

Geographic availability of perinatal services in Brazil*

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Abstract

Access to medical technology has proven crucial for saving a mother's and newborn's lives. However, how health systems should organize to guarantee such access is still an open question. This paper contributes to answering it by describing the multidimensionality of the geographical access to public perinatal services in Brazil between 2007 and 2021. We classify health facilities according to the availability of medical technology by production input - infrastructure, human resources, and equipment. Then, we estimate the distance of each municipality to the closest facility and its production input. Results show significant inequalities in access to facilities with the highest technology that persist throughout the decade. Further, we find imbalances between inputs, indicating that some improved more. As production inputs in health tend to be complementary, these differences could limit the facility's capability to provide a certain level of care, thus worsening the already existing inequalities.

1 Background

Extensive evidence shows that the capabilities and care provided by a delivery facility influence the outcomes of mothers and babies, especially if they are of high risk. These studies

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usually examine the differential outcomes of births happening at high-level or high-volume facilities with respect to other delivery facilities, finding a positive impact on survival rates and a reduction on postnatal complications in developed and developing countries (Lorch et al., 2021). Despite the evidence, policy implications are still unclear. For instance, the level of care summarizes several inputs that determine the facilities’ capabilities to address perinatal complications should they arrive. However, access to a certain level of care does not automatically imply an improvement in the quality of care; as shown by Profit et al (Profit et al., 2016). Further, the effectiveness of access to high levels of care varies geographically within countries, such as UK (Mújica-Mota et al., 2020) and Portugal (Lorch et al., 2021). Hence, a more detailed and context-specific analysis is required to determine a precise policy recommendation regarding access and organization of perinatal care, with health system design and geography being strong candidates of underlying factors for consequent studies.

Brazil is no exception when it comes to geographic inequality in terms of health service delivery (Souza et al. (2015); Arruda et al. (2018); Travassos et al. (2006); Monteiro et al. (2017)). Despite having a Universal Health System which stresses equity as a guiding principle, in practice parts of the country remain unattended by specific individual inputs (Menezes et al. (2018)) and, more concerning, by provision as a whole, when lacking reachable health facilities for its population (Rocha et al. (2017)). Taking too long in displacing to a service was defined as the “second delay” (Thaddeus and Maine (1994)) and is linked to negative outcomes for mothers (Pacagnella et al. (2014)). Displacing was also found associated with negative birth outcomes for newborns (Leal et al. (2020)).

How does the supply component influence such a complex scenario? First, one should keep in mind that the healthcare system should allocate mothers according to their cases’ needs and does not always succeed: at least 40% of mothers did not receive any direction and 16.2% end up going to multiple facilities (Viellas et al. (2014)). Consequently, birth-facility match is often inappropriate regarding level of care, leading to the “inverse care law” (Hart (1971); de Azevedo Bittencourt et al. (2015))¹. Investigating distances from mothers to facilities provides a fundamental point of view in this branch of research and, while some work has been done with actual traveled routes (Rocha et al. (2017); Almeida and Szwarcwald (2012); Cristina da Silva et al. (2020)), the set of potential facilities alongside their complexity classification is a matter yet to be explored.

This paper describes the geographic accessibility to public health system’s delivery facilities in Brazil from 2007 to 2017. We classify facilities by level of care based on the Brazilian norms and then estimate the minimum distance from each municipality to all possible des-

¹“*Nascer no Brasil*” (Birth in Brazil) project covers many scenarios and challenges in this medical area - <https://nascernobrasil.ensp.fiocruz.br>

tinations where a certain type of facility is available. Contrary to previous studies (see e.g. (Barfield et al., 2012; Phibbs et al., 2007)), we create a classification by health production input, based on three domains: equipment, infrastructure and human resources. By analyzing these domains, we show the multidimensionality of access to qualified perinatal care in Brazil.

Our analysis progresses in three stages. First, we describe the distribution of delivery facilities by perinatal level of care across time and space. Then, we contrast this distribution with that of births, identifying where deliveries took place along time. Finally, we analyze changes in the minimum distance to health facilities, infrastructure, equipment and human resources by perinatal level of care, establishing inequalities in the geographical access to perinatal care.

2 Methods

2.1 Data

The study data comes from the Data Science Platform applied to Health (Plataforma de Ciência de Dados aplicada à Saúde - PCDaS in Portuguese)(Instituto de Comunicação e Informação Científica e Tecnológica em Saúde, Instituto de Comunicação e Informação Científica e Tecnológica em Saúde), which in turn, gathers information from the Brazilian Health Management Information System (HMIS), DATASUS, for 2007-2021. The data belongs to the National Registry of Health Facilities (Cadastro Nacional de Estabelecimentos de Saúde - CNES in Portuguese) and the Live Births Information System (Sistema de Informações sobre Nascidos Vivos - SINASC in Portuguese). The former registers all health facilities' installed capabilities - infrastructure, equipment, and human resources - regardless of their administration - private, public, or other (Brazil. Ministerio da Saúde, 2022a). The latter collects mother-child birth characteristics - including the birth facility - and socioeconomic information from official birth certificates. This document is compulsory, which ensures SINASC national coverage (Brazil. Ministerio da Saúde, 2022b). We summarize SINASC information by year and health facility's CNES code, to join it with CNES database on a second step.

We focus on facilities that deliver 50 births per year at least once between 2006 and 2021 and provide services in the public health system, the SUS system (Sistema Único de Saúde in Portuguese). ² After applying these filters, we remain with a panel that contains 3611

²We consider that a facility belongs to the SUS if 85% of its obstetric beds are reserved for SUS patients.

health facilities; approximately, 2900 facilities per year, with 2277 complete cases (63%), i.e., present every available year.

2.2 Classification of levels of care

The CNES provides a classification of the facility level of care based on the Ministry of Health (MoH) norms. Nevertheless, this classification is not specific to maternal and neonatal services. Hence, we examine MoH norms of those services and use data from three domains, infrastructure, equipment, and human resources, to assort facilities by perinatal levels of care.

