Multidimensional poverty in Brazil's north region

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Abstract

Purpose – This article aims to analyse the spatial and temporal evolution of multidimensional poverty in Brazil's North Region and its relationship with territorial, economic and population dynamics.
Design/methodology/approach – A multidimensional poverty index (MPI) was calculated using the Alkire-Foster method and a spatial econometric model was estimated. The data come from population censuses conducted by the Brazilian Institute of Geography and Statistics (IBGE) for the years 1991, 2000 and 2010.
Findings – The results show a decrease in multidimensional poverty over the period analysed. However, they show this reduction occurred in a heterogeneous way in time and space, with emphasis on microregions in which, despite a reduction in the rate, the percentage of the population considered multidimensionally poor remained high during the 30 years of the study.
Research limitations/implications – The quality of available data.
Practical implications – It is possible to point out that public policies focused on improving infrastructure in medium-sized locations tend to have two positive effects: first, making production and consumption more accessible and sustainable for local communities, given that currently the cost of transport and logistics are factors that hinder socioeconomic development; second, to reduce the pressure of demand that this population of small and medium-sized locations exerts on public services currently offered only in larger locations. Although the logic of concentrating most public services in the largest cities makes sense in terms of economic efficiency, the particularities of the northern region and the recognition of its environmental importance point to the need for incentives for more spatially distributed economic activity.
Social implications – From the paper results, it is possible to think about more local public policies which are able to improve people's lifes without to damage the environment.
Originality/value – This is the first study on multidimensional poverty that covers the entire North region of Brazil (Amazon region) and that contemplates both the temporal and spatial dynamics of poverty.
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Keywords Poverty, Multidimensional index, The north region of Brazil
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1. Introduction

Brazil's North region includes a large part of the world-renowned Amazon Forest, with its great biodiversity and natural resources. Since the final decades of the 20th century, the region has undergone a considerable expansion of urbanization (Browder and Godfrey, 1997). According to Browder and Godfrey (2006), this process was stimulated by national

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integration projects for the growth of agricultural, forestry and mining activities. These projects are directly and indirectly related to the migratory flow (interregional, interstate and intermunicipal) to the metropolitan regions of Belém and Manaus from the 1960s onwards (Cardoso *et al.*, 2015).

The region's peculiarities in relation to the rest of the national territory, among them its accentuated socioeconomic inequality and geographic isolation in relation to the more developed regions of Brazil, are important. While having some of the worst social indicators in the country, these contrast with the expressive economic and population growth in the region, which are above the national average. According to IBGE data (2018), 8% of the national population lives in the North region, while 26.1% of the people in poverty in the country live there.

With the expansion of economic activities in the region, new territorial dynamics and living conditions were imposed on local population made up of Indians, rubber tappers, riverside dwellers, *caboclos* and *quilombolas* (Silva and Bacha, 2014). According to the authors, the economic and population growth in the region has not occurred in a balanced and sustainable manner, since, according to the authors, the population experiences a lack of access to basic sanitation and education services, due mainly to the difficulty in accessing the better equipped cities, which, in most of the region, depends on river transport.

Despite the importance the North region's economy both for the economic growth and the development of Brazil, while a significant number of studies seek to analyse aspects of the region's biome and resources, relatively little effort has been made to investigate multidimensional poverty. By focusing the analysis on the North region, it is possible to obtain specific insights into the living conditions of the population and capture the particularities of the incidence of multidimensional poverty.

In studies with a national scope, such as that carried out by Serra (2017), both multidimensional poverty and the spatial issue are addressed. In that study, practically the whole of Brazil's North region is seen to have high levels of high multidimensional poverty in relation to the other regions of the country. The author's findings, despite being an important contribution to the subject, do not allow us to understand the intra-regional dynamics and the particularities of poverty in the region.

In Brazil as a whole, the estimation and discussion of poverty are becoming increasingly important due to empirical evidence of the reduction of extreme monetary poverty in the country. One reason for this fall is the success of nationwide social policies aimed at combating poverty over time (Fahel *et al.*, 2016). On the other hand, few studies have sought to analyse multidimensional poverty, which considers aspects other than income, while focusing on the North region. The available studies focus on specific cities or regional areas, such as Rodrigues *et al.* (2020), Sousa *et al.* (2016a, b). As each region has very specific characteristics, studies that focus on the aspects and dynamics of intra-regional poverty are needed to ensure better understanding and inform public policy makers.

Therefore, it is fitting to ask, despite the local economic growth and the reduction in the number of people living in extreme monetary poverty in the country, if and how multidimensional poverty has changed in Brazil's North region and what particularities can be observed within its microregions? Thus, this article aims to analyse multidimensional poverty and understand the spatiotemporal dynamics of poverty in microregions in the North region. By doing so, it is hoped to contribute to reduce the gap in the literature regarding both the magnitude and nature of the deprivations that most affect the local population.

