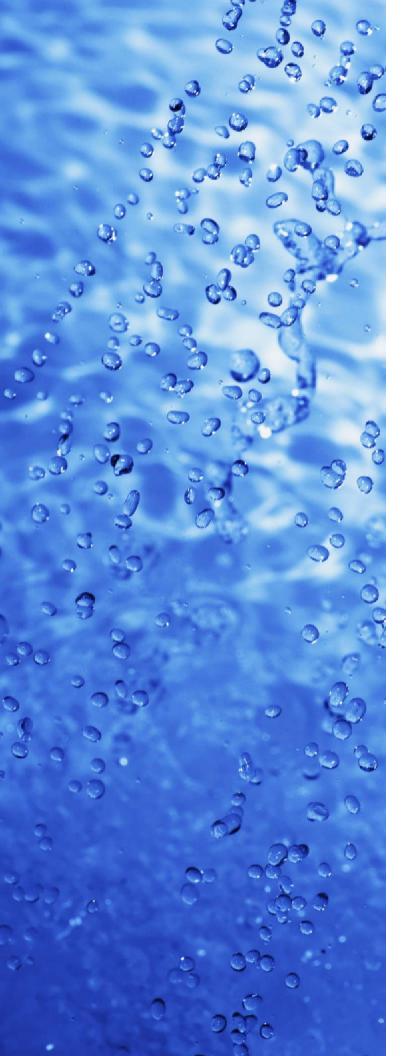
# FUTURE WATER DEMAND IN 2050: EFFICIENCY AND CLIMATE CHANGE CHALLENGES













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# 1

### INTRODUCTION

In 2020, according to the Environmental-Economic Accounting for Water in Brazil (IBGE, 2023), Brazilian households used approximately 9,084 million m³ of water, of which approximately 8,392 million m³ came from water distribution networks and 692 million m³ were directly collected on the properties for self-consumption. This volume is practically the same as that observed in 2013, indicating that residential water consumption expanded very little — only 2.1% over the course of those seven years.

This evolution partly reflects the water crisis that began in 2014, but it is also a result of low-income growth and reduced demographic expansion. These factors influence consumption growth trends, which are also decisively affected by urbanization patterns and by the coverage and regularity of water supply systems.

This study aims to outline future water demand scenarios in Brazilian households in 2050, identifying the main variables that shape different trends in consumption growth. The purpose of developing demand scenarios is to capture the potential future demand for water under different economic, demographic, consumption patterns, and environmental conditions.

The analysis takes into account statistics on water consumption, demographics, and the economy from 2008 to 2023, and is based on academic literature on the subject. In this study, we employed a classical methodology to design future demand scenarios. This methodology is widely applied in prospective analyses of sales and production of goods and services in the economy

in general. It is used for long-term planning, whether by companies or by the public sector, a particularly important aspect in the management of environmental resources.

A good example of the application of this methodology to the design of future water demand scenarios is the study developed by researchers from the University of Illinois at Urbana-Champaign for the State of Illinois Department of Natural Resources [Meyer et al. (2019)]. The study by Meyer et al. (2019) projects global water demand in the Rock River Basin for 2060, both for domestic use and for economic purposes (agriculture, industry, and services). The methodology begins with an analysis of the determinants of water demand, which identifies the conditions that affect the level of consumption, in order to project water demand under different scenarios. Scenarios are sets of different conditions that represent the spectrum of economic, demographic, consumption patterns, and environmental possibilities.

Following this methodology, the present study first analyzes the relationships between population, income, degree of urbanization, and climate, on the one hand, and household water consumption, on the other. This analysis is used to estimate the volume of water consumed in municipalities that do not report this statistic to the Ministry of Cities or that report it in a non-standardized manner. This procedure makes it possible to estimate Brazil's consumption level more accurately and to assess the situation of municipalities in the reference year of the analysis (2023).

Then, the study outlines four demand scenarios based on projections of demographic expansion, economic

growth, and consumption patterns between 2023 and 2050. Following Meyer et al. (2019), the present study employs a single demographic scenario, with individualized rates for each Brazilian municipality. The four consumption scenarios differ from each other due to:

(i) different economic contexts – more or less optimistic – which lead to distinct projections of per capita income growth across Brazilian states and municipalities; and

(ii) consumption contexts that depend on the coverage of water supply services and on the degree of urbanization in Brazilian cities. Regarding this second aspect, the perspectives vary according to the year in which the universalization targets set by the New Sanitation Regulatory Framework will be achieved – either in 2033, as intended, or in 2040.

Finally, these scenarios are used to project (i) the evolution of per capita water consumption, by municipality and by state, and (ii) the expansion of total demand for treated water in these regions between 2023 and 2050.

#### Main findings

The findings of the study reveal that the expansion of water demand will be significant, which poses a major challenge for system operators, as increasing water supply over the next 27 years will require substantial effort. In addition, climate risks introduce new concerns. The main findings are as follows:

 The analyses identified a significant increase in demand associated with demographic expansion, economic growth, and the universalization of service coverage for households. The estimates

- show that consumption growth may reach 59.3% over 27 years. In this situation, consistent with a faster economic growth path, in which GDP per capita increases at a rate of 2.7% per year, potential water demand is expected to reach 17.224 billion m<sup>3</sup> in 2050.
- 2. Assuming that potential water demand is fully met in 2050, it will be necessary to deliver 7.249 million m<sup>3</sup> more water to Brazilian cities than what was effectively delivered in 2023. The increase in demand would therefore be 72.7% in 27 years, requiring a supply expansion of at least 2.0% per year over 27 years for demand to be fully met.
- 3. Given the current level of losses, meeting future water demand through 2050 would require a very large increase in production. Considering that additional consumption up to 2050 will amount to 6.414 billion m<sup>3</sup>, the additional water production required would be 10.672 billion m<sup>3</sup>, which corresponds to a 59.3% increase compared to the water production level in the sanitation sector in 2023 (GTA1001 from SINISA), which was 18.002 billion m<sup>3</sup>.
- 4. Part of this issue could be mitigated by reducing water losses in distribution. According to SINISA data, the average water loss in distribution in the country was 39.9% in 2023, meaning that for every



100 liters of water captured and treated, approximately 40 liters did not reach the population. In that year, total losses reached 7.257 billion m<sup>3</sup>. This volume would be sufficient to supply the incremental future water demand through 2050.

- 5. This strongly suggests that meeting future incremental water demand should be achieved, to a large extent, faster through а process rationalization and reduction of distribution losses. With losses reduced to 20%, the required water production would be 2.726 billion m<sup>3</sup> lower than it would be if losses remained at their current level. This would help supply incremental demand without placing such intense additional extraction pressure on water sources.
- 6. Another extremely important issue within more-than-two-decade this analytical horizon is climate change. Reports from the Green Climate Fund -GCF (2017) - and from the Brazilian Panel on Climate Change (2014) identified that climate change involves increased temperature, variations in precipitation, rising sea transformations in climate patterns, and risk of water shortages.
- 7. The parameters of the econometric climate analysis model presented in this study indicate a trend of increasing both maximum and minimum annual temperatures in Brazil through 2050, along with an increase in temperature range. The maximum temperature

- is expected to rise by approximately 1°C compared to 2023, and the minimum temperature is expected to increase by 0.47°C, indicating an increase in temperature range of 0.52°C by 2050. Other trends include a reduction in the number of rainy days and the occurrence of more intense rainfall events, two additional factors that affect water supply and demand in Brazilian cities.
- 8. Based on this trend and on the parameters of the demand equation, climate change is expected to further increase per capita water consumption among Brazilian households. Due to temperature increases, consumption is expected to grow 12.4% in addition to the growth driven by economic and demographic factors. This would result in incremental demand of 2.113 billion m<sup>3</sup> per year and require an additional 3.515 billion m<sup>3</sup> per year of water production (assuming the 2023 level of distribution losses remains unchanged). This indicates challenges even greater than those associated with demographic and economic expansion, due to ongoing climate change.
- 9. Beyond the increase in consumption, it should be noted that projected climate change through 2050 may also disrupt the balance between water supply and demand due to other factors. Increasing temperatures and the prospect of fewer rainy days may lead several regions of the country toward desertification and expand the area of the Brazilian semiarid region, which includes the driest municipalities and those facing greater

difficulty in meeting demand. In the regions that are already drier, warming may lead to supply failures with high probability.

10. On average, considering Brazilian cities as a whole, climate trends point to a 3.4% supply restriction over the course of the year. This means that the country will experience, on average, about 12 days of water rationing per year. In regions where average precipitation and number of rainy days are already lower – such as parts of the Northeast and Central-West - rationing is expected to exceed 30 days, with severe consequences for public health and quality of life.

#### **Analysis outline**

In addition to this introduction, the study contains four sections with the following distribution of topics:

Chapter 2: presents the analysis of the determinants of residential water demand. considering the international literature on the subject and the estimates based on information from Brazilian municipalities;

Chapter 3: presents the methodology used in the analyses of economic growth and demographic dynamics, and provides the estimates from the econometric models;

**Chapter 4**: outlines the scenarios for the 2050 horizon and presents projections of per capita water consumption in municipalities and states, considering different economic and consumption pattern scenarios;

Chapter 5: discusses important two environmental issues related to the theme: (i) water losses distribution within the supply system, and (ii) the potential effect of climate change on the balance between demand and supply of treated water.

The document concludes with the bibliography and the methodological annexes.



## Determinants of water demand

#### 2.1. Methodological approaches

The articles by Epsey et al. (1997) and Arbués et al. (2003) provide strong reviews of studies and methodologies used to estimate the determinants of residential water consumption. Both articles review studies on the price elasticity of residential water demand published between 1967 and 2002. There are three main approaches: microeconomic studies, mesoeconomic studies, and macroeconomic studies.

The so-called micro approach analyzes household consumption data and correlates water use patterns with socioeconomic and locational information from residences. The historical reference for this approach is the study by Howe and Linaweaver (1967). In addition to allowing the measurement of the effects of water price and income on consumption, fundamental parameters for market analyses, this type of approach enables a more precise assessment of the influence of locational factors and household and housing characteristics on water demand.

The approach based on municipality or district-level estimates, consisting of mesoeconomic studies, is the most prevalent in the literature. It evaluates information at a more aggregated level, considering average data from regional units. Examples of this approach include the study by Schleich and Hillenbrand (2009), which analyzes demand in 600 water supply areas in Germany, and the study by Meyer et al. (2019), which analyzes district-level data from municipalities in the Rock River Basin in Illinois, United States. The study by Wentz and Gober (2007) develops a spatial analysis of residential water demand in the city of Phoenix, Arizona. In this latter study, the city was divided into quadrants, each representing a household water consumption lot.

In addition to these approaches, there are macroeconomic studies that analyze even more aggregated data for large regions, such as states, provinces, or countries.

An example of this approach is the study by Babel et al. (2007) for the Kathmandu region in Nepal. Another example is the model developed by Corral, Fischer, and Hatch (1999), who analyze the determinants of water demand and the price elasticity of demand using aggregated data from three districts of the city of San Francisco, in the United States.

The predominance of mesoeconomic studies is justified by two factors: municipal planning authority and data availability. Water operations are mostly organized at the municipal territorial level, so average per capita consumption has meaningful interpretation, while these studies can be carried out using consolidated data from sanitation utilities, without requiring household surveys, which involve higher data collection costs. Moreover, authors who adopt a mesoeconomic approach argue that it offers the advantages of allowing information to be aggregated into broader levels (states, provinces, or watersheds, for example) and that the databases provide a larger volume of observations. In the case of Brazil, the volume of municipal information on sanitation and the regularity with which it is collected are much greater than what is available for macroeconomic and microeconomic data.

Regardless of the approach, the main objective is to establish the theoretical relationships that describe the determinants of water consumption. In this view, the volume of water consumed in a given society – which is called the dependent variable – is determined by demographic, economic, technical, and social factors – called independent or explanatory variables – which are generally considered exogenous.

Many hypothetical relationships have been formulated, and many independent variables have been tested to explain the quantity of water demanded, but there is a set of indicators that appears in most analyses available in the literature.

Epsey et al. (1997) highlight the following independent variables: water price, average household income, population density, household size, seasonality, evapotranspiration, average temperature, and geographic location. Arbués et al. (2003) emphasize a similar set: water price, average income, climate, household density, physical characteristics of dwellings, billing method, and type of use (indoor vs. outdoor).

In addition to these overlapping variables, Meyer et al. (2019) include the share of the economically active population in the total population of each city in the sample as one of the explanatory variables. Wentz and Gober (2007), in turn, consider the percentage of homes with swimming pools, the average lot size, the share of lot area used for non-residential purposes, and the average size of residences in each area. The study by Schleich and Hillenbrand (2009) includes in its set of explanatory variables the percentage of dwellings with a well for water extraction.

The theoretical relationships are estimated using econometric techniques that employ statistical information on both dependent and independent variables. Time-series models use historical information, preferably over long periods, with 20 to 30 observations per dependent variable, to obtain an adequate number of degrees of freedom for inference. Cross-section models rely on data from different regional units – as in studies that use municipalities as the regional unit – at a given point in time. Finally, there is the possibility of combining time-series techniques with cross-sectional data, a method known as panel analysis. In this unified view of the two statistical approaches, the dimensions of time and space act upon the variables, making it possible to identify trends and regularities in the relationships.

In terms of statistical techniques, the studies available in the literature point to the need

to address the issue of simultaneity in determining water supply and demand. The demand for this type of common good, provided by a public utility and subject to administered pricing, is generally constrained by the supply capacity of the operators — on this subject, see Arbués (2003). Simultaneous equation estimation techniques or instrumental variable methods — see Wooldridge (2006) — are the most appropriate for avoiding simultaneity bias when estimating demand coefficients.

### 2.2. Econometric models and database

In this study, we opted for a mesoeconomic modeling approach, in which the basic unit is the average water consumption, in daily liters per inhabitant, in Brazilian municipalities. Among the statistical techniques, the choice fell on panel models, using annual data for the 5,570 Brazilian cities between 2008 and 2023. In the present analysis, in addition to demand conditions, the model simultaneously incorporates the conditions of water supply and the determination of the average consumption price or tariff. A broad set of variables that measure climatic conditions, considered exogenous factors that affect water consumption, was also included in the modeling.

The methodological approach used in this study closely follows that of the article by Meyer et al. (2019), but it incorporates supply conditions and price determination. The difference, therefore, lies in the fact that the price or tariff is not considered a strictly exogenous variable. On the contrary, it is assumed that the price or tariff is determined by the interaction between supply and demand, given supply conditions. The model is a system of simultaneous equations describing behavior (q<sub>D</sub>) and water supply (q<sub>S</sub>) – equations (1) and (2) - the market equilibrium condition equation (3) - and the water price formation mechanism - equation (4). These variables are interconnected and are endogenous variables of the model, meaning that they are determined simultaneously in the market.

. The market equilibrium defines the level of water demanded and supplied per inhabitant per day in a given municipality. In the equations, index i identifies the municipality and index t identifies the time period.

- (1)  $q^D = f(urbanization, income, price, climate)$
- (2)  $q_i^S = f(network coverage, employees, price, climate, losses)$
- $(3) \quad q_i^D = q_i^S$
- (4) p = f(costs, losses, wages, scale)

Daily per capita water demand (supply) is defined by variable IN022 from SNIS and variable IAG2006 from SINISA, which represent the gross daily per capita water consumption in the municipalities. According to SNIS and SINISA definitions, gross daily per capita water consumption is calculated by the volume of water consumed, subtracting the volume of treated water exported, and dividing the result by the total population served by water supply. The consumed volume of water (code AG010 in SNIS and GTA1211 in SINISA), in turn, is defined as: the metered volume (code AG008 and GTA1214 in SINISA), plus the estimated consumption volume for connections without water meters or with non-functioning meters, plus the volume of treated water exported (code AG019 in SNIS and GTA1203 in SINISA) to another service provider.

Therefore, the numerator of per capita consumption takes into account both the effectively metered consumption and an estimated share. In 2023, this estimated share corresponded to 12.7% of the per capita consumption value. In some municipalities, likely due to the estimation rule applied, extremely high values are observed, which are statistical outliers. This is the case of the municipality of Miranda do Norte, whose daily per capita consumption was 6,375 liters. Another example is Fortaleza dos Nogueiras, where daily per capita consumption was reported as 2,325 liters. Despite these issues, the econometric model used has the advantage of

filtering out the portion of consumption considered a measurement error, thus correcting the consumption value for the municipalities in which this occurs. Given the large availability of data and the statistical techniques employed, these measurement errors do not affect the parameter estimates that measure the relationships between dependent and explanatory variables.

Another point that deserves attention is that the variables defining per capita consumption (codes IN022 from SNIS and IAG2006 from SINISA) include urban consumption, which, beyond residential use, also comprises commercial, service (including public sector), and small industrial demand, all customers served by water supply operators. Therefore, it is necessary to include among the explanatory variables an indirect measure of the size of these activities in Brazilian cities.

The water price variable corresponds to the average water tariff indicator (codes IN005 from SNIS and IFA1002 from SINISA). It is defined as the ratio between direct operating revenue from water services and the billed volume of water (excluding exported water).

It is important to highlight that, in the econometric model, the quantity supplied by sanitation operators is the amount that effectively reaches households. Thus, for the purpose of calculating the level of production required to meet demand, distribution losses must be considered in the determination of supply levels. Distribution losses are conceptually an undesired self-consumption of water by sanitation operators. In this sense, distribution losses constitute economic waste or, alternatively, technical inefficiency. By increasing the operator's costs, losses also influence the water price or tariff level in municipalities.

The determinants of daily per capita water demand and supply, as well as of the average water price or tariff, are the following variables: **Coverage:** percentage of the urban population in the municipality with access to treated water supply services (code IN023 from SNIS and IAG0002 from SINISA);

**Income:** total labor income, in BRL per inhabitant per year, estimated using data from the Ministry of Labor (RAIS) and IBGE;

Climate: the climate of a municipality is represented by four variables estimated for Brazilian cities based on data from the National Institute of Meteorology (INMET); the variables are monthly averages of maximum and minimum temperatures recorded throughout the year, the monthly average relative humidity throughout the years, and the monthly average number of rainy days observed in Brazilian cities; the methodology used to estimate these variables is presented in the Methodological Annex;

**Urbanization:** share of the urban population in the total population of the municipalities, based on data from IBGE, SNIS, and SINISA;

**Network:** the length of the water distribution network in the municipality, in meters per inhabitant;

**Employees:** number of employees of the water utility per 100,000 inhabitants;

**Costs:** operating cost per billed m<sup>3</sup> (variable IN026 from SNIS and IFA2004 from SINISA); and

**Average real wage:** index of the average monthly wage paid in the city, a variable that influences labor cost in Brazilian municipalities. This variable is also referred to as labor income.

The study employed the econometric formulation of simultaneous equation estimation using three-stage least squares (3SLS) – for details on the method, see Wooldridge (2006). The estimated equations are linear, as defined in expression (5). The endogenous dependent variables

(5) 
$$y_{it} = \beta_0 + \beta_x X_{it} + u_{it}$$
  $u_{it} \sim N(0,\sigma^2)$ 

**Table 2.1** presents the descriptive statistics of the variables. The sample contained 89,120 observations. However, there were 74,183 cases in which all information required for the econometric model was available. The choice of the period 2008 to 2023 was based on two factors: 2023 is the most recent year with sanitation data available, and 2008 is the first year with more consistent reporting in the SNIS dataset. With the exception of 2023, the year SINISA was created, the number of observations was higher in more recent years.

#### 2.3. Estimation results

**Table 2.2** presents the model adequacy of the estimates of the determinants of the volume of water demanded and supplied in Brazilian municipalities between 2008 and 2023.

