying this to data on the US, Canada and the Euro Area, they found that by the end of 2022 the r^* levels were similar to those on the pre-pandemic era, but the estimated natural level of output was lower.

Wynne and Zhang (2018) contribute to the literature by applying a model broadly based on Laubach and Williams (2003) to estimate the world natural interest rate, potential output, and the trend growth rate of potential output. They observe a decline over the past five decades in both the global natural interest rate and the global trend potential output growth rate. Also, they find that the decline in the growth rate plays a significant role in the decline of the natural rate, despite the lack of robustness in the relationship between these two variables.

Del Negro et al. (2017) apply two models to estimate r^* in the United States: a vector autoregression (VAR) with common trends, to isolate the permanent component of the real interest rate using data on nominal bond returns, inflation, and long-term survey expectations; and a medium-scale dynamic stochastic general equilibrium (DSGE) model, which offers a structural perspective on the fundamental forces influencing interest rates. Both result in similar estimates of the low-frequency component of the natural rate: a trend that peaked in the 1990s and has been declining consistently ever since. The primary factors behind this decline were the increasing premiums associated with the safety and liquidity of Treasury bonds (referred to as the *convenience yield*), as well as slower economic growth.

Alternatively, Carvalho, Ferrero, and Nechio (2016) focus on the demographic transition as a key driver to not only r^*, but also to the "Secular Stagnation" hypothesis, a state in which the natural interest rate would be low and potentially negative, leading to a chronically binding zero lower bound (ZLB) (Eggertsson, Mehrotra, and Robbins, 2019). They use a life-cycle model calibrated to encompass characteristics of the demographic transition in developed economies, and their findings reveal that the overall impact of this transition is a decrease in the natural interest rate from 1990 to 2014 (by 1.5 percentage points in their "representative developed country").

The model established by Platzer and Peruffo (2022) endeavors to capture the effects of changes in demographics, productivity, inequality and public policy on r^* in the United States in one unified framework. Their exercise is split in two main analysis. Firstly, they compare two steady state economies: one where the chosen drivers are at the observed 2015 levels, and a counterfactual one where they are at 1975 levels. This analysis explains a 2.2 percentage point decline in the natural interest rate, in which total factor productivity (TFP) growth, demographic factors, and inequality are the first, second, and third most important drivers, respectively. Secondly, they analyze a transition path between two steady states, beginning in a post-World War II economy in 1950 and projecting the trend of r^* into the future, until 2060. The results indicate that r^* follows a decline starting from 1970, reaching a low of 0.38% in 2031. Afterwards, there is a slow reversal, culminating in a long-term equilibrium of 1%.

In the Brazilian case, as stated in BCB (2023a), some methodologies used to estimate the natural interest rate include: extracting ex-ante real interest rates from the BCB's Focus survey; isolating high and low frequency rates from a previously calculated long run rate; discounting the term premium from market interest rates; adding the risk premium to foreign rates; applying a semi-structural small-scale model; and, finally, employing a DSGE model adapted by the BCB to the Brazilian economy (Stochastic Analytical Model with a Bayesian Approach - SAMBA), in which productivity is a key element. Table 1 shows the results for each model estimated by the BCB for Q1 2023 (First Quarter 2023). Both the mean and the median of the estimates are 4.8%.

Goldfajn and Bicalho (2011) divide the natural interest rate into two components: a long term natural interest rate, affected by structural factors, and a short term interest rate, defined by the same structural factors but also affected by cyclical ones. In their estimation, they find that the decline of both the risk premium and debt-to-GDP ratio, and the rise of the credit-to-GDP ratio (which, in the long run, can reflect advances in the institutional structure of the financial market) contributed to the fall of the long term natural rate. Their findings also suggest that the short term natural rate oscillates around the long term rate over time, depending on the cyclical factors, and that it declined during the global financial crisis. The cyclical factors considered are the global output gap, real interest rate, tax expenditure, real exchange rate, and directed credit.

Table 1 – Varied natural interest rates estimates by the BCB for Brazil in 1Q23

Methodology	Rate (% p.a.)
Ex-ante real Selic rate from the Focus survey	
Real Selic expected in 4 years	4.7
Real Selic expected in 1 year, HP filter	5.0
High frequency neutral rates	
Band-Pass gap	4.9
Beveridge-Nelson gap	5.4
Semi-structural model gap	4.3
Low frequency neutral rates	
Band-Pass gap	4.3
Beveridge-Nelson gap	4.4
Semi-structural model gap	4.1
Real market rates discounted of the term premium	
5 years	4.7
10 years	4.9
20 years	5.0
5 to 10 years	5.1
5 to 20 years	5.1
10 to 20 years	5.1
Uncovered interest rate parity	
Treasury 1y + Embi + exchange rate risk premium	4.4
TIPS 5y + Embi + exchange rate risk premium	4.7
TIPS 5y + CDS + exchange rate risk premium	4.1
Laubach-Williams (two-sided) + Embi + exchange rate risk premium	5.5
Laubach-Williams (two-sided) + CDS + exchange rate risk premium	4.9
Natural interest rate from the Samba model	
Two years future rate	4.5
Five years future rate	4.8
Neutral real interest rate from the PCQ	
Short-term median	4.8
2 years median	4.8
5 years median	4.5
Summary	
Mean	4.8
Median	4.8
25th percentile	4.5
75th percentile	5.0

Source: BCB (2023a).

3 Methods

For the quantitative section of this thesis, an estimation of the Brazilian natural interest rate was performed using HLW 2023. This model was chosen because, since it was originally published in Laubach and Williams (2003), it has been widely used for estimating the natural interest rate in many countries, and in Holston, Laubach, and Williams (2023) it was adjusted to encompass the volatility imposed by the pandemic, which is the period of interest of this study.

3.1 Empirical Framework

This section briefly outlines the empirical framework used to estimate the natural interest rate, as described in Holston, Laubach, and Williams (2023) and Holston, Laubach, and Williams (2017). The estimation was conducted using the replication code provided by the Federal Reserve Bank of New York (2024).