The North region is composed of seven states: Amazonas, Roraima, Amapá, Pará, Tocantins, Rondônia and Acre, totalling 64 microregions, according to Appendix (Figures A1 and A2). Only 7.9% of the national population lived in the North region in 2010, totalling 15,864,454 million inhabitants. And, between 1940 and 2010 its Gross Domestic Product

(GDP) saw significant increase, growing by 338.6%, while national average was 140.4% (IBGE, 2010).

To carry out this analysis, data from the 1991, 2000 and 2010 demographic censuses were used, which cover a period during which there was considerable economic growth in Brazil and significant restructuring of the social protection system.

The use of microregional data to measure multidimensional poverty is expected to reveal local heterogeneities. According to Breitbach (2008), using microregions as the analytical space enables a more realistic degree of approximation with regard to the economic and social relations that represent the "local environment". For the author, the microregional agglomeration is understood to be a sufficiently small space, in which neighbouring municipalities contribute to the development of a local economic system.

Following this introduction, the article is divided into five sections: the second section presents a review of the literature on conceptual and methodological measurement of poverty, the third describes the methodology used to measure the multidimensional poverty index and to estimate the spatial model; the four presents the results and discussions on the multidimensional poverty model; and, finally, the five section, presents the final remarks.

2. Literature review

The main evolutionary milestones and the current state of the conceptual, theoretical and methodological debate are highlighted starting from the conceptual perspective. In classical studies, poverty was defined by means of survival needs that would or would not be met through the financial income commanded by a person or family. From this one-dimensional approach, which was the only approach until the second half of the twentieth century, the measurement was based in the monetary poverty lines that became more popular from the studies of Rowntree (1901).

However, from the studies of Townsend (1979), Streeten (1981) and Sen (1981, 1985a, b) poverty gained relevance as a multidimensional phenomenon. From this perspective, income is treated as one of the dimensions for calculating poverty and no longer as the only relevant deprivation to define who is poor. The need for this advancement occurs for two main reasons, which are: First, the high inclusion and exclusion errors between individuals who are deprived in relation to income and those deprived in other dimensions of well-being (Baulch and Masset, 2003; Ruggeri Laderchi *et al.*, 2003). The second reason is the fact that not all the monetary attributes can be observed, due to lack or imperfections in the markets, as is observed in underdeveloped countries (Bourguignon and Chakravarty, 2003).

Understood as a multidimensional phenomenon and following the perspective of human development and the capability approach, poverty is characterized by the impossibility of achieving minimum capabilities for social life (Sen, 2018; UNDP, 1997). Poverty, through the lens of Sen's capabilities approach (1981, 1985a, b, 1992, 1993), is seen as a state of deprivation of individuals in which the capability of individuals to be and do is taken into account. In other words, it does not represent a state of deprivation of means (such as income) alone, but consists of a state of deprivation of "capabilities" (substantive freedoms) to carry out the "functionings" (ends) that people are right to value.

According to Espósito and Chiappero-Martinetti (2008), studies on multidimensional poverty can be separated into three categories: (1) studies that aim to build a multidimensional poverty index (Foster *et al.*, 2010; Tsui, 2002; Bourguignon and Chakravarty, 2003; Bossert *et al.*, 2009; Alkire and Foster, 2008); (2) works aimed at establishing ranking criteria for poverty and (Foster and Shorrocks, 1988a, b; Duclos *et al.*, 2006; Alkire and Foster, 2008; Bourguignon and Chakravarty, 2003); and (3) works that aim to analyse poverty indicators (Krishnakumar, 2007; Kakwani and SIlber, 2008; Asselin, 2002).

In this context, Alkire and Foster (2008) proposed a new class of multidimensional poverty measures based on a class of one-dimensional poverty measures. The measure developed by the authors is remarkably simple under the conceptual and computational aspects, being applied in several empirical studies (Alkire and Seth, 2015; Santos and Ura, 2008; Batana, 2008) and its empirical detail is in the nest section of this manuscript.

3. Methodology

3.1 Data, dimensions and indicator's

Using data from the demographic censuses of 1991, 2000 and 2010, which cover a period during which there was considerable economic growth in Brazil and significant restructuring of the social protection system, we build a multidimensional poverty index. The total number of observations per year were: 1991 = 867,303; 2000 = 1,500,546; and 2010 = 1,443,679 individuals for the region.

Following Serra (2017), the unit of identification is the individual, while the global MPI identifies the overlapping deprivations suffered by families, based on the household (Qasim, 2013). There are two reasons for choosing the individual as the unit of measurement: the first is that the database provides individual microdata; the second is related to education, when the household is the unit of identification, as proposed by the global MPI, if there is only one member with a minimum education in the family, the entire household is considered not to be deprived in this dimension.