**Table 2.1** Descriptive statistics of the variables, 2008 to 2023

		DC	scriptive stati	istics of the v	ariabics, 200	00 10 2025
Variables	Transformatio n	Observations	Mean	Standard deviation	Minimum	Maximum
Per capita water consumption	In	80,258	4.85496	0.40120	-2.30259	8.76013
Income	In	89,120	8.45574	0.92017	0.00000	12.11455
Price or tariff	In	78,086	1.60009	0.76880	-16.06632	7.33208
Degree of industrialization		88,740	0.63955	0.22021	0.01871	1.63839
Network length	In	81,327	1.16408	0.76444	-5.67143	4.85277
Operator employees	In	79,507	4.01976	0.84804	-0.74795	8.92450
Costs	In	80,208	8.84583	0.75846	-6.78744	16.14797
Average city wage	In	89,120	10.37896	3.76646	-3.64860	16.60142
Losses in distribution		78,511	0.32830	0.28369	-53.75000	1.00000
Minimum temperature		89,040	18.83530	2.56243	14.02445	25.45879
Maximum temperature		89,040	29.91975	2.44711	23.94135	36.13954
Rainy days		89,040	11.21668	1.23323	8.53930	17.20134
Relative humidity		89,040	72.27122	3.78720	60.69959	86.11762

Source: Ministry of Cities, Ministry of Labor and Employment, IBGE, and INMET.

Table 2.2
Adequacy of the 3SLS model, 2008 to 2023

6	0.32615	99.6%	17,300,000	0.0%
7	0.33750	99.5%	16,500,000	0.0%
31	0.51351	91.6%	857,715	0.0%
	7	6 0.32615 7 0.33750	6 0.32615 99.6% 7 0.33750 99.5%	6 0.32615 99.6% 17,300,000 7 0.33750 99.5% 16,500,000

Source: Ex Ante Consultoria Econômica.

. All three equations presented very high R<sup>2</sup> values, which could pose a problem of inflated standard errors, given that they are cross-section models estimated using 3SLS. However, this issue is offset by the fact that the sample size is very large. On this point, see Wooldridge (2006).

**Table 2.3**, in turn, shows the estimated coefficients, the standard error of the estimates, the t-statistic, the p-value of the t-statistic, and the confidence interval of the coefficients. In the first block are the estimates for the demand equation, followed by the estimates for the supply and price equations (blocks 2 and 3). All coefficients in the demand equation are significantly different from zero and display the expected signs.

The higher the degree of urbanization of a city, the higher the daily per capita water consumption. For each one-percentage-point increase in the share of the urban population in the municipality's total population, consumption is expected to increase by 0.96%.

Consumption also increases as per capita income rises, as expected, but the negative second derivative makes the income-consumption curve grow at decreasing rates: the higher the municipality's income level, the smaller the effect of economic growth on water demand. The coefficient associated with income was estimated at 1.0265. Considering the average per capita income in Brazil, which was 8.456 in the sample mean, this value is relatively close to that obtained by Schleich and Hillenbrand (2009) when estimating the effects of municipalities' average per capita income on water demand in Germany: 1.452. In Meyer et al. (2019), the influence of average income on water demand in cities in the Rock River Basin, Illinois, is smaller: 0.198.

The water tariff negatively affects demand, but the coefficient is low (-0.254), indicating that water demand is price inelastic: large

price variations are associated with small variations in demand, a typical behavior of regulated-price services. This value is close to those obtained by Schleich and Hillenbrand (2009), -0.242, and by Meyer et al. (2019), -0.122.

Maximum city temperature has a positive effect on demand: the hotter the city, the higher the daily per capita consumption. For each additional degree Celsius, water demand increases by 24.9%. Per capita water demand decreases as minimum temperature increases. The estimated coefficient was -0.267. This indicates that an increase in the temperature range may affect water consumption patterns even when there is no change in average temperature.

Relative humidity positively influences per capita water consumption: the higher the relative humidity, the higher the consumption. On average across Brazilian cities, each one-percentage-point increase in relative humidity leads to a 3.6% increase in per capita water consumption (coefficient 0.036). In the study by Babel et al. (2006), the impact was negative (-0.210) and, in Schleich and Hillenbrand (2009), the coefficient was -0.147, a value very close to what was found for Brazil. The main reason for these differences is associated with the fact that the cited studies were conducted in the Northern Hemisphere, where winters are generally humid and summers are dry.

All coefficients of the supply equation are also significantly different from zero and display the expected signs. The water tariff positively affects water supply, and the coefficient is also low (0.128), indicating that water supply is price inelastic: large price variations are associated with small variations in supply. The larger the operational structure of water distribution – extensive networks and utilities with more employees - the greater the per capita water supply.

Maximum temperature in the cities also has a positive effect on the level of supply:

Table 2.3 Estimated coefficients of the 3SLS model, 2008 to 2023

	Coefficient	Standard error	,	p/z)	Confidence interval	
	Coemcient	Standard error	Z	p(z) _	Lower	Upper
		Demand equation				
Degree of urbanization	0.00956	0.00345	2.77	0.60%	0.00281	0.01632
Income	1.02652	0.00102	26.10	0.00%	1.02453	1.02852
Price or tariff	-0.25393	0.00200	-127.15	0.00%	-0.25784	-0.25001
Maximum temperature	0.24939	0.00107	232.24	0.00%	0.24729	0.25150
Minimum temperature	-0.26664	0.00133	-200.41	0.00%	-0.26925	-0.26404
Relative humidity	0.03568	0.00018	203.33	0.00%	0.03534	0.03603
		Supply equati				
Price	0.12774	0.00152	-84.13	0.00%	0.12476	0.13072
Employees	0.03327	0.00099	33.54	0.00%	0.03133	0.0352
Network length	0.02311	0.00131	17.64	0.00%	0.02054	0.02568
Maximum temperature	0.34362	0.00126	273.22	0.00%	0.34115	0.34608
Minimum temperature	-0.33979	0.00150	-226.12	0.00%	-0.34274	-0.33685
Rainy days	0.17400	0.00076	230.01	0.00%	0.17251	0.17548
Losses in distribution	-0.03905	0.00295	-13.23	0.00%	-0.04484	-0.03327
		Price equatio	n			
Costs	0.55706	0.00291	191.33	0.00%	0.55135	0.56277
osses in distribution	0.15644	0.00643	24.33	0.00%	0.14384	0.16904
Average real wage	0.06100	0.00179	34.15	0.00%	0.05750	0.0645
Network length	-0.06992	0.00283	-24.73	0.00%	-0.07546	-0.0643
Regional dummies						
Rondônia	-4.16375	0.03099	-134.37	0.00%	-4.22449	-4.1030
Acre	-4.86414	0.03463	-140.47	0.00%	-4.93201	-4.7962
Amazonas	-5.02773	0.03226	-155.85	0.00%	-5.09096	-4.96450
Roraima	-4.67170	0.03705	-126.10	0.00%	-4.74431	-4.59909
Pará	-4.57509	0.02920	-156.66	0.00%	-4.63232	-4.5178
Amapá	-4.83670	0.03755	-128.79	0.00%	-4.91030	-4.76310
Tocantins	-3.83839	0.02768	-138.68	0.00%	-3.89264	-3.7841
Maranhão	-4.41795	0.02793	-158.17	0.00%	-4.47270	-4.3632°
Piauí	-4.15726	0.02870	-144.87	0.00%	-4.21351	-4.10102
Ceará	-4.18055	0.02850	-146.67	0.00%	-4.23641	-4.12468
Rio Grande do Norte	-3.93972	0.02874	-137.08	0.00%	-3.99605	-3.88339
Paraíba	-4.06674	0.02848	-142.81	0.00%	-4.12256	-4.01093
Pernambuco	-3.76152	0.02745	-137.01	0.00%	-3.81533	-3.70772
Alagoas	-3.82594	0.02878	-132.93	0.00%	-3.88235	-3.76953
Sergipe	-3.67822	0.02928	-125.62	0.00%	-3.73560	-3.62083
Bahia	-3.89353	0.02808	-138.68	0.00%	-3.94856	-3.8385
Minas Gerais	-4.04281	0.02774	-145.73	0.00%	-4.09719	-3.9884
Espírito Santo	-3.80547	0.02875	-132.36	0.00%	-3.86182	-3.74912
Rio de Janeiro	-3.93832	0.02932	-134.33	0.00%	-3.99578	-3.8808
São Paulo	-4.29892	0.02861	-150.24	0.00%	-4.35500	-4.2428
Paraná	-3.85794	0.02855	-135.11	0.00%	-3.91390	-3.8019
Santa Catarina	-3.73743	0.02871	-130.20	0.00%	-3.79369	-3.68116
Rio Grande do Sul	-3.71950	0.02872	-129.49	0.00%	-3.77579	-3.6632
Mato Grosso do Sul	-3.89817	0.03006	-129.69	0.00%	-3.95708	-3.8392
Mato Grosso	-4.26498	0.02788	-152.97	0.00%	-4.31963	-4.21033
Goiás	-4.10752	0.02700	-141.03	0.00%	-4.16460	-4.05044
Joine	-4.33900	0.10059	-43.13	0.00%	-4.53616	-4.14184

the hotter the city, the greater the daily per capita water supply. For each additional degree Celsius, water supply increases by 34.4%. Per capita water supply decreases as minimum temperature rises, with an estimated coefficient of -0.340. As observed in the demand equation, an increase in temperature range may affect the water supply pattern even when there is no change in average temperature.

The number of rainy days positively influences per capita water supply: cities with more frequent rainfall are associated with higher levels of supply. On average across Brazilian cities, each additional rainy day in the monthly average increases per capita water supply by 17.4% (coefficient of 0.174). Thus, municipalities in tropical areas, with high temperatures or near the coast, have greater water supply levels compared to cities in the Brazilian semiarid region, which also experience high temperatures but record little precipitation. This results in supply constraints in the Cerrado and Caatinga regions.

Finally, the price equation reveals a positive relationship between price and costs, indicating that tariff formation in the sector follows a mark-up pricing structure (margin over costs). Losses in distribution increase water prices and tariffs, while the scale of operation, indicated by network length, negatively affects price: larger scale to lower prices. The estimates indicate that the relative cost of labor in Brazilian cities has a positive effect on water prices and tariffs: in cities where labor is more highly valued, water tends to be more expensive. The dummy variables associated with each state (regional dummies) indicate that there are significant differences in price levels among Brazilian states. Acre, Amazonas, Roraima, and Amapá recorded relatively lower prices on average over the period analyzed, whereas the southern states showed higher average prices. São Paulo and Brasília, two areas with reliable

water supply, had relatively lower prices.

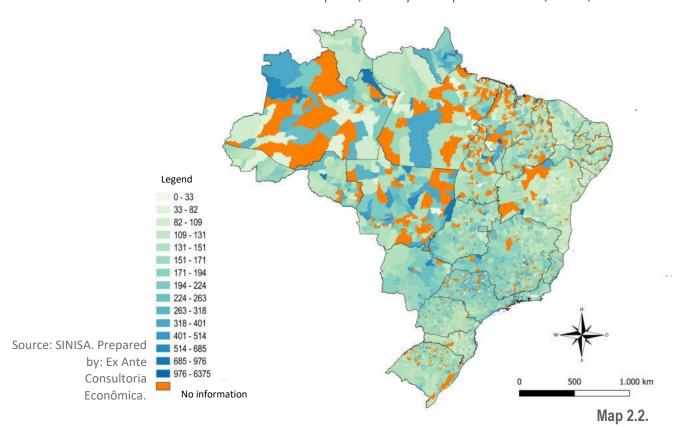
#### 2.4. Estimates of water consumption in Brazil in 2023

In 2023, water consumption statistics in Brazil, as mentioned previously, were available for 5,079 cities, representing 91.2% of the country's 5,570 municipalities. In population terms, these cities were home to 201.720 million people, of which 170.231 million lived in urban areas. In relative terms, the total population of these cities corresponded to 97.1% of the Brazilian population (207.767 million people), and the urban population represented 98.1% of the total number of inhabitants living in urban areas in the country.

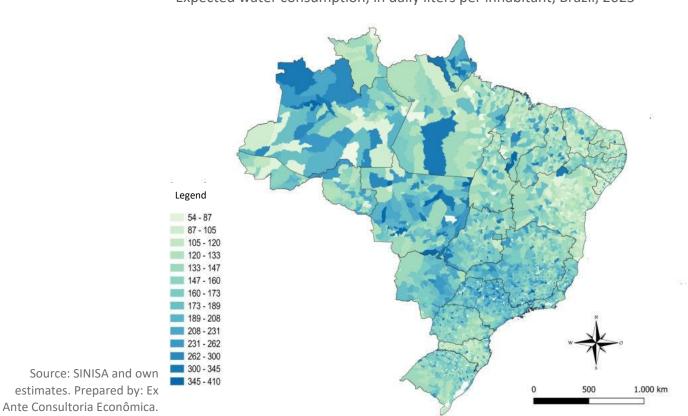
According to SINISA data, 9.974 billion m<sup>3</sup> of water were consumed in 2023. This volume corresponds to a daily average of 131.53 liters per person in the country, including in the consumption figure the share that is not directly measured by operators, and in the denominator the total population of 207.767 million Brazilians. Considering only the population with access to a water supply (167.559 million people), the average daily consumption was 163.09 liters per inhabitant.

According to SINISA, there were cities with an average daily per capita consumption of 8.8 liters, while others exceeded 6,000 liters per inhabitant per day. Adjusting the data for estimated consumption, that is, excluding from consumption the portion considered a measurement error and incorporating the estimates for municipalities that did not report data to SINISA, results in a total volume of 10.725 billion m<sup>3</sup>. This volume corresponds to a daily average of 175.38 liters per person in the country, including the amount of water lost in distribution.

Map 2.1. Water consumption, in daily liters per inhabitant, Brazil, 2023



Expected water consumption, in daily liters per inhabitant, Brazil, 2023



These data provide a good sense of the spatial distribution of consumption, but to project water consumption through 2050, it is necessary first to estimate consumption values for cities that lack information and adjust values considered outliers. For long-term projections, the lack of this information is a minor issue. The greater problem is the lack of data homogeneity: some municipalities produce water for export, but these flows are not properly recorded, artificially increasing average daily consumption figures, and some operators overestimate water consumption that is not directly measured by water meters. As a result, extremely high daily per capita consumption values remain in the dataset (e.g., over 450 liters). To address this issue, the econometric estimates obtained in the previous section were used as the basis for projections.

A simple method is used to construct this new dataset. When values are known and fall within a reasonable range, the available SINISA data are used. But when values are outside the acceptable interval (up to 450 liters per person per day) or missing, the estimates derived from the explanatory variables and from the coefficients of the econometric model estimated in the previous section are employed instead.

Map 2.2 presents the expected values of daily per water consumption for Brazilian municipalities in 2023. The ranges, as in the previous map, represent natural breaks in the distribution of the variable. The lowest range municipalities with daily per capita consumption of up to 54 liters, while the darkest range groups those with values above 345 liters per inhabitant per day. The intermediate range concentrated municipalities with annual per capita consumption between 160 and 173 liters per inhabitant per day. The national average was estimated at approximately 172 liters per inhabitant per day.

Additionally, **Table 2.4** shows the average daily per capita water consumption in the major regions and states in 2023 (first numeric column). The table also presents the total population of the country, including those who still do not have access to treated water supply services (second numeric column). Multiplying these two values yields the total water consumption that would need to be supplied in a scenario of universal access. This value appears in the third data column.

The 13.037 billion m³ that would have to be supplied to meet the consumption of the entire Brazilian population in 2023 is 30.7% higher than the consumption recorded that same year in the SINISA database, which was 9.974 billion m³. It is worth noting that this increase in supply of approximately 3 billion m³ is the component of expanded water consumption in the 2050 consumption scenario that results specifically from the universalization of access to treated water supply services. The remaining components stem from demographic expansion and economic growth, factors analyzed in the next chapter.

Table 2.4 Observed and expected water consumption, in daily liters per inhabitant, 2023

	5 10	Observed	(SINISA)	Expected consumption		
	Population (people)	consumption Per capita consumption	Consumpti on (million m³)	Per capita consumption (daily liters per	Consump tion (million m³)	
North	17 009 562	(daily liters per 75.35	494.98	158.52	1,041.41	
Rondônia	<b>17,998,562</b> 1,661,549	72.37	<b>494.96</b> 43.89	179.55	1,041.41	
Acre	854,943	70.95	22.14	168.11	52.46	
	4,107,635	98.41	147.55	176.40	264.47	
Amazonas	4, 107,635 675,535	95.60	23.57	164.16	40.48	
Roraima	,	95.60 54.46			420.54	
Pará	8,387,422		166.72 26.02	137.37		
Amapá	767,508	92.88		238.41	66.79	
Tocantins	1,543,971	115.51	65.09	155.78	87.79	
Northeast	55,869,913	94.93	1,935.79	142.90	2,914.14	
Maranhão	6,892,750	83.18	209.28	166.99	420.13	
Piauí	3,322,964	113.86	138.10	177.55	215.35	
Ceará	9,011,405	94.86	312.01	128.87	423.88	
Rio Grande do Norte	3,373,553	99.78	122.87	138.54	170.59	
Paraíba	4,058,836	87.93	130.27	134.73	199.60	
Pernambuco	9,295,622	97.77	331.74	170.43	578.26	
Alagoas	3,173,527	75.04	86.93	114.66	132.81	
Sergipe	2,249,884	110.39	90.65	118.83	97.58	
Bahia	14,491,372	97.17	513.96	127.79	675.95	
Southeast	86,704,832	161.19	5,101.35	195.18	6,176.96	
Minas Gerais	20,927,216	142.23	1,086.43	177.47	1,355.57	
Espírito Santo	3,965,505	147.83	213.97	190.39	275.58	
Rio de Janeiro	16,626,981	155.29	942.42	208.06	1,262.70	
São Paulo	45,185,130	173.32	2,858.54	199.07	3,283.12	
South	30,518,312	143.20	1,595.12	168.37	1,875.48	
Paraná	11,632,650	141.85	602.28	161.33	684.97	
Santa Catarina	7,830,668	141.30	403.86	164.51	470.21	
Rio Grande do Sul	11,054,995	145.97	588.98	178.51	720.30	
Central-West	16,675,023	139.17	847.06	169.03	1,028.81	
Mato Grosso do Sul	2,828,430	141.65	146.24	172.74	178.33	
Mato Grosso	3,746,025	140.14	191.61	184.67	252.50	
Goiás	7,201,648	130.21	342.27	152.29	400.32	
Federal District	2,898,920	157.77	166.94	186.80	197.65	
Brazil	207,766,642	131.53	9,974.31	171.91	13,036.80	

Source: Ex Ante Consultoria Econômica.



# Economic growth and demographic dynamics

This chapter presents the theoretical approaches and econometric models that describe Brazil's economic growth and demographic expansion between 2008 and 2023. These analyses form the basis for projecting economic and population growth through 2050 using scenarios. Based on these scenarios, the 2050 water consumption scenario will then be constructed in **Chapter 4.** In the following sections, the theoretical models are described (**Section 3.1**), along with the information sources used and the econometric estimates of the factors that influence income growth and demographic expansion in the country (**Section 3.2**).

#### 3.1. Theoretical approaches

To project water consumption in 2050, it is first necessary to project labor income and the population of Brazilian cities for that future time horizon. These projections are based on theoretical and statistical models from the fields of economic growth and demographic dynamics.

#### **Economic growth**

Economic growth theory is based on modeling the dynamics of GDP expansion. This analysis is grounded in the main theoretical framework regarding the determinants of long-term economic growth, which is the Solow Growth Model, developed by economist Robert Solow, Nobel Prize winner in 1987. In addition to this foundation, the analysis also incorporates contributions from, among others, Mankiw, Romer, and Weil (1992), who introduced the role of human capital into the discussion on economic growth.