3.1.1 Description of model

The model uses an intertemporal IS equation (1) and Philips curve (2) relationship, modeling the output gap and inflation dynamics as a function of the real interest rate gap, as follows:

$$\tilde{y}_t = a_{y,1}\tilde{y}_{t-1} + a_{y,2}\tilde{y}_{t-2} + \frac{a_r}{2}[(r_{t-1} - r^*_{t-1}) + (r_{t-2} - r^*_{t-2})] + \epsilon^{\tilde{y}}_t \tag{1}$$

$$\pi_t = b_\pi \pi_{t-1} + (1 - b_\pi)\pi_{t-2,4} + b_y \tilde{y}_{t-1} + \epsilon^\pi_t \tag{2}$$

Where $\tilde{y}_t$ is the output gap, calculated as $\tilde{y}_t = 100(y_t - y^*_t)$, in which y_t is the logarithm of real GDP and y^*_t is the logarithm of the unobserved natural rate of output. In (2), π_t is the consumer price inflation, and $\pi_{t-2,4}$ represents the average of its second to fourth lags. In (1), r_t denotes the real short-term interest rate, r^*_t is the natural rate of interest, which is assumed to follow the law of motion:

$$r^*_t = c g_t + z_t \tag{3}$$

In which g_t is the trend growth rate of the natural rate of output and z_t captures other determinants of r^*_t. As represented by c, the trend growth rate and the natural rate of interest are not assumed to follow a one-to-one relationship.

The logarithm of potential output is assumed to follow a random walk with a stochastic drift g, which, along with z, follows a random walk:

$$y_t^* = y_{t-1}^* + g_{t-1} + \epsilon_{y^*,t} \tag{4}$$

$$g_t = g_{t-1} + \epsilon_{g,t} \tag{5}$$

$$z_t = z_{t-1} + \epsilon_{z,t} \tag{6}$$

3.1.2 Estimation Procedure

The estimation procedure in HLW follows three steps. In the first step, the interest rate gap is omitted in the IS equation (1) and g is assumed constant, so as to calculate the natural rate of output via Kalman filter. The median unbiased estimator of the signal-to-noise ratio $\lambda_g = \frac{\sigma_g}{\sigma_{y^*}}$ is calculated and then incorporated in the second step, along with the real interest gap in the IS equation (1) and, assuming that z is constant, the model equations are estimated. The median unbiased estimator of the signal-to-noise ratio $\lambda_z = \frac{a_r \sigma_z}{\sigma_{\tilde{y}}}$ is then calculated. In the final step, the remaining model parameters are estimated using the values of λ_g and λ_z.

Due to the specific nature of Brazilian data, characterized by periods of both high inflation and interest rates, the lower bound of b_y[1] was increased to 0.25, following Moreira (2019), who argues that maintaining the original restriction of $b_y > 0.025$ led to inconsistencies in the estimation. On the other hand, the upper bound for a_r[2] remained -0.0025, as per the original model.

3.1.3 COVID-19 adjustments

Holston, Laubach, and Williams (2023) address two issues that arise when applying the HLW method to COVID-19 data.

Firstly, COVID-19 represents an extreme tail event, and therefore the GDP and inflation data collected in this period violate the assumption that the IS and Phillips curve equations follow a Gaussian distribution.

In HLW 2023, this is solved by allowing variances of the stochastic innovations to the these equations to be higher during the pandemic, while maintaining the

[1] The parameter which represents the slope of the Phillips curve in Equation 2
[2] The slope of the IS curve in Equation 1

assumption that the stochastic innovations to the equations of y^*, g and z are normally distributed. This is accomplished by introducing a new parameter k_t which multiplies the variances of the innovations to the IS and Phillips curve equations and is estimated by maximum likelihood for 2020, 2021 and 2022, while assuming value 1 otherwise.

Secondly, the effects on output and inflation of the sequence of lockdowns and re-openings that took place during the pandemic display serial correlation, which is inconsistent with the model assumption that stochastic innovations to the IS and Phillips curve equations are mutually uncorrelated. To solve this issue, an additional supply shock is incorporated as an adjustment to the level of potential output in the output gap specification:

$$\tilde{y}_{t,COVID-adj.} = 100(y_t - y_t^*) + \phi d_t \tag{7}$$

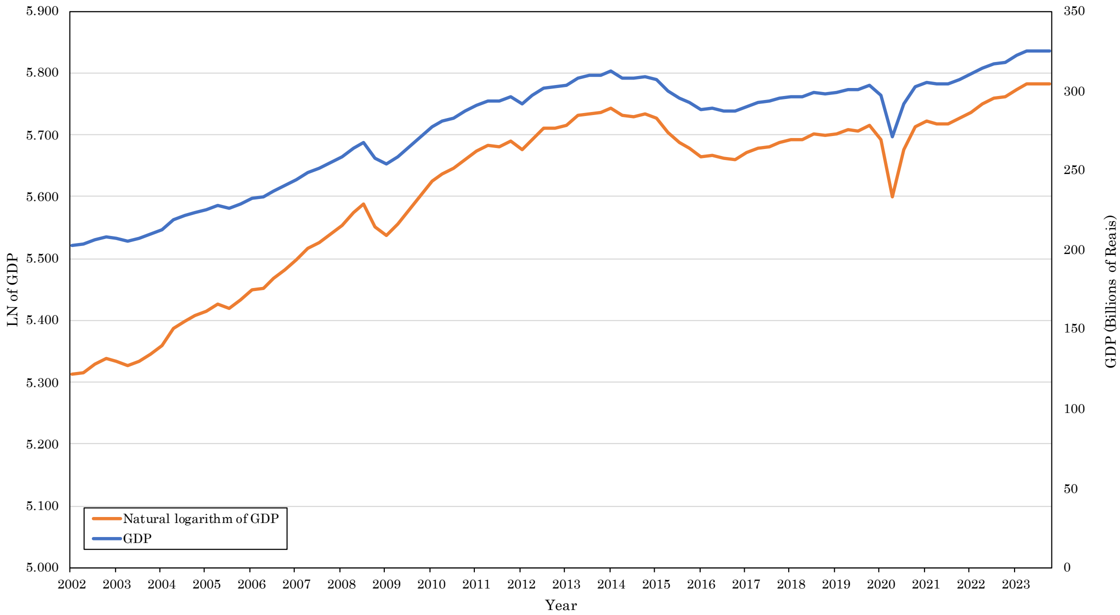
Where d_t is a proxy for the direct effects of the government restrictions implemented during the pandemic, and equals the quarterly average of the COVID-19 Stringency Index from the Oxford COVID-19 Government Response Tracker. Moreover, ϕ is an estimated parameter which translates d_t into effects on output.