We define the following levels of perinatal care:

- **Level I:** A facility capable of assisting low-risk births. The *infrastructure* of the facility should have at least one pre-labor, labor, post-labor room or bed. The facility needs at least one health professional qualified to assist with eutocic deliveries and one nurse technician (*human resources*). Finally, the facility should have basic life support *equipment*
- **Level II:** A facility capable of assisting high-risk births requiring obstetric surgical interventions and intermediate neonatal care. Human resources should include a surgical team and a pediatrician, whereas infrastructure should contain surgical-obstetric and neonatal intermediate care beds. Incubators, ultrasound, x-rays, and phototherapy machines should be among the required equipment.
- **Level III:** A facility capable of assisting high-risk births requiring obstetric or neonatal critical care. This facility needs NICU and ICU, accompanied by a more comprehensive health staff that includes phonologists and physical therapists.

If a facility satisfies infrastructure, human resources, and equipment level-of-care criteria, we classify it as capable of providing that level of care. If one of the criteria is not satisfied for a certain level of care, the facility receives the minimum level of care of the three domains. We create a residual category called *Level 0* for the group that does not satisfy any of the three levels of care criteria. Details of the classification can be found in Section B of the Appendix. We have an indicator per domain and two aggregated indicators. The first one, available between 2007 and 2021, uses only infrastructure and equipment information

If the facility does not possess obstetric beds, then it belongs to the SUS if it has a formal vinculation to the system, regardless the specific services provided.

because the human resources information is incomplete. The second indicator is available for 2012-2021 and classifies facilities based on the three domains.

After identifying each facility’s level of perinatal care, we verify the consistency of our classification by comparing it against the classification of the facility’s complexity of care (not specific to maternal and newborn health). In addition, we analyze the volume of births and the allocation of very high-risk births, either preterm or low birthweight, by perinatal levels of care. This is because previous studies have found a positive correlation between volume and the level of care (Lorch et al., 2021) and because we expect very high-risk births to happen in higher levels of care (Brazil. Ministerio da Saúde, 2012). Extremely preterm births are those with 22 weeks or less of gestational age. Babies with very low birthweight weigh 1500 grams or less at birth.

2.3 Geographic access measures

We estimate the minimum distance to health facilities, infrastructure, equipment, and human resources by the perinatal level of care, e.g., the distance to a Level I facility, and each health input individually, e.g., the distance to NICU beds. Our measure of distance is the required length to travel between two municipalities using public roads, expressed in kilometers. The distances come from Universidade Federal de Minas Gerais’s inter-municipality matrix that contains all possible origin-destination combinations in Brazil, i.e., is a matrix of 5570 by 5570 municipalities (de Carvalho et al., 2021).

Identifying the minimum distance to a certain facility or health input happens as follows. First, we restrict the inter-municipality matrix to distances smaller than 2000 kilometers. Second, for each municipality of residence, we select the destinations where the facility or health input of interest is available without any additional exclusion criteria. Thus, the destinations are not restricted by demand or supply factors, such as the history of births in the facility or the health system’s referral norms. Finally, we calculate the minimum distances to all possible destinations in the selected subset.

To facilitate the identification of cross-section and time patterns in the data, we aggregate the results at state, regional, and national levels. For that purpose, we estimate the average of the municipal minimum distances within a geographic area, either state, region, or nation, weighted by the births of those municipalities.

3 Results

The section will be developed in two parts. First, we validate the levels of perinatal care using auxiliary statistics and show the trends in the number of facilities and births by the level of care and across regions. Second, we show the geographic accessibility to each level of care, measured by the minimum distance to each type of facility.

3.1 Trends in perinatal levels of care

We classified SUS birth facilities by perinatal level of care between 2007 and 2021. This section presents the classification based on infrastructure and equipment criteria over time. In the Appendix, we present the classification that includes human resources variables, only available for 2012 to 2021. Both classifications follow similar time and geographic patterns (Tables A.2 and A.3).

Table 1 shows the characteristics of the facilities by the level of care in 2015.³ This table aims to show the validity of the level-of-care classification we have created. As we can see, the percentage of hospitals increased with the perinatal level of care; 46% of level 0 facilities are hospitals and that percentage increases to 95.6% for level III facilities. Similarly, outpatient facilities were only allocated at levels 0 or I. The perinatal levels of care were correlated with the MoH classification of levels of care. For instance, 90.6% of the level III facilities provided high complexity inpatient care, whereas 66.1% of level I facilities provided medium complexity inpatient care.

As expected, the patient volume, given by the number of births, increased with the perinatal level of care: 85% of level III facilities assisted more than 550 births per year compared to only 17.6% of level I facilities with such patient volume. Likewise, we find that the number of extremely preterm and very low birthweight births assisted by a facility increased with the level of care. Eighty nine percent of level III facilities took care of more than three very low birthweight births per year, while 55.6% of level I facilities did not assist with this type of birth. We observe similar differences for extremely preterm births. Furthermore, we estimated analogous statistics for 2007 and found similar results, indicating that the fitness of our classification remained unchanged (Table A.1).

³MOH's classification of the facilities' complexity of care is available only until 2015, so we cannot present 2021's statistics.