Economic growth theory is based on modeling the dynamics of GDP expansion. The main approach in this field established the theoretical foundations of growth in the mid-1950s, and since then, the research agenda on economic growth has continued to refine theoretical models and develop empirical investigation methodologies. In Solow's theory, a country's aggregate output, that is, its gross domestic product, is determined by the level of employment of production factors (physical capital, human capital, and labor). This theoretical relationship is called a production function, and it is described by Equation (6), in which is the GDP of country i, is the level of factor productivity defined by the levels of technological and institutional development, is the stock of capital (machinery, equipment, facilities, livestock, and forests), is the stock of human capital, and is the labor force. .

Human capital is defined as the labor force multiplied

by its qualification level, denoted as hi.

It is assumed that this qualification level is proportional to the average level of schooling

of workers. Thus, by definition,  $H_i = L_i \cdot h_i$ .

GDP per worker (Yi / Li), under conditions of production homogeneity, is given by Equation (7), in which Ki / Li represents the stock of capital per worker.

(6) 
$$Y_i = f(A_i, K_i, H_i)$$
  
 $i \quad i \quad i$   
(7)  $Y_i / L_i = f(A_i, K_i / L_i, h_i)$ 

As a result of Equation (6), it follows that the

variation of GDP over time (gY), which corresponds to economic growth, depends on four variations: gA, which is the increase in productivity; gK, which is capital accumulation; gL, which is the expansion of the labor force; and gh, which is the increase in the average schooling level of the labor force.

In the long-run equilibrium, it is assumed that the

. In Solow's model, capital accumulation depends on the economy's investment rate, which corresponds to the share of income (GDP) spent on acquiring capital goods (construction, machinery and equipment, forests, and livestock). This share is identical to the economy's savings rate (s), defined as the ratio between aggregate savings and GDP.

Under these conditions, the long-run equilibrium level of output per worker is given by Equation (8), which already expresses the relationships in terms of natural logarithms. In this expression, a is a constant (called the technological constant), and d is the capital depreciation rate, which is assumed to be constant and identical across all countries or regions. The coefficient  $\phi$  measures the return on education in the economies.

(8) 
$$\ln\left(\frac{Y}{L}\right)_{i}^{*} = a + \frac{\alpha}{(1-\alpha)} \cdot \ln s_{i} - \frac{\alpha}{(1-\alpha)} \cdot \ln(g_{L} + g_{A} + d)_{i} + \phi \cdot h_{i}$$

If, hypothetically, the shares of the population employed in production and the share of income saved are constant, and if schooling remains constant, then in the long run the growth rate of GDP per worker will equal the rate of increase in productivity, and

economic growth will equal the sum of the rates

of productivity growth and population expansion. These relationships are described in Equation (9):

(9) 
$$g_{Y_i/L_i} = [g_{Y_i} - g_{L_i}] \implies g_{Y_i} = g_{L_i} + g_{A_i}$$

supplies of labor and capital equal the demands for labor and capital (full employment). The equilibrium levels define the remuneration of capital and labor, which in turn determine the distribution of income between profits and the labor payroll.

However, changes in the investment rate and demographic expansion, on the one hand, and increases in the average level of schooling of the labor force, on the other, may alter the equilibrium levels and, therefore, may temporarily affect economic growth. For an economy in transition – that is, an economy that has not yet reached the long-run steadystate equilibrium – the GDP growth rate per worker will be affected by the savings rate, demographic growth, and the expansion of schooling.

Equation (10) defines this relationship, which in the economic literature is known as the conditional convergence equation. In this expression, the coefficient  $\lambda$  indicates the average convergence rate of economies toward long-run equilibrium.

$$g_{Y_{i}/L_{i}} = \lambda \cdot \left(\frac{Y_{i}}{L_{i}}\right)_{t-1} + \lambda \cdot \frac{\alpha}{(1-\alpha)} \cdot \ln \left[\frac{s_{i}}{(g_{L} + g_{A} + d)_{i}}\right] + \lambda \cdot \phi \cdot h_{i}$$

$$(10) \quad g_{Y/L} = \lambda \cdot \left(\frac{1}{L}\right)_{t-1} + \lambda \cdot (1-\alpha) \cdot \ln \left[(g + g_{A} + d)_{i}\right] + \lambda \cdot \phi \cdot h_{i}$$

$$\left[L + A + i\right]$$

In this theoretical framework, the average remuneration of labor corresponds to its marginal productivity. Because of this relationship, the growth of average labor income is also determined by productivity growth, that is, by the growth of GDP per worker. Thus, the evolution of the average wage in the economy (*gw*) is defined by Equation (10), with wage increases as the dependent variable. This equation will be estimated in **Section 3.2**, both for GDP per capita and for average wages in the economy, and the empirical results will be used to generate the projections of economic growth for 2050 in **Section 3.3**.

#### **Demographic dynamics**

Demographic dynamics follow the modeling of the flows that cause populations to grow or decline. The so-called natural population flows are determined by birth rates and mortality rates. In addition to these two processes, there are migratory flows, which either increase or decrease population size. Populations grow when the inflow of immigrants exceeds the outflow of emigrants from a given area.

Thus, the natural population growth rate is obtained from the difference between the fertility rate (f) and the mortality rate (m) of each locality. The demographic growth rate (n) is the sum of natural growth and the net migration rate (x). Equation (11) identifies these relationships.

(11) 
$$n_i = f_i - m_i + x_i$$

#### 3.2. Statistical models

#### **Growth of labor income**

To estimate the contribution of improvements in sanitation to the expansion of income per worker

and to average wages in Brazilian cities,

two econometric models were developed to determine the growth rates of GDP per capita and of average wages.

. These models are based on the database developed for this study, containing information for the 5,570 Brazilian municipalities from 2008 to 2021, in the case of GDP per capita, and from 2008 to 2023, in the case of average wages.

To construct GDP per worker, the following statistics were used: (i) municipal GDP, calculated by IBGE; (ii) the population of each Brazilian city, also calculated by IBGE; and

(iii) the implicit GDP deflator, to eliminate the effect of inflation on nominal values. To construct the average wage, the following statistics were used:

(i) average wages in the municipalities, calculated by the Ministry of Labor and Employment; and (ii) the CPI (Consumer Price Index), to eliminate the effect of inflation on nominal values. The determinants of the growth of GDP per worker and the growth of average wages in the municipalities are:

**Savings rate:** ratio between investment and GDP in each municipality, based on IBGE data<sup>1</sup>;

**Demographic expansion:** population growth rate between 2008 and 2023, based on IBGE data;

**Lagged GDP per capita:** municipal GDP per inhabitant lagged one year, a variable that captures the convergence effect; and

**Education:** school enrollment rate of the

school-age population, based on data from the Ministry of Education (2025) and the Ministry of Health (2025).

<sup>&</sup>lt;sup>1</sup> The Methodological Annex provides details on the

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In addition to the variables representing stocks of productive factors, variables were also included to control for the evolution of labor productivity, physical capital, and human capital in each city and in each year. These variables are:

Quality of education: to approximate education quality, the student-teacher ratio in elementary and high schools in Brazilian cities was used, based on data from the Ministry of Education (2025), under the assumption that the higher the number of students per teacher, the lower the quality of education;

Technological level: an indicator ranging from 0 to 1 that captures the presence of high-technology firms in Brazilian cities, according to data from the Ministry of Labor (2025)<sup>2</sup>;

**Sanitation:** the population coverage rates for water supply services and sewage collection, and the sewage treatment index in each city, according to data from the Ministry of Cities (SNIS and SINISA), used to indicate public health conditions in Brazilian cities and their effects on labor productivity.

Population density: in the analysis of sustained average wage growth in Brazilian cities, a variable measuring the number of inhabitants per km<sup>2</sup> was also included; this variable also serves to adjust the estimates for scale-economy effects on labor productivity.

The study used an econometric panel regression approach. Equation (12) describes the statistical relationship based on the theoretical conditional convergence equation. In the case of average wages, only the dependent variable changes.

(12) 
$$g_{Y_{tt}/L_{tt}} = \lambda \cdot \left(\frac{Y_{tt}}{L_{tt}}\right)_{t-1} + \lambda \cdot \frac{\alpha}{(1-\alpha)} \cdot \ln \left[\frac{s_{t}}{(g_{L} + g_{A} + d)_{tt}}\right] + \lambda \cdot \phi \cdot h_{tt} + u_{tt}$$

$$L_{tt}$$

The regression sample used to estimate the GDP per capita growth rate included 77,980 municipal observations from 2008 to 2021. The model estimation employed the Arellano-Bond technique to correct for endogeneity of the variables. This method uses the lagged endogenous variable and instrumental variables with two lags.

Table 3.1 presents the descriptive statistics of the variables used in the model. The regression included 61,129 observations, arranged in

5,565 groups (cities), with a minimum of 3 and a maximum of 11 observations per municipality. A total of 76 instruments were used. The estimates were generated using the Generalized Method of Moments (GMM).

Table 3.2 presents the estimation results for the determinants of economic growth in Brazilian municipalities. The ten independent variables proved to be significant at the 5% level, except for the coefficient associated with the share of the population served by sewage collection, which was significant at 6%, an acceptable significance level.

As theoretically expected, the coefficient associated with lagged GDP per capita is negative, indicating that municipalities with lower per capita income tend to grow faster. Also in line with theory, the investment rate positively affects the GDP per capita growth rate, and demographic expansion (break-even rate) has a negative effect. The enrollment rate has a positive effect, indicating that cities with higher enrollment rates of school-age children and youth tend to grow faster. An increase in the student-to-teacher ratio, on the other hand, reduces per capita income growth, indicating that

the lower the quality of education – assuming that higher levels of education quality

are achieved with smaller student-to-teacher ratios - the lower the rate of per capita income expansion. The high-technology activity index

<sup>&</sup>lt;sup>2</sup> The Methodological Annex provides details on the methodology used to estimate this variable at the municipal level based on data from the Ministry of Labor (2025).

has a positive effect on GDP per capita growth in Brazilian cities, indicating that a significant portion of income growth dynamics is associated with the presence of these economic activities.

Finally, it is worth highlighting that the sanitation variables indicate that improvements in sanitation increase the sustained growth of GDP per capita in cities. The presence of treated water for 100% of the population enables a per capita GDP growth rate that is 4.55 percentage points higher than the growth rate of a city without

water supply for its residents, a considerable difference in level. On the other hand, the estimates indicate that 100% sewage collection can increase the GDP per capita growth rate by 0.84 percentage point compared with cities without sewage collection services, while universal sewage treatment can increase the growth rate by 1.18 percentage point compared with a city without sewage treatment.

The regression sample used to determine the growth rate of average wages included 83,520 municipal observations from 2008 to 2023.

**Table 3.1.** Descriptive statistics of the variables in the GDP per capita growth regression, Brazil, 2008 to 2021

Variables	Number of observations	Mean	Standard deviation	Minimum	Maximum
GDP per capita growth rate	72,382	0.01757	0.16283	-2.52712	4.02706
Lagged GDP per capita (In)	72,383	-3.69482	0.70567	-7.44542	0.48108
Investment rate (In)	77,960	-5.99494	0.75583	-6.90776	-1.77975
Break-even rate (In)	72,399	-2.83963	0.20822	-5.62977	-1.74074
Enrollment rate (In)	77,867	-0.23930	0.10362	-1.30338	0.62027
Student-teacher ratio (In)	77,911	2.74490	0.28576	0.78238	3.81492
Productivity index	77,980	0.00441	0.02562	0.00000	0.91143
Population with access to water (%)	77,960	0.62081	0.30697	0.00000	2.02023
Population with sewage collection (%)	77,960	0.22597	0.33872	0.00000	1.92263
Sewage treated relative to water consumed	77,980	0.15613	0.30272	-0.12090	8.75230
(%)					

Source: IBGE, Ministry of Education, Ministry of Labor, and Ministry of Cities.

**Table 3.2.** Regression estimates of the economic growth equation, Brazil, 2008 to 2021

Coefficient	Standard error	z	P>(z)
0.08565	0.00288	29.77	0.0%
-1.21832	0.00368	-331.37	0.0%
0.14785	0.00262	56.47	0.0%
-0.11147	0.00989	-11.27	0.0%
0.03715	0.01655	2.24	2.5%
-0.01435	0.00671	-2.14	3.2%
0.19052	0.04262	4.47	0.0%
0.04547	0.00413	11.01	0.0%
0.00841	0.00447	1.88	6.0%
0.01180	0.00494	2.39	1.7%
-3.88802	0.04296	-90.50	0.0%
	0.08565 -1.21832 0.14785 -0.11147 0.03715 -0.01435 0.19052 0.04547 0.00841 0.01180	0.08565 0.00288 -1.21832 0.00368 0.14785 0.00262 -0.11147 0.00989 0.03715 0.01655 -0.01435 0.00671 0.19052 0.04262 0.04547 0.00413 0.00841 0.00447 0.01180 0.00494	error           0.08565         0.00288         29.77           -1.21832         0.00368         -331.37           0.14785         0.00262         56.47           -0.11147         0.00989         -11.27           0.03715         0.01655         2.24           -0.01435         0.00671         -2.14           0.19052         0.04262         4.47           0.04547         0.00413         11.01           0.00841         0.00447         1.88           0.01180         0.00494         2.39

Source: Ex Ante Consultoria Econômica.

The number of observations is larger than in the previous regression because this second dependent variable includes data up to 2023, that is, two additional years of sampling compared to GDP per capita. Table 3.3 presents the descriptive statistics of the variables used in the model.

The model estimation also employed the Arellano-Bond technique to correct for the endogeneity of the variables. The regression included 66,690 observations, arranged in

5,565 groups (cities), with a minimum of 3 and a

maximum of 13 observations per municipality. A total of 94 instruments were used. The estimates were also obtained using the Generalized Method of Moments (GMM). Table 3.4 presents the results of the estimates of the determinants of economic growth in Brazilian municipalities.

The eleven independent variables proved to be significant at less than 1%, revealing a higher degree of fit in this second equation. The coefficient associated with lagged average wage is

**Table 3.3.** 

Descriptive statistics of the variables in the average wage growth regression, Brazil, 2008 to 2023

Variables	Number of observations	Mean	Standard deviation	Minimum	Maximum
Average wage growth rate	83,520	0.01485	0.12674	-3.60551	3.50964
Lagged average wage (In)	83,521	7.70206	0.22680	4.34921	9.31110
Investment rate (In)	83,538	-5.96189	0.77361	-6.90776	-1.65608
Break-even rate (In)	83,537	-2.85945	0.21897	-5.62977	-1.74074
Enrollment rate (In)	88,997	-0.23758	0.10371	-1.30338	0.66630
Student-teacher ratio (In)	89,046	2.72777	0.29013	0.78238	3.81492
Productivity index	89,120	0.00470	0.02570	0.00000	0.91143
Population density (In)	83,538	3.24675	1.43308	-3.45979	9.58832
Population with access to water (%)	83,537	0.62612	0.30482	0.00000	2.02023
Population with sewage collection (%)	83,535	0.23100	0.34119	0.00000	1.92263
Sewage treated relative to water consumed  (%)	89,120	0.16378	0.31473	-0.12090	10.23817

Source: IBGE, Ministry of Education, Ministry of Labor, and Ministry of Cities.

Regression estimates of the average wage growth equation, Brazil, 2008 to 2023

Variables	Coefficient	Standard error	z	P>(z)
Lagged average wage growth rate	-0.01263	0.00311	-4.06	0.0%
Lagged average wage (In)	-1.18309	0.00403	-293.53	0.0%
Investment rate (In)	0.12463	0.00166	74.94	0.0%
Break-even rate (In)	-0.05892	0.00606	-9.73	0.0%
Enrollment rate (In)	0.23047	0.01099	20.97	0.0%
Student-teacher ratio (ln)	-0.06237	0.00441	-14.13	0.0%
Productivity index	0.27736	0.02822	9.83	0.0%
Population density (In)	-0.24774	0.00905	-27.37	0.0%
Population with access to water (%)	0.00754	0.00274	2.76	0.6%
Population with sewage collection (%)	0.00979	0.00296	3.30	0.1%
Sewage treated relative to water consumed (%)	0.01247	0.00328	3.80	0.0%
Constant	9.00886	0.04276	210.67	0.0%

Source: Ex Ante Consultoria Econômica.

negative, indicating that average income in municipalities with lower average wages tends to grow at a faster pace. Also as theoretically expected, the investment rate has a positive effect on wage growth, while demographic expansion (break-even rate) has a negative impact. The enrollment rate has a positive effect, indicating that in a city with a high enrollment rate of school-age children and youth, the average wage tends to grow more rapidly. An increase in the student-teacher ratio, on the other hand, reduces wage growth, indicating that the lower the quality of education, the lower the rate of average wage expansion. The high-technology activity index positively affects average wage growth in Brazilian cities, just as observed in the GDP per capita regression, revealing that a significant portion of labor income growth dynamics is associated with the presence of these economic activities. Finally, high population density

slows the pace of wage growth, since in large cities, high urban concentration generates negative externalities.

The sanitation variables indicate that improvements in sanitation increase the sustained growth of average wages in Brazilian cities. Providing treated water to 100% of the population enables an average wage growth rate 0.75 percentage point higher than that of a city without water supply services. On the other hand, the estimates indicate that 100% sewage collection can increase the average wage growth rate by 0.98 percentage point compared with cities without collection services, while universal sewage treatment can increase the average wage growth rate by 1.25 percentage point compared with a city without sewage treatment.



**Table 3.5.** Descriptive statistics of the variables in the demographic dynamics regression, Brazil, 2008 to 2023

Variables	Number of	Mean	Standard	Minimum	Maximum
Valiables	observations	Weari	deviation	Willilliam	Waxiiiiuiii
Fertility rate	89,120	0.01314	0.00377	0.00000	0.10028
Mortality rate	89,120	0.00660	0.00214	0.00000	0.04128
Migration rate	89,120	-0.00269	0.04347	-0.68077	4.03092
Year	89,120	2016	5	2008	2023
Latitude	89,120	-16.45151	8.28156	-33.68677	4.58930
Longitude	89,120	-46.23485	6.41164	-72.97186	-32.41593
Altitude	89,120	422.72670	282.95400	0.00000	1639.15500
Labor income per capita (In)	89,120	7.26930	0.42211	0.00000	9.26619

Source: IBGE and Ministry of Labor and Employment.

**Table 3.6.** Regression estimates of demographic dynamics, Brazil, 2008 to 2023

Models	Variables	Coefficient	Standard error	Z	P>(z)
	Year	-0.00014	0.00000	-94.27	0.0%
	Latitude	0.00022	0.00001	41.27	0.0%
Fertility	Longitude	-0.00015	0.00001	-23.30	0.0%
	Altitude	0.00000	0.00000	-4.37	0.0%
	Constant	0.28365	0.00291	97.35	0.0%
	Year	0.00018	0.00000	194.25	0.0%
	Latitude	-0.00013	0.00000	-52.05	0.0%
Mortality	Longitude	0.00007	0.00000	24.41	0.0%
	Altitude	0.00000	0.00000	-1.67	9.5%
	Constant	-0.34531	0.00182	-189.47	0.0%
	Year	-0.00069	0.00005	-12.59	0.0%
	Latitude	-0.00010	0.00002	-4.74	0.0%
Migration flow	v Longitude	-0.00012	0.00003	-4.74	0.0%
	Altitude	0.00000	0.00000	-0.10	92.4%
	Labor income per capita (In)	0.00390	0.00061	6.45	0.0%
	Constant	1.34252	0.10631	12.63	0.0%

Source: Ex Ante Consultoria Econômica. R<sup>2</sup> values: fertility (23.4%), mortality (34.0%), and migration flow (4.3%).