4 Data

The HLW COVID-Adjusted model takes as input data for GDP, inflation, inflation expectations, the nominal interest rate, and a COVID indicator variable, to act as proxy for the lockdowns implemented during the pandemic. The data was collected from the Brazilian Institute of Geography and Statistics (IBGE) and from the Brazilian Central Bank (BCB).

The GDP data used was the natural logarithm of seasonally adjusted GDP at market prices, in billions of chained 1995 Brazilian Reais, as shown in Figure 2. This data was retrieved from the 6613 series table of the SIDRA data system (IBGE, 2024a).

Figure 2 – Brazilian real GDP and natural logarithm of GDP from 2002 to 2023



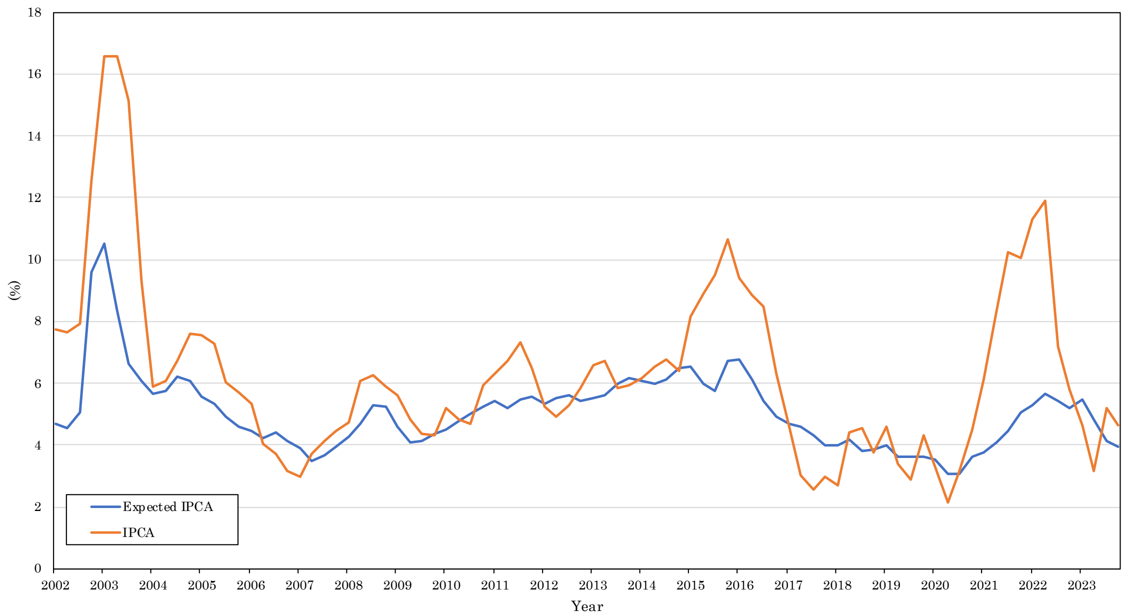
Source: IBGE (2024a). Compiled by the author.

Figure 3 shows the data for both inflation and inflation expectations. The inflation measure was calculated as the accumulated percentage change of the previous four quarters of the Brazilian consumer price index (IPCA), which was obtained from the 1737 series table of the SIDRA data system (IBGE, 2024b).

For the expected inflation, which the model subtracts from the nominal interest rate to calculate the ex-ante real interest rate, the median of the smoothed 12-month-ahead IPCA expectation from the FOCUS survey was used, as found in the

Market Expectations System (BCB, 2024c). Because the BCB's FOCUS survey - which compiles economic indicators forecasts from banks, asset managers and other institutions - only started being published in 2002, and because the estimation process uses data beginning 4 quarters prior to the sample start, the estimation timeline ranges from the first quarter of 2003 (Q1 2003) to the fourth quarter of 2023 (similarly, Q4 2023).

Figure 3 – IPCA and expected IPCA in Brazil from 2002 to 2023



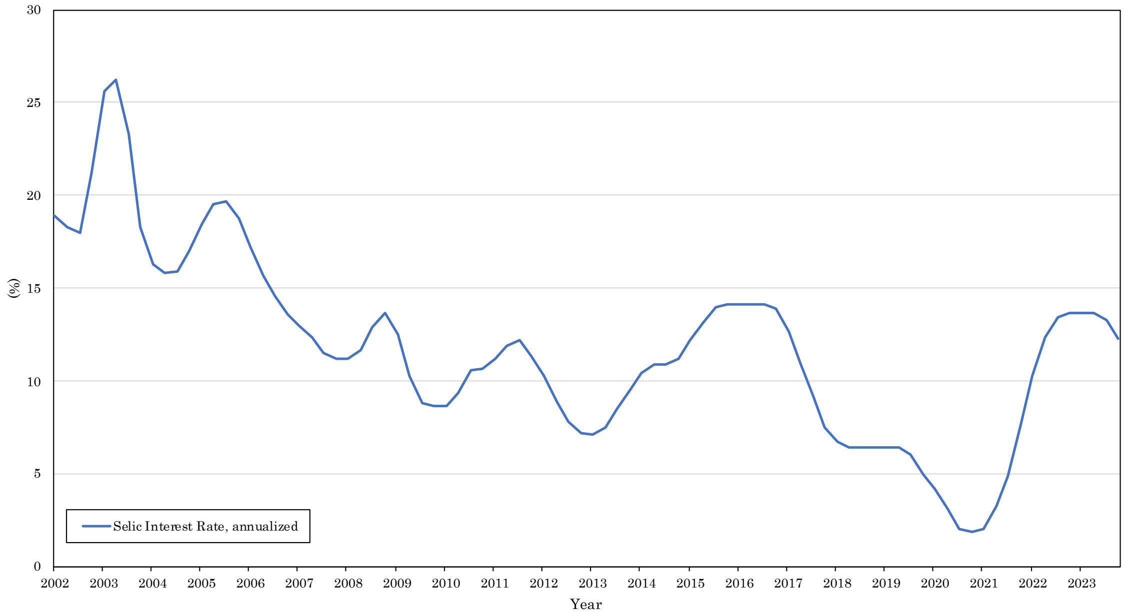
Source: IBGE (2024b) and BCB (2024c). Compiled by the author.