To calculate the index, four dimensions and 11 indicators are considered, as shown in Table S1 Supplementary Materials.

3.2 The index

The Multidimensional Poverty Index (MPI) developed by Alkire and Foster (2008) will be used in the development of this study. This index is used to adjust the calculation of the traditional poverty rate and analyses the poverty of individuals in relation to other deprivations (dimensions). The multidimensional index ranges from 0 to 1 and, to identify whether or not an individual is in situation of multidimensional poverty, it is necessary to determine a cut-off point. In this case, if the individual is deprived in k dimensions or more. Thus, the poverty rate is calculated using the following equation (1):

$$H = \frac{n}{N} \tag{1}$$

where, n represents the number of people who suffer deprivation in k or more dimensions and N represents the total sample. This calculation alone is not enough to express multidimensional poverty and since it will not increase if the poorest people become even more deprived, that is, if they suffer deprivation in other dimensions. Thus, the average intensity of deprivations is defined, providing the index with greater precision, as expressed in the following equation (2).

$$A = \sum_{i=1}^{n} \frac{Index}{n} \tag{2}$$

In this case, A represents the average number of dimensions of deprivation suffered by the sample. Where, improvements in the standard of living reduce the value of A. The Alkire-Foster method proposes the Multidimensional Poverty Index, also known as the adjusted headcount index, represented by M_0, which is arrived at by multiplying the traditional poverty rate by the average deprivation intensity. The M_0, tests not only whether people are

in poverty, but also the intensity at which they suffer deprivation. Thus, if the absolute number of poor people remains unchanged, a decrease in the average intensity of deprivation would result in an improvement in the standard of living. By contrast, this change is not reflected when calculating one-dimensional poverty. In this study, four equally weighted dimensions of deprivation are adopted. Therefore, M_0 can be disaggregated into four components according to equations (3) below:

$$M_0 = \sum_{i=1}^{n} \frac{Index_i}{N} = \sum_{i=1}^{n} \frac{Income}{N} + \sum_{i=1}^{n} \frac{Education}{N} + \sum_{i=1}^{n} \frac{Health}{N} + \sum_{i=1}^{n} \frac{Standard\ of\ living}{N} \tag{3}$$

Each of the four components is defined as the censored ratio of a dimension of deprivation, which represents the proportion of the poor population that is simultaneously in poverty and deprived in a given dimension.

3.3 The spatial model

In regional data analysis, basically two types of spatial effects can occur: spatial heterogeneity and spatial dependence (Anselin, 1988). When spatial effects are not considered, the estimators may be inefficient, biased or inconsistent (Almeida, 2012). Autocorrelation, or spatial dependence, expresses the lack of independence between the cross-section and the considered database. This assumption assumes that there is an inverse relationship between the strength of interactions and the distance. About spatial heterogeneity, it means that a region can present different properties in a given geographic space, that is, the parameters can vary according to the location.

To empirically assess the relevance of using spatial econometrics, a non-spatial linear model is used as a parameter of comparison. Using the Ordinary Least Squares (OLS) method, estimates from the classical linear regression model are obtained:

$$y = X\beta + u$$

where: y is the dependent variable that represents its n observations, from an $n \times 1$ vector; X is an $n \times k$ matrix that contains the observations of the k (exogenous) explanatory variables; β is the vector $n \times k$ of the regression coefficients; and u is an $n \times 1$ vector of the error terms, that is, it aggregates all unobserved values in the equation.

In the event of spatial, error or lag autocorrelation, the above equation is poorly specified. Two spatial models must be tested, one considering that the autocorrelation occurs in the error and the other in the dependent variable. We can replace the error term above with an error term that represents a spatial error model, given by:

$$u = \lambda Wu + v$$

Note that λ is the coefficient representing the spatial autocorrelation in the error. Thus, the hypotheses are H_0: $\lambda = 0$ and H_1: $\lambda \neq 0$ and if H_0 is accepted the classical model is adequate.

Starting from the classic non-spatial model, we can insert autocorrelation as a spatial dependence on the dependent variable. Now the test that verifies the spatial dependence presents as the null hypothesis, H_0: $\rho = 0$, which would validate the classical linear regression model and if H_1:$\rho \neq 0$ we have the occurrence of a spatial lag model.

$$y = \rho Wy + X\beta + u$$

In both cases, W represents a matrix of spatial weights, in the present study we used the Queen pattern of order 1. The remaining variables are the same as those already defined.

4. Results and discussion on multidimensional poverty

4.1 Evolution of multiple deprivations

When constructing a multidimensional poverty measure it is important to determine the limit of poverty. In Alkire and Foster's method, this poverty threshold is called k. In the present study, in accordance with Sial *et al.* (2015), the poverty limit is $k = 2$.

