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More Spatial balance with a health calamity? Accounting for the effects of the COVID-19 pandemic on the Brazilian regional income inequality

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ABSTRACT
The COVID-19 crisis has left negative economic marks on Brazil, with the GDP dropping by approximately 3.9% between 2019 and 2020. However, its impact on regional income disparity remains unclear. Less developed states, with fragile healthcare systems, face greater challenges in dealing with the health issues brought by the pandemic, while more prosperous ones, with more structured economies, suffer more from restrictions and lockdowns. Additionally, government policies such as the Emergency Aid played a crucial role in income redistribution, benefiting the most in need. This study, using data from PNADC between 2012 and 2022 and inequality analysis methods, examines the dynamics of regional income disparity in Brazil pre and post-pandemic. The results suggest that the crisis has contributed to reducing regional income disparities, highlighting the relevance of public policies and changes in market income sources.

KEYWORDS
Pandemic, COVID-19, Regional disparities

Mais equilíbrio espacial com uma calamidade de saúde? Considerando os efeitos da pandemia de COVID-19 na desigualdade de renda regional no Brasil

RESUMO
A crise do COVID-19 deixou marcas econômicas negativas no Brasil, com o PIB caindo cerca de 3,9% entre 2019 e 2020. Contudo, seu impacto na disparidade regional de renda ainda é pouco claro. Estados menos desenvolvidos, com sistemas de saúde frágeis, enfrentam maiores dificuldades diante dos desafios de saúde trazidos pela pandemia, enquanto os mais prósperos, com economias mais estruturadas, sofrem mais com as restrições e bloqueios. Ademais, políticas governamentais como o Auxílio Emergencial desempenharam um papel crucial na redistribuição de renda, beneficiando os mais necessitados. Este estudo, utilizando dados da PNADC entre 2012 e 2022 e métodos de análise de desigualdade, examina a dinâmica da disparidade regional de renda no Brasil pré e pós-pandemia. Os resultados sugerem que a crise contribuiu para diminuir as discrepâncias regionais de renda, evidenciando a relevância das políticas públicas e das mudanças nas fontes de renda do mercado.

PALAVRAS-CHAVE
Pandemia, COVID-19, Desigualdade regional

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1. Introduction

Affected by the pandemic of COVID-19, following a worldwide pattern, the Brazilian GDP dropped by 3.9% between 2019 and 2020, an annual contraction stronger than those observed during the recession of 2015 and 2016 (IBGE, 2022). In addition to the intensity of the COVID-19 pandemic recession, which is notable in itself, there is one less perceived feature of it: its regionally differentiated impacts. In this sense, with information from the PNADC, it is possible to register, for example, that while the nine richest states (Distrito Federal, São Paulo, Rio de Janeiro, Rio Grande do Sul, Santa Catarina, Paraná, Mato Grosso do Sul, Mato Grosso e Goiás) showed an average reduction of 9% in their per capita income (a reduction close to that of the richest state, São Paulo), the nine poorest ones (Maranhão, Piauí, Ceará, Alagoas, Paraíba, Bahia, Rio Grande do Norte, Pará and Amapá) showed average stability in this income and the state of Maranhão (the poorest one) even showed some growth in per capita income (about 2.8%) in the period 2019-2020[1].

Regional differences regarding the effects of the pandemic, in fact, seem far from being specific to the Brazilian case. Ascani et al. (2021), for example, have shown that the richest Italian regions, located in the north of the country and more industrialized, were more affected by the economic effects of COVID-19 pandemic than the poorest, located in the south of the country. Also studying the Italian case, Cerqua and Letta (2022) indicated that regions of the country more specialized in service activities were more impacted by the recession associated with de COVID-19. Similar evidence was found by Carvalho et al. (2022) for the Portuguese economy. These authors have shown that the more urbanized and central regions of Portugal were more impacted by the crisis of COVID-19 than less urbanized and central ones. Exploring spatial effects of the COVID-19 pandemic in US, Desmet and Wacziarg (2022), on the other hand, has shown that stronger effects of COVID-19 pandemic have occurred in poorer and urban centers with lower levels of education.

In Brazil, the nature of the pandemic and the public policy reaction to the health calamity are quite probably behind these observed regional differentiated effects of the COVID-19 pandemic recession. If, on the one hand, the richest states have better material conditions and health services to face the contingencies of the pandemic, on the other hand, the greater degree of formalization and the greater dependence of their economies on urban densification and service activities make them potentially more sensitive to the shutdowns (lockdown) and contagions by the virus. Besides, the public policy's immediate reaction to the COVID-19 pandemic effects in Brazil acted through the exorbitant expansion of federal income transfer to the population more affected (The Auxílio Emergencial program). Despite including non-poor people, such expansion included poor people linked to the pre-existing Bolsa Família program, a program already known to be relatively more favorable to the Brazilian poorest states

[1]This ordering of UFs according to the per capita income is based on the situation in 2012, our initial year of analysis.

(Silveira-Neto and Azzoni, 2012).

Albeit the potential channels for the impact of COVID-19 pandemic pointed out above and the Brazilian experience with income transfer policies, very little is known about the sources explaining the regional income inequality dynamic in Brazil during the COVID-19 pandemic. Bógus and Magalhães (2022), for example, mention regional differences in the impact of COVID-19 pandemic on poverty and inequality but do not analyze the sources of income responsible for such differences. More recently, Azzoni and Castro (2023) present evidence that the first year of the economic crisis associated with the COVID-19 pandemic has favored regional wage convergence among Brazilian federation units. Their analysis, however, is limited to the formal labor income.

The objective of this work is to fill this gap; specifically, using the PNADC data for the period 2012-2022 and techniques for decomposing traditional inequality indices, the research documents and decomposes the dynamics of inequality in the period based on the different sources of income. Our set of evidence makes it possible to associate the dynamics of market income (formal work, informal work, and income from properties) and non-market-based sources (retirements and pensions, Benefício de Prestação Continuada (BPC), and other social policies, such as the Auxílio Emergencial and the Auxílio Brasil programs, to the variation in regional income inequality, revealing the role of each of these different sources of income in the observed dynamic of regional inequality. Our evidence therefore allows us to verify how both incomes associated with the market and those associated with public policies behaved regionally during the economic crisis brought about by the COVID-19 pandemic.

The results of the research indicate that between 2012 and 2019 there was no important change in regional income disparities in Brazil, but that in the periods 2019-2020 and 2019-2022 (i.e., before x after the COVID-19 pandemic) there were significant reductions of the disparity in per capita income between Brazilian states (we got 11% and 9% reductions in the Gini coefficient during the periods 2019-2020 and 2019-2022, respectively), contributing to this both the dynamics of the formal labor market, as well as the social policies implemented from 2020 (mainly, the Auxílio Emergencial and Auxílio Brazil programs). For different reasons, these dynamics are basically explained by the labor income and the income from social programs: we document that while the great expansion of income transfer programs (that increases the share of this source of income in the total income) and the dynamic of the formal labor market (that has negatively affected more the richest states) has acted to reduce the per capita income Brazilian regional disparities, the dynamic of the informal labor market has acted to increase it (because it has negatively affected more the poorest states).

In addition to this introduction, the paper presents four sections. In the next section, we present theoretical arguments for possible differences in the COVID-19 pandemic effects on regional incomes and the available empirical evidence about them. In the third section, we present and discuss the empirical strategy employed in the

research. In sections four and five, we present, respectively, the research results and concluding remarks.