#### **Empirical model of demographic** dynamics

To project demographic dynamics for the coming years, it is sufficient to obtain estimates of the three rates that combine to form the population growth pace: the mortality rate, the fertility rate, and migration flows. These rates follow well-defined time trends, such as the

secular decline in mortality rates and the increase in life expectancy at birth, but they may also be related to exogenous variables and random factors. One example of exogenous variables that affect the pace of demographic growth is the economic opportunity that attracts migrants to emerging cities. Another example, this time a random factor, is the occurrence of Covid-19, which unexpectedly

increased mortality rates while there was no effective means to combat and control the disease.

In this study, we build three statistical models to estimate the trends of mortality and fertility rates and to generate parameters for the migration phenomenon. These models are based on the database developed for this study, with information for the 5,570 Brazilian municipalities from 2008 to 2023.

The dependent variables are:

Fertility rate: the ratio between the number of live births in each city and year and its respective population;

Mortality rate: the ratio between the number of deaths in each city and year and its respective population; and

Migration rate: the ratio between the net inflow and outflow of residents in each city and year and its respective population.

The only model that includes an explanatory independent variable is the migration model, in which

per capita labor income is assumed to be a factor that attracts migratory movements.

**Table 3.5** presents the descriptive statistics of the variables used in the demographic models. The regressions included 89,120 observations arranged in 5,570 groups (cities), with 16 observations per municipality. Table 3.6 shows the results of the estimates of the determinants of demographic Brazilian municipalities. dynamics in independent variables were significant at less than 5%, with the exception of the coefficient associated with altitude in the mortality-rate and migrationflow regressions. This means that these coefficients are close to zero, i.e., that a municipality's altitude does not influence these two rates.

Although the coefficients are significant, the R<sup>2</sup> statistics indicate that the three processes, especially migration flow, are dominated by random events, with relatively little influence from trends, geographic location, and labor income, in the case of migration flow. Even so, the coefficients are suitable for projections, since the random component has a mean of zero and constant variance, as desired.



## Scenarios through 2050

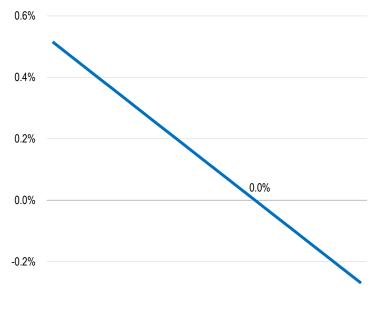
This chapter presents the demographic expansion and economic growth scenarios for Brazil from 2023 to 2050. These analyses are based on the parameters estimated in the previous chapter and outline some assumptions regarding the evolution of key variables through 2050. These assumptions form what are called scenarios, which assign reference values to certain (independent) variables in order to project the values of other (dependent) variables in the future. In the following sections of this chapter, the demographic expansion scenario for the period from 2023 to 2050 is described (Section 4.1), along with the income growth scenarios for the same time horizon (Section 4.2). Finally, Section 4.3 presents the water consumption scenario for the period from 2023 to 2050.

#### 4.1. Demographic expansion scenario

This study adopted only one demographic expansion scenario. The scenario is based on the projection of fertility rates, mortality rates, and net migratory flows for the period from 2023 to 2050. The projection takes into account the parameters estimated in the previous section, as well as a few assumptions for the future. The first assumption is that the temporal trend will remain constant from 2023 to 2050, that is, that each additional year in the projection will have the same effect as observed in the past. For example, in the case of the fertility rate, one additional year reduced the rate by 0.014%; it is expected that this effect will remain unchanged going forward. The second assumption is that average wages will increase according to the evolution of labor productivity, the same assumption adopted in the next section, which discusses the economic growth scenarios. Finally, the third assumption is that wage differentials that stimulate migratory flows will remain in the future at the same magnitude as they exist today.

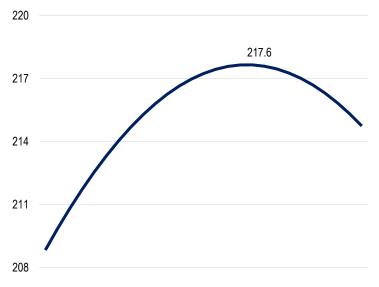
Based on these assumptions, Brazil's demographic expansion rate is projected to average 0.1% per year from 2023 to 2050, a rate 0.8 percentage point lower than that observed from 2000 to 2023. This annual average reflects the systematic reduction in Brazil's demographic expansion rates over these years. As illustrated in **Chart 4.1**, the rate decreases from 0.52% per year in 2024 to 0.0% per year at the end of 2041,

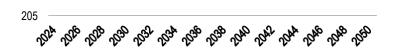
Chart 4.1. Demographic expansion rate, (%) per year, Brazil, 2024 to 2050



Source: Ex Ante Consultoria Econômica.

Chart 4.2. Population, in millions of inhabitants, Brazil, 2023 to 2050





after which it is expected to become negative. In 2050, a demographic decline of 0.27% is expected compared to 2049. As a result, the Brazilian population is expected to reach a peak of 217,649,748 inhabitants in 2041 - see Chart 4.2.

As shown in **Table 4.1**, demographic expansion rates decline across all Brazilian regions and states between the periods 2000-2023 and 2023–2040, although they remain positive. Between 2023-2040 and 2040-2050, rates continue to fall and remain positive only in a few regions and states. The cumulative result between 2023 and 2050 is a demographic contraction in the South and Southeast regions, except for Minas Gerais, and positive growth in the North, Northeast, and Central-West. In the North, the highlights will be the states of Acre, Amazonas, Amapá, and Roraima. In the Northeast, only Maranhão is expected to maintain a demographic growth rate above 0.5% per year.

At the municipal level, the changes will also be significant. During the period 2000-2023, municipal demographic expansion rates ranged from -4.1% per year to 9.6% per year, with a growth rate standard deviation of 1.1%. In the following period, 2023-2050, both the range and the standard deviation of the demographic expansion rates decrease. Rates are expected to vary between -0.4% per year and 1.5% per year, with a standard deviation of -0.3%. This result partly reflects the strong downward trend in fertility rates across the country. Additionally, rates with lower variation are associated with the fact that the demographic scenario assumes milder migratory movements.

Maps 4.1 and 4.2 show the demographic expansion rates of Brazilian municipalities between 2000-2023 and 2023-2050, respectively. There is a noticeable reduction

**Table 4.1.** Population and demographic expansion rate, 2000 to 2050

	2000	0000	00.40	0050				
	2023	2033	2040	2050	2023-2033	2033-2040	2040-2050	2023-2050
North	17,998,562	19,964,930	21,081,508	22,200,676	1.0%	0.8%	0.5%	0.8%
Rondônia	1,661,549	1,833,388	1,928,515	2,019,378	1.0%	0.7%	0.5%	0.7%
Acre	854,943	960,141	1,022,533	1,089,853	1.2%	0.9%	0.6%	0.9%
Amazonas	4,107,635	4,632,128	4,947,395	5,294,920	1.2%	0.9%	0.7%	0.9%
Roraima	675,535	777,017	841,490	918,636	1.4%	1.1%	0.9%	1.1%
Pará	8,387,422	9,247,346	9,721,613	10,171,356	1.0%	0.7%	0.5%	0.7%
Amapá	767,508	857,899	910,607	965,900	1.1%	0.9%	0.6%	0.9%
Tocantins	1,543,971	1,657,010	1,709,356	1,740,633	0.7%	0.4%	0.2%	0.4%
Northeast	55,869,913	59,022,656	60,224,141	60,381,608	0.6%	0.3%	0.0%	0.3%
Maranhão	6,892,750	7,484,665	7,784,798	8,020,871	0.8%	0.6%	0.3%	0.6%
Piauí	3,322,964	3,565,292	3,677,199	3,743,384	0.7%	0.4%	0.2%	0.4%
Ceará	9,011,405	9,642,292	9,925,873	10,076,651	0.7%	0.4%	0.2%	0.4%
Rio Grande do Norte	3,373,553	3,570,075	3,646,647	3,661,040	0.6%	0.3%	0.0%	0.3%
Paraíba	4,058,836	4,272,431	4,347,762	4,341,581	0.5%	0.3%	0.0%	0.2%
Pernambuco	9,295,622	9,749,427	9,896,148	9,846,188	0.5%	0.2%	-0.1%	0.2%
Alagoas	3,173,527	3,315,992	3,357,030	3,327,470	0.4%	0.2%	-0.1%	0.2%
Sergipe	2,249,884	2,346,528	2,372,477	2,347,203	0.4%	0.2%	-0.1%	0.2%
Bahia	14,491,372	15,075,953	15,216,206	15,017,219	0.4%	0.1%	-0.1%	0.1%
Southeast	86,704,832	88,333,647	87,854,816	84,899,715	0.2%	-0.1%	-0.3%	-0.1%
Minas Gerais	20,927,216	21,424,462	21,381,340	20,763,687	0.2%	0.0%	-0.3%	0.0%
Espírito Santo	3,965,505	4,032,155	4,004,748	3,862,256	0.2%	-0.1%	-0.4%	-0.1%
Rio de Janeiro	16,626,981	16,850,220	16,696,572	16,048,574	0.1%	-0.1%	-0.4%	-0.1%
São Paulo	45,185,130	46,026,809	45,772,156	44,225,199	0.2%	-0.1%	-0.3%	-0.1%
South	30,518,312	30,939,766	30,666,843	29,490,797	0.1%	-0.1%	-0.4%	-0.1%
Paraná	11,632,650	11,875,779	11,828,632	11,454,684	0.2%	-0.1%	-0.3%	-0.1%
Santa Catarina	7,830,668	7,917,857	7,833,249	7,512,257	0.1%	-0.2%	-0.4%	-0.2%
Rio Grande do Sul	11,054,995	11,146,131	11,004,962	10,523,856	0.1%	-0.2%	-0.4%	-0.2%
Central-West	16,675,023	17,526,634	17,818,630	17,771,077	0.5%	0.2%	0.0%	0.2%
Mato Grosso do Sul	2,828,430	2,951,404	2,985,138	2,954,961	0.4%	0.2%	-0.1%	0.2%
Mato Grosso	3,746,025	4,016,013	4,139,828	4,211,182	0.7%	0.4%	0.2%	0.4%
Goiás	7,201,648	7,531,783	7,629,917	7,569,809	0.4%	0.2%	-0.1%	0.2%
Federal District	2,898,920	3,027,434	3,063,746	3,035,125	0.4%	0.2%	-0.1%	0.2%
Brazil	207,766,642	215,787,633	217,645,938	214,743,873	0.4%	0.1%	-0.1%	0.1%

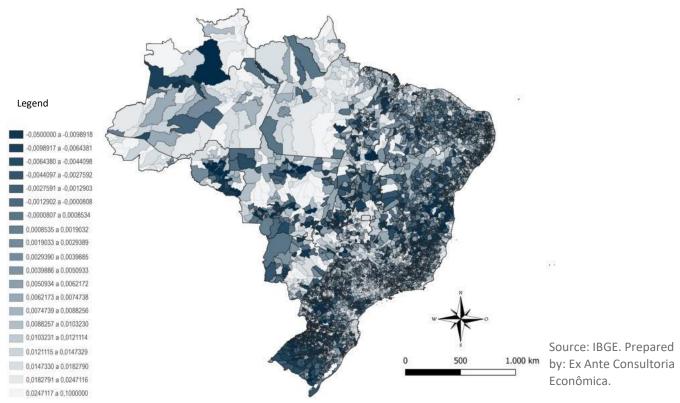
Source: IBGE and Ex Ante Consultoria Econômica. Prepared by: Ex Ante Consultoria Econômica.

in the contrast between municipalities with high expansion rates (light colors) and those with significant demographic contraction (dark colors). Cities located farther west and farther north in the country are expected to maintain higher rates, while coastal cities and those farther south are expected to experience population decline between 2023 and 2050.

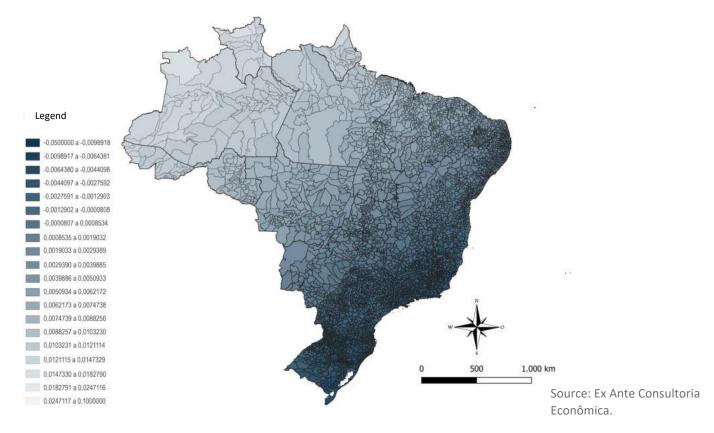
The aggregate results of these estimates can be compared with projections made in other

studies. During the revision of the National Housing Plan, the Fluminense Federal University (UFF) developed a demographic scenario for the Ministry of Regional Development (MDR), presented in the book by Givíziez and Oliveira (2018). According to that scenario, the Brazilian population was expected to grow at a rate of 0.4% per year between 2017 and 2040. This figure is consistent with the projection of 0.3% per year shown in **Table 4.1.** The regional pattern of population growth

Demographic expansion rate, (%) per year, 2000 to 2023



Map 4.2.
Demographic expansion rate, (%) per year, 2023 to 2050



shown in that study is similar to that presented in **Table 4.1**, with the states in the North, Northeast, and Central-West regions showing higher growth rates than those in the Southeast and South regions in the period from 2017 to 2050.

Another reference is the projection made by IBGE (2024) for the Brazilian population by gender and age group. That study projects that demographic expansion should remain at 0.6% per year between 2023 and 2040. The rate is expected to drop to – 0.09% in the following period, between 2040 and 2050. Thus, the average annual rate between 2023 and 2050 was projected at 0.12% per year, a value very close to what is projected in the present study.

#### 4.2. Economic growth scenarios

In this study, two economic growth scenarios are outlined, both based on the statistical relationships between growth and its determinants estimated in **Section 3.2.** The option was to work with the relationship between average labor earnings and the explanatory variables. Thus, the determinants of growth are: the rate of growth of the average wage, lagged average wage (ln), investment rate (ln), break-even rate (ln), enrollment rate (ln), student-to-teacher ratio (ln), the municipal productivity index, population with access to water (%), population with sewerage collection (%), and treated sewage relative to water consumed (%).

In both economic scenarios analyzed, a few assumptions are kept constant. Both scenarios adopt the municipal demographic dynamics described in the previous section, which affects the break-even rate. They also assume identical hypotheses regarding: (i) the enrollment rate (In), for which convergence toward a level of 97% in all Brazilian cities by 2030 is expected, and (ii) the student-to-teacher ratio (In), for which convergence toward a maximum of 15 students per teacher by 2050 is expected, a level considered adequate for the development standard of the

country. The assumptions regarding the evolution of sanitation, which is another variable that affects labor productivity, are also identical in both scenarios. In this case, it is assumed that all cities will reach the targets established by the New Sanitation Regulatory Framework by 2033, except for small cities in the North, Northeast, and Central-West, which are expected to meet the targets by 2040.

Thus, what differentiates the two economic growth scenarios are the assumptions related to the investment rate — expenditures on construction, machinery and equipment, livestock and forests relative to GDP — and the evolution of the productivity index. In the more conservative scenario (Scenario 1), investment is assumed to remain around 17% of GDP, a level observed between 2015 and 2022, a period marked by low gross capital formation and relatively weak economic growth, including brief periods of recession. Regarding productivity, this first scenario assumes only modest productivity gains, which are directly linked to a slower pace of capital replacement.

In the more optimistic scenario (**Scenario 2**), investment is assumed to increase to the level observed between 2008 and 2014, a period that mixed higher and lower economic growth experiences, with fluctuations in investment rates, but averaging 23% higher than in the 2015–2022 period. Regarding productivity, this second scenario assumes more expressive productivity gains, with the introduction of new technologies occurring at a faster pace. As a result of these assumptions, economic growth is higher in the second scenario.

According to the data in **Table 4.2**, which presents projections based on the assumptions of **Scenario 1**, the growth of labor income per capita resulting from the maintenance of investment at the reduced level observed between 2015 and 2022 is expected to be

**Table 4.2.** Scenario 1: Labor income per capita, in BRL per inhabitant\*, 2002 to 2050

	2023	2033	2040	2050 -		Average i	variation	
	2023	2033	2040	2050	2023-2033	<u>annual</u> 2033-	2040-2050	2023-2050
North	35,198.60	39,378.85	41,018.51	45,295.44	1.1%		1.0%	0.9%
						0.6%		
Rondônia	29,434.37	32,860.05	33,942.77	36,251.91	1.1%	0.5%	0.7%	0.8%
Acre	26,569.55	24,758.43	25,734.80	28,509.87	-0.7%	0.6%	1.0%	0.3%
Amazonas	31,665.29	33,899.10	35,768.04	41,070.07	0.7%	0.8%	1.4%	1.0%
Roraima	32,753.24	36,191.71	37,256.42	40,044.48	1.0%	0.4%	0.7%	0.7%
Pará	39,174.39	44,447.94	46,332.00	51,087.72	1.3%	0.6%	1.0%	1.0%
Amapá	22,978.41	29,517.79	30,681.54	33,537.26	2.5%	0.6%	0.9%	1.4%
Tocantins	41,126.73	50,163.83	51,439.37	54,768.52	2.0%	0.4%	0.6%	1.1%
Northeast	27,329.78	34,536.93	36,057.92	40,978.05	2.4%	0.6%	1.3%	1.5%
Maranhão	26,576.24	30,823.96	31,778.64	34,443.68	1.5%	0.4%	0.8%	1.0%
Piauí	29,468.06	32,910.53	33,786.24	36,406.39	1.1%	0.4%	0.7%	0.8%
Ceará	27,245.11	37,925.28	40,625.07	50,367.25	3.4%	1.0%	2.2%	2.3%
Rio Grande do Norte	24,953.86	30,856.55	31,787.45	34,699.22	2.1%	0.4%	0.9%	1.2%
Paraíba	29,558.64	40,134.30	41,522.15	45,755.86	3.1%	0.5%	1.0%	1.6%
Pernambuco	26,843.24	34,340.26	36,226.44	42,198.90	2.5%	0.8%	1.5%	1.7%
Alagoas	25,118.18	32,698.58	33,643.69	35,992.46	2.7%	0.4%	0.7%	1.3%
Sergipe	26,394.35	32,843.25	33,767.54	36,386.53	2.2%	0.4%	0.7%	1.2%
Bahia	28,121.00	34,331.60	35,609.13	39,718.93	2.0%	0.5%	1.1%	1.3%
Southeast	34,715.14	42,728.77	46,376.72	62,144.85	2.1%	1.2%	3.0%	2.2%
Minas Gerais	30,620.31	43,193.85	45,725.19	56,569.82	3.5%	0.8%	2.2%	2.3%
Espírito Santo	32,633.99	43,518.66	45,215.93	50,889.94	2.9%	0.5%	1.2%	1.7%
Rio de Janeiro	28,427.64	34,235.72	36,996.38	47,404.01	1.9%	1.1%	2.5%	1.9%
São Paulo	39,107.92	46,136.06	50,691.60	71,038.41	1.7%	1.4%	3.4%	2.2%
South	36,821.71	46,834.89	49,297.58	58,894.06	2.4%	0.7%	1.8%	1.8%
Paraná	35,435.20	44,796.86	46,659.43	53,259.59	2.4%	0.6%	1.3%	1.5%
Santa Catarina	40,827.81	52,920.35	56,110.17	67,694.98	2.6%	0.8%	1.9%	1.9%
Rio Grande do Sul	35,443.00	44,581.06	47,167.27	58,722.95	2.3%	0.8%	2.2%	1.9%
Central-West	42,491.27	45,904.31	47,745.28	53,979.49	0.8%	0.6%	1.2%	0.9%
Mato Grosso do Sul	40,775.48	44,210.83	45,230.75	48,130.08	0.8%	0.3%	0.6%	0.6%
Mato Grosso	41,240.78	51,359.81	52,864.65	56,997.98	2.2%	0.4%	0.8%	1.2%
Goiás	33,562.28	41,959.02	43,232.82	47,897.30	2.3%	0.4%	1.0%	1.3%
Federal District	67,963.11	62,192.56	67,008.76	84,190.06	-0.9%	1.1%	2.3%	0.8%
Brazil	33,704.57	41,195.30	43,949.53	55,104.02	2.0%	0.9%	2.3%	1.8%

Note: (\*) values at 2024 prices. Source: IBGE, Ministry of Labor and Employment, and Ex Ante Consultoria Econômica.