Table 1 shows the values of the index and its components calculated for the North Region and the states within it. An initial analysis of the adjusted headcount index (H) shows that in 1991 Pará state had the largest share of its population in this condition, with 64% of individuals being considered multidimensionally poor, higher than the regional average of 62.2%.

The state with the lowest incidence of poverty in 1991 was Roraima, with 47.8% of the population being multidimensionally poor. Its economic activity is mainly based on Public

Territories	1991 H	1991 A	1991 M_0	2000 H	2000 A	2000 M_0	2010 H	2010 A	2010 M_0
North	0.622	0.732	0.455	0.531	0.690	0.366	0.267	0.651	0.174
Acre	0.637	0.738	0.470	0.562	0.709	0.398	0.276	0.659	0.182
Amapá	0.491	0.684	0.336	0.440	0.652	0.287	0.236	0.631	0.149
Amazonas	0.558	0.726	0.405	0.546	0.697	0.380	0.340	0.672	0.228
Pará	0.640	0.730	0.467	0.562	0.691	0.388	0.323	0.659	0.213
Rondônia	0.571	0.730	0.417	0.396	0.654	0.259	0.119	0.599	0.071
Roraima	0.478	0.700	0.334	0.412	0.677	0.279	0.234	0.650	0.152
Tocantins	0.744	0.751	0.559	0.556	0.698	0.388	0.161	0.594	0.096

Ranking of microregions with the highest adjusted headcount index (M_0)

1991 UF	1991 Microregion	1991 M_0	2000 UF	2000 Microregion	2000 M_0	2010 UF	2010 Microregion	2010 M_0
AM	Japurá	0.734	AC	Rio Branco	0.723	RO	Porto Velho	0.754
AM	Purus	0.728	RO	Guajará Mirim	0.728	PA	Portel	0.630
PA	Portel	0.716	RR	Caracaraí	0.751	PA	Furos de Breves	0.611
TO	Jalapão	0.708	RO	Porto Velho	0.750	RR	Nordeste de Roraima	0.524
AM	Juruá	0.704	RO	Ji Paraná	0.742	AM	Juruá	0.523
RO	Alvorada D'Oeste	0.678	PA	Belém	0.733	AM	Alto Solimões	0.517
PA	Furos de Breves	0.674	AM	Rio Preto da Eva	0.775	AC	Tarauacá	0.499
TO	Bico do Papagaio	0.671	RR	Boa Vista	0.754	PA	Almeirim	0.486
PA	Guamá	0.668	AP	Macapá	0.764	AM	Japurá	0.476
AC	Tarauacá	0.667	AM	Manaus	0.750	PA	Guamá	0.473

Ranking of the microregions with the lowest adjusted headcount index (M_0)

1991 UF	1991 Microregion	1991 M_0	2000 UF	2000 Microregion	2000 M_0	2010 UF	2010 Microregion	2010 M_0
RR	Caracaraí	0.379	AC	Tarauacá	0.271	TO	Araguaína	0.137
AM	Rio Preto da Eva	0.351	PA	Bragantina	0.270	RO	Ariquemes	0.131
AC	Rio Branco	0.347	AM	Purus	0.241	TO	Rio Formoso	0.111
RO	Vilhena	0.323	AM	Boca do Acre	0.216	RO	Ji Paraná	0.108
RO	Guajará Mirim	0.296	AM	Madeira	0.216	RO	Cacoal	0.107
AP	Macapá	0.266	TO	Jalapão	0.214	PA	Belém	0.102
RO	Porto Velho	0.236	RO	Alvorada D'Oeste	0.193	RO	Colorado do Oeste	0.101
RR	Boa Vista	0.213	PA	Santarém	0.171	TO	Gurupi	0.096
PA	Belém	0.207	PA	Furos de Breves	0.157	TO	Porto Nacional	0.087
AM	Manaus	0.196	PA	Cametá	0.045	RO	Vilhena	0.082

Source(s): Elaborated by the authors based on Census data (1991, 2000 and 2010)

Table 1. The adjusted headcount index (H), intensity (A) and the multidimensional poverty index (M_0) and ranking of microregions with the highest and the lowest adjusted headcount index (M_0). for the North region and its states

Administration, known as the "paycheck economy". In 2000, approximately 54% of the state GDP of Roraima was via Public Administration, while with the exception of rice, soy and vegetable farming, the technological value of the primary sector of the economy is low (De Mello and Silva, 2005).