2. Regionally differentiated economic impacts of the COVID-19 pandemic: channels and evidence

It is possible to highlight at least three different channels behind the regionally differentiated impacts of the COVID-19 pandemic on local economies and well-being. First, there is a geographic/climatical argument based on the idea that viral infections are known by their climate and season dependency (Stewart, 2016). As pointed out by Chen et al. (2021), viruses tend to be more resistant in places with low temperature and humidity and in environments with low UV radiation. Thus, to the extent that such conditions vary within countries, they tend to generate regional disparities in contagion rates and health conditions associated with the virus of COVID-19, which end up affecting work conditions and economic activity.

Second, regionally differentiated impacts of the COVID-19 pandemic on local economies may arise due to different local productive structures. To the extent economic activities differ in terms of the need for manual work, the possibility of remote work, and the necessity of personal interactions among agents regionally differentiated impacts of the pandemic on the activity may occur. In this regard, service activities may be cases of contagion and lockdown policies than those in agriculture, for example. Even regional productive differentiations within services may be associated with different economic influences of the COVID-19 pandemic, as some services present stronger dependence on personal contact than others. In addition, regional differentiations in terms of the degree of formalization of the activities and dependence on urban densification and service activities may also generate economic regionally differentiated impacts of the COVID-19 pandemic since they imply different degrees of sensitivity to the shutdowns (lockdown) and contagions by the virus across regions.

Finally, there may be regionally differentiated economic impacts of the COVID-19 pandemic due to spatial differences in terms of development levels and families' dependence on public resources. On one hand, with better public service infrastructures, wealthier regions are in a better position to deal with the challenges associated with meeting people's demands during the pandemic. On the other hand, greater dependence on public resources to sustain the local levels of activities and as a complementary source of income for families in poorer regions may make the economy of these regions less sensitive to the impact of the COVID-19 pandemic.

The empirical evidence on such mechanisms is still in progress. The available works indicate that the geographic/climatical channel appears convincing, but such influence does not appear significant to explain the regional variations in economic activities during the COVID-19 pandemic. Working with Spanish provinces, Paez et al. (2021), for example, showed that the incidence of the disease is lower at higher tem-

peratures and higher levels of humidity. In contrast, the authors also found a positive association between sunshine and the incidence of the disease. Similarly, Correa-Araneda et al. (2021) found that transmission of COVID-19 was greater in colder and drier Chilean cities. Working with a cross-section of countries, the evidence obtained by Chen et al. (2021) indicated that the closer to the equator, the fewer the number of contagion cases per million inhabitants; accordingly, we may expect a decline in new COVID-19 cases during summer and a resurgence during winter. As for the Brazilian situation, dos Santos et al. (2023) showed that increases of 1% in the solar incidence, average temperature, and relative humidity of the air reduced COVID-19 prevalence rates by 0.16%, 0.049%, and 0.22%, respectively, considering the 11-day moving average.

As for the role of the local productive structures on the economic impact of the COVID-19 pandemic, although still fragile, the evidence appears more compelling. Working with Italian regions, Ascani et al. (2021), for example, showed that the most industrialized regions were more affected by the COVID-19 pandemic than the less industrialized ones, a circumstance attributed by the authors to differences in production structures. In the same sense and also studying the Italian case, Cerqua and Letta (2022) indicated that regions of the country more specialized in services activities were more impacted by the recession associated with the COVID-19 pandemic. Interestingly, a similar result was obtained by Carvalho et al. (2022) studying the economic impact of the COVID-19 pandemic in Portuguese regions. These studies appear to favor the idea that dependence on urban densification and service activities may turn local economies more sensitive to the impacts of the COVID-19 pandemic, either due to the possibility of greater contagion or due to greater sensitivity to confinement or lockdown policies. In the Brazilian case, using traditional growth regressions, recently Azzoni and Castro (2023) showed that the first year of the COVID-19 pandemic in Brazil (2020) favored the reduction of regional inequality in formal labor income. This indicates that, at least in terms of the formal sources of labor income, the economic impacts of the COVID-19 pandemic were weaker in the Brazilian poorer states.

The evidence about the relevance of spatial differences in terms of development levels and families' dependence on public resources for explaining regional differences in the economic impact of the COVID-19 pandemic generally relies on poverty and inequality indicators within spatial units, but not on income inequality among spatial units. Mahler et al. (2022), for example, provided evidence of increasing worldwide inequality and poverty due to the COVID-19 pandemic. The explanation is associated with the greater sensitivity of low-skilled individual incomes to the general reduction of the level of economic activities. In the case of Brazil, Cardoso et al. (2021) showed that poorer families tend to be more affected by the economic crisis, and Komatsu and Menezes-Filho (2020) and Neri (2022) showed the COVID-19 pandemic increased poverty and inequality in the Brazilian states. Indeed, Bógus and Magalhães (2022) highlighted that the impact of the COVID-19 pandemic on poverty indicators was stronger in the Brazilian poorest states than in the richest ones. These works, how-

ever, did not consider the impact of the crisis on regional income inequality [2]. In this regard, Azzoni and Castro (2023) showed that in Brazil economic crisis generally brings regional income reduction, and this pattern was present in their short analysis based on formal labor incomes for the case of COVID-19 crisis. Note that, in the case of the COVID-19 crisis, the expansion of income transfers to the poorest families through programs such as Auxílio Emergencial may have also helped to mitigate the reduction of income, especially in the Brazilian poorest states, given the pro-poor states bias of these programs highlighted by Silveira-Neto and Azzoni (2012). Our analysis presents evidence regarding the relevance of arguments associated with differences in productive structure and the role of public policies in this dynamic during the years 2019-2022. The results of the current research, thus, extend the work by Azzoni and Castro (2023) in two fundamental directions: they reveal the roles of market incomes from both formal and informal sectors and of incomes from the federal government programs and consider a period of analysis that includes the more recent years of 2021 and 2022.

3. Empirical Strategy

3.1 Inequality decompositions

Our empirical strategy closely follows that presented by Silveira Neto and Azzoni (2011) for the study of regional inequality in Brazil based on different sources of family income. From the initial decomposition proposed by Gregor (1981) and Kakwani (1980), when it is possible to obtain the income of the states or regional subunits as the sum of portions from different sources, as is known, the Gini coefficient and the measures of Generalized Entropies can be decomposed from plots that reflect the different contributions of these sources to the level of inequality in the regional distribution of per capita income (López-Feldman et al., 2007; Arslan and Taylor, 2012). Specifically, considering the Gini index, this can be expressed by the sum of the ratios or concentration coefficients multiplied by the respective weights of the different sources of income. Formally, the value of the Gini coefficient (G) can be expressed as:

$$G = \sum_{f=1}^{N} \alpha_f C_f, \tag{1}$$

where N is the number of sources of income, α_f is the share of the source of income f, and C_f is the Concentration Coefficient of the source f. This coefficient is obtained from the Concentration Curve, which shows how maintaining the ascending order of total labor income per capita, the accumulated proportion of the f portion varies as a function of the accumulated proportion of the population (states). More specifically, defining β_f as the area between de Concentration Curve of the source f and the

[2] Notice that greater increases in poverty in the poorest Brazilian states are not inconsistent, for example, with a regional income inequality drop, once these states present relatively more families closer to the poverty line.