1.6% per year between 2023 and 2030, a value lower than that recorded in the period from 2008 to 2023 (2.1%). In the following period (2040 to 2050), growth is higher (2.3% per year) due to the expected reduction in demographic expansion during that period.

Thus, labor income per capita is expected to grow at an annual rate of 1.8% between 2023 and 2050, accumulating an increase of 63.5% over 27 years. Considering the projected population increase of 3.4% between 2023 and 2050, total labor income should increase by 69.0% over those 27 years.

The data in **Table 4.3**, which present the projections for labor income per capita in Scenario 2, indicate higher growth. Between 2023 and 2040, expansion should reach 2.0% per year, and between 2040 and 2050, the pace should reach 4.0% per year. This result is driven by higher investment and by a faster pace of productivity expansion than projected in Scenario 1. In addition to the factors mentioned above, the projected decline in population also contributes to the significant increase in labor income per capita, as it reduces the denominator of per capita income.

Table 4.3. Scenario 2: Labor income per capita, in BRL per inhabitant\*, 2002 to 2050

	0000	0000	2040	2052		Average in	variation	
	2023	2033	2040	2050 -	2023-2033	annual 2033-	2040-2050	2023-2050
North	35,198.60	41,290.81	43,212.91	49,157.45	1.6%		1.3%	1.2%
						0.7%		
Rondônia	29,434.37	34,412.93	35,652.14	38,759.46	1.6%	0.5%	0.8%	1.0%
Acre	26,569.55	25,952.01	27,100.31	31,242.67	-0.2%	0.6%	1.4%	0.6%
Amazonas	31,665.29	35,601.71	37,818.20	45,228.47	1.2%	0.9%	1.8%	1.3%
Roraima	32,753.24	37,912.16	39,156.50	42,924.81	1.5%	0.5%	0.9%	1.0%
Pará	39,174.39	46,600.95	48,799.74	55,379.89	1.8%	0.7%	1.3%	1.3%
Amapá	22,978.41	30,948.75	32,313.90	36,287.31	3.0%	0.6%	1.2%	1.7%
Tocantins	41,126.73	52,535.50	54,033.96	58,609.42	2.5%	0.4%	0.8%	1.3%
Northeast	27,329.78	36,253.85	38,095.45	45,417.05	2.9%	0.7%	1.8%	1.9%
Maranhão	26,576.24	32,299.82	33,432.04	37,306.12	2.0%	0.5%	1.1%	1.3%
Piauí	29,468.06	34,476.78	35,522.77	39,536.81	1.6%	0.4%	1.1%	1.1%
Ceará	27,245.11	39,942.52	43,265.54	58,014.57	3.9%	1.1%	3.0%	2.8%
Rio Grande do Norte	24,953.86	32,327.03	33,432.83	38,179.16	2.6%	0.5%	1.3%	1.6%
Paraíba	29,558.64	42,095.36	43,773.58	49,828.49	3.6%	0.6%	1.3%	2.0%
Pernambuco	26,843.24	36,088.89	38,370.76	47,021.17	3.0%	0.9%	2.1%	2.1%
Alagoas	25,118.18	34,251.57	35,357.45	38,599.09	3.1%	0.5%	0.9%	1.6%
Sergipe	26,394.35	34,416.78	35,520.86	39,192.25	2.7%	0.5%	1.0%	1.5%
Bahia	28,121.00	36,013.85	37,558.01	43,733.29	2.5%	0.6%	1.5%	1.6%
Southeast	34,715.14	45,116.32	49,726.01	75,400.56	2.7%	1.4%	4.3%	2.9%
Minas Gerais	30,620.31	45,468.11	48,657.47	67,676.23	4.0%	1.0%	3.4%	3.0%
Espírito Santo	32,633.99	45,686.32	47,772.83	56,053.73	3.4%	0.6%	1.6%	2.0%
Rio de Janeiro	28,427.64	36,131.68	39,578.24	55,266.41	2.4%	1.3%	3.4%	2.5%
São Paulo	39,107.92	48,788.88	54,566.78	87,680.49	2.2%	1.6%	4.9%	3.0%
South	36,821.71	49,250.67	52,322.42	67,681.22	3.0%	0.9%	2.6%	2.3%
Paraná	35,435.20	47,061.19	49,377.52	59,054.22	2.9%	0.7%	1.8%	1.9%
Santa Catarina	40,827.81	55,689.28	59,642.81	77,163.65	3.2%	1.0%	2.6%	2.4%
Rio Grande do Sul	35,443.00	46,902.50	50,157.36	70,544.97	2.8%	1.0%	3.5%	2.6%
Central-West	42,491.27	48,174.86	50,413.39	59,975.62	1.3%	0.7%	1.8%	1.3%
Mato Grosso do Sul	40,775.48	46,304.61	47,527.18	51,584.91	1.3%	0.4%	0.8%	0.9%
Mato Grosso	41,240.78	53,813.82	55,596.53	61,393.58	2.7%	0.5%	1.0%	1.5%
Goiás	33,562.28	43,976.12	45,515.12	53,629.52	2.7%	0.5%	1.7%	1.8%
Federal District	67,963.11	57,551.43	62,773.85	84,848.14	-1.6%	1.2%	3.1%	0.8%
Brazil	33,704.57	43,387.61	46,832.27	64,727.37	2.6%	1.1%	3.3%	2.4%

Note: (\*) values at 2024 prices. Source: IBGE, Ministry of Labor and Employment, and Ex Ante Consultoria Econômica.

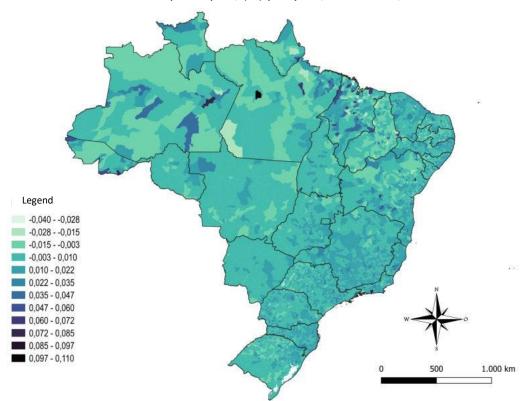
Thus, in **Scenario 2**, labor income per capita is expected to grow at an annual rate of 2.7% between 2023 and 2050, accumulating an increase of 108.0% over 27 years. Considering the projected population increase of 3.4% between 2023 and 2050, total labor income is expected to increase by 115.0% over those 27 years under this second projection.

Maps 4.3 and 4.4 illustrate the dynamics of economic growth in Brazilian cities in both scenarios, showing ranges of variation in labor income per capita. In Scenario 1, most municipalities are expected to experience

positive growth in labor income per capita – all shown in darker shades of blue. Scenario 2 preserves approximately the same regional distribution of economic growth, but there is a greater concentration of municipalities in relatively darker shades of blue. Notably, the higher investment levels and increasing productivity in Scenario 2 have more significant effects in the Southeast and South regions of the country.

**Charts 4.3** and **4.4** show the projected trajectories of the average salary (in BRL per month) and total wage bill (in BRL trillions) in Brazil from 2023

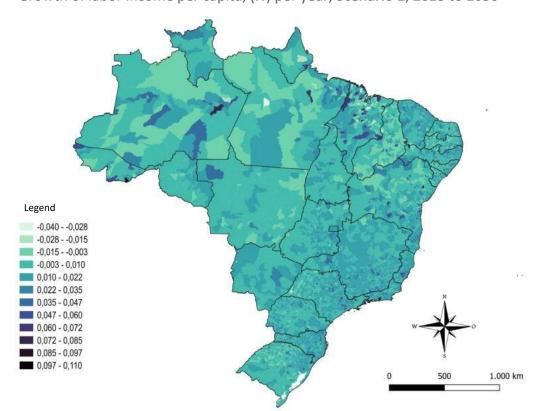
Map 4.3.
Growth of labor income per capita, (%) per year, Scenario 1, 2023 to 2050



Source: IBGE and Ex Ante Consultoria Econômica.

Map 4.4.

Growth of labor income per capita, (%) per year, Scenario 2, 2023 to 2050



Source: IBGE and Ex Ante Consultoria Econômica. to 2050 in both economic scenarios. In **Scenario 1**, the average monthly wage starts at BRL 2,915.49 and reaches BRL 4,766.57 per month in 2050. In the scenario with faster economic growth, the average monthly labor income reaches BRL 6,063.98 per month in 2050. The difference is a monthly income 27.2% higher in **Scenario** 

2. In aggregate terms, total labor income is expected to increase from BRL 3.090 trillion in 2023 to BRL 5.052 trillion in 2050 in **Scenario** 1. The projections for **Scenario** 2 point to total labor income reaching BRL 6.428 trillion in 2050.

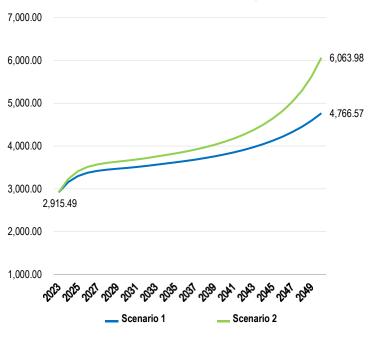
#### 4.3. Water consumption scenarios

This section presents the water consumption scenarios for Brazil through 2050, highlighting developments within the intermediate periods up to 2033 and 2040. In total, four scenarios are presented, each resulting from different economic and behavioral assumptions. **Figure 4.1** shows the structure of the four scenarios.

All scenarios take into account two trends observed in the country since the early 2000s. First, there is a trend of rising prices for water supply and sewage collection relative to the average price of the Brazilian consumer basket. Between 2000 and 2024, the CPI increased at an average rate of 6.2% per year, whereas prices for water supply and sewage collection and treatment services rose by 8.4% per year. This trend is partially associated with increasing energy costs in Brazil, an input that is heavily used in the

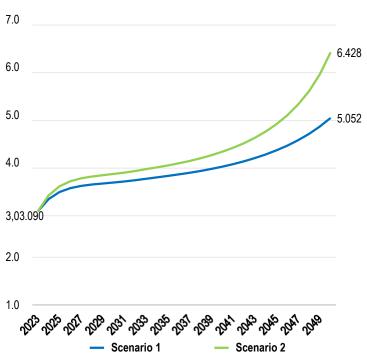
sector's operations. On the other hand, this trend reflects the decreasing cost of industrial goods that make up household consumption baskets, which caused the CPI to grow more slowly than goods and services that are energy-intensive. Since price negatively affects per capita consumption, this trend decreases per-inhabitant consumption over time.

Chart 4.3.
Real average wage, in BRL per month,
Brazil, 2023 to 2050



Source: Ex Ante Consultoria Econômica.

Chart 4.4. Total labor income, in BRL trillions, Brazil, 2023 to 2050



Source: Ex Ante Consultoria Econômica.

Water consumption scenarios, by economic situation and consumption pattern, Brazil, 2023 to 2050

		Economic scenarios						
		Scenario 1 Scenario 2 (conservative) (optimistic)						
lization	by 2040	Α	В					
Universalization	by 2033	С	D					

Source: Ex Ante Consultoria Econômica.

Another assumption present in all water demand scenarios is the gradual reduction of water losses in distribution. In 2023, many municipalities recorded extremely high losses exceeding 80% of total production, meaning that for every liter of water that reached households, it was necessary to produce and send 5 liters through the system. These losses were largely due to pipeline leakage and water diversion (unauthorized consumption). In the scenarios outlined in this study, it is assumed that losses will be consistently reduced by 0.6% per year on average across Brazilian cities until 2050. This will help prevent excessive growth in consumption as universalization of services advances.

The four scenarios differ based on additional assumptions. Scenarios A and B are based on different assumptions regarding urbanization and the pace of achieving universal access to treated water supply compared to Scenarios C and D. In Scenarios A and B, the intensity of water consumption growth is linked to a perspective of slower urbanization, which results in a slower pace of city densification. Furthermore, it is assumed that universal access to water supply services nationwide is

only achieved in 2040. In **Scenarios C** and **D**, urbanization advances more rapidly, as does the pace of convergence toward universal water supply service in all Brazilian cities. Under this second perspective, universal access to water supply services nationwide is achieved as early as 2033. In this sense, **Scenarios C** and **D** can be seen as situations in which consumption patterns across Brazilian cities converge to a higher level within a shorter time frame.

Charts 4.5 and 4.6 show the main difference in the trajectories of population served with treated water supply, which results in the number of people served by water supply services in 2033. In Scenarios A and B, there will still be a service deficit in 2033 of around 20 million people. In the remaining scenarios, service is already universalized by that year.

What varies between **Scenarios A** and **C**, on one hand, and **Scenarios B** and **D**, on the other, is the economic outlook. In **Scenarios A** and **C**, the growth rate corresponds to the conservative economic growth scenario (**Economic Scenario 1**), in which labor income per capita grows only 1.8% per year between 2023 and 2050, and total labor income

grows 2.0% per year. In **Scenarios B** and **D**, which reflect the income growth estimates of **Economic Scenario 2**, the economy grows more: labor income per capita grows 2.7% per year and total labor income grows 2.9% per year between 2023 and 2050. In both alternative economic outlooks, it is worth noting that the growth rates of labor income per capita are higher in the sub-period from 2040 to 2050, when the economy is more mature and the population shows slight contraction.

#### Per capita consumption

**Table 4.4** shows the evolution of per capita consumption in **Scenarios A** and **C**, in which the growth of labor income per capita is less pronounced (**Economic Scenario 1**). In this projection, the country's average per capita consumption is expected to increase from 175.29 liters per

person per day in 2023 – considering access to the water supply system – to an average volume of 202.61 liters per person per day in 2033 (**Table 4.4**). This indicates an average annual growth rate of 1.5%, a pace lower than the increase in labor income per

capita over the same period, which was projected at 2.0% per year. The expansion of consumption is expected to remain below income growth due to the reduction of losses, on the one hand, and the slight increase in prices, which restrains demand growth, on the other.

In the following period, between 2033 and 2040, when per capita income is expected to grow at a rate of 0.9% per year, consumption expansion is also lower. Since continued reduction of losses and a moderate pace of relative price increases are projected, per capita demand is expected to decrease by 0.5% per year during this time span.

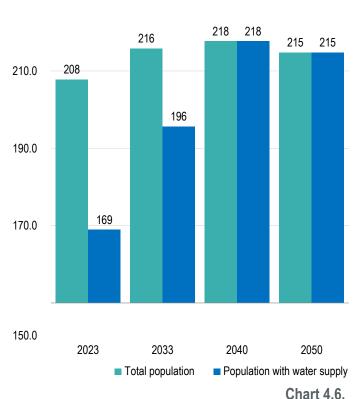
In the third sub-period, from 2040 to 2050, per capita labor income is projected to grow at a higher rate of 2.3% per year.

Chart 4.5.

230.0

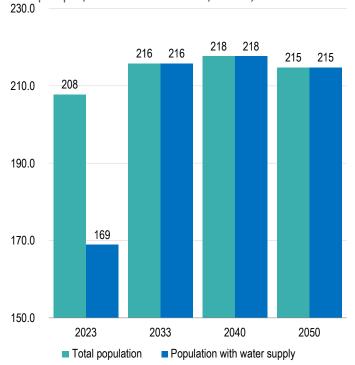
Total population and population served with water supply, in millions of people,

Scenarios A and B, Brazil, 2023 to 2050



Total population and population served with water supply, in millions of

people, **Scenarios C** and **D**, Brazil, 2023 to 2050



44 | SCENARIOS THROUGH Source: Ex Ante Consultoria Econômica.

**Table 4.4**.

Daily per capita water consumption, **Scenarios A** and **C**, in liters per person/day and (%) per year, Brazil, 2023 to 2050

		Lper person/	day		, A	verage annu	al variation (	%)
	<u>iters</u>	2033	2040	2050	2023-2033	2033-2040	2040-2050	2023-2050
	2023							
North	160.98	176.69	171.70	167.67	0.9%	-0.4%	-0.2%	0.2%
Rondônia	176.60	188.37	180.73	175.38	0.6%	-0.6%	-0.3%	0.0%
Acre	171.65	178.55	171.48	171.68	0.4%	-0.6%	0.0%	0.0%
Amazonas	178.82	204.28	204.47	200.74	1.3%	0.0%	-0.2%	0.4%
Roraima	173.25	175.90	167.03	161.45	0.2%	-0.7%	-0.3%	-0.3%
Pará	137.38	148.65	144.86	140.94	0.8%	-0.4%	-0.3%	0.1%
Amapá	238.94	280.65	272.13	265.11	1.6%	-0.4%	-0.3%	0.4%
Tocantins	157.71	175.57	168.20	161.05	1.1%	-0.6%	-0.4%	0.1%
Northeast	145.24	173.73	167.69	164.53	1.8%	-0.5%	-0.2%	0.5%
Maranhão	184.29	209.02	197.46	191.51	1.3%	-0.8%	-0.3%	0.1%
Piauí	195.32	189.64	174.14	168.36	-0.3%	-1.2%	-0.3%	-0.5%
Ceará	129.66	166.09	161.68	162.00	2.5%	-0.4%	0.0%	0.8%
Rio Grande do Norte	142.60	164.34	157.25	152.52	1.4%	-0.6%	-0.3%	0.2%
Paraíba	138.74	165.98	156.29	151.72	1.8%	-0.9%	-0.3%	0.3%
Pernambuco	174.65	216.61	208.60	206.54	2.2%	-0.5%	-0.1%	0.6%
Alagoas	114.45	140.37	136.77	132.04	2.1%	-0.4%	-0.4%	0.5%
Sergipe	119.68	138.99	132.88	128.05	1.5%	-0.6%	-0.4%	0.3%
Bahia	128.74	150.99	146.21	142.84	1.6%	-0.5%	-0.2%	0.4%
Southeast	196.00	228.95	223.86	230.54	1.6%	-0.3%	0.3%	0.6%
Minas Gerais	178.48	230.98	222.53	222.22	2.6%	-0.5%	0.0%	0.8%
Espírito Santo	192.64	249.74	239.61	233.43	2.6%	-0.6%	-0.3%	0.7%
Rio de Janeiro	208.19	246.14	241.34	249.70	1.7%	-0.3%	0.3%	0.7%
São Paulo	199.07	220.36	216.73	227.24	1.0%	-0.2%	0.5%	0.5%
South	170.16	202.31	195.36	195.79	1.7%	-0.5%	0.0%	0.5%
Paraná	161.50	192.43	185.25	182.01	1.8%	-0.5%	-0.2%	0.4%
Santa Catarina	166.84	209.41	203.10	205.62	2.3%	-0.4%	0.1%	0.8%
Rio Grande do Sul	181.82	207.82	200.73	203.77	1.3%	-0.5%	0.2%	0.4%
Central-West	168.00	187.42	182.55	180.61	1.1%	-0.4%	-0.1%	0.3%
Mato Grosso do Sul	172.14	175.57	169.71	162.58	0.2%	-0.5%	-0.4%	-0.2%
Mato Grosso	182.61	210.57	202.52	195.94	1.4%	-0.6%	-0.3%	0.2%
Goiás	151.19	177.96	172.24	167.30	1.6%	-0.5%	-0.3%	0.5%
Federal District	186.80	192.48	193.76	210.10	0.3%	0.1%	0.8%	0.4%
		203.06						
Brazil	175.31	203.06	195.87	196.57	1.5%	-0.5%	0.0%	0.4%

Source: Ex Ante Consultoria Econômica.