Table 1: Facility characteristics by perinatal level of care (2015)

	Level 0		Level I		Level II		Level III	
	%	N	%	N	%	N	%	N
Type of facility:								
Hospital	46.0	206	82.9	1605	83.4	256	95.6	153
Normal Delivery Center	0.4	2	0.3	5	0	0	0	0
Other hospitals	2.2	10	3.7	71	15.0	46	4.4	7
Emergency units	3.8	17	0.5	10	1.3	4	0	0
Other facilities	47.5	213	12.6	244	0.3	1	0	0
Type of care:								
Outpatient	26.2	116	0.5	10	0	0	0	0
Inpatient	73.8	327	99.5	1905	100	306	100	159
Complexity of inpatient care:								
Low	13.5	44	8.1	155	1.3	4	0	0
Medium	67.9	222	66.1	1260	26.8	82	2.5	4
Medium + Diagnostics	8.9	29	15.2	289	31.0	95	6.9	11
High	9.8	32	10.6	201	40.8	125	90.6	144
Patient volume (births):								
≤ 37	66.7	299	27.6	535	7.5	23	8.8	14
37-157	18.1	81	28.8	558	6.2	19	1.9	3
157-550	12.9	58	25.9	501	19.2	59	4.4	7
>550	2.2	10	17.6	341	67.1	206	85	136
Extremely preterm births:								
≤ 0	86.2	386	64.3	1244	20.8	64	10.6	17
0-2	12.3	55	22.4	434	21.2	65	3.8	6
>2	1.6	7	13.3	257	58.0	178	85.6	137
Very low birthweight:								
≤ 0	79.9	358	55.6	1075	16.9	52	9.4	15
0-1	11.4	51	18.1	351	9.8	30	1.3	2
1-3	6.5	29	11.9	230	11.1	34	0.6	1
>3	2.2	10	14.4	279	62.2	191	88.8	142
Observations	448		1935		307		160	

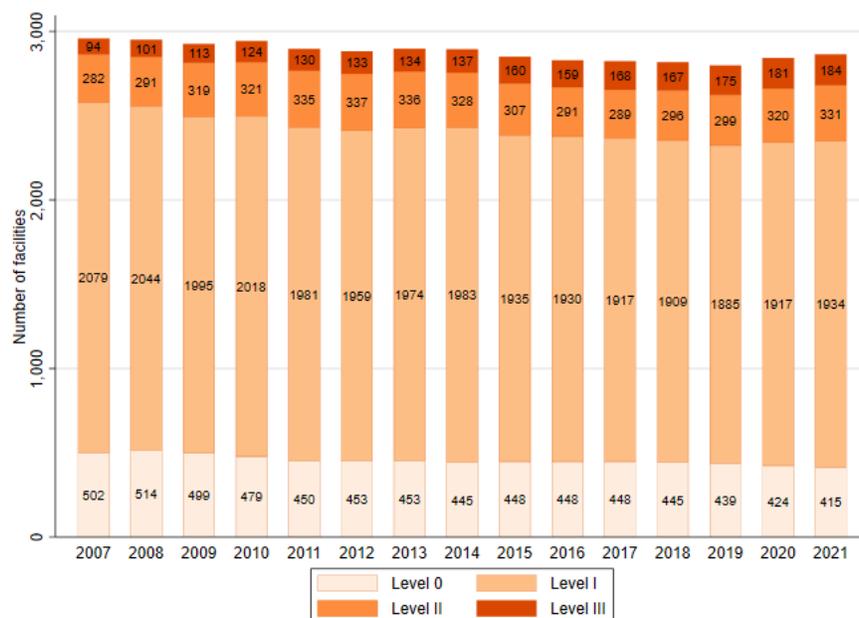
Notes: Level I: A facility capable of assisting low-risk births. Level II: A facility capable of assisting high-risk births requiring obstetric surgical interventions and intermediate neonatal care. Level III: A facility capable of assisting high-risk births requiring obstetric or neonatal critical care. Level 0: Residual level, not satisfying any of the criteria above.

Complexity of inpatient care is the MOH's facility classification. Low-complexity facilities perform basic and first referral outpatient procedures, deliveries, pediatric hospitalizations, minor clinician and surgical procedures. Medium-complexity facilities perform first and second referral outpatient procedures and medium-complexity hospital procedures. All specialized hospitals belong in this category. Medium+Diagnostics facilities provide high complexity outpatient diagnostic services in addition to medium-complexity facilities' procedures. High-complexity facilities focus on inpatient and outpatient highly complex procedures (Brazil. Ministerio da Saúde, 2022a). Extremely preterm births are those with 22 weeks or less of gestational age. Very low birth weights are those with 1500 grams or less of weight at birth.

SUS delivery facilities decreased from 2957 to 2864 between 2007 and 2021 (Figure 1). In parallel, the number of level III and level II facilities increased. In 2007, there were 94 level III facilities, but in 2021 this quantity increased to 184. The rise in level II facilities was less salient, changing from 282 to 331. The overall reduction of facilities but the increase of level II and III facilities resulted in larger participation of these facilities in 2021 with respect to 2007.

In 2007, SUS delivery facilities assisted 1.77 million births in Brazil, which reduced to 1.65 million in 2021 (Table 2). Besides this reduction, the distribution of births by the perinatal level of care changed significantly, as shown in Figure 2a. The percentage of births at level-I facilities decreased from 58 to 43, while the percentage at level-III facilities increased from 11 to 27. This result suggests a tendency of births to concentrate in high-volume level-III facilities instead of level-I or level-0 facilities. The percentage of births happening at level 0 facilities was already small, and it reduced further over time, from 5 to 1%.

Figure 1: Evolution of health facilities by perinatal level of care (2007-2017)

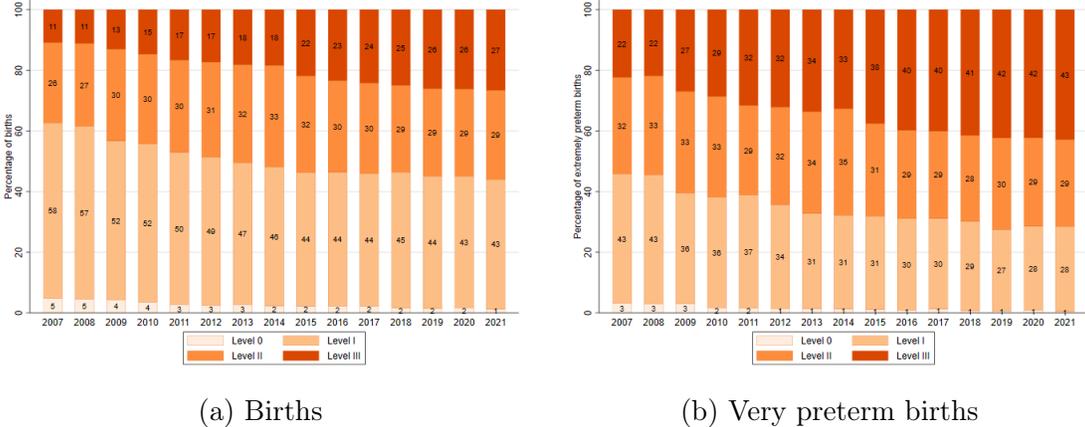


Note: Figure values can be found in Table A.2, with shares between parenthesis.