abscissas axis, the Concentration Coefficient of the source of income f is obtained as:

$$C_f = 1 - 2\beta_f, \tag{2}$$

where it can be shown that $-1 < C_f < 1$. This interval, which differs from the Gini index interval $0 \leq G < 1$, stems from the fact that, since the ordering on the ordinate axis is given through the ascending ordering of total income (and not the f portion of income), the concentration curve it is concave (and not convex, as in the case of the Lorenz Curve). For two dates, *t* and *t-1*, one can observe how much of the variation in the Gini index is determined by the variation in inequality of the different income parcels and how much derives from the variation in the participation of these parcels in the income. In fact, it is possible to decompose the variation of the Gini index as:

$$\Delta G = \sum_{f=1}^{N} \left(\bar{C}_f - \bar{G}_f\right) \alpha_f + \sum_{f=1}^{N} \bar{\alpha}_f \Delta C_f, \quad \text{onde} \quad \bar{G} = \frac{1}{2}\left(G_t - G_{t-1}\right) \tag{3}$$

With the first sum representing the participation effect, it is observed that the increase in the participation of a source that presents a lower (greater) level of concentration than that verified for the total income contributes to a decrease (increase) in the inequality of the total income of the work. The second sum, which represents the total concentration effect, shows the impact of variations in the levels of concentration of different sectors' income parcels on the variation in the level of inequality of total income[3].

Similar decompositions can be obtained using Generalized Entropy measures. For

$$GE(2) = \left(\frac{1}{2}\right)\left[\frac{1}{n}\sum_{i=1}^{n}\left(\frac{y_i}{\mu}\right)^{\alpha} - 1\right] = \frac{\sigma^2}{2\mu^2} \tag{4}$$

example, with , where y_i is the per capita income of *i*, μ the mean of the income distribution, and n correspond to the numbers of osbervations, it can be obtained:

$$GE(2) = \sum_{f=1}^{N} \rho_f \alpha_f \sqrt{GE(2) GE_f(2)} \tag{5}$$

where, ρ_f is the correlation between the component f and the total income, α_f again is the share of *f*, and $G_f(2)$ and is the index itself for the referred income component. From this relationship, it is immediately possible to obtain the participation of each source of income in total inequality and, for a given period of analysis, how much each portion is responsible for the variation in the inequality index (expression analogous to equation (4) obtained for the Index).

[3]A similar decomposition was proposed by Leman and Ytzihak (1985), but it considers three factors in the equation (1), instead of two, and does not directly inform about the nature (for the poorest/richest unities of analysis) of the distribution of each source of income, as it is revealed directly by the Coefficient of Concentration.

3.2 Data and sources of income

Given the richest characterization of the inequality dynamics possible to be obtained from the Gini decomposition, the following evidence focuses on the results of the inequality decomposition from this index. We use microdata from PNADC (*Pesquisa por Amostra de Docimicílios Continua*) from the IBGE for the period 2012-2022 and aggregate the values to the level of UF (*Unidades da Federação*). The period of analysis was chosen due to the availability of information (the microdata of PNADC is available only from 2012 on) and because was possible to incorporate a few years after the arrival of the COVID-19 pandemic in Brazil (which occurred in 2020). It should be also noted that this period of analysis includes two periods of important declines in economic activity in Brazil (2015-2107 and 2020-2021) for very different reasons, which is an aspect analytically interesting. Notice that this source of information presents two crucial advantages for the current research. Firstly, the PNADC microdata allows obtaining households and UFs per capita income by adding different sources of income. Here we consider total income as the product of the sum of six different sources of income, three of them derived from market (Y_M) income and the other three from non-market incomes (Y_{NM}). Secondly, this source of information allows disaggregating information of income by formal and informal activities.

The three sources of market income are income from formal labor (Y_F), informal labor (Y_{INF}), and income from proprieties or capital (Y_{PROP}). Sources of income not derived from the market, in turn, corresponding to BPC (*Benefício de Prestação Continuada*) income (Y_{BPC}), income from social programs (Y_{SP}), and income from retirement, pensions, donations, insurance, and alimony (Y_{AP}). Thus, from the PNADC microdata, we aggregate values to obtain the total per capita income of a UF i (y_{ti}) as:

$$y_{ti} = \frac{\sum_j Y_{Mij} + \sum_l Y_{Mil}}{pop_i} \tag{6}$$

Or, more specifically,

$$y_{ti} = \frac{Y_{Fi} + Y_{lNFi} + Y_{PROPi}}{pop_i} + \frac{Y_{BCPi} + Y_{SPi} + Y_{APi}}{pop_i} \tag{7}$$

Where pop_i is the population of the UF i.

Notice that the possibility of accounting for the role of incomes from social programs is extremely important since during the period 2020-2022, as a strategy of attenuating the economic effects of COVID-19 pandemic, the federal government implemented two new programs of income transfers, the *Auxílio Emergencial* program (from April of 2020 to March of 2021) and the *Auxílio Brasil* program (from October 2021 to December 2022). More specifically, the *Auxílio Emergencial* program involved an income transfer of R$ 600 during the year 2020 and R$ 300 during the three months of 2021 for low-income families[4]. In turn, the *Auxílio Brasil* program came

[4]Individuals eligible for the program were people over 18 years old, with income up to half the mini-

into force in October 2021 replacing the *Bolsa Família* program and paid R$ 400 monthly to families (a 20% increase concerning the value paid by the *Bolsa Família* program). It should be noted that the magnitudes of the resources involved in these programs were far from negligible. For the *Auxílio Emergencial* program, in 2020 and 2021, they amounted to around R$ 298 billion and R$ 60 billion, respectively; as for the *Auxílio Brasil*, they amounted to about R$ 90 billion in 2022[5].

Notice that, just like the resources of *Bolsa Família* program (Silveira Neto and Azzoni, 2012), the tendency of the resources of these new programs to benefit the poorest Brazilian federation units was clear; for the year 2021, for example, all the nine states with the highest per capita values of the *Auxílio Emergencial* program belonged to the North and Northeast regions of Brazil, while all the nine states with the lowest per capita values were located in the Brazilian South, Southeast, and Midwest regions.

The other important advantage of using the information from PNADC is that it allows the consideration of the most recent possible information about UFs' incomes. Note that this is also a crucial and pertinent characteristic since we are interested both in the immediate and overtime impacts of the COVID-19 pandemic on income regional inequality.

In the following Table 1, we present the values of the total and of each source of per capita income used to decompose the regional inequality. The values refer to 2022 and UFs are ordered from the poorest to the richest based on the current values of this last year. The set of information turns clear that in general, compared to the total income, market sources of income favored the richest UFs and non-market sources of income favored the poorest ones Silveira-Neto and Azzoni (2012), patterns that are clearer for "Other market" and "Social Policies" components, respectively.

As a result, we observe that the share of non-market (market) components in total income was higher for the poorest (richest) UFs; for example, while non-market sources of income amount to about 32.8% of total income in Maranhão, the correspondent number was about 12.6% in São Paulo. As we discuss later, due to different reasons, these patterns were more marked before the COVID-19 pandemic.

mum salary (MS) per capita or family income of up to three MSs, limited to two quotas per family. Note that this includes beneficiaries of the *Bolsa Família* program, but also informal, self-employed people, and micro-entrepreneurs

[5]Notice that, in 2019, the value of the expenditure of the *Bolsa Família* program amounted to R$33 billion (see https://portaldatransparencia.gov.br/programas-e-acoes/programa-orcamentario/2019-inclusao-social-por-meio-do-bolsa -familia–do-cadastro-unico). See https://aplicacoes.cidadania.gov.br/vis/data3/index.php?g=2, for the values of the *Auxílio Emergencial* and *Auxílio Brasil* programs.