In the second analysed period, the states of Pará and Acre had the same poverty rate, with 56.2% of the population being considered multidimensionally poor, a level close to the regional average, which was 53.1%. The economy of the state of Acre is based on the exploitation of natural resources, mainly nuts and rubber tree sap, in addition to the export of coconut, cashew and wood. Other agricultural products include beans, rice, cassava and sugarcane, with a large part of the industrial segment being composed of small food processing companies (Menezes and Fernandes, 2005).

By 2010, the poverty rate saw a considerable reduction, compared to 1991. The state of Amazonas had the highest rate of multidimensional poverty with around 34% of the population in that situation, the regional average being 26.7%, while the state with the lowest rate was Rondônia, with 11.9%. The state of Amazonas has the most diversified economy among the states of the North region, consisting of both in activities the agricultural and industrial sectors, mainly in the Manaus Free Trade Zone and in the tertiary sector, especially ecotourism in the Amazon (Sedecti, 2017).

The state of Tocantins, in 2010, had a poverty rate of 16.1%, the second lowest among the states in the North region. This is largely due to its economic activities, according to the Final Report (2015) published by the Secretariat for Planning and Budget (Seplan). The economy of the state of Tocantins, in comparison with other states in the federation, showed the greatest real growth, at 14.2% for the year 2010, while Brazil, on average, grew 7.5%.

According to Table 1, a comparison of the microregions over the period, it can be seen that in 1991 the highest adjusted headcount index (M_0) was in Japurá, Amazonas, where 73.4% of the people suffered from all possible deprivations the population as a whole could face. This microregion is formed by only two cities, Japurá and Maraã, which have particular problems related to provision of health services for those in need of hospitalization, in addition to the logistical problems due to the lack of roads, being characterized by riverside cities. The population is predominantly rural and the average household income *per capita* went from R$109.29 in 1991 to R$163.15 in 2010, a small increase compared to the other microregions.

In 2010 in the microregion of Porto Velho, Rondônia, 75.4% of the people suffered from all the possible deprivations a population as a whole could face. The Porto Velho microregion is comprised of seven municipalities: Buritis, Campo Novo de Rondônia, Candeias do Jamari, Cujubim, Itapuã do Oeste, Nova Mamoré and Porto Velho. These municipalities have low and medium HDI scores, with the exception of Porto Velho, which has a high score (0.736), referring to the year 2010. This microregion's urbanization rate is 84.10% and the average household income *per capita* was R$789.56 in 2010. Despite the apparently high values compared to other microregions, the fact Porto Velho is the capital of the state of Rondônia distorts the figures somewhat, since the remaining municipalities face shortages in terms of health and education factors.

In the comparison between the microregions, one can also note the locations with the lowest adjusted effective index (M_0), as shown in Table 1. A comparison of the analysed periods by microregion reveals that in 1991 the microregion with the lowest effective index adjusted (M_0) was Manaus, in Amazonas, where 19.6% of the people suffered from all the possible deprivations that the population as a whole could face. This microregion is composed of seven municipalities: Autazes, Careiro, Careiro da Várzea, Iranduba, Manacapuru, Manaquiri and the state capital, Manaus. In 1991, the rate of urbanization rate was 91.19% and *per capita* household income was R$ 380.88. The main economic activities were related to the primary sector, such as agriculture and permanent crops of

orange, banana, passion fruit, corn, watermelon and cassava. Regarding the secondary sector, the Manaus Free Trade Zone has the third largest industrial park in Brazil.

Throughout the analysed period, only the microregions of Belém and Vilhena remained ranked among the locations with the lowest adjusted headcount index (M_0). In 2010, the microregion of Vilhena, in the state of Rondônia, had the lowest (M_0), with 8.2% of people suffering from all the possible deprivations that the population as a whole could face. This region had an average *per capita* income of R$ 690.68 and an urbanization rate of 68.18% in 2010.

4.2 The spatial analysis results

The results shown in Table 2 unequivocally express that the variation in multidimensional poverty is characterized as a spatial phenomenon in the north region of Brazil, between 1991 and 2010. The evidence for this is that both LM tests for spatial autocorrelation LM-error and LM-lag are significant. This does not just mean that there are spatial components that explain why the region is poor in relation to Brazil, which is something that is widely known in the literature, but that there are spatial components related to deprivation within the northern region itself, which is a novel result. It is important to note that as an econometric model gives answers in relation to the average, when considering only the northern region as a sample (and not the country as a whole), since this average is very different from the national average, the coefficients and indicators have meaning and interpretation. Different from those already published.

Following Klasen and Misselhorn (2008) and Serra (2017), we chose to use the absolute variation of H, given that low poverty incidence means that small variations in percentage points mean high relative variation, which would potentially generate distortion in the estimates. The two spatial models are superior to the classical model, by the criteria s LIK (maximized log likelihood), AIC (Akaike Infomation Criteria) and SC (Schwartz Criteria) exposed in the table, with no ambiguity. The Spatial Error model (model II) presents the best fit, which is confirmed by the usual diagnostic tests in the spatial econometric literature.