For the nominal interest rate - depicted in Figure 4 -, the Selic[1] daily rate was compounded for each quarter and subsequently annualized. The Selic interest rate used can be in found in the SGS data system (BCB, 2024d), series code 11.

Lastly, the COVID indicator variable used was the "Government Response Stringency Index" for Brazil from the Oxford Covid-19 Government Response Tracker (OxCGRT) (Hale et al., 2021), displayed in Figure 5. This variable was set equal to zero from 2002 to Q4 2019 and, as it ceased being disclosed in Q4 2022, a linear decay was calculated which would reach zero in Q4 2024, as conducted by Holston, Laubach, and Williams (2023).

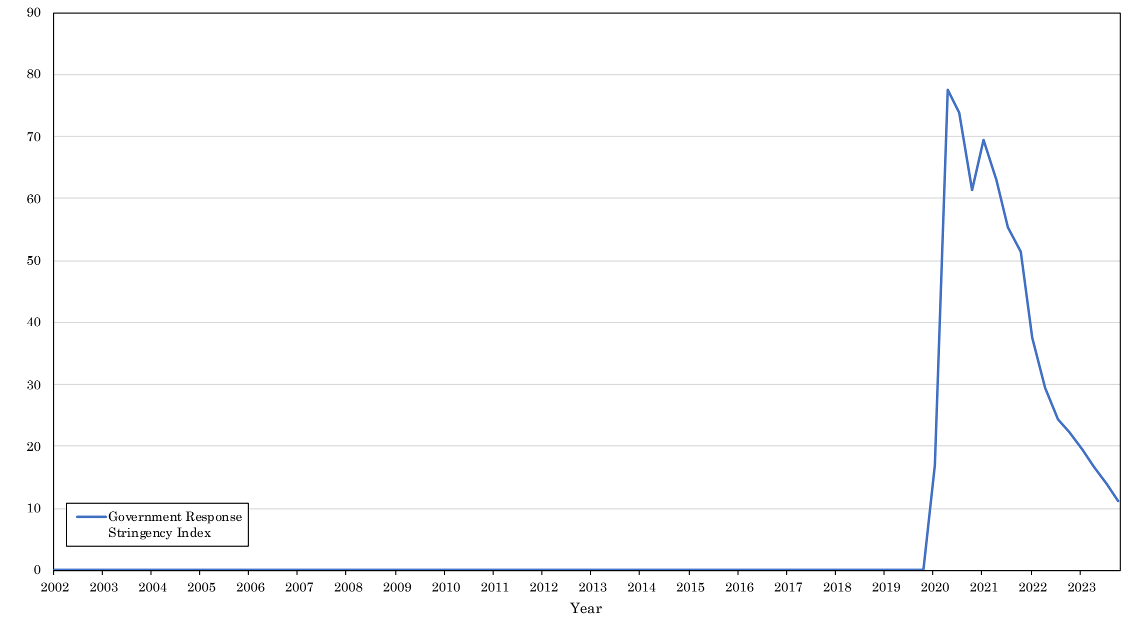
[1] Selic is the interest rate used by the BCB in the implementation of monetary policy. (BCB, 2024b)

Figure 4 – Annualized quarterly Selic interest rate in Brazil from 2002 to 2023



Source: BCB (2024d). Compiled by the author.

Figure 5 – Government Response Stringency Index for Brazil from 2002 to 2023



Source: Hale et al. (2021). Compiled by the author.

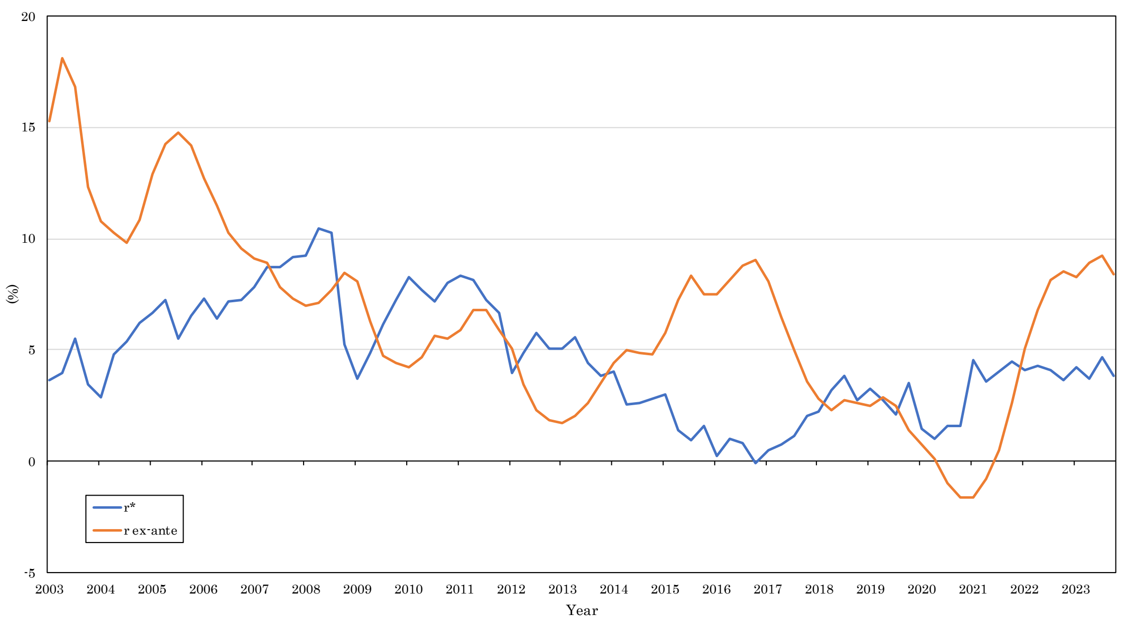
5 Estimation Results

5.1 Estimates of r^*, g and $\tilde{y}$

The resulting variables of the HLW 2023 model are the trajectory of the natural interest rate (r^*), the trend growth rate of the natural rate of output (g) and the output gap ($\tilde{y}$).