Between 2007 and 2021, extremely preterm births assisted by facilities increased from 8.4 to 10.2 thousand (Table A.4). Combined with the decrease in births over the decade, this trend implies that facilities passed from assisting 2.84 to 3.56 extremely preterm births per thousand births by the end of 2021. As with total births, very preterm births also became more frequent at level-III facilities while reducing at level-I facilities (Figure 2b). Similar movements in the availability of facilities and births across levels suggest a suppressed demand for specialized perinatal services. Nonetheless, it does not seem that the demand increase was led by more frequent preterm occurrences or improvements in the risk-facility match. If this were the case, we would expect a more prominent rearrangement of risky births to level-III facilities. For instance, in 2007, the percentage of extremely preterm births assisted at level-III facilities was twice that of total births (22 versus 11%). In 2021,

the odd ratio of extremely preterm births versus total births assisted at level-III facilities dropped to 1.6 (43 versus 27%), indicating no higher concentration of very preterm births at level-III facilities.

Figure 2: Evolution of facility births by perinatal level of care (2007-2017)



In spite of the improvements in the availability of level-III and level-II facilities, regional disparities in the facility of birth persisted throughout time. In 2007, 23% of Southeast’s births happened in level-III facilities, the largest share of Brazil. In 2021, the Southeast region still held the largest share of births delivered in level III facilities, which are 43% of total births. On the other hand, only 6% of births in the North region happened in level-III births in 2007. This percentage increased to 15 in 2021, but it is still the lowest share among the regions (Table 2).

There are some improvements in regional disparities. The ratio of level-III birth shares between the North and Southeast regions diminished over the decade. In 2007, the share of level-III births in the Southeast region was 3.6 times higher than in the North. In 2021, this ratio reduced to 2.9, indicating some convergence between these regions. Another region that increased the fraction of births at level-III facilities is the South region. The percentage of births at level-III facilities in the South augmented from 13% in 2007 to 39% in 2021. Specific to extremely preterm births, Table A.4 shows how regions North and Northeast have increased their share of risky births in level-III facilities around threefold and fourfold, respectively. Other regions have held milder differences, pointing to another sign of convergence.

Table 2: Regional distribution of births by perinatal level of care in 2007 and 2021

	Level 0		Level I		Level II		Level III		Total	
	%	N	%	N	%	N	%	N	%	N
Regions (2007):										
North	5.2	11029	66.6	141606	22.1	46944	6.2	13080	100.0	212659
Northeast	7.3	52983	66.2	477588	23.8	172132	2.7	19212	100.0	721915
Southeast	3.0	16485	44.0	241993	30.4	167038	22.6	124194	100.0	549710
South	1.7	2655	57.8	88117	27.1	41281	13.4	20407	100.0	152460
Central-west	2.0	2595	55.0	71748	30.8	40202	12.3	15994	100.0	130539
Total	4.9	85747	57.8	1021052	26.5	467597	10.9	192887	100.0	1767283
Regions (2021):										
North	0.8	1945	52.7	128909	31.6	77457	14.9	36456	100.0	244767
Northeast	2.2	13401	47.5	287922	35.2	213240	15.2	91903	100.0	606466
Southeast	0.6	3175	32.2	164944	24.4	125080	42.7	218721	100.0	511920
South	0.7	1044	37.1	59620	23.4	37619	38.8	62241	100.0	160524
Central-west	1.2	1540	51.0	63310	23.7	29426	24.1	29875	100.0	124151
Total	1.3	21105	42.8	704705	29.3	482822	26.7	439196	100.0	1647828

Notes: Level I: A facility capable of assisting low-risk births. Level II: A facility capable of assisting high-risk births requiring obstetric surgical interventions and intermediate neonatal care. Level III: A facility capable of assisting high-risk births requiring obstetric or neonatal critical care. Level 0: Residual level, not satisfying any of the criteria above.

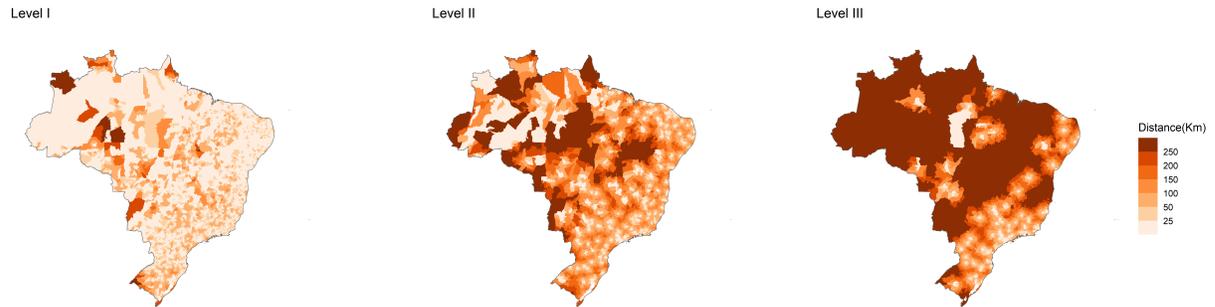
Odd columns (“%”) contain the percentage of births by perinatal level of care. Each row percentages should sum to 100%. Even columns (“N”) contain the number of births by perinatal level of care. The last two columns contain the total number of births of the row, expressed in percentage and number.