Table 1. Per capita income by sources of income (R$) – Brazilian UFs – 2022.

UF	BPC	Social Policies	Retir. and Pension	Other Non-market	Formal Labor	Informal Labor	Total
MA	17	61	190	8	335	206	818
AL	30	60	212	14	437	186	938
AM	18	46	135	13	490	268	970
BA	22	58	214	16	439	266	1014
PE	22	55	235	18	485	210	1015
AC	12	48	178	6	524	237	1042
CE	30	54	262	22	460	221	1056
PA	24	55	193	17	501	272	1066
PB	21	61	246	18	460	303	1098
PI	18	65	270	26	498	235	1113
AP	26	37	148	9	711	250	1182
SE	20	58	246	12	618	293	1147
RR	18	28	132	31	661	376	1245
RN	19	46	207	17	480	321	1091
RO	16	20	176	7	779	332	1330
TO	22	27	210	15	746	333	1353
MG	17	24	315	43	871	265	1535
GO	15	16	344	39	931	245	1590
MT	13	21	184	5	1084	318	1625
ES	15	22	338	53	1002	303	1732
MS	11	19	243	37	1074	311	1695
PR	12	22	311	43	1024	342	1854
RJ	18	43	306	20	960	251	1598
SC	7	11	434	36	1277	352	2116
RS	9	17	391	25	1124	293	1859
SP	18	40	307	13	1371	324	2073
DF	18	46	135	13	1906	357	2930

Source: Authors' calculations based on PNADC microdata of 2022.

It is also important to highlight some limits and advantages of using the PNADC as a source of information for regional studies. As a household survey, it does not provide full information about all individual's market incomes, as capital incomes tend to be underreported. Since most of the production tends to be in the richest federation units, this fact implies a sub-estimation of the regional income inequality if it is measured solely using the market incomes of PNADC. A second limitation is that this source of information accounts only for the individual gross income since it does not inform about direct taxes. As the lowest-income individuals are relatively more prevalent in the Brazilian poorest states Silveira-Neto and Azzoni (2012), this aspect favors an overestimation of the regional welfare inequality when it is measured solely using the market incomes of PNADC. Despite these limitations, the possibility of measuring individuals' income from different sources (market and public policies) makes the PNADC a unique source of information in Brazil for the current investigation.

4. Results

4.1 COVID-19 and regional convergence: The Brazilian regional income inequality during the period 2019-2022

We begin by presenting the trajectories of the Brazilian UFs' per capita income for the period 2012-2022. To evidence regional differences and sum up the relevant

information, in the following Figure 1, we present these trajectories using means of per capita income for three groups of the total of 27 Brazilian UFs based on the initial levels of income (i.e., in 2012): the 9 richest UFs, compose by all states of the regions South and Midwest plus São Paulo and Rio de Janeiro; the 9 poorest UFs, composed by UFs of MA, PI, AL, CE, RN, PB, and BA from the Northeast region and PA and AP from the North region; and the 9 UFs of intermediary levels of per capita income, composed by PE and SE from the Northeast region, UFs of AC, TO, AM, RO, and RR from the North region and MG and ES from the Southeast region. We have adjusted prices for 2022 using the price indexes proposed by IBGE for values of the PNADC.

Note that our grouping highlights the clear and well-known Brazilian spatial disparity of income, the progress of the FUs in the Midwest in the recent decades, and makes it easier to observe the evolution of the participation of groups in total income (since all groups are composed by the same number of UFs). We highlight three important pieces of evidence from the numbers in Figure 1. First, the notion of a country divided, in terms of income, between the Center-South and the North-Northeast spaces remains current and significant at the beginning of the third decade of the 21st century: the averages per capita income of the poorest and intermediary states were only 53% and 63% of the average observed for the richest states, all located in South, Midwest, and Southeast regions, in 2022. Second, different from the first decade of the 21st century, the evolutions of income in Figure 1 indicate no signal of consistent income convergence from 2012 to 2022 among the three groups of UFs.

The third piece of evidence relates to the dynamics of income after the COVID-19 pandemic: the evolutions indicate a more severe effect of the pandemic on the rich Brazilian UFs than on poor ones. Actually, the information of the PNADC indicates that while the average per capita income drops in the period 2019-2022 for the richest and income intermediary UFs (respectively, of about 4.6% and 0.7%), an increase in the average income is observed for the poorest UFs (about 4%). Note that the influence of the COVID-19 pandemic on regional evolution is even clearer immediately after the presence of the virus in Brazil (from 2019 to 2020).

The change in regional inequality dynamic with the advent of the COVID-19 pandemic is maybe clearer when observing the relationship between per capita income growth and initial level of income of Brazilian UFs for the periods before and after it. In the following Figure 2, we present this relationship for the entire period of analysis (2012-2022), for the pre-COVID-19 period (2012-2019), and for two periods in the post-COVID-19 era (2019-2020 and 2019-2022).

Figure 2 makes clear that there is no decisive pattern of convergence of income when considering the entire period of analysis (2012-2022) and that no relationship at all is obtained considering the pre-COVID-19 pandemic period (2012-2019). On the other hand, the so-called beta-convergence Barro and Sala-i Martin (1992) is observed during the post-COVID-19 period: clearly, the poorest UFs tend to grow fast than the richest ones. Note that this convergence is even clearer when considering the short

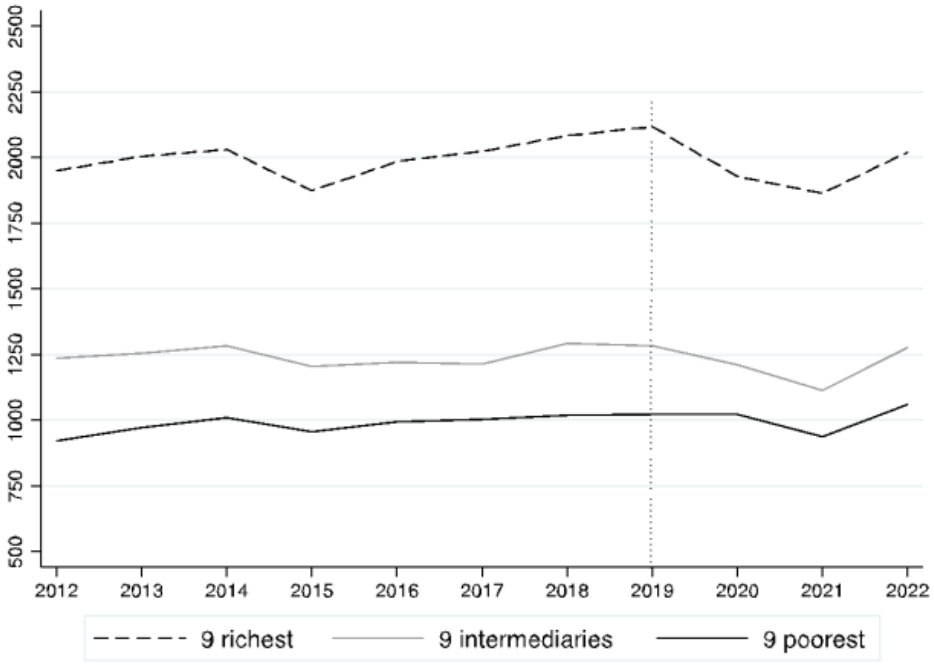

Figure 1. Average per capita income of groups of Brazilian UFs.

period immediately after the detection of the pandemic in Brazil (2019-2020).