In order to interpret r^*, its trajectory was compared to the ex-ante real interest rate (r) in Figure 6. As discussed in Chapter 1, if r is greater (lesser) than r^*, this should generate a restrictive (expansionary) effect on the economy.

Figure 6 – Estimated trajectory of the natural interest rate (r^*) and ex-ante real interest rate (r ex-ante) in Brazil from 2003 to 2023

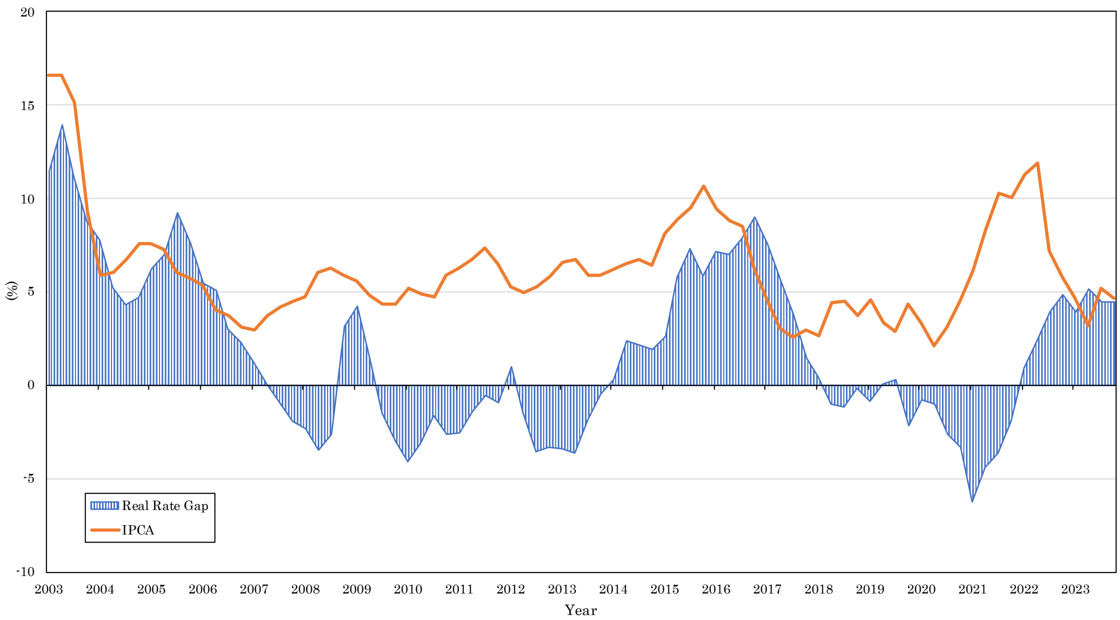


Source: BCB, IBGE, and Holston, Laubach, and Williams (2023). Calculations by the author.

Figure 7 illustrates this from another perspective, contrasting inflation[1] to the estimated real rate gap, calculated as the difference between the natural interest rate and the ex-ante real interest rate and thus a proxy for the monetary policy's effect on the economy.

[1] Represented by the Brazilian consumer price index, IPCA, whose rise would prompt the BCB to tighten monetary policy

Figure 7 – Inflation and estimated real rate gap in Brazil from 2003 to 2023



Source: BCB, IBGE, and Holston, Laubach, and Williams (2023). Calculations by the author.

From Q1 2003 to Q2 2007, r exceeds r^*, which would imply a restrictive monetary policy was set in place by the BCB. As we can see in Figure 7, inflation was high in the beginning of this interval. With a slowdown in both inflation and the uncertainty that marked the beginning of then President Lula's first term, the BCB is able to ease interest rates, which contributed to the recovery of activity that followed (Abreu, 2015).

During the same period, r^* is in an upward trajectory. This movement could be attributed to a rise in productivity, as this was a period of expansion of the global economy (Malan, 2018). Another contributing driver could be a fall of income distribution inequality, since the per capita income of the poorest 20% of the population grew much more rapidly from 2002 to 2010 than that of the richest 10% (Abreu, 2015).