3.2 Geographic accessibility

The average minimum distance to SUS delivery facilities increases with the perinatal level of care. In 2021, 21, 71, and 175 Km were the average minimum distances to level-I, level-II, and level-III facilities (Table A.5). We excluded the distance to level 0 facilities because they assisted only 3% of SUS births. Beyond national patterns, the minimum distances to the perinatal levels of care hid considerable regional differences in access to healthcare. Level-I facilities are the most accessible and less unequal because the minimum distance to them is less than 50 Km for the majority of the municipalities of Brazil, as shown in Figure 3. There are some exceptions in the north and the south of the country.

On the other hand, the minimum distance to level-II facilities ranged between 0 and more than 250 Km. Level-II facilities are located in capitals and cities along the eastern coasts of Brazil, noticeable by the white spots in Figure 3. For instance, in 2021, the average minimum distances to these facilities were 69 and 45 Km in the Northeast and Southeast regions, respectively (Table A.6). Nevertheless, the average minimum distances in the North region were 1.6 and 2.4 times greater than those. Regional differences for level-III facilities were more extreme, as they primarily concentrated in cities of the Southeast region.

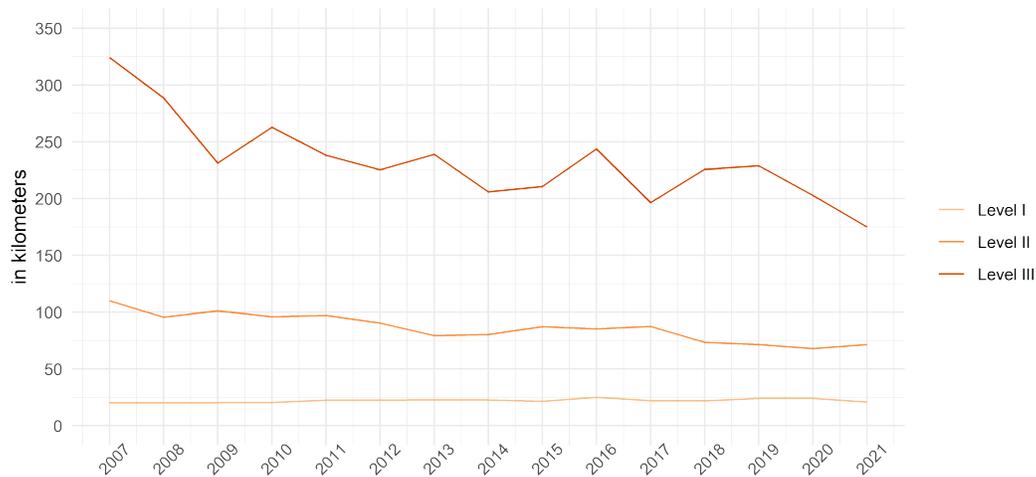
Figure 3: Municipal maps of minimum distances to health facilities by perinatal level of care (2021)



Note: Figure shows the shortest traveling distance between one municipality and another containing a facility of a certain level of care. Level I: A facility capable of assisting low-risk births. Level II: A facility capable of assisting high-risk births requiring obstetric surgical interventions and intermediate neonatal care. Level III: A facility capable of assisting high-risk births requiring obstetric or neonatal critical care.

Consistent with the increase in level-III facilities between 2007 and 2021, the average minimum distance to these facilities was reduced from 324 to 175 Km. The average minimum distance to level II facilities reduced from 110 to 71 Km, and the distance to level I facilities remained relatively constant (Figure 4). There were also regional improvements between 2007 and 2021, particularly in the access to level-II facilities that can be seen by contrasting 2007 and 2021 municipal maps (Figures 3 and A.1) and are detailed below.

Figure 4: Evolution of the minimum distance to a facility by perinatal level of care (2007-2021)



Note: Figure shows the national average minimum distance between one municipality and another containing a facility of a certain level of care. Level I: A facility capable of assisting low-risk births. Level II: A facility capable of assisting high-risk births requiring obstetric surgical interventions and intermediate neonatal care. Level III: A facility capable of assisting high-risk births requiring obstetric or neonatal critical care.

Figures 5-8 describe states' average minimum distances for the first and the last available