To get a general measure of the evolution of regional inequality, we calculated Gini and GE(2) indexes for the distribution of per capita income among Brazilian UFs during the period 2012-2022 [6]. The following Figure 3 presents these evolutions and the respective contributions of their market and no market components (according to equations (1) and (4)). We highlight three main messages from this figure.

First, consistent with the previous evidence in Figure 2, while we observe no important variation of these inequality indicators between 2012 and 2019, there is a clear regional inequality reduction between 2019 and 2022 and important drops of both indicators from 2019 to 2020 (i.e., after the detection of the presence of the virus). To be precise, we observe reductions of about 11.1% and 9.9% in the Gini index, respectively, for the periods 2019-2020 and 2019-2022. The economic magnitude of these numbers is far from being irrelevant. These inequality reductions are, for example, close to that obtained by Silveira-Neto and Azzoni (2012), when measuring the reduction of Brazilian regional income inequality during the period between 1995 and 2006 (about 12%) and are also of the same magnitude of those observed for the reduction of Brazilian personal income inequality during the 2010 years.

Importantly, our evidence about the decreasing of regional income inequality after the COVID-19 pandemic is in line with the dynamic of regional inequality observed in the same period for the regional distribution of the mean of the formal labor income using information from RAIS, a survey from the Minister of Labor and Employment

[6]Notice that similar pattern for the evolution of the Brazilian regional income inequality are obtained by using other inequality indexes, such as the Coefficient of Variation and the Variance.

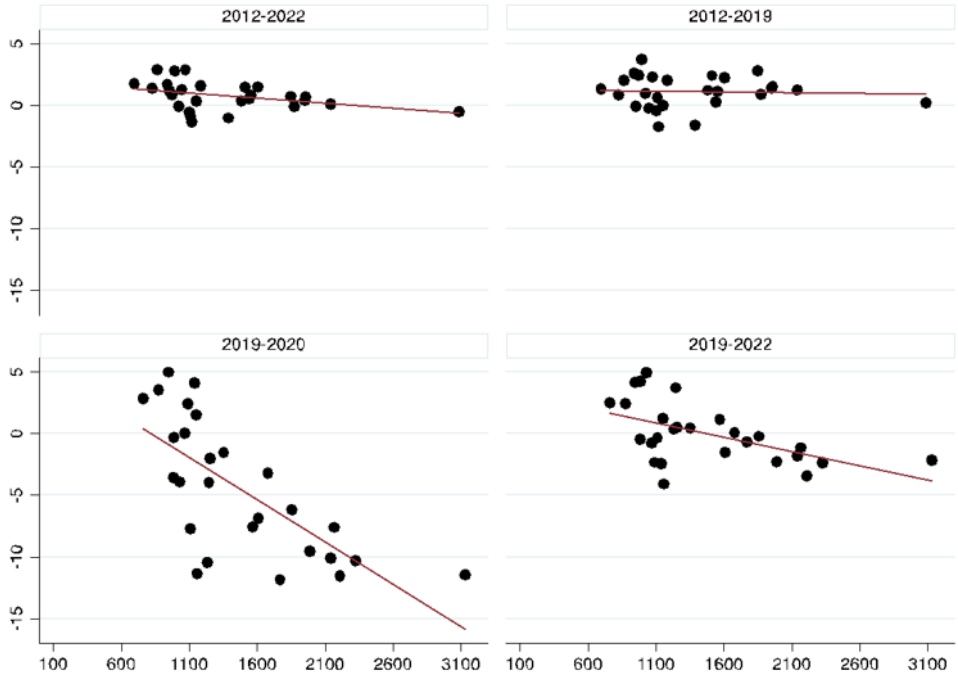

Figure 2. Annual growth rate of UF per capita income and initial income.

that considers solely firms in the formal sector, and with that of the per capita GDP, obtained using information from the Contas Regionais provided by the IBGE. Using the information of the mean of the formal labor income from RAIS, we observe reductions of about 6.6% and 6.8% of the Gini index for the distribution of this income among Brazilian federation units, respectively, in the periods 2019-2020 and 2019-2022. As for the regional distribution of the per capita GDP, the numbers allow observing a drop of about 2.2% of the Gini index between 2019 and 2020 [7].

The second message of Figure 3 relates to the contributions of market and non-market related sources of income. Like the numbers of Silveira-Neto and Azzoni (2012), we obtained a much more important contribution of the market than of non-market sources in explaining Brazilian regional income inequality; for example, measured by the Gini index, about 89% of regional income inequality arises from market sources of income in 2022. Finally, note from Figure 3 that both market and non-market sources of income appear to contribute to regional income inequality reduction in Brazil observed after 2019. As we fully discuss in the next section, different reasons are behind these contributions for the regional income convergence arising from market and non-market sources of income.

We finalize this subsection by presenting the evolution of the sources of total per capita income of the three previously presented groups of UFs (see Figure 1) in the following Figure 4. Overall, this figure indicates much higher values for incomes from labor than from other sources (for example, formal and informal labor incomes together amount to about 75% of total income in 2022). Figure 4 also shows that the

[7]The information on the regional GDP is only available up to 2022.

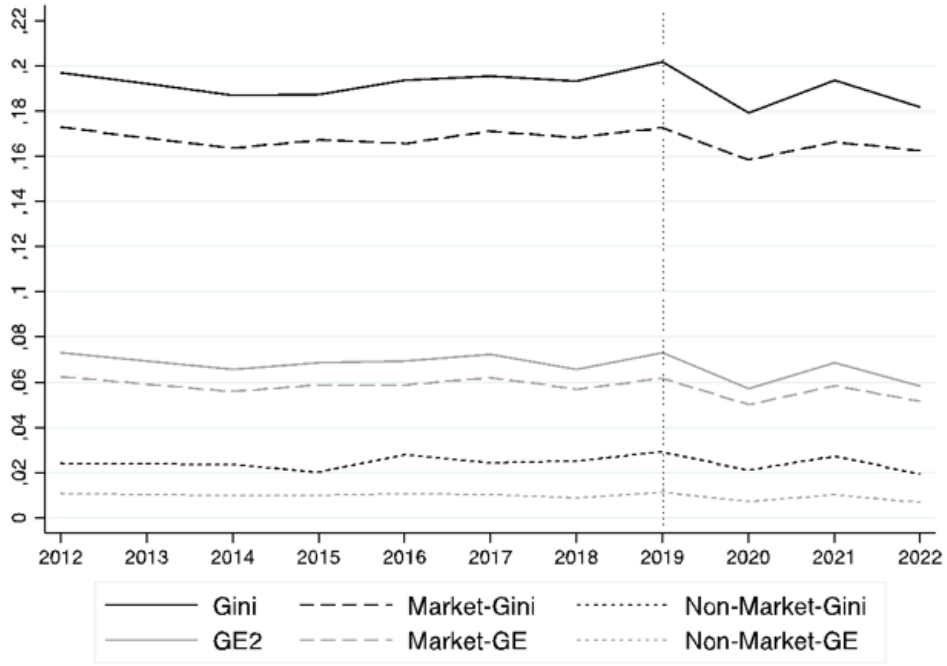

Figure 3. Gini and GE(2) indexes for the distribution of per capita income among Brazilian UFs and their correspondent market and non-markets components.

main changes in the evolution of sources of income happened after 2019 and are clearer for three income components: social policies, formal labor, and informal labor. Note, however, that while we observe increases in incomes from the social policies for the three groups of UFs after 2019, certainly explained by the implementation of the Auxílio Emergencial program, the movement is stronger for the set of the richest UFs (the mean growth for the group between 2019 and 2020 is of about 739%) than for the set of the poorest UFs (where the correspondent rate of growth was of about 398%). We observe that this difference is in line with the much weaker focus of the new Auxílio Brasil program on poor people than the previous (before 2020) Bolsa Família program.