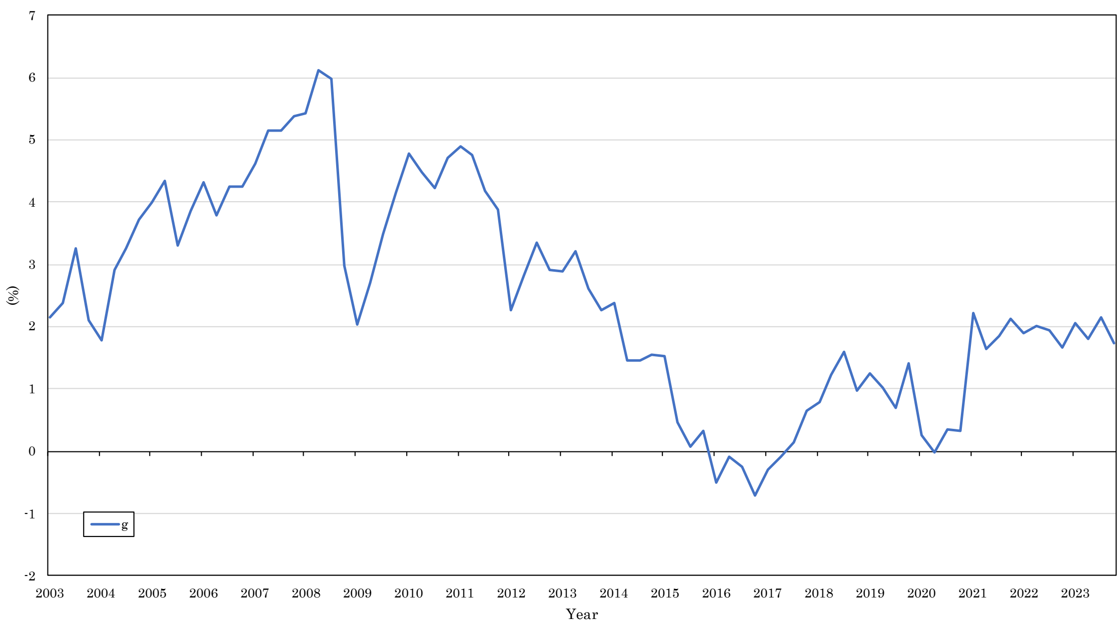
Another interval which indicates a noticeable tightening of monetary policy is between Q1 2014 and Q2 2018. From 2014 to 2016 there is both a rise in r - probably in response to a surge in inflation, which peaked at 10.7% at the end of 2015 - and a decline in r^*, in all likelihood associated to the recession that marked the Brazilian economy at this time. Following that, from 2017 to 2018, there is an easing of monetary policy, as inflation subsides and the Brazilian economy starts to recover.

By the start of the COVID-19 pandemic, the BCB had already begun to cut interest rates since Q3 2019, and continues to do so until reaching the historical low of 2% in October of 2020, where the Selic target remains until January of 2021 (BCB, 2024e). Meanwhile, r^* also drops considerably, averaging 1.4% in 2020, as we can see in Figure 6. This could be linked to a decline in productivity caused by the lockdowns implemented as means to reduce the spread of the virus. Even so, an extraordinarily high level of monetary stimulus is generated throughout the economy (BCB, 2020). As a reaction to the subsequent rise of inflation - which reaches 10.3% in Q3 2021 and 11.9% in Q2 2022 -, the BCB begins to tighten monetary policy in 2021, and only starts to cut rates again in Q3 2023.

In the meantime, r^* rebounds in Q1 2021 to 4.57%, and has revolved around 4% ever since, notably higher than the 3% average of 2018 and 2019. Thus, the estimation results indicate that the Brazilian natural interest rate has remained in a higher level afterwards the pandemic.

There are many factors which could explain this movement. Firstly, there was an increase in the trend growth rate of the natural rate of output, as we see in Figure 8. As discussed in Chapter 2, a rise of productivity in the economy could lead to a rise in r^*.

Figure 8 – Estimated trajectory of the trend growth rate of the natural rate of output (g) in Brazil from 2003 to 2023



Source: BCB, IBGE, and Holston, Laubach, and Williams (2023). Calculations by the author.

Nazareno and Galvao (2023) study the impacts of the pandemic and of the Emergency Aid program[2] on inequality, poverty, unemployment, and labour force participation in Brazil. They find that inequality and poverty were reduced considerably, as the Emergency Aid effectively addressed the needs of the most vulnerable.

As discussed in Chapter 2, theoretically a reduction in inequality should lead to a higher r^*, due to a decrease in aggregate savings. Additionally, the higher government borrowing which financed the Emergency Aid could drive up the demand for savings and consequently the natural interest rate.

Although one could argue that the Emergency Aid does not constitute a long-term structured program, and therefore should not have a significant impact in the saving behaviour of the population, it was followed by an expansion of permanent social welfare policy in Brazil in 2021 with the Auxílio Brasil. The Auxílio Brasil was a social welfare program established in 2021 designed to replace and expand the scope of Bolsa Família, increasing the amount each family received and the number of covered families. (Duque, 2024). In this case, it could have a positive effect on r^*, by means of discouraging savings.

Table 2 displays the parameters estimated in the model and Figures 9 shows the estimated output gap ($\tilde{y}$).

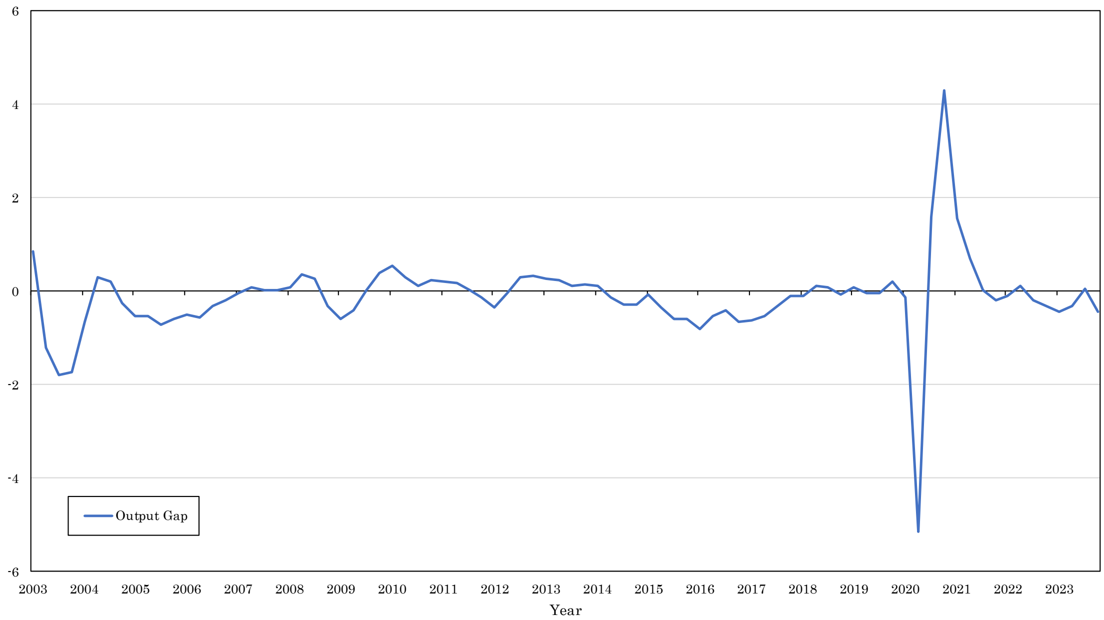
[2] An emergency cash transfer policy set in place by the Brazilian government, in which 4% of the country's 2020 GDP was transferred to 39% of Brazilian households. (Nazareno and Galvao, 2023)