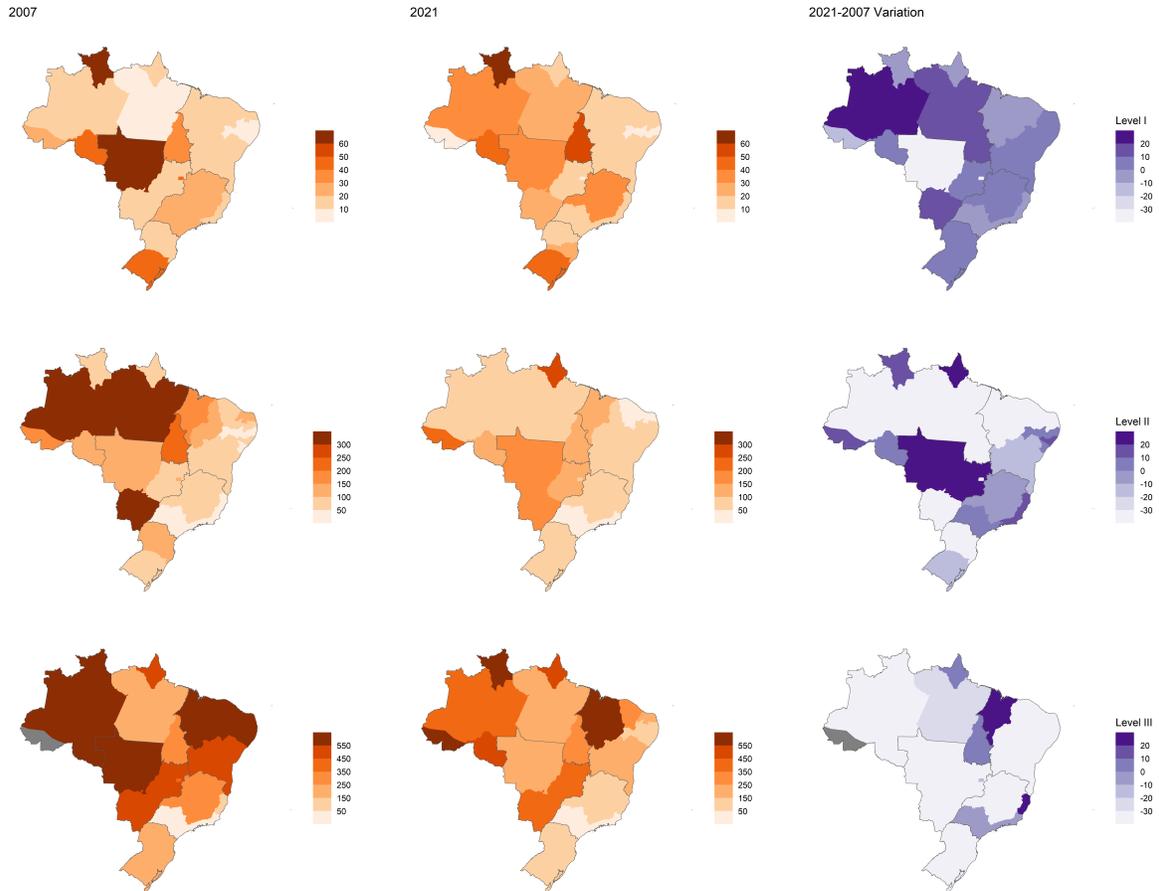
year of our sample and the difference between them. Each row corresponds to a perinatal level of care: I, II, or III. Excepting the human resources component (Figure 8), whose time series begins in 2012, data traces back to 2007. Figure 5 presents the distances to the aggregated level of care, i.e., the classification combining infrastructure and equipment requirements. For level I facilities, distances have remained largely stable, with increases or reductions of at most 10 kilometers in magnitude for most states. Only Amazonas recorded an increase surpassing 20 kilometers; on the other extreme, Mato Grosso's numbers fell more than 30 kilometers. State variation in the distance to levels II and III facilities was more significant; most states followed the decreasing trend observed at the national level. Amazonas and Pará states significantly reduced their distance to level-II facilities from more than 300 Km in 2007 to 50 to 100 Km in 2021. We observe a similar reduction in Mato Grosso do Sul and the distance to level-III facilities in Mato Grosso, Ceará, Rio Grande do Norte, Alagoas, and Pernambuco. The changes in the remaining states were smaller.

It is important to note that any transformation is influenced by (i) opening and closing facilities; and (ii) including or excluding a component in a pre-existing facility. For this reason, we analyze each component of the level-of-care classification separately. Figure 6 depicts distances to perinatal levels of care based only on infrastructure criteria. Level I presents the same stability as in the general classification, with almost no increases over 20 kilometers, except Amazonas. Distance to level-II facilities is smaller if we consider only infrastructure criteria instead of all criteria. In 2007, only Acre, Pará, and Tocantins had distances to level-II facilities over 175 Km. In 2021, almost all states had an average distance to level-II facilities smaller than 175 Km (the exception is Amapá). However, over the period, the reductions in the distance to level-II facilities were less drastic than that of level-III facilities. Notice that in 2007 the distance to level-III facilities in several states was above 350 Km, while in 2021, this distance was below 250 Km in most cases (except Roraima and Goiás).

Figure 7 shows distances to levels of care based on the equipment component. Level I is still rapidly approachable and has less margin for variation. Levels II and III follow the overall reduction tendency observed in the infrastructure component. As with infrastructure, the distance to level-II facilities is smaller if we consider only equipment criteria. However, the reduction over time is milder for the equipment component. Lastly, Figure 8 shows the third and final component, human resources. Repeating a pattern seen before, level I do not vary too much in magnitude. However, human resources for level-II facilities are more distant, and for level-III facilities are closer than their infrastructure and equipment counterparts. Regarding the changes over time, we observe a mild reduction in the distance to level-II facilities and a more drastic one in the distance to level-III facilities, similar to

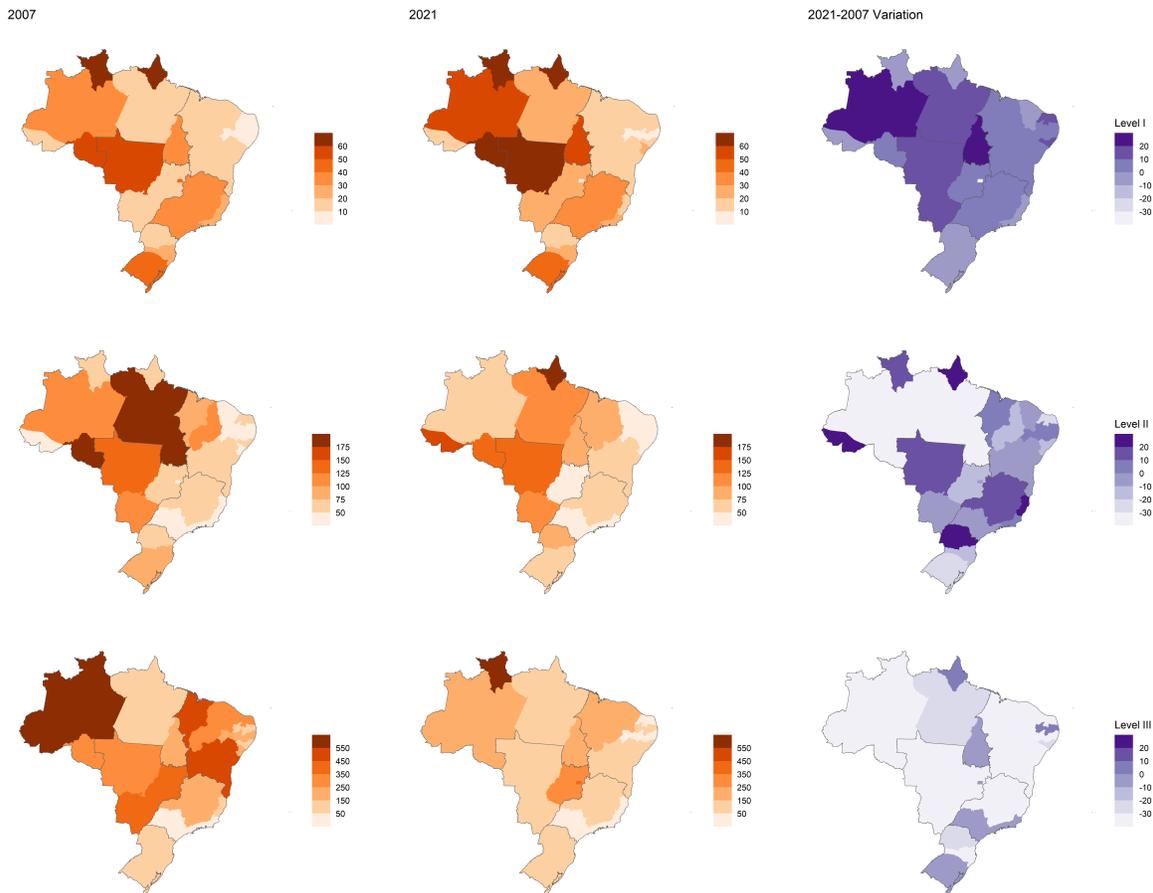
what happens with the infrastructure component.