On the other hand, from the set of evidence of Figure 4, we observed income reductions arising from both formal and informal labor after 2019. Interestingly, notice that now the reduction observed for the formal labor income is stronger for the group of the richest UFs than for the group of the poorest ones, a pattern consistent with both the greater importance of this source of income and more sensitiveness of it to cyclical movements in these UFs. On the other hand, more similar reductions in informal labor incomes are observed for three groups.

4.2 The COVID-19 and Brazilian regional income inequality dynamic: what are the sources of convergence?

We now account for the roles of sources of income in the observed Brazilian regional income inequality reduction after COVID-19 presence in the country. Remember that, according to equation (3), when measuring the inequality by the Gini index, the income inequality variation through time depends on the variations in the participation of the

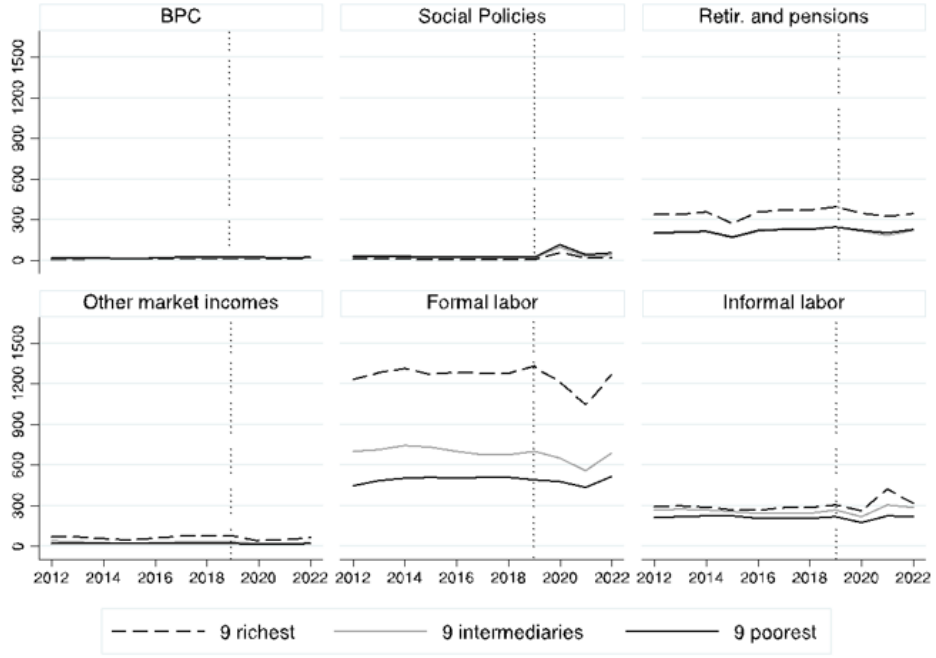

Figure 4. Evolution of per capita income by sources of income (R$ of 2022) for groups of Brazilian UFs according to the total per capita income.

sources of income, on how the sources are distributed across the UFs relative to the total income distribution, and on the changes in the distributions of each source of income. Thus, in the following Figure 5, we begin by presenting the evolution of the shares of each source of income in the total income in the period 2012-2022.

Essentially, the evolutions presented in Figure 5 indicate the important movements in the shares of sources of income have occurred after 2019, i.e., in the post-COVID-19 period. Specifically, we perceive an increase in the share of income from social policies and a decrease in the shares of formal and informal labor incomes from 2019 to 2020; but, differently from the behavior of the formal labor income, the share of informal labor income growth after 2020. The influence of these different dynamics of the shares of sources of income on regional inequality depends on how they are regionally more or less concentrated when compared to the regional distribution of the total income (see equation (3)). In the case of Social Policies' source of income, as its regional distribution favors poorer Brazilian UFs, the increase in its importance certainly contributes to reducing regional inequality. Note that, since formal labor income is more regionally concentrated than total income, we also may expect a contribution to regional inequality reduction arising from the reduction of the share of formal labor source of income.

But the dynamic of regional inequality also depends on the dynamic of regional distribution observed for each source of income, i.e., using the Gini index to measure regional inequality, it also depends on the behavior of the Concentration Coefficients of sources of income. To study these dynamics, in the following Figure 6, we present

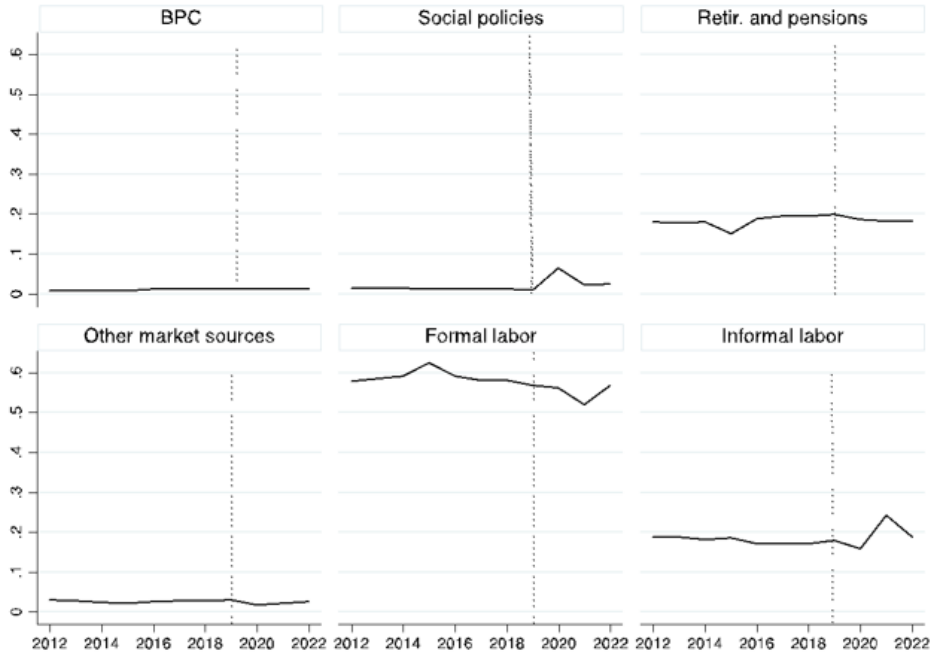

Figure 5. Evolution of shares of sources of income in the total income. The dotted vertical line refers to the 2019 year.

the evolution of the Concentration Coefficient of each source of income during the period 2012-2022, together with the evolution of the Gini index itself (the dash lines in each graphic).