Table 2 – Estimated Parameters

Parameters	Values
λ_g	0.17
λ_z	0.05
$a_{y,1}$	0.70
	(4.26)
$a_{y,2}$	-0.59
	(4.19)
a_r	-0.07
	(2.67)
b_π	0.97
	(9.49)
b_y	1.70
	(3.84)
$\sigma_{\tilde{y}}$	0.17
	(2.53)
σ_π	0.78
	(8.28)
σ_y^*	0.92
	(17.10)
ϕ	-0.06
	(3.15)
c	1.69
	(2.85)
$\kappa_{2020Q2-Q4}$	19.51
	(1.74)
κ_{2021}	1.00
	(1.01)
κ_{2022}	2.91
	(2.96)
	Standard error (sample average)
y^*	0.41
r^*	1.75
g	1.06
	Standard error (final observation)
y^*	0.42
r^*	2.15
g	1.48
	Restrictions
a_r	≤ -0.0025
b_y	≥ 0.25

Source: BCB, IBGE, and Holston, Laubach, and Williams (2023).
Calculations by the author.
Note: t-statistics are in parenthesis

Figure 9 – Estimated trajectory of the output gap in Brazil from 2003 to 2023



Source: BCB, IBGE, and Holston, Laubach, and Williams (2023). Calculations by the author.

5.2 Comparison to peers

BCB (2023a) estimates r^* for Q1 2023 in Brazil using a variety of methods in their June 2023 Inflation Report, and their results are summarized in Table 1. These results have a mean and median of 4.8%, above our estimation of 4.2% for the same quarter.

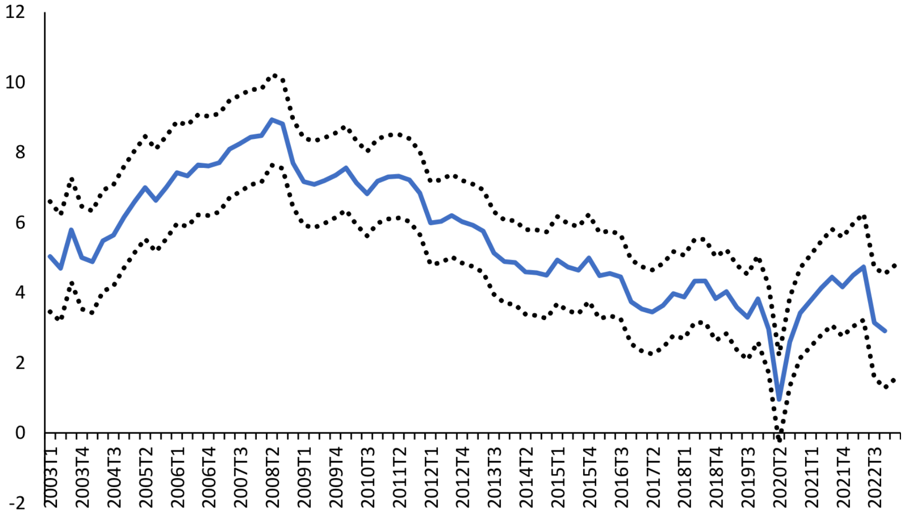
Carvalho (2023) offers an interesting contrast, as it estimates r^* in a similar interval, but using HLW 2017, which is not adjusted for COVID. Most likely because of this, their estimated decline of r^* in 2020 is much more pronounced than in our results, as shown in Figure 10. Moreover, despite there also being a 2021 rebound in r^*, their last data points suggest an inflection in r^*'s trajectory to lower levels, as opposed this study.

Moreira (2019) also estimates r^* using the HLW 2017 model, but from 3Q1999 to 1Q2018, as shown in Figure 11. Their estimated r^* averages 3.9% from Q2 2014 to Q1 2018, while ours averaged 1.48% for the same interval.

Gottlieb (2013) applies Laubach and Williams (2003) to estimate r^* from 2005 to 2012, but adds a global output gap $\tilde{y}^{global}$ [3] to the IS curve (Equation 1) in order to

[3] $\tilde{y}^{global} = \gamma(y^{global}_{t-1} - y^{*global}_{t-1})$

Figure 10 – Estimated trajectory of r^* in Brazil from 2003 to 2022, by Carvalho (2023)



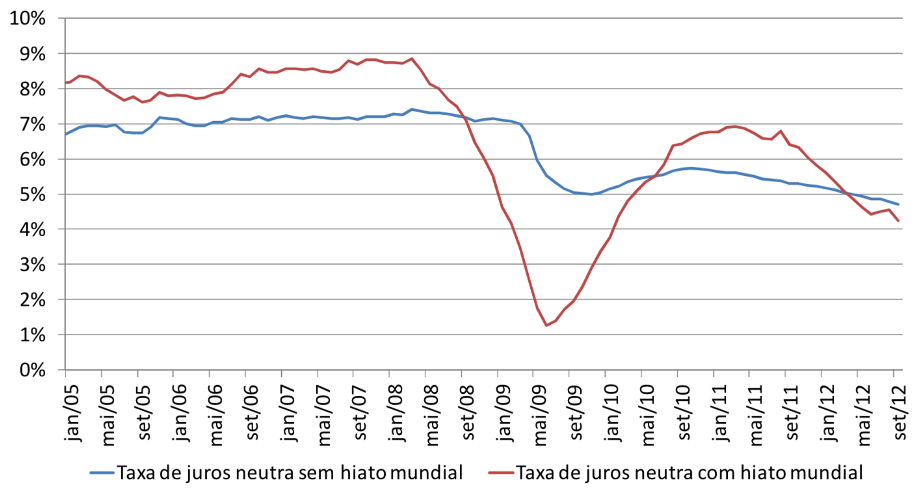
Source: Carvalho (2023)