Figure 5: State map of minimum distances to a facility by perinatal level of care: 2007-2021 comparison



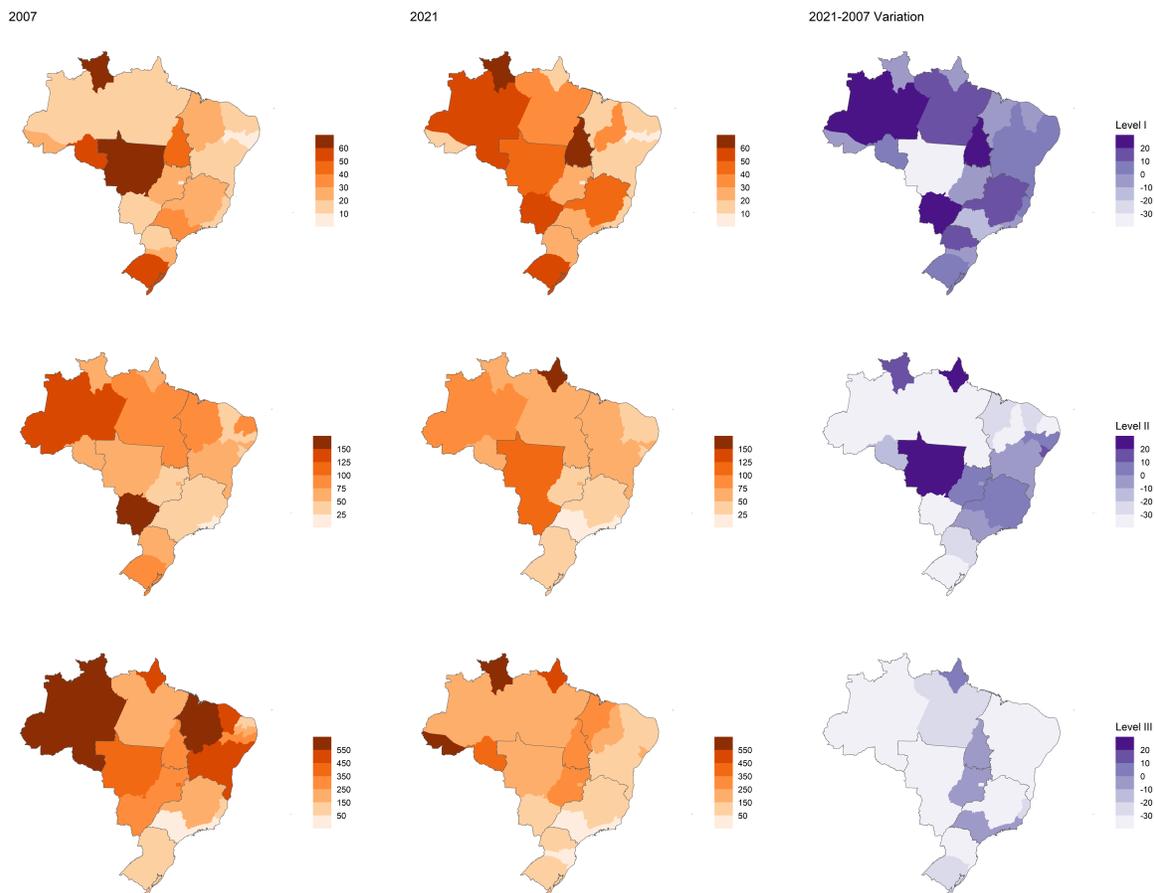
Note: Figure shows the state average minimum distance between one municipality and another containing a facility of a certain level of care. Level I: A facility capable of assisting low-risk births. Level II: A facility capable of assisting high-risk births requiring obstetric surgical interventions and intermediate neonatal care. Level III: A facility capable of assisting high-risk births requiring obstetric or neonatal critical care.