The set of evidence in Figure 6 is quite informative. Firstly, notice that non-market and informal labor sources of income present their Coefficients of Concentration always lower than the Gini index, the opposite happening for formal labor and "Other market sources" sources of income. Thus, when compared to the regional distribution of the total income, the regional distributions of the first group of sources of income favor the poorer UFs, while the regional distributions of the second favor the richer UFs. Note, particularly, that the Coefficients of Concentration for the BPC and Social Policies are always negative, indicating their strong bias for the poorest UF; on the other extreme, the income of "Other market sources" present the higher Coefficient of Concentration, indicating its bias for the richest UFs. These results are entirely consistent, on one hand, with the character pro-poor of the Brazilian social programs that, given the Brazilian spatial poverty concentration, favor the poorest UFs Silveira-Neto and Azzoni (2012) and, on the other hand, with the still high spatial concentration of economic activity in richest UFs (Silveira-Neto and Azzoni, 2012).

But not least importantly, also note that after 2019 we observe important movements of redistribution among UFs mainly for the "Social policies" and formal labor sources of income and in opposite directions. Specifically, we observe an increase in the Coefficient of Concentration of the income of "Social policies", indicating less biased distribution for poorer UF after 2019. The movement is entirely consistent with

the strong expansion of income transfer associated with the Auxílio Emergencial (in 2020) and Auxílio Brasil (in 2021 and 2022) programs implanted by the federal government, much less focused on poor people than the previous Bolsa Família program of 2019. Interestingly, this less precise focus on poor people in these programs also brought a less favorable distribution to the poorest Brazilian UFs. On the other hand, the reduction of the regional concentration of the formal labor income (as indicated by the drop of its Concentration Coefficient) reflect a stronger decrease of this source of income in the Brazilian richest UFs than in the poorest ones (see the previous Figure 4). As indicated by the increase of its Concentration Coefficient, also note that there is some reduction in the bias for the poorest UFs of the informal labor source of income that is explained by the stronger increase of this source of income in the richest UFs than in the poorest ones (see again the Figure 4).

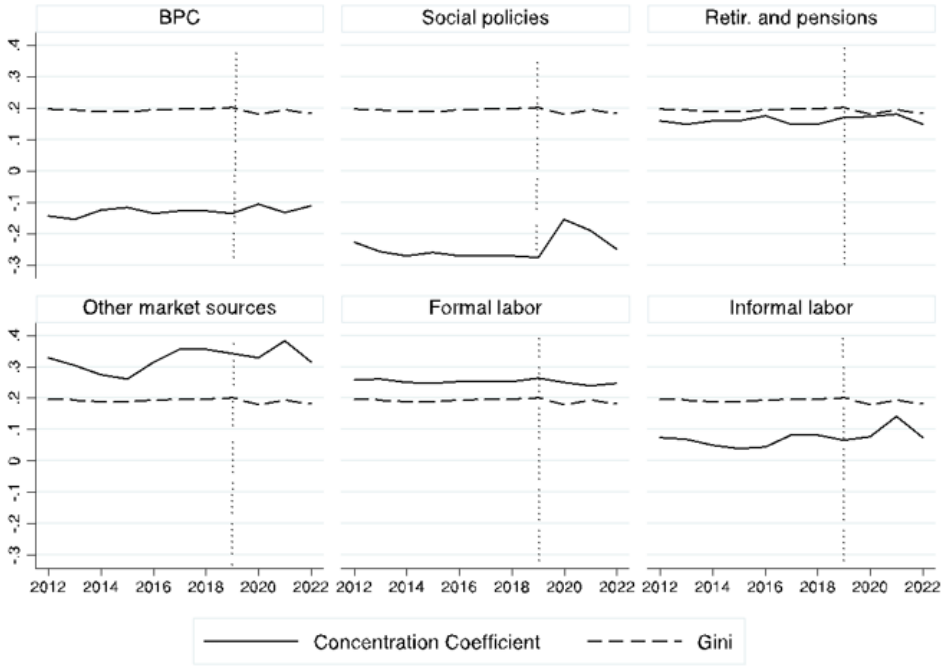

Figure 6. Evolution of the Concentration Coefficient by the sources of income. The dotted vertical line refers to the 2019 year.

Complementing the pictures revealed through Figures 5 and 6, in Table 2, we present values of shares and Coefficient of Concentrations of sources of income for the years 2012, 2019, 2020, and 2022, together with contributions of these sources for the value of Gini index of these years (obtained by simply summing the products between share and Coefficient of Concentrations columns; see equation (1)). Note that the value of the Gini index for Brazilian regional income inequality is explained basically by market sources of income. With always more than 56% of the total income, the income from formal labor accounts for more than 75% of Gini index values in all these years. As expected from the previous discussion, there are only minor changes between 2012 and 2019, being the most significant variations verified between 2019 and 2020. In this regard, note that the important drop in the value of the Concen-

tration Coefficient for formal labor income before and after the COVID-19, and the increase in the relevance of the income for Social Policies for the total income [8].

Table 2. Shares (α_f) and Coefficients of Concentration (CC_f) of sources of income

	2012			2019		
	α_f	CC_f	% Gini	α_f	CC_f	% Gini
Panel A – Pre-Pandemic						
Market						
Formal Labor	0.5786	0.2574	75.6	0.5689	0.2647	74.6
Informal Labor	0.1881	0.0731	7.0	0.1794	0.0765	7.6
Other Sources	0.0310	0.3296	5.2	0.0294	0.3410	5.0
Non-Market						
Retirem. and pensions	0.1801	0.1578	14.4	0.1907	0.1692	16.7
BPC	0.0053	-0.1449	-1.7	0.0083	-0.1149	-1.0
Social Programs	0.0138	-0.2265	-1.6	0.0194	-0.2735	-1.4
Total Income	**1.0000**	**0.1970**	**100.0**	**1.0000**	**0.2020**	**100.0**
	2020			2022		
	α_f	CC_f	% Gini	α_f	CC_f	% Gini
Panel B – Post-Pandemic						
Market						
Formal Labor	0.5617	0.2499	78.2	0.5675	0.2478	77.3
Informal Labor	0.1574	0.0762	6.7	0.1875	0.0752	7.7
Other Sources	0.0188	0.3291	3.9	0.0251	0.3193	5.5
Non-Market						
Retirem. and pensions	0.1860	0.1732	17.9	0.1819	0.1492	14.9
BPC	0.0119	-0.1075	-0.7	0.0127	-0.1007	-0.7
Social Programs	0.0643	-0.1566	-4.5	0.0253	-0.4287	-3.5
Total Income	**1.0000**	**0.1795**	**100.0**	**1.0000**	**0.1820**	**100.0**

Source: Authors' estimation using microdata from PNADC- IBGE.

Finally in Table 3, we present the sources of variation in Brazilian regional income inequality reduction during the period immediately after COVID-19 (2019-2020) (Panel A) and from 2019 to 2022 (Panel B). As we have shown before, measured by the Gini index, Brazilian regional inequality presented reductions of about 11.1% and 9.9%, respectively, in these two periods. The numbers in Table 3 were obtained from equation (3) and refer to the concentration and participation or share effects (absolute contributions and in the percentage of the Gini index variation) by sources of income.

Focusing first on the immediate post-COVID-19 period, we perceive that about 70.7% and 29.3% of the 11.1% drop in the Gini index observed in the period are explained, respectively, by non-market and market sources of income. The most important factor to this dynamic, this more important contribution of non-market sources is entirely explained by the dynamic of the participation effect of the social policies component (this specific effect amounts to almost 93% of the Gini index drop in the period). This effect, in turn, is certainly associated with the strong increase in income transfer promoted by the Auxílio Emergencial program in 2020 [9]. On the other

[8] Note that the program Auxílio Emergencial brought this source of income for about 6% of total income in 2020; in 2022, the program Auxílio Brasil maintained it in about 2% of the total income.