Figure 11 – Ex-ante r (“Taxa Real ex-ante”) and estimated trajectory of r^* in Brazil from 1999 to 2018, by Moreira (2019)

Source: Moreira (2019)

capture an international factor, particularly significant in global crises such as 2008. Figure 12 shows the authors estimations for r^* with and without $\tilde{y}^{global}$. We can see that, in the specification with $\tilde{y}^{global}$, the impact of the 2008 crisis is much greater. Considering the specification without $\tilde{y}^{global}$, which is the most comparable to this study, the author's results for r^* are lower than ours: they average 6.62% from 2005 to 2010 and 5.22% from 2011 to 2012, while ours average 7.37% and 6.26% for the same intervals, respectively.

Figure 12 – Estimated trajectory of r^* in Brazil from 2005 to 2012, with ("Taxa de juros neutra com hiato mundial") and without ("Taxa de juros neutra sem hiato mundial") a global output gap, by Gottlieb (2013)



Source: Gottlieb (2013)

Table 3 displays the average of r^* estimated in this study for selected periods of time and compares it to the results of Carvalho (2023), Moreira (2019) and Gottlieb (2013). This study's results for r^* were consistently below that of Carvalho (2023) and Moreira (2019) - who estimate r^* with HLW 2017 - and above that of Gottlieb (2013) - who apply LW 2003 in their estimation.

Table 3 – Comparing averages of estimated r^* (in percentage) in selected intervals to peers

<table>
<tr><th>Interval</th><th>Gottlieb (2013)</th><th>This study</th><th>Carvalho (2023)</th><th>Moreira (2019)</th></tr>
<tr><td>2002</td><td rowspan="3"></td><td></td><td></td><td rowspan="4">7.8[1]</td></tr>
<tr><td>2003</td><td rowspan="2">4.50</td><td rowspan="6">7.3</td></tr>
<tr><td>2004</td></tr>
<tr><td>2005</td><td rowspan="6">6.62</td><td rowspan="4">7.74</td></tr>
<tr><td>2006</td><td></td></tr>
<tr><td>2007</td><td rowspan="3">7.7[2]</td></tr>
<tr><td>2008</td></tr>
<tr><td>2009</td><td rowspan="2">6.63</td><td rowspan="8">5.06</td></tr>
<tr><td>2010</td><td></td></tr>
<tr><td>2011</td><td rowspan="2">5.22</td><td rowspan="2">6.26</td><td rowspan="3">7.2</td></tr>
<tr><td>2012</td></tr>
<tr><td>2013</td><td rowspan="11"></td><td rowspan="4">2.49</td></tr>
<tr><td>2014</td><td rowspan="3">4.9[3]</td></tr>
<tr><td>2015</td></tr>
<tr><td>2016</td></tr>
<tr><td>2017</td><td rowspan="3">2.34</td><td rowspan="3">3.47</td><td>1.7</td></tr>
<tr><td>2018</td><td>1.4</td></tr>
<tr><td>2019</td><td rowspan="5"></td></tr>
<tr><td>2020</td><td>1.41</td><td rowspan="3">3.34</td></tr>
<tr><td>2021</td><td>4.15</td></tr>
<tr><td>2022</td><td>4.04</td></tr>
<tr><td>2023</td><td>4.11</td><td></td></tr>
</table>

Source: Carvalho (2023), Moreira (2019), Gottlieb (2013) and calculations by the author

[1]excludes 1Q 2002

[2]excludes 1Q 2007

[3]excludes 1Q 2014

6 Concluding Remarks

In times of crisis, policymakers' fast and effective response, based on precedent literature, is central to avoiding further economic downturns - be it in a pandemic, or other economic shocks. This thesis aims to add to the current literature's understanding of the economic impacts of the COVID-19 pandemic, and whether these will prove to be lasting. More specifically, it aims to assess how the changes the pandemic generated in our society, be it on the labour market, on public debt, or on the population's saving behavior, have affected the natural interest rate in the long run.

To that end, this study's purpose is to estimate the natural interest rate during and after the pandemic, as well as to analyze the drivers behind these movements. Our estimation results for the trajectory of the Brazilian natural interest rate can be found in Figure 6 in Section 5.1, spanning from 2003 to 2023. While adjusting for the pandemic period, they were slightly lower than that of most analyzed peers, as seen on Table 3 in Section 5.2.

Furthermore, we found that r^* averaged 4.08% in the years following the pandemic, 2022 and 2023, as opposed to 2.96% in 2018 and 2019. There are many drivers which could explain this movement, such as a rise in the trend growth rate of the natural rate of output, lower inequality, higher social welfare transfers and higher government borrowing. These specific impacts have not been tested on this study and present an opportunity for further research.

The Laubach-Williams model was used, which applies the Kalman filter to jointly estimate the (i) natural interest rate, (ii) the potential output and (iii) its trend growth rate. We followed Holston, Laubach, and Williams (2023), adjusted to the volatility and serial correlation displayed in data from the pandemic period. The IMF (2023) raised doubts as to whether the LW Model is fit to be applied to emerging economies, as it was originally designed for advanced economies. In this sense, and due to the nature of Brazilian data, we followed guidelines of Moreira (2019) in adjusting parameters, specifically b_y, which represents the slope of the Phillips curve.

Most recently, in their June 2024 reunion, the Monetary Policy Committee (Copom) of the BCB elevated the assumption for the natural interest rate to be used in their models to 4.75% BCB (2024a). Although their estimates of r^* are higher than that of this study (our latest output data point is a 4.11% average in

2023), their decision corroborates to the notion of a presently higher natural interest rate, as discussed above and throughout Chapter 5 (Results), indicating the need of a more restrictive monetary policy in order to control inflation and therefore a more costly disinflation process.

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