The four variables used to explain the variation in multidimensional poverty between 1991 and 2010 show the theoretically expected signs and are statistically strongly significant. The functional forms adopted respect the empirical literature, such as Santos *et al.* (2019) and Serra (2017).

The coefficient of variable H (1991) shows that poorer localities within the northern region experienced greater success in reducing multidimensional poverty, which is known as beta-convergence in the macroeconomic literature. This phenomenon is usually associated with the higher marginal productivity of capital in less developed regions, where small increases in income tend to have a large effect on production, consumption and consequently well-being – although the occurrence of high inequality tends to reduce the impact of economic growth.

Table 2.
Estimated econometric model results

Absolut var H (1991/2010)	Model I (OLS)	Model II (spatial error)	Model III (spatial dep)
Relative Income Var (91/10)	−0.0011	−0.0010	−0.0010
Absolut Gini Var (91/10)	0.5784	0.3843	0.4765
H (1991)	−0.2589	−0.3634	−0.2838
Urb rate (1991)	0.0026	0.0021	0.0027
λ		0.5594	
ρ			0.2851
R^2	0.667	0.755	0.707
LIK	75.130	81.8100	78.5211
AIC	−140.261	−153.620	−145.042
SC	−129.466	−142.826	−132.083

Increasing productive capacity in the reduction of multidimensional poverty and gains in well-being. In regimes of high income concentration, productive gains tend to benefit small portions of society.

However, the second result that deserves to be highlighted is precisely the impact of the variation in inequality in relation to the variation in poverty: localities that reduced the Gini index reduced the H indicator more successfully than localities that increased income without reducing inequality (just to compare the size of the partial coefficients of the respective explanatory variables). This result is in agreement with the literature, suggesting that poverty should not be seen only as a problem related to the capacity to produce wealth. This argument being empirically valid even in a region of low economic dynamism is especially relevant, since capital additions should have high returns, based on the aforementioned long-term macroeconomic theory. Thus, it can be speculated that without the reduction in inequality that occurred in the period, the convergence of variable H would have been weaker, or in other words, for there to be some kind of convergence, it is recommended that the increase in the production process be accompanied by a reduction of inequality.

The urbanization rate in 1991, despite being statistically significant, had little impact on poverty reduction. This may be due to the fact that–given the difficulties of mobility in a predominantly fluvial environment–having low urbanization close to a large center such as Manaus or even Belém, generates a different impact than having low urbanization in isolated regions, such as Alto Solimões or Tefé. This argument is consistent with the analysis by Silva and Bacha (2014) for the region, in the light of the New Economic Geography (NGE) and may be reinforced further with the analysis of multidimensional poverty clusters.

Finally, from a strictly spatial point of view, the statistically significant coefficient λ indicates that the variation in poverty is spatially associated with variables not included in the modeling, which is to say that the errors are not independent in space. Such an analysis can be complemented with local spatial association tests (LISA), where it is possible to identify poverty clusters. Note that such clusters are not located in regions of greater population density and urbanization, which reinforces the thesis that having low urbanization close to these centers is not a problem of the same magnitude as having low urbanization in more distant regions as can be seen in Figure 1.

The spatial dependence of multidimensional poverty is of a positive nature (regions with similar poverty levels are geographically close) and has consistently increased in the analyzed period, which is visually evident and is confirmed by the Moran Global Indicator, which increased from 5.5% in 1991 to 51.4% in 2010. There is a cluster of poverty that persists in the three analyzed decades, located on the border of Amazonas and Acre with Colombia and Peru. In these locations, characterized by a low rate of urbanization, some 450 thousand people lived in 1991 and 620 thousand people in 2010, which is equivalent to approximately 4% of the region's population, in both periods. As pointed out by Silva and Bacha (2014), poverty in the northern region is influenced by the difficulty of access and mobility, which prevents the flow of production and greater economic dynamism. River transport is the most common in most locations and the journey to a more urbanized center can take weeks. This is potentially the strongest explanation for the persistence of this first poverty cluster.