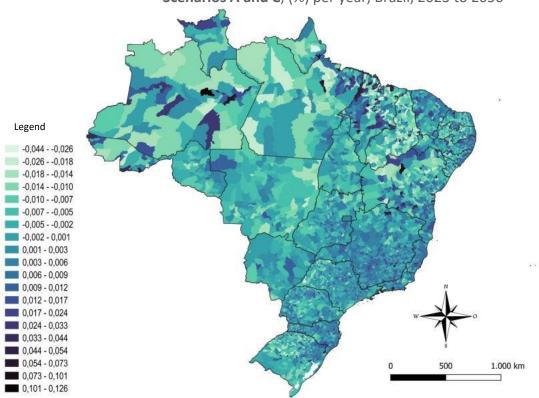
. This is the result of continued investment and increased productivity, on the one hand, and of the expected demographic decline over the period, on the other. This stronger expected increase in income during the 2040s will cause per capita consumption in the country to remain stable.

Thus, for the period from 2023 to 2050, per capita water consumption is expected to grow at an average annual rate of 0.4%, accumulating an increase of

12.2% over 27 years. Note that per capita consumption growth rates vary relatively little across states, as shown in **Table 4.4.** 

**4.4.** Nevertheless, states with a more pronounced increase in labor income per capita over the period (**Table 4.2**) should also show higher per capita consumption growth rates, reinforcing the tendency driven by the faster expansion of coverage levels in regions that currently have

Map 4.5. Rate of growth of daily per capita water consumption, Scenarios A and C, (%) per year, Brazil, 2023 to 2050



Source: IBGE and Ex Ante Consultoria Econômica.

lower coverage rates. Map 4.5 shows the rates of expansion of daily water consumption per inhabitant in Brazilian cities. In some municipalities, per capita consumption is expected to grow at rates higher than 7.5% per year, while in others a decline is projected. In this latter case are the cities that, in 2023, had very high levels of water losses in distribution.

Table 4.5 presents the evolution of per capita consumption in Scenarios B and D, in which the growth of labor income per capita is higher (Economic Scenario 2). In this second projection, the country's average per capita consumption is expected to increase from 175.29 liters per person per day in 2023 to 204.86 liters per person per day in 2033. This indicates an average annual growth rate of 1.6%, also below the growth of labor income per capita

during this period, which was projected at 2.6% per year in Economic Scenario 2. The expansion of consumption is also expected to remain below income growth due to the reduction of losses, on the one hand, and the slight increase in prices, which restrains demand growth, on the other.

Between 2033 and 2040, when per capita income is expected to grow at a rate of 1.1% per year, consumption expansion is also lower. As observed in Scenarios A and C, the continued reduction of losses and the moderate pace of relative price increases lead per capita demand to show a reduction of 0.5% per year.

Finally, in the period from 2040 to 2050, a higher increase in per capita labor income is projected, of 3.3% per year. This is the result of higher investment levels and a

Table 4.5.

Daily per capita water consumption, Scenarios B and D, in liters per person/day and (%) per year, Brazil, 2023 to 2050

	li	iters per person	per day			Average annu	ual variation (	%)
_	2023	2033	2040	2050	2023-2033	2033-2040	2040-2050	2023-2050
North	160.98	177.83	170.28	168.82	1.0%	-0.6%	-0.1%	0.2%
Rondônia	176.60	189.46	178.74	173.75	0.7%	-0.8%	-0.3%	-0.1%
Acre	171.65	179.84	171.90	191.86	0.5%	-0.6%	1.1%	0.4%
Amazonas	178.82	205.73	203.44	204.09	1.4%	-0.2%	0.0%	0.5%
Roraima	173.25	176.91	165.02	159.34	0.2%	-1.0%	-0.4%	-0.3%
Pará	137.38	149.56	143.38	140.33	0.9%	-0.6%	-0.2%	0.1%
Amapá	238.94	282.53	270.50	267.85	1.7%	-0.6%	-0.1%	0.4%
Tocantins	157.71	176.56	165.89	157.94	1.1%	-0.9%	-0.5%	0.0%
Northeast	145.24	174.95	167.07	171.96	1.9%	-0.7%	0.3%	0.6%
Maranhão	184.29	210.42	196.02	200.55	1.3%	-1.0%	0.2%	0.3%
Piauí	195.32	190.75	172.49	175.21	-0.2%	-1.4%	0.2%	-0.4%
Ceará	129.66	167.46	162.67	175.39	2.6%	-0.4%	0.8%	1.1%
Rio Grande do Norte	142.60	165.34	155.77	158.64	1.5%	-0.8%	0.2%	0.4%
Paraíba	138.74	167.12	155.30	153.83	1.9%	-1.0%	-0.1%	0.4%
Pernambuco	174.65	218.24	208.57	215.65	2.3%	-0.6%	0.3%	0.8%
Alagoas	114.45	141.24	135.26	131.55	2.1%	-0.6%	-0.3%	0.5%
Sergipe	119.68	139.84	131.46	127.10	1.6%	-0.9%	-0.3%	0.2%
Bahia	128.74	152.01	145.47	149.37	1.7%	-0.6%	0.3%	0.6%
Southeast	196.00	231.11	228.64	274.25	1.7%	-0.2%	1.8%	1.3%
Minas Gerais	178.48	232.91	224.38	261.59	2.7%	-0.5%	1.5%	1.4%
Espírito Santo	192.64	251.54	238.80	239.41	2.7%	-0.7%	0.0%	0.8%
Rio de Janeiro	208.19	248.56	247.25	289.94	1.8%	-0.1%	1.6%	1.2%
São Paulo	199.07	222.55	222.95	277.54	1.1%	0.0%	2.2%	1.2%
South	170.16	204.00	197.25	219.82	1.8%	-0.5%	1.1%	1.0%
Paraná	161.50	193.87	185.50	191.00	1.8%	-0.6%	0.3%	0.6%
Santa Catarina	166.84	211.29	205.90	229.70	2.4%	-0.4%	1.1%	1.2%
Rio Grande do Sul	181.82	209.63	203.72	244.15	1.4%	-0.4%	1.8%	1.1%
Central-West	168.00	190.08	182.75	185.20	1.2%	-0.6%	0.1%	0.4%
Mato Grosso do Sul	172.14	176.54	167.60	160.27	0.3%	-0.7%	-0.4%	-0.3%
Mato Grosso	182.61	211.87	200.57	195.90	1.5%	-0.8%	-0.2%	0.3%
Goiás	151.19	179.07	170.70	174.78	1.7%	-0.7%	0.2%	0.5%
Federal District	186.80	202.10	203.45	220.61	0.8%	0.1%	0.8%	0.6%
Brazil	175.31	204.86	197.77	219.74	1.6%	-0.5%	1.1%	0.8%

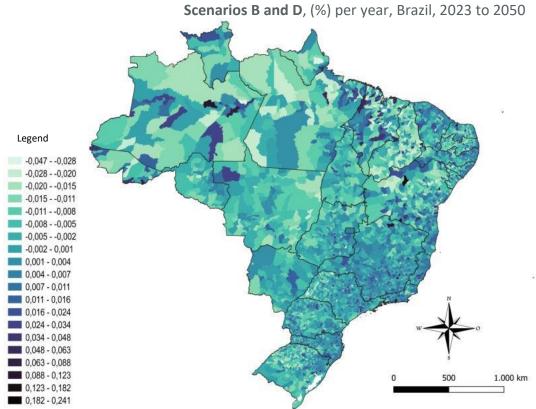
Source: Ex Ante Consultoria Econômica.

stronger increase in productivity. This stronger expected increase in income in the 2040s will cause the per capita consumption growth rate to rise again, although at a moderate level of 1.1% per year.

Thus, for the period from 2023 to 2050, average annual growth of 0.8% in per capita water consumption is expected in **Scenarios B** and **D**, resulting in a cumulative increase of 25.3% over 27 years. Again,

per capita consumption growth rates vary relatively little across states, as shown in **Table 4.5**, and the states with the strongest increase in per capita labor income over the period (**Table 4.3**) are also expected to show higher per capita consumption growth rates. **Map 4.6** shows the rates of expansion of daily water consumption per inhabitant in Brazilian cities. Per capita consumption growth rates above 7.5% per year are expected for a larger number of cities.

Map 4.6. Rate of growth of daily per capita water consumption,



#### Source: IBGE and Ex Ante Consultoria Econômica.

#### Aggregate consumption

By combining the assumptions regarding the evolution of the population served and the scenarios of growth in daily water consumption per person, four scenarios of growth in aggregate demand for water for human consumption in the country are obtained. In accumulated terms, total water consumption is expected to range between 4.598 billion m<sup>3</sup> per year and 6.414 billion m<sup>3</sup> per year, depending on the assumptions adopted in **Scenarios** A through D.

Table 4.6 presents the estimates for Scenario A, in which economic growth is more moderate and universal access to water supply services is reached only in 2040. In this outlook, total water consumption rises from 10.8 billion m<sup>3</sup> in 2023 to 14.5 billion m<sup>3</sup> in 2033. This represents an average annual increase of 3.0% in aggregate demand for treated water and an accumulated increase of 34.1%

over ten years. Between 2033 and 2040, consumption continues to increase, but at a slower pace of 1.0% per year. After this period, aggregate consumption stabilizes and begins a slight decline, following the expected demographic downturn for that decade. By the end of the period, aggregate consumption in Scenario A is estimated at 15.4 billion m<sup>3</sup>, a volume 42.5% higher than that observed in 2023.

**Table 4.7** presents the estimates for **Scenario B**, in which economic growth is faster, although universal access to water supply services is also reached only in 2040. In this second outlook, total water consumption rises from 10.8 billion m<sup>3</sup> in 2023 to 14.6 billion m<sup>3</sup> in 2033, a volume very close to that projected in **Scenario A**. The average annual growth rate of aggregate demand for treated water is 3.1%, with an accumulated increase of 35.3% over ten years..

**Table 4.6.**Aggregate water consumption, **Scenario A**, in million m<sup>3</sup>, Brazil, 2023 to 2050

		million m	3			Average annu	al variation (	%)
	2023*	2033	2040	2050	2023-2033	2033-2040	2040-2050	2023-2050
North	614.498	995.005	1,321.172	1,358.684	4.9%	4.1%	0.3%	3.0%
Rondônia	53.457	91.915	127.221	129.271	5.6%	4.8%	0.2%	3.3%
Acre	26.104	46.345	64.000	68.295	5.9%	4.7%	0.7%	3.6%
Amazonas	202.583	300.804	369.236	387.968	4.0%	3.0%	0.5%	2.4%
Roraima	26.544	40.214	51.301	54.135	4.2%	3.5%	0.5%	2.7%
Pará	206.046	359.022	514.026	523.229	5.7%	5.3%	0.2%	3.5%
Amapá	25.944	58.693	90.448	93.466	8.5%	6.4%	0.3%	4.9%
Tocantins	73.820	98.013	104.942	102.320	2.9%	1.0%	-0.3%	1.2%
Northeast	2,132.408	3,219.433	3,686.067	3,626.029	4.2%	2.0%	-0.2%	2.0%
Maranhão	238.537	420.975	561.071	560.660	5.8%	4.2%	0.0%	3.2%
Piauí	155.940	204.204	233.722	230.036	2.7%	1.9%	-0.2%	1.5%
Ceará	329.161	520.274	585.767	595.837	4.7%	1.7%	0.2%	2.2%
Rio Grande do Norte	128.255	184.338	209.308	203.806	3.7%	1.8%	-0.3%	1.7%
Paraíba	141.223	219.697	248.027	240.429	4.5%	1.7%	-0.3%	2.0%
Pernambuco	420.600	665.224	753.473	742.266	4.7%	1.8%	-0.1%	2.1%
Alagoas	93.654	144.825	167.589	160.369	4.5%	2.1%	-0.4%	2.0%
Sergipe	88.023	113.305	115.070	109.704	2.6%	0.2%	-0.5%	0.8%
Bahia	537.014	746.591	812.038	782.921	3.3%	1.2%	-0.4%	1.4%
Southeast	5,535.811	7,018.734	7,178.477	7,144.026	2.4%	0.3%	0.0%	0.9%
Minas Gerais	1,101.157	1,643.323	1,736.645	1,684.116	4.1%	0.8%	-0.3%	1.6%
Espírito Santo	221.570	331.667	350.251	329.068	4.1%	0.8%	-0.6%	1.5%
Rio de Janeiro	1,090.054	1,420.548	1,470.756	1,462.702	2.7%	0.5%	-0.1%	1.1%
São Paulo	3,123.030	3,623.197	3,620.825	3,668.140	1.5%	0.0%	0.1%	0.6%
South	1,641.483	2,141.318	2,186.765	2,107.473	2.7%	0.3%	-0.4%	0.9%
Paraná	595.650	783.177	799.790	760.964	2.8%	0.3%	-0.5%	0.9%
Santa Catarina	418.625	571.101	580.695	563.802	3.2%	0.2%	-0.3%	1.1%
Rio Grande do Sul	627.209	787.039	806.280	782.706	2.3%	0.3%	-0.3%	0.8%
Central-West	885.940	1,125.458	1,187.270	1,171.519	2.4%	0.8%	-0.1%	1.0%
Mato Grosso do Sul	149.125	175.206	184.915	175.347	1.6%	0.8%	-0.5%	0.6%
Mato Grosso	201.070	280.579	306.012	301.176	3.4%	1.2%	-0.2%	1.5%
Goiás	347.456	461.190	479.669	462.238	2.9%	0.6%	-0.4%	1.1%
Federal District	188.289	208.483	216.673	232.757	1.0%	0.6%	0.7%	0.8%
Brazil	10,810.140	14,499.949	15,559.752	15,407.731	3.0%	1.0%	-0.1%	1.3%

Source: Ex Ante Consultoria Econômica. (\*) Considering estimates for the consumption of cities that did not provide information to SINISA.

Between 2033 and 2040, consumption also continues to grow, but at a slower pace, at 1.0% per year. The difference lies in the fact that, after 2040, aggregate consumption maintains a positive growth trajectory at a rate of 0.9% per year, even with the expected demographic decline during the 2040s. By the end of the period, aggregate consumption under **Scenario B** is estimated at 17.2 billion m³, a volume 59.3% higher than that observed in 2023.

Scenario C, where economic growth is milder but the universalization of water supply services is achieved already in 2033, shows an outcome identical to Scenario A when looking at 2050, but a different trajectory between the two time endpoints. The data in Table 4.8 show that total water consumption rises from 10.8 billion m³ in 2023 to 15.8 billion m³ in 2033, a volume significantly higher than that projected in Scenario A due to the faster pace of expansion in the coverage rate of treated water supply services.

**Table 4.7.** Aggregate water consumption, Scenario **B**, in million m<sup>3</sup>, Brazil, 2023 to 2050

		million m	3			Average annu	al variation (	%)
	2023*	2033	2040	2050	2023-2033	2033-2040	2040-2050	2023-2050
North	614.498	1,001.381	1,310.226	1,367.983	5.0%	3.9%	0.4%	3.0%
Rondônia	53.457	92.444	125.816	128.063	5.6%	4.5%	0.2%	3.3%
Acre	26.104	46.680	64.157	76.320	6.0%	4.6%	1.8%	4.1%
Amazonas	202.583	302.936	367.379	394.426	4.1%	2.8%	0.7%	2.5%
Roraima	26.544	40.444	50.686	53.426	4.3%	3.3%	0.5%	2.6%
Pará	206.046	361.222	508.783	520.970	5.8%	5.0%	0.2%	3.5%
Amapá	25.944	59.088	89.906	94.432	8.6%	6.2%	0.5%	4.9%
Tocantins	73.820	98.567	103.500	100.346	2.9%	0.7%	-0.3%	1.1%
Northeast	2,132.408	3,241.967	3,672.539	3,789.777	4.3%	1.8%	0.3%	2.2%
Maranhão	238.537	423.791	556.982	587.132	5.9%	4.0%	0.5%	3.4%
Piauí	155.940	205.405	231.517	239.402	2.8%	1.7%	0.3%	1.6%
Ceará	329.161	524.562	589.335	645.069	4.8%	1.7%	0.9%	2.5%
Rio Grande do Norte	128.255	185.459	207.338	211.993	3.8%	1.6%	0.2%	1.9%
Paraíba	141.223	221.201	246.455	243.776	4.6%	1.6%	-0.1%	2.0%
Pernambuco	420.600	670.211	753.387	775.019	4.8%	1.7%	0.3%	2.3%
Alagoas	93.654	145.726	165.735	159.766	4.5%	1.9%	-0.4%	2.0%
Sergipe	88.023	113.998	113.838	108.893	2.6%	0.0%	-0.4%	0.8%
Bahia	537.014	751.615	807.953	818.727	3.4%	1.0%	0.1%	1.6%
Southeast	5,535.811	7,084.718	7,331.749	8,498.484	2.5%	0.5%	1.5%	1.6%
Minas Gerais	1,101.157	1,657.028	1,751.139	1,982.509	4.2%	0.8%	1.2%	2.2%
Espírito Santo	221.570	334.059	349.055	337.508	4.2%	0.6%	-0.3%	1.6%
Rio de Janeiro	1,090.054	1,434.506	1,506.784	1,698.364	2.8%	0.7%	1.2%	1.7%
São Paulo	3,123.030	3,659.124	3,724.770	4,480.103	1.6%	0.3%	1.9%	1.3%
South	1,641.483	2,159.154	2,207.905	2,366.188	2.8%	0.3%	0.7%	1.4%
Paraná	595.650	789.052	800.905	798.556	2.9%	0.2%	0.0%	1.1%
Santa Catarina	418.625	576.211	588.705	629.820	3.2%	0.3%	0.7%	1.5%
Rio Grande do Sul	627.209	793.891	818.295	937.812	2.4%	0.4%	1.4%	1.5%
Central-West	885.940	1,141.460	1,188.569	1,201.283	2.6%	0.6%	0.1%	1.1%
Mato Grosso do Sul	149.125	176.174	182.611	172.861	1.7%	0.5%	-0.5%	0.5%
Mato Grosso	201.070	282.318	303.070	301.117	3.5%	1.0%	-0.1%	1.5%
Goiás	347.456	464.060	475.381	482.910	2.9%	0.3%	0.2%	1.2%
Federal District	188.289	218.907	227.507	244.395	1.5%	0.6%	0.7%	1.0%
Brazil	10,810.140	14,628.681	15,710.988	17,223.714	3.1%	1.0%	0.9%	1.7%

Source: Ex Ante Consultoria Econômica. (\*) Considering estimates for the consumption of cities that did not provide information to SINISA.

. The average annual expansion of aggregate demand for treated water is 3.9%, and the accumulated increase over the period is 46.6% in ten years. In this third scenario, after 2033, consumption begins to decline as a result of demographic contraction in the 2040s and the gradual reduction of distribution losses. By the end of the period, aggregate consumption in Scenario C reaches the same level projected for Scenario A, at 15.4 billion m³.

Finally, Scenario D presents the figures for a situation in which economic growth is stronger and universal access to water supply services is achieved in 2033. The outcome is identical to that of **Scenario** B when focusing on 2050, but the trajectory between the two time points differs. The data in Table 4.9 show that total water consumption rises from 10.8 billion m³ in 2023 to 16.0 billion m³ in 2033. The average annual expansion of aggregate demand for treated water is 4.0%, and the accumulated increase over the period is 47.8% in ten years.