[9] Remember that this program implied income transfers of about R$ 290 billion, much greater than

hand, the expansion of the income arising from social policies due to the pandemic of COVID-19 and which was less focused on the poorest people favored relatively more the non-poorest UFs and avoided a greater Gini index reduction (precisely, note that this effect amounts to almost 20% of the Gini variation).

Note that we also confirm here that a stronger drop in the formal labor income in the richest UFs contributed (with about 37% of the Gini index variation) to a total concentration effect favoring the inequality reduction (about 7.1%). We highlight that this result is entirely in line with the one obtained by Azzoni and Castro (2023) when working with growth convergence regressions and using data from RAIS (formal labor). As previously mentioned, these authors showed an increase in the convergence speed associated when considering the 2020 year. Despite being less important to explain the Gini index reduction, a quite different situation is verified concerning the dynamic of the income from informal labor; here, because this source of income became relatively less favorable to the poorest UFs and less relevant to the total income, both the concentration and participation effects avoided a greater regional inequality reduction.

When considering the period 2019-2022, we got more similar roles for market and non-market sources of income in explaining Brazilian regional inequality reduction: these channels now explain about 53% and 47% of Gini index reduction (of 9.9%), respectively. The change of pattern certainly occurred because of the reduction in the amount of income transfer with the Auxílio Brasil program as compared to the previous transfer through Auxílio Emergencial program. Also notice that different from the period 2019-2020, now most of the Gini reduction arose from the Concentration Effect (about 60% of it).

This stronger effect arising from the Concentration Effect is mostly explained by the reduction in regional concentration (relative to total income) of the formal labor source of income: alone it explains almost 45% of the Gini index reduction. Interestingly, as in the previous period, the informal labor source of income became more regionally concentrated and avoided a stronger regional inequality drop. These movements suggest an increasing importance of informal labor income mainly in the Brazilian richest UFs after COVID-19. On the other hand, non-market sources of income contributed to the regional inequality reduction between 2019 and 20122 mainly through the Participation Effect, and this channel of contribution is entirely explained by the increasing relevance of social policies' source of income (remember from Table 2 that its share in the total income increased form to 1% to 2.5% between in the period): about 31.6% of Gini index drop came from this specific channel.

the previous R$ 40 billion of the Bolsa Família program in 2019.

Table 3. Decomposition of per capita income regional inequality (Gini index) variation by sources of income – Concentration and Participation Effects

	2019-2020					
	Concent. Effect	%	Particip. Effect	%	Total	%
Panel A						
Market	**-0.0072**	**31.9**	**0.0006**	**-2.7**	**-0.0066**	**29.3**
Formal Labor	-0.0084	37.2	0.0005	2.1	-0.0089	39.3
Informal Labor	-0.0013	5.6	-0.0015	6.5	-0.0028	12.1
Other Sources	-0.0003	1.3	0.0005	2.1	0.0001	6.8
Non-Market	**0.0056**	**-24.8**	**-0.0215**	**95.5**	**-0.0159**	**70.7**
Retirem. and pensions	0.0056	-24.8	-0.0215	95.5	-0.0159	70.7
BPC	0.0003	-1.5	0.0001	0.6	0.0003	-2.0
Social Programs	0.0045	-19.9	0.0019	8.5	-0.0174	-7.7
Total Income	**-0.016**	**7.1**	**-0.0209**	**92.9**	**-0.0225**	**100.0**
	2019-2022					
	Concent. Effect	%	Particip. Effect	%	Total	%
Panel B						
Market	**-0.0090**	**44.8**	**-0.0016**	**8.3**	**-0.0106**	**-53.1**
Formal Labor	-0.0096	48.3	0.0001	0.4	-0.0097	48.7
Informal Labor	-0.0012	6.1	0.0014	7.0	-0.0004	1.8
Other Sources	-0.0007	3.7	0.0016	7.9	-0.0005	2.1
Non-Market	**-0.0030**	**15.3**	**-0.0063**	**31.6**	**-0.0094**	**-46.9**
Retirem. and pensions	0.0038	19.1	-0.0063	31.6	-0.0025	10.6
BPC	0.0005	-2.4	0.0001	0.6	0.0004	-1.8
Social Programs	0.0035	-17.0	0.0012	6.0	-0.0200	100.0
Total Income	**-0.0120**	**60.1**	**-0.0080**	**39.9**	**-0.0200**	**100.0**

Source: Authors' estimation using microdata from PNADC- IBGE.

5. Concluding remarks

Following a worldwide pattern, the Brazilian economy was strongly affected by the COVID-19 pandemic after 2019. As a continental country known for its high regional income unbalance, it would be a surprise if the different regions of the country were equally affected by the calamity. The regional picture of the effects of this health calamity in Brazil, however, is far from obvious. While the richest states have better material conditions and health services to face the contingencies of health calamities, their greater degree of formalization and dependence on urban and service activities make them potentially more sensitive to the shutdowns (lockdown) and contagions by the virus. Furthermore, the public policies implemented by the Brazilian government brought an expansion of federal income transfer to the population more affected, which tends to favor the poorest states (Silveira Neto and Azzoni, 2012). In the current research, we provide evidence of the effects of the COVID-19 pandemic on Brazilian regional income inequality exploring different sources of income as potential channels for these effects.

Our results indicate that the economic downturn associated with the health calamity of COVID-19 implied an important reduction in the Brazilian regional income inequality; measured. By the Gini index, we observed drops of about 11% and 9.9% in the

periods 2019-2020 and 2019-2022, and both movements were explained by market (mainly through lower regional concentration of the formal labor income) and non-market sources of income (mainly through the expansion of income from social policies). In the short period of 2019-2020, despite the contribution of the dropped of the formal labor income that turned this source of income less concentrated, we observed that the main responsible for the regional income reduction was the expansion of income transfers from the social policies (here, the Auxílio Emergencial program appears fundamental). Increasing its participation in the total income, and this source of income was responsible for about 90% of Gini index reduction. For the entire period 2019-2022, we observed that the Gini index reduction arose mainly from the weaker regional concentration of formal labor income during the period, a movement caused by a stronger drop in this source of income in the Brazilian richest UFs.

To sum up: yes, in terms of per capita income, we got a more spatial balance with the health calamity of COVID-19 in Brazil, but this picture arose mainly due to the greater weakening of formal activities in the richest UFs, the current greater relevance of informal activities in the poorest UFs, and the expansion of public cash transfers of social policies. Thus, our results favor both the arguments that highlight the roles of different local productive structures and the regionally differentiated impacts of public policies for understanding the economic impact of COVID-19 pandemic across Brazilian federation units.

In this scenario, two points deserve to be highlighted. First and more obviously, due to its effects on current and future productivity, it is strongly undesirable to reduce the Brazilian regional inequality by turning the richest UFs more like the poorest UFs by reducing the relevance of the formal labor income. In this regard, one limitation of the current study is not providing a deeper understanding of the dynamic of income by economic activities during the COVID-19 pandemic. Second, despite the necessary and important response given by the public income transfer policy during COVID-19, the assessment of the long-term economic efficacy of these current larger income transfers via social policies has become even more fundamental and this point is not treated in the article either. Both themes are in the authors' agenda of research.

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