In 2010, a second poverty cluster appears, also basically composed of low urbanization locations in Pará (the exception is Mazagão, which is located in Amapá and is more urbanized). More than 900,000 people live in this cluster, half of them in Cametá, which, despite being relatively populous for the region, has an urbanization rate of only 50%. In total, in 2010, 1.5 million people lived in areas where poverty was spatially associated, which is equivalent to 10% of the population of the northern region. Note that Moran's I suggests spatial dependence on the order of 50%, a high value, but only 10% of the population resides

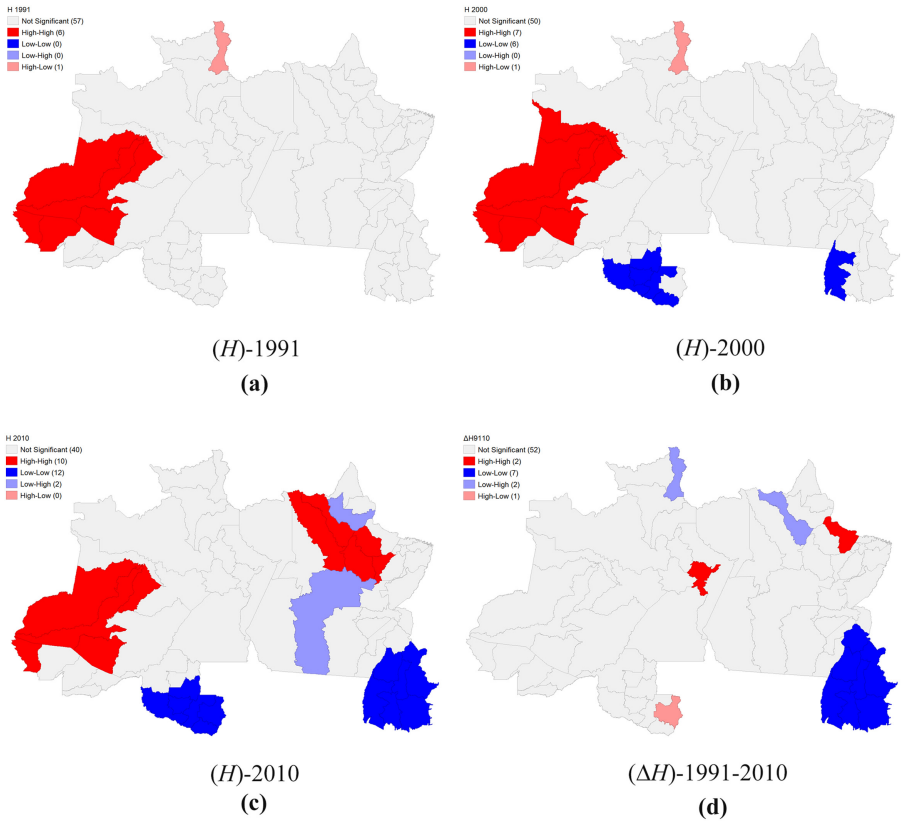

Figure 1.
Maps of LISA clusters for the incidence of multidimensional poverty (H) in the North region of Brazil

Source(s): The authors (2022)

in areas where poverty is effectively a spatial phenomenon, which means that we have proportionately more poor places than people living in poor places in the northern region.

In summary, the poorest regions of the region are characterized by low urbanization, although it has increased in the period, low-complexity economic activities, accessibility problems due to rivers and forests, in addition to extensive areas of environmental protection. Note that there is a cause-and-effect relationship between these obstacles, where the causes are essentially geographical in nature, an aspect on which public policy has limited impact. This does not mean that public efforts to improve accessibility are not desirable, as was the case, for example, with the construction of the BR-364 road, only that there is a limit for accessibility to be improved, imposed by the nature of the region, whose preservation must be a commitment priority. The challenge for the government is to improve these people's access to consumption and public services such as education and health without giving up biological diversity and environmental preservation.

5. Final remarks

Brazil's North region, due to the nature of its local economies, being mainly river-based, distant from the large urban centres and predominantly focused on nature and rural

activities, have over time enhanced their ability to survive from the Amazon biome in a balanced way. However, they tend to suffer from lack of income as well as in other dimensions of poverty. It is at this point that the trade-off between economic growth, population growth and environmental preservation is established.

Calculating and analysing the multidimensional poverty index for the region, its states and microregions has revealed the heterogeneous pattern of the temporal and spatial dynamics of multidimensional poverty index. For example, comparing the states of Tocantins and Pará, while they had the highest indices of multidimensional poverty in 1991 and despite a reduction in poverty in both, it was Tocantins that became the state with the lowest incidence of poverty, while Pará still faces a higher-than-average incidence of multidimensional poverty in the North region.

Furthermore, the study highlighted the importance of regional and intra-regional analysis. When analysing the results for the ten microregions with the highest and lowest multidimensional poverty, there is clear evidence of a process of metropolitanisation of poverty between 1991 and 2000. In 1991, none of the state capitals were among the ten microregions with the most poverty. In 2000, six of the ten microregions with the highest poverty rates were within state capitals. In the following decade, this process is reversed and by 2010, only Belém was among the ten microregions with the highest incidence of poverty.