**Table 4.8**. Aggregate water consumption, **Scenario C**, in million m³, Brazil, 2023 to 2050

		million m	3		A	verage annu	al variation (	%)
	2023*	2033	2040	2050	2023-2033	2033-2040	2040-2050	2023-2050
North	614.498	1,284.107	1,321.172	1,358.684	7.6%	0.4%	0.3%	3.0%
Rondônia	53.457	124.192	127.221	129.271	8.8%	0.3%	0.2%	3.3%
Acre	26.104	61.418	64.000	68.295	8.9%	0.6%	0.7%	3.6%
Amazonas	202.583	354.580	369.236	387.968	5.8%	0.6%	0.5%	2.4%
Roraima	26.544	48.970	51.301	54.135	6.3%	0.7%	0.5%	2.7%
Pará	206.046	501.815	514.026	523.229	9.3%	0.3%	0.2%	3.5%
Amapá	25.944	87.567	90.448	93.466	12.9%	0.5%	0.3%	4.9%
Tocantins	73.820	105.563	104.942	102.320	3.6%	-0.1%	-0.3%	1.2%
Northeast	2,132.408	3,718.214	3,686.067	3,626.029	5.7%	-0.1%	-0.2%	2.0%
Maranhão	238.537	557.513	561.071	560.660	8.9%	0.1%	0.0%	3.2%
Piauí	155.940	234.687	233.722	230.036	4.2%	-0.1%	-0.2%	1.5%
Ceará	329.161	582.204	585.767	595.837	5.9%	0.1%	0.2%	2.2%
Rio Grande do Norte	128.255	211.505	209.308	203.806	5.1%	-0.1%	-0.3%	1.7%
Paraíba	141.223	252.059	248.027	240.429	6.0%	-0.2%	-0.3%	2.0%
Pernambuco	420.600	761.066	753.473	742.266	6.1%	-0.1%	-0.1%	2.1%
Alagoas	93.654	170.891	167.589	160.369	6.2%	-0.3%	-0.4%	2.0%
Sergipe	88.023	117.895	115.070	109.704	3.0%	-0.3%	-0.5%	0.8%
Bahia	537.014	830.393	812.038	782.921	4.5%	-0.3%	-0.4%	1.4%
Southeast	5,535.811	7,374.169	7,178.477	7,144.026	2.9%	-0.4%	0.0%	0.9%
Minas Gerais	1,101.157	1,795.560	1,736.645	1,684.116	5.0%	-0.5%	-0.3%	1.6%
Espírito Santo	221.570	365.017	350.251	329.068	5.1%	-0.6%	-0.6%	1.5%
Rio de Janeiro	1,090.054	1,511.267	1,470.756	1,462.702	3.3%	-0.4%	-0.1%	1.1%
São Paulo	3,123.030	3,702.326	3,620.825	3,668.140	1.7%	-0.3%	0.1%	0.6%
South	1,641.483	2,269.140	2,186.765	2,107.473	3.3%	-0.5%	-0.4%	0.9%
Paraná	595.650	831.155	799.790	760.964	3.4%	-0.5%	-0.5%	0.9%
Santa Catarina	418.625	600.643	580.695	563.802	3.7%	-0.5%	-0.3%	1.1%
Rio Grande do Sul	627.209	837.342	806.280	782.706	2.9%	-0.5%	-0.3%	0.8%
Central-West	885.940	1,199.380	1,187.270	1,171.519	3.1%	-0.1%	-0.1%	1.0%
Mato Grosso do Sul	149.125	190.036	184.915	175.347	2.5%	-0.4%	-0.5%	0.6%
Mato Grosso	201.070	306.922	306.012	301.176	4.3%	0.0%	-0.2%	1.5%
Goiás	347.456	489.730	479.669	462.238	3.5%	-0.3%	-0.4%	1.1%
Federal District	188.289	212.692	216.673	232.757	1.2%	0.3%	0.7%	0.8%
Brazil	10,810.140	15,845.010	15,559.752	15,407.731	3.9%	-0.3%	-0.1%	1.3%

Source: Ex Ante Consultoria Econômica. (\*) Considering estimates for the consumption of cities that did not provide information to SINISA.

. In this final scenario, consumption begins to decline between 2033 and 2040 as a result of the gradual reduction of distribution losses, but it starts growing again after 2040 due to the sharper economic expansion. By the end of the period, aggregate consumption in **Scenario D** reaches the same level as projected for **Scenario B**, at 17.2 billion m³.

Table 4.9. Aggregate water consumption, Scenario **D**, in million m³, Brazil, 2023 to 2050

		million	m³		F	verage annu	al variation (	%)
	2023*	2033	2040	2050	2023-2033	2033-2040	2040-2050	2023-2050
North	614.50	1,292.15	1,310.23	1,367.98	7.7%	0.2%	0.4%	3.0%
Rondônia	53.46	124.90	125.82	128.06	8.9%	0.1%	0.2%	3.3%
Acre	26.10	61.85	64.16	76.32	9.0%	0.5%	1.8%	4.1%
Amazonas	202.58	357.06	367.38	394.43	5.8%	0.4%	0.7%	2.5%
Roraima	26.54	49.25	50.69	53.43	6.4%	0.4%	0.5%	2.6%
Pará	206.05	504.79	508.78	520.97	9.4%	0.1%	0.2%	3.5%
Amapá	25.94	88.15	89.91	94.43	13.0%	0.3%	0.5%	4.9%
Tocantins	73.82	106.16	103.50	100.35	3.7%	-0.4%	-0.3%	1.1%
Northeast	2,132.41	3,743.99	3,672.54	3,789.78	5.8%	-0.3%	0.3%	2.2%
Maranhão	238.54	561.25	556.98	587.13	8.9%	-0.1%	0.5%	3.4%
Piauí	155.94	236.03	231.52	239.40	4.2%	-0.3%	0.3%	1.6%
Ceará	329.16	586.92	589.33	645.07	6.0%	0.1%	0.9%	2.5%
Rio Grande do Norte	128.26	212.81	207.34	211.99	5.2%	-0.4%	0.2%	1.9%
Paraíba	141.22	253.73	246.45	243.78	6.0%	-0.4%	-0.1%	2.0%
Pernambuco	420.60	766.72	753.39	775.02	6.2%	-0.3%	0.3%	2.3%
Alagoas	93.65	171.95	165.74	159.77	6.3%	-0.5%	-0.4%	2.0%
Sergipe	88.02	118.61	113.84	108.89	3.0%	-0.6%	-0.4%	0.8%
Bahia	537.01	835.97	807.95	818.73	4.5%	-0.5%	0.1%	1.6%
Southeast	5,535.81	7,442.84	7,331.75	8,498.48	3.0%	-0.2%	1.5%	1.6%
Minas Gerais	1,101.16	1,810.33	1,751.14	1,982.51	5.1%	-0.5%	1.2%	2.2%
Espírito Santo	221.57	367.64	349.06	337.51	5.2%	-0.7%	-0.3%	1.6%
Rio de Janeiro	1,090.05	1,526.07	1,506.78	1,698.36	3.4%	-0.2%	1.2%	1.7%
São Paulo	3,123.03	3,738.79	3,724.77	4,480.10	1.8%	-0.1%	1.9%	1.3%
South	1,641.48	2,287.76	2,207.90	2,366.19	3.4%	-0.5%	0.7%	1.4%
Paraná	595.65	837.31	800.90	798.56	3.5%	-0.6%	0.0%	1.1%
Santa Catarina	418.62	605.96	588.70	629.82	3.8%	-0.4%	0.7%	1.5%
Rio Grande do Sul	627.21	844.49	818.30	937.81	3.0%	-0.4%	1.4%	1.5%
Central-West	885.94	1,215.97	1,188.57	1,201.28	3.2%	-0.3%	0.1%	1.1%
Mato Grosso do Sul	149.12	191.08	182.61	172.86	2.5%	-0.6%	-0.5%	0.5%
Mato Grosso	201.07	308.80	303.07	301.12	4.4%	-0.3%	-0.1%	1.5%
Goiás	347.46	492.77	475.38	482.91	3.6%	-0.5%	0.2%	1.2%
Federal District	188.29	223.33	227.51	244.40	1.7%	0.3%	0.7%	1.0%
Brazil	10,810.14	15,982.71	15,710.99	17,223.71	4.0%	-0.2%	0.9%	1.7%

Source: Ex Ante Consultoria Econômica. (\*) Considering estimates for the consumption of cities that did not provide information to SINISA.



## Challenges and risks

This study evaluated the potential growth in water demand in Brazilian cities up to 2050. The modeling used to build future scenarios of residential water demand in Brazil closely follows the analysis developed by Meyer et al. (2019), a study conducted by researchers at the University of Illinois at Urbana-Champaign for the Department of Natural Resources of the State of Illinois, United States. The methodological modeling of this study can be summarized in five steps:

- i. First, the theoretical models most used in the literature on the determinants of residential water demand were analyzed;
- ii. Next, statistical (econometric) models were developed, based on data from Brazilian municipalities, to assess the influence of these factors on water consumption by the population;
- iii. Based on the econometric analysis, estimates were produced to consolidate the information for all Brazilian municipalities in the year 2023, which was chosen as the base period for the projections;
- iv. Then, scenarios were developed up to 2050 to project the evolution of demographic, economic, and consumption-pattern variables that affect residential water demand; and
- v. Finally, projections were made of the potential residential water demand in 2050 under the different scenarios.

#### **Supply challenges**

The analyses identified a significant increase in demand associated with demographic expansion, economic growth, and the universalization of service coverage for households. The

results are summarized in **Figure 5.1**, which presents the cumulative growth rates of water consumption up to the years 2033 and 2050, always taking 2023 as the reference year, along with the increases in demand in billions of m<sup>3</sup> per year. The data show that consumption can expand by up to 59.3% over 27 years. In the scenario consistent with Scenarios B and **D**, in which economic growth is faster, potential water demand may reach 17.224 billion m<sup>3</sup> in 2050, representing an additional 6.414 billion m<sup>3</sup> per year compared to the potential demand in 2023. Even under the scenario with slower economic growth, the increase in demand is projected at 4.598 billion m<sup>3</sup> by 2050.

It is worth noting that, in 2023, potential demand was not fully met due to insufficient supply, partly explained by the water crisis that occurred in some areas of the country that

year. Observed consumption was 9.974 billion m<sup>3</sup> in 2023. The potential demand for that year - a concept in which all citizens in the country receive treated water — is estimated at 13.037 billion m<sup>3</sup> (Table 2.4), which already indicates a shortfall of 3.062 billion m<sup>3</sup> in the supply of treated water.

Assuming that potential water demand is fully met by 2050, it will be necessary to deliver 7.249 billion m<sup>3</sup> more water to Brazilian cities than was effectively delivered in 2023. Demand growth would therefore be 72.7% over 27 years, which would require an expansion of supply at 2.0% per year for 27 years in order to fully meet demand.

This scenario raises key considerations regarding the challenges of expanding water production in the coming years. These challenges are

Figure 5.1.

Water consumption scenarios, by economic situation and consumption pattern, Brazil, 2023 to 2050

		by 2033				by 2050				
		Economic scenarios					Economic s	cenarios		
			Scenario 1 (conservative)	Scenario 2 (optimistic)			Scenario 1 (conservative)	Scenario 2 (optimistic)		
Cumulative growth	ılization	by 2040	34.1%	35.3%	lization	by 2040	42.5%	59.3%		
rate	Universalization	by 2033	46.6%	47.8%	Universalization	by 2033	42.5%	59.3%		
			Economic scenarios				Economic scenarios			
			Scenario 1 (conservative)	Scenario 2 (optimistic)			Scenario 1 (conservative)	Scenario 2 (optimistic)		
Expansion of water	Universalization	by 2040	3.690	3.819	Universalization	by 2040	4.598	6.414		
water consumption in billion m <sup>3</sup>	Universe	by 2033	5.035	5.173	Universa	by 2033	4.598	6.414		

Source: Ex Ante Consultoria Econômica.

associated with the pace of reduction of inefficiencies in the sanitation sector, especially regarding distribution losses, and with potential supply-and-demand imbalances that may be caused by ongoing climate change.3

#### **Losses in distribution**

This increase in demand represents a major challenge, especially in regions where there are significant constraints on water supply. However, an additional problem of major proportions is the issue of water losses in distribution. According to SNIS, the water loss level reached 37.8% in the national average in 2022, which amounted to a waste of 7.062 billion m³ of treated water that year. In the current scenario, marked by recurring water shortages in several regions of Brazil and strong demand growth, containing these losses becomes even more urgent. In 2023, this situation did not improve. According to SINISA data, the average water loss in distribution in the country was 40.3% in 2023, meaning that for every 100 liters of water collected and treated, about 40 liters did not reach the population. In that year, total losses exceeded 7 billion m<sup>3</sup>.

In 2021, the Ministry of Regional Development (MDR) issued Ordinance 490/2021, which established the goal of reaching a maximum distribution loss rate of 25%, or 216 liters per connection/day in volumetric losses, if the share of the national average is lower than the 25% index, by the 2033-2034 biennium. This 25% rate is considered an achievable target given the technical and economic limitations of reducing these losses to zero.4

Based on this target, the Instituto Trata Brasil study (2024a) estimated that the volume of water saved would be approximately 1.3 billion m<sup>3</sup>, which is equivalent to the consumption of about 22 million Brazilians in one year, more than half of the number of inhabitants without access to water supply in 2022. Thus, the study found that there is a potential gross gain of BRL 40.9 billion from reducing water losses by 2034. Considering the investments required to reduce losses, the net benefit generated by this reduction would be approximately BRL 20.4 billion over 11 years.

At the current level of losses, future water demand through 2050 would require a very large increase in production. Considering Scenarios B and D, additional consumption through 2050 will total 6.414 billion m<sup>3</sup>, as previously discussed. With the loss rate from 2023, which was 40.3%, the additional water production required would be 10.672 billion m³, representing an increase of 59.3% compared to water production in the sanitation sector in 2023 (SINISA's GTA1001), which was 18.002 billion m3.

This strongly suggests that meeting future incremental water demand should be achieved, to a large extent, through a faster process of rationalization and reduction of distribution losses. The amount of treated water wasted in 2023 (7.257 billion m³) would have been more than enough to meet the incremental demand (6.414 billion m<sup>3</sup>), without adding extractive pressure on water sources. With losses reduced to 20%, the need for water production would fall by 2.726 billion m<sup>3</sup> compared to what would occur if the loss rate remained at 40.3% of production.

<sup>&</sup>lt;sup>3</sup> Another issue frequently mentioned among the challenges of the sanitation sector is financing. Although credit scarcity and high interest rates negatively affect virtually all types of investment, this factor weighs more heavily on the sanitation sector, especially in cities where operators are small or linked to municipal or state governments. In such cases, lack of scale and governments' financial constraints substantially limit debt financing, making the sector's expansion unfeasible. For more information on this subject, see the study by Instituto Trata Brasil (2020).

<sup>&</sup>lt;sup>4</sup> The economic limit is defined as the volume beyond which the cost of reducing losses exceeds the intrinsic value of the recovered volume, and the technical limit is defined as the minimum loss volume that can be achieved using current technologies, materials, tools, equipment, and logistics.

#### Climate change

Another extremely important issue within this more-than-two-decade analytical horizon is climate change. Reports from the Green Climate Fund - GCF (2017) - and from the Brazilian Panel on Climate Change (2014) outline the challenges Brazil will face in the coming decades regarding climate change. These changes involve rising temperatures, changes in precipitation patterns, risk of water shortages, rising sea levels, and transformations in climate behavior as some of the main impacts already identified.

Ferreira Filho (2020) compiled several climate indicators for the states of São Paulo and Ceará based on data extracted from the study by Xavier et al. (2018). In that study, the authors consolidated information collected from 3,625 rain gauges and 735 automatic climate-monitoring stations over

the period from 1980 to 2015. Regarding Ceará, Ferreira Filho (2020) identified a decrease in rainfall of 53.9 mm per decade between 1980 and 2015, totaling a reduction of 188.65 mm over more than three decades. With respect to temperatures, there was an increase of 1.33°C in maximum temperature during this period, as well as an increase of 0.73°C in minimum temperature and 1.01°C in average temperature. As a result, temperature variation also increased. In the state of São Paulo, on the other hand, there was a reduction of 70.7 mm in average rainfall volume between 1980 and 2015. Over the same period, an increase of 0.98°C in maximum temperature was observed, as well as a decrease of 0.35°C in minimum temperature and an increase of 0.49°C in average temperature, with a consequent increase in temperature variation.

In addition to the data extracted from Xavier et al. (2018), Ferreira Filho (2020) also cites information



from the Brazilian Panel on Climate Change and from other authors for the Northeast and Southeast regions of the country through 2070. Figure 5.2 summarizes the key information. The studies indicate an increase in air temperature by 2070 of 1.5°C to 2.5°C in the Northeast, and 1.5°C to 2.0°C in the Southeast. Conversely, a reduction of 25% to 35% in rainfall patterns is expected in the Northeast, and an increase of 15% to 20% in rainfall patterns in the Southeast of the country. Some studies point to an increase in consecutive dry days in both the Northeast and the Southeast, as well as a high likelihood of increased irregularity in precipitation distribution throughout the year.

More recently, the Intergovernmental Panel on Climate Change's climate change report (2022) indicated that the continued rise in global greenhouse gas (GHG) emissions has accelerated the rate of global warming. In addition to analyzing past

trends, the study outlined five future scenarios through 2100. In the best-case scenario, where GHG emissions are significantly reduced, meaning netzero CO<sub>2</sub> emissions by 2050, an increase of 1.6°C is estimated between 2041 and 2060, reaching 1.4°C between 2081 and 2100. In the worst-case scenario, where GHG emissions are very high, meaning tripling current CO<sub>2</sub> emission levels by 2075, an increase of 2.4°C is estimated between 2041 and 2060, reaching 4.4°C between 2081 and 2100.

The parameters of the econometric climate analysis model presented in the Methodological Annex of this study indicate a trend of increasing both annual maximum and minimum temperatures in Brazil through 2050, with an increase in thermal amplitude. The maximum temperature is expected to increase by approximately 1°C compared to that recorded in 2023, and the minimum temperature is expected to

Figure 5.2. Climate projections for the Southeast and Northeast

Analyzed variables	Trends			
	Northeast	Southeast		
Air temperature through 2070	Increase of 1.5°C to 2.5°C (PBMC, 2014a)	Increase of 1.5°C to 2.0°C (PBMC, 2014a)		
Precipitation	Decrease between 25% and 35% in rainfall patterns (PBMC, 2014a)	Increase of 15% to 20% in rainfall patterns (PBMC, 2014a)		
Consecutive dry days through 2100	Increase in consecutive dry days to more than 30 days (MARENGO et al, 2011)	Increase in consecutive dry days (TORRES, 2016-2017)		
Increase in irregularity of rainfall distribution throughout the year	High probability (MARENGO et al, 2011; PBMC, 2014a)	High probability (TORRES, 2016-2017; PBMC, 2014a)		

Source: Ferreira Filho (2020).

rise by 0.47°C, indicating an increase in variation of 0.52°C by 2050. Other trends include a reduction in the number of rainy days and the occurrence of heavier precipitation events.

#### Risks associated with climate change and mitigation

As discussed in Chapter 2, the maximum and minimum temperatures observed in cities decisively affect residential water consumption: the higher the maximum temperature in a city, the higher the daily per capita consumption, and the higher the minimum temperature, the lower the per capita demand, indicating that a decrease in minimum temperature should increase consumption. In this sense, an increase in temperature range implicitly results in an increase in per capita consumption.

Based on this trend and on the parameters of the demand equation, climate change is expected to further increase per capita water consumption among Brazilian households. Due to rising temperatures, consumption is expected to grow an additional 12.4% beyond the increase resulting from economic factors. This would result in an incremental demand of 2.113 billion m<sup>3</sup> per year and require an additional production volume of 3.515 billion m<sup>3</sup> per year (keeping the 2023 distribution loss rate). This indicates challenges even greater than those arising from demographic and economic expansion, due to ongoing climate change.