At the same time, the results show poverty persisted among certain microregions within the North region. Among the microregions with the greatest poverty, six of those with the highest incidence in 1991 are also among those with the highest percentages in 2010, four of which belong to the state of Pará and three to the state of Amazonas, which are among the most economically important states in the region. The state of Tocantins, which had three microregions among the 10 regions with the highest poverty rates in 1991, only had one in 2000 and none in 2010.

On the other hand, among the regions with less poverty, there is less persistence. And, among the microregions that included the capitals, five were among those with less poverty in 1991, none in 2000 and only Belém in 2010. This shows that despite the metropolitanisation of poverty having intensified between 1991 and 2000 and calmed down between 2000 and 2010, multidimensional poverty cannot be said to have been eradicated in the most populous regions in the north of the country.

In summary, the results, in addition to highlighting the heterogeneities in the incidence of multidimensional poverty, make it possible to identify the dimensions that demand greater attention from the policy makers. Once the MPI has as an important attribute the possibility of identifying the share of deprivation of the poor and the number of people in each dimension in the multidimensional poverty indicator, the results are useful both for understanding the effects of public policies at both the state and regional levels. Furthermore, the results are useful to identify, in a more focused way, the priority dimensions that still need attention in specific localities.

From the spatial analysis, it is possible to point out that public policies focused on improving infrastructure in medium-sized locations tend to have two positive effects: first, making production and consumption more accessible and sustainable for local communities, given that currently the cost of transport and logistics are factors that hinder socioeconomic development; second, to reduce the pressure of demand that this population of small and medium-sized locations exerts on public services currently offered only in larger locations. Although the logic of concentrating most public services in the largest cities makes sense in terms of economic efficiency, the particularities of the northern region and the recognition of its environmental importance point to the need for incentives for more spatially distributed economic activity.

Therefore, this study provides the range of information necessary for public policy makers to develop public policies focused on the real needs of this heterogeneous and important region for Brazil. Thus, the work highlights the need for more investments in health, such as hiring

professionals in the health area, acquiring equipment, improving physical infrastructure and moving patients; it also highlights the need for investments in terms of the standard of living of the local population, especially with regard to basic sanitation.

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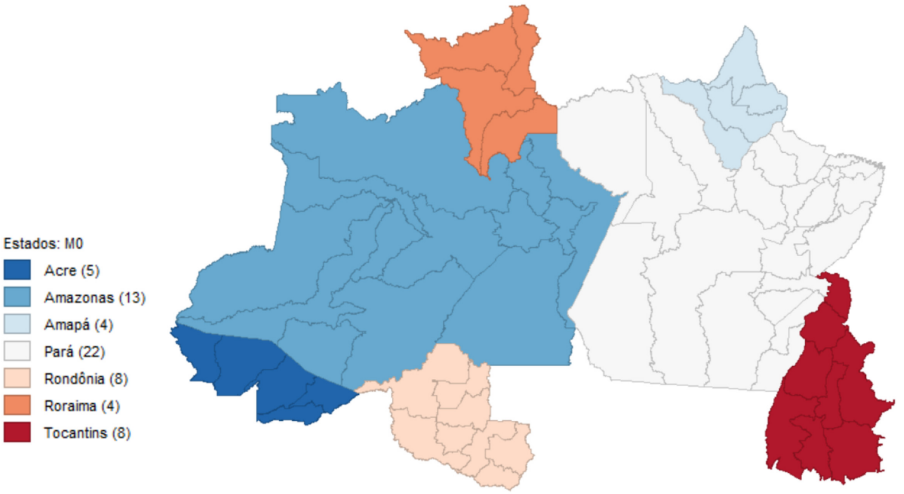
Appendix

Source(s): Elaborated by the authors

Figure A1.
Map showing the location of the North region of Brazil



Source(s): Elaborated by the authors

Figure A2.
Map showing the states in the North region of Brazil

Supplementary Materials

Dimension	Indicator	Deprived if	Weight
Income	Household income *per capita*	Household income *per capita* less than R$140.00, at 2010 prices	1
Standard of living	Access to electricity	No electrical network inside the home	0.25
	Density of residents per bedroom	More than two residents per dormitory	0.25
	Access to toilet facilities	No sanitary device in the toilet	0.25
	Assets	Not having one of the assets at home (television, radio, refrigerator and telephone)	0.25
Health	Waste collection	The household does not have municipal waste collection	0.25
	Drinking water	There is no drinking piped water in the home	0.25
	Sewage system	The residence does not have sewage drainage pipes	0.25
	Infant mortality	After the seventh month of pregnancy, the foetus is born without vital signs	0.25
Education	Elementary school incomplete	Did not complete at least four years of schooling	0.5
	Head of household can read and write	The reference person in the household does not know how to read and write	0.5

Source(s): Elaborated by the authors (2021)

Table S1.
Dimensions, indicators, cut-offs and weights

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