Beyond the increase in consumption, it should be noted that projected climate change through 2050 may also disrupt the balance between water supply and demand due to other factors. Increasing temperatures and the prospect of fewer rainy days may lead several regions of the country toward desertification and expand the area of the Brazilian semiarid region, which includes the driest municipalities and those facing greater difficulty meeting demand. In the regions that are already drier, warming may lead to supply failures with high probability.

On average across Brazilian cities, climate trends indicate a 3.4% reduction in water supply

over the year. This means that the country will experience, on average, about 12 days of water rationing per year. Where average precipitation and the number of rainy days are already lower – such as parts of the Northeast and Central-West - it is expected that rationing will last more than 30 days without water, a situation with consequences for public health and quality of life. It is important to note that "30 days without water," in practice, means a longer period of restrictions in supply, since contingency policies operate in rotation cycles; for example, one day with water and two days without. In this latter case, rationing could last three months or more.

The Instituto Trata Brasil study (2024b) analyzed the effects of climate change on the basic sanitation sector. The study used climate scenario models based on CMIP (Coupled Model Intercomparison Project), an international climate-modeling initiative. Among the scenarios presented in the IPCC (2022) study, the one selected for the risk analysis assumes that CO<sub>2</sub> emissions will double by 2100, increasing the global average temperature by 2.1°C between 2041-2060 and by 3.6°C between 2081–2100. The study's analysis period covered the historical trajectory from 1895 to 1994, the more recent historical trajectory from 1995 to 2014, and the climate projections for 2030 (2021 to 2040) and 2050 (2041 to 2060).

The study analyzed three climate-related threats associated with material risks to the sanitation sector: storms, heat waves, and droughts. The climate modeling combined the climate scenario with a series of risk-exposure and vulnerability indicators for Brazilian municipalities, creating a risk indicator ranging from 0 to 1 that reflects exposure levels from very low to very high.

For the water supply system, the Instituto Trata Brasil study (2024b) identified 16 impacts: 6 related to heat waves, 6 to meteorological droughts, and 4 to storms. These impacts affect all stages of water supply operations, from the water source,

through treatment at the Water Treatment Plant (WTP), and ending with distribution. In summary:

- Heat waves reduce water volume and increase pollutant concentration at water sources, damage infrastructure and overload equipment, increase energy demand at treatment plants, raise the probability of contamination and disease spread, and increase water consumption.
- Droughts lead to higher pollutant concentration at water sources, increase demand for groundwater, and cause conflicts over water use. In treatment plants, droughts increase production costs and reduce treatment efficiency. Finally

- , during the distribution stage, droughts tend to cause rationing and the use of alternative sources.
- Storms increase sediment accumulation at water sources, reducing storage capacity and making water treatment more difficult. At water treatment plants, storms cause physical damage to structures and block water transport. During storm periods, treatment efficiency is also expected to decrease, as water flow exceeds the designed capacity and power outages commonly occur, affecting plant operations.

The study also classified the risk level of each of these climate threats at each stage of sanitation operations for every



- A high risk of storms affecting water sources is expected in the states of Espírito Santo, Rio de Janeiro, and Goiás;
- A high risk of storms affecting the operation of water treatment plants was identified in the states of Santa Catarina, Paraná, Rio de Janeiro, Goiás, and Pará;
- Heat waves are expected to pose a high risk to water sources in the countryside of São Paulo, the southwest of Minas Gerais, the coastal region of Pernambuco, and some municipalities in the states of Ceará, Rio Grande do Norte, Acre, and Amazonas;
- Heat waves are expected to pose a high risk to treatment plant operations in regions such as Amazonas, southern Mato Grosso do Sul, northwestern Paraná, western São Paulo, Rio Grande do Norte, and Ceará;
- A medium risk of heat waves affecting water consumption is expected in the following regions: São Paulo, Espírito Santo, and areas in Minas Gerais and Rio de Janeiro, much of the Northeastern coastline, and areas in Southern states such as Paraná and Santa Catarina; and
- High-risk droughts are expected to affect the operation of water treatment plants in the Northeast region, particularly in the Agreste and Backlands areas.

A natural question arising from the identification of climate change and its associated risks is to determine which actions are currently underway in the sanitation sector to mitigate these issues. The study by Ferreira Filho (2020) on the basic sanitation

sector in the states of São Paulo and Ceará – which included an analysis of the state utilities in each state and the respective regulatory agencies – addressed this point. The study concluded, based on interviews conducted with employees of the utilities and the agencies, that stakeholders viewed the phenomenon of climate change as something concrete and inevitable. However, the study found that future climate scenarios were hardly taken into account when planning the expansion and maintenance of basic sanitation operations in these two states.

According to Ferreira Filho (2020), water demand was an imminent concern for the sanitation sector in both states, to the point that it was ranked as a priority impact when considering climate change, as had already occurred in previous decades. The drought from 2012 to 2018 in parts of the Northeast was considered the longest by the region's sanitation sector, causing damage to water demand and to sanitation systems in urban and rural areas. The drought from 2013 to 2015 in the Southeast, especially in São Paulo, was identified by the basic sanitation sector as the longest-lasting drought in that region.

Ferreira Filho (2020) found that stakeholders acknowledge that extreme climate events tend to recur in the future. However, the uncertainty surrounding future climate impacts was still an indicator of resistance within the basic sanitation sector, which appeared to be poorly prepared to face these new extreme climate events, especially those related to drought. The group of professionals interviewed by Ferreira Filho (2020) indicated that the main impacts of climate change would be: (i) the risk of water shortages in cities; (ii) the need to seek new water sources; and (iii) increases in water tariffs to offset investments. In addition, the professionals interviewed identified the following general impacts related to extreme climate events (droughts and floods): (i) impacts on water infrastructures

due to low reservoir levels during drought periods; (ii) impacts of flooding on wastewater treatment systems (WWTPs); and (iii) impacts on sanitation systems caused by illegal connections between stormwater and sewer networks.

Ferreira Filho (2020) also sought to understand how climate change has transformed the search for water supply availability. It was observed that in São Paulo and Ceará, gray infrastructure projects were prioritized during the extreme drought events of the 2010s. These projects involved interconnecting reservoirs or dams, constructing and repairing new pipelines, expanding water supply systems, conducting studies on water reuse plants for nonpotable purposes, and conducting studies on installing a seawater desalination plant, as planned for the Metropolitan Region of Fortaleza.

It is important to highlight that, as noted by Ferreira Filho (2020), these projects were carried out during the occurrence of extreme climate events, which affected the basic sanitation sector severely. This indicates that changes to the water supply strategy were implemented only after the states suffered severely from the impacts of climate change, and not as preventive actions taken before crises.

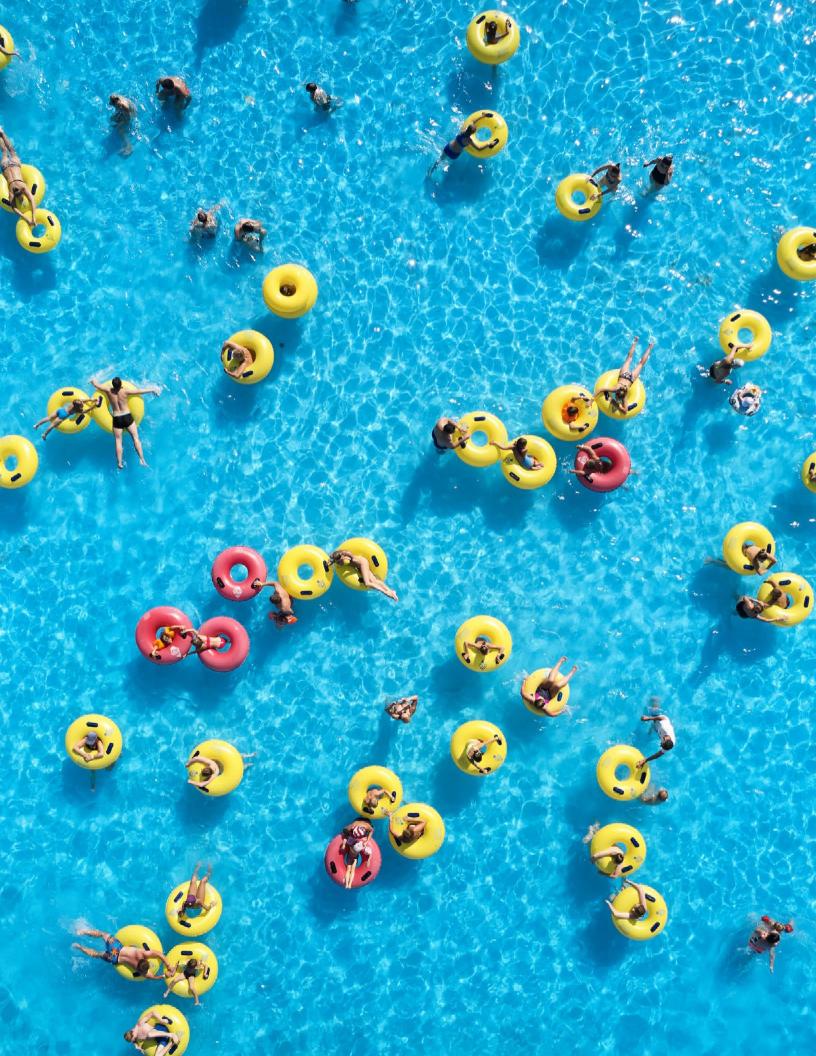
As recommendations for the basic sanitation sector in view of climate change and the impact on water supply and demand, Ferreira Filho (2020) proposed the following points:

i) Understand the vulnerabilities caused by climate change within the territories

where water and wastewater services operate;

- ii) Include in operational and investment planning the historical climate variability data from the past decades to better understand the impacts of past extreme climate events;
- Include the climate variable in the necessary iii) investments, in terms of financial resources, for basic sanitation system operations;
- iv) Incorporate climate projections into future scenario planning so that operations are not affected; and
- v) Ensure that sanitation companies allocate investments to reinforce resilience in drinking water supply, maintain operating systems, and expand wastewater collection and treatment.

In his study, Ferreira Filho (2020) also highlighted recommendations from the literature regarding the adoption of alternative water supply models. Among these models, the most relevant are decentralized technologies water vlagus infrastructure, approaches that prioritize the restoration of ecosystems so that they become sources of water supply for the population.



## **BIBLIOGRAPHY**

ARBUÉS, F., GARCÍA-VALIÑAS, M.A. e MARTÍNEZ-ESPIÑEIRA, R. Estimation of residential water demand: a state-of-the-art review. *Journal of Socio-Economics*, vol 32, p. 81–102, 2003.

BABEL, M.S., DAS GUPTA,A. e PRADHAN, P. A multivariate econometric approach for domestic water demand modeling: An application to Kathmandu, Nepal. *Water Resource Management*, vol 21, p.573–589, 2007.

CORRAL, L., FISHER, A. C. e HATCH, N. W. *Price and non-price influences on water Conservation: an econometric model of aggregate demand under nonlinear budget constrain*. Department of Agricultural and Resource Economics, UCB, UC Berkeley, 1999.

ESPEY, M., ESPEY, J. e SHAW, W.D. Price elasticity of residential demand for water: A metaanalysis. *Water Resource Research*, vol 33, n 6, p. 1369–1374, 1997.

FERREIRA FILHO, R. A. Mudanças Climáticas e o Acesso à Água e Esgotamento Sanitário — Desafios e Oportunidades para os Estados do Ceará e São Paulo, Brasil. 2020. 142 f. Dissertação (Mestrado) — Faculdade de Saúde Pública, Universidade de São Paulo, São Paulo, 2020.

FUNDAÇÃO INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). *Contas Municipais, de 2002 a 2021*. Rio de Janeiro, vários anos.

FUNDAÇÃO INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). *Contas econômicas e ambientais da áqua: Brasil, 2018 a 2020.* Rio de Janeiro, 2023.

FUNDAÇÃO INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). *Projeção da População, revisão 2024*. Rio de Janeiro, 2024.

GIVISIEZ, G. H. N.; OLIVEIRA, E. L. *Demanda futura por moradias: demografia, habitação e mercado*. Niterói, RJ: UFF, Pró-Reitoria de Pesquisa, Pós-Graduação e Inovação, 2018.

INSTITUTO NACIONAL DE METEREOLOGIA (INMET). Séries históricas de medição da umidade relativa do ar. Brasília, 2025.

INSTITUTO TRATA BRASIL. Cenário para investimentos em saneamento no Brasil após a aprovação do novo marco legal. São Paulo, 2020.

INSTITUTO TRATA BRASIL. *Perdas de água 2024: Desafios para disponibilidade hídrica e avanço da eficiência do saneamento básico*, São Paulo, 2024a.

INSTITUTO TRATA BRASIL. As Mudanças Climáticas no Setor de Saneamento: Como tempestades, secas e ondas de calor impactam o consumo de água? São Paulo, 2024b.

INTERGOVERNMENTAL PANEL OF CLIMATE CHANGE, IPCC. Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp., doi:10.1017/9781009325844.

MARENGO, J. A. et al. Variabilidade e mudanças climáticas no semiárido brasileiro. In: Medeiros SS, Gheyi HR, Galvão CO, Paz VPS, organizadores. *Recursos hídricos em regiões áridas e semiári- das Campina Grande: Instituto Nacional do Semiárido*; p.384-422. 2011.

MEYER, S.C., DZIEGIELEWSKI, B., ZHANG, Z., ABRAMS, D. e KELLY, W.R. *Water demand in the Rock River water supply planning region, 2010-2060*. Illinois State Water Survey. Prairie Research Institute University of Illinois at Urbana-Champaign. 2019.

MINISTÉRIO DAS CIDADES. Sistema Nacional de Informações em Saneamento Básico. Brasília, 2025.

MINISTÉRIO DAS CIDADES. Sistema Nacional de Informações sobre Saneamento. Brasília, 2023.

PAINEL BRASILEIRO DE MUDANÇAS CLIMÁTICAS. Base científica das mudanças climáticas. Contribuição do Grupo de Trabalho 1 do Painel Brasileiro de Mudanças Climáticas ao Primeiro Relatório da Avaliação Nacional sobre Mudanças Climáticas [T. Ambrizzi, & M. Araújo, (Orgs.)]. Rio de Janeiro: COPPE, Universidade Federal do Rio de Janeiro. 2014.

SCHLEICH, J. e HILLENBRAND, T. Determinants of water demand in Germany. *Ecological Economics*, vol 68, p.1756-1769, 2009.

TORRES, R. R. Qual é o conhecimento disponível hoje e quais informações ainda faltam para São Paulo. Dezembro/2016. In: DI GIULIO, G. M. et al. *Relatório Técnico-Científico Workshop Mudanças climáticas e o processo decisório na megacidade de São Paulo*: análise das discussões promovidas, 2016-2017.

WENTZ, E.A. e GOBER, P. Determinants of Small-Area Water Consumption for the City of Phoenix, Arizona. *Water Resource Management*, vol 21, p. 1849–1863, 2007.

WOOLDRIDGE, W. *Introdução à econometria: uma abordagem moderna*. Editora Thompson, São Paulo, 2006.

XAVIER, A. C. et al. An update of Xavier, King and Scanlon (2016) daily precipitation gridded data set for the Brazil. In: *Anais do Simpósio Brasileiro de Sensoriamento Remoto*, Campinas, GALOÁ, 2018.

XAVIER, A. C. et al. *Daily gridded meteorological variables in Brazil* (1980-2013). Int. J Climatol 36: 2644-2659. 2015.

# Methodological annex

### Annex 1

Table A.1.

Parameters of the econometric climate analysis model, Brazil, 2000 to 2024

	Coefficient	Standard error	z	p(z)	Confidence interval	
					Lower	Upper
		Minimum				
Trend	0.01724	0.00135	12.82000	0.00%	0.01461	0.01988
Latitude	0.29883	0.00120	248.96000	0.00%	0.29648	0.30118
Longitude	-0.01217	0.00129	-9.47000	0.00%	-0.01469	-0.00965
Altitude	-0.00095	0.00003	-31.94000	0.00%	-0.00101	-0.00089
		Average tempe				
Trend	0.02573	0.00143	18.03000	0.00%	0.02293	0.02853
Latitude	0.30497	0.00127	240.33000	0.00%	0.30249	0.30746
Longitude	0.01419	0.00133	10.64000	0.00%	0.01157	0.01680
Altitude	0.00000	0.00003	-0.04000	96.70%	-0.00006	0.00006
		Maximum temp	erature			
Trend	0.03665	0.00159	23.06000	0.00%	0.03354	0.03977
Latitude	0.29376	0.00141	208.35000	0.00%	0.29100	0.29653
Longitude	0.03395	0.00151	22.56000	0.00%	0.03100	0.03690
Altitude	0.00098	0.00004	27.77000	0.00%	0.00091	0.00105
		Average precip	oitation			
Trend	-0.08256	0.05994	-1.38000	16.80%	-0.20005	0.03493
Latitude	0.75713	0.05298	14.29000	0.00%	0.65328	0.86097
Longitude	-3.85852	0.05661	-68.16000	0.00%	-3.96947	-3.74757
Altitude	-0.00839	0.00133	-6.33000	0.00%	-0.01099	-0.00579
		Rainy days				
Trend	-0.04630	0.00382	-12.13000	0.00%	-0.05379	-0.03882
Latitude	0.06617	0.00344	19.22000	0.00%	0.05942	0.07292
Longitude	-0.19079	0.00365	-52.34000	0.00%	-0.19793	-0.18364
Altitude	-0.00149	0.00009	-17.35000	0.00%	-0.00165	-0.00132
		Relative hum	nidity			
Trend	-0.09383	0.00663	-14.15000	0.00%	-0.10682	-0.08083
Latitude	-0.07723	0.00591	-13.07000	0.00%	-0.08881	-0.06565
Longitude	-0.44037	0.00610	-72.20000	0.00%	-0.45232	-0.42841
Altitude	-0.00910	0.00015	-61.22000	0.00%	-0.00939	-0.00881

Source: Ex Ante Consultoria Econômica.

### Annex 2. Estimates of saving and investment rates

The estimates of municipal saving/investment rates considered three databases:

- National Accounts, 2008–2023
- Municipal Accounts, 2008–2021
- Annual Report of Social Indicators (RAIS), from the Ministry of Labor

Brazil's gross fixed capital formation was broken down by municipality through its four main components: (i) investments in construction works; (ii) investments in machinery and equipment; (iii) software and patents; and (iv) formation of forests and livestock. The national value of each of these four investment components was distributed across municipalities using the following factors:

- (i) Each city's share in civil construction, based on the annual payroll of formal construction workers;
- (ii) Each city's share in the payroll of industrial facilities (to distribute the value invested in machinery and equipment);
- (iii) Each city's share in the IT sector and in engineering and architecture project firms, laboratory testing, R&D activities, and consulting services, based on the annual payroll of formal workers in these sectors; and
- (iv) Each city's share in the agricultural sector, based on the annual payroll of formal workers in that sector.

The saving/investment rate corresponds to the ratio between the sum of these three components of gross fixed capital formation in each city and the average GDP of Brazilian cities for the period from 2008 to 2023.

### Annex 3. Estimates of technological intensity

The estimates of the technology index were based on the Annual Report of Social Indicators (RAIS), from the Ministry of Labor. For each city and year of the analysis, payroll data were collected from the following sectors: 'Information technology service activities', 'Data processing, web hosting, and related activities', 'Business management consulting activities', 'Architectural and engineering services and related technical activities', 'Testing and technical analysis', 'Experimental research and development in physical and natural sciences', 'Experimental research and development in social and human sciences', 'Market and public opinion research'. The technological intensity variable was then defined as the municipality's share of the payroll in these sectors relative to the total wages paid in each municipality in each year.