Figure 6: State map of minimum distances to a facility's infrastructure by perinatal level of care: 2007-2021 comparison



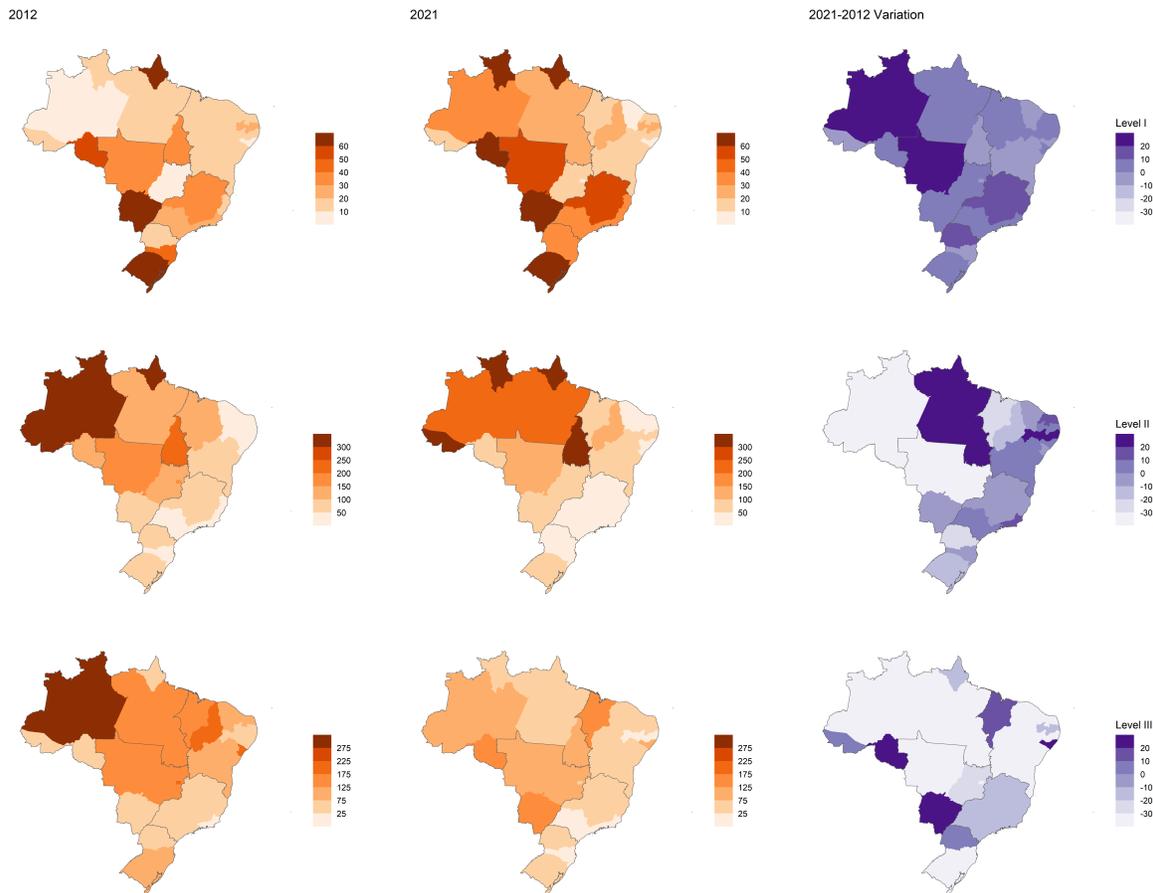
Note: Figure shows the state average minimum distance between one municipality and another containing a facility of a certain level of care, defined only by infrastructure requirements. Level I: A facility capable of assisting low-risk births. Level II: A facility capable of assisting high-risk births requiring obstetric surgical interventions and intermediate neonatal care. Level III: A facility capable of assisting high-risk births requiring obstetric or neonatal critical care.

Figure 7: State map of minimum distances to a facility's equipment by perinatal level of care: 2007-2021 comparison



Note: Figure shows the state average minimum distance between one municipality and another containing a facility of a certain level of care, defined only by equipment requirements. Level I: A facility capable of assisting low-risk births. Level II: A facility capable of assisting high-risk births requiring obstetric surgical interventions and intermediate neonatal care. Level III: A facility capable of assisting high-risk births requiring obstetric or neonatal critical care.

Figure 8: State map of minimum distances to a facility’s human resources by perinatal level of care: 2012-2021 comparison



Note: Figure shows the state average minimum distance between one municipality and another containing a facility of a certain level of care, defined only by human resources requirements. Level I: A facility capable of assisting low-risk births. Level II: A facility capable of assisting high-risk births requiring obstetric surgical interventions and intermediate neonatal care. Level III: A facility capable of assisting high-risk births requiring obstetric or neonatal critical care.

4 Conclusion

In this article, we focused on a description of distances to health facilities, depending on level-of-care and its specific components (infrastructure, equipment, and human resources). The geographic distribution matters in terms of appropriate and timely access to services, and some evidence points to a relationship - although not causal - to the worsening of health outcomes for mothers and newborns Pacagnella et al. (2014); Leal et al. (2020), since traveling could potentially be, for instance, a source of distress and delays Thaddeus and Maine (1994). Supply conditions will be particularly relevant considering pregnant women report not receiving guidance on where to attend Viellas et al. (2014), despite a structured

public health system such as SUS in Brazil, our case of study.

Between 2007 and 2021, the delivery facilities decreased, especially among levels I and 0. These are, respectively, the most basic level of care for births and a residual category. On the other hand, level-III and level-II facilities have expanded both in number and in accomplished births. Despite this progress, equal geographic accessibility to these facilities has not yet improved. While the average distance to level-I facilities remained stable, low, and equal throughout the country, the distance to level III stayed high and irregular across regions, even though in a descending trend. Policymakers should use this information to allocate resources correctly to build new establishments or to improve specific components in already existing health centers (given their complementarity), besides investigating local demand for risk-appropriate services. In particular, our assessment shows that the distance to specialized infrastructure, equipment, and human resources improved individually. However, the simultaneous progress of all the inputs has been slower and diluted over time and across regions.

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Appendices

A Additional results

Table A.1: Facility characteristics by perinatal level of care (2007)

	Level 0		Level I		Level II		Level III	
	%	N	%	N	%	N	%	N
Type of facility:								
Hospital	43.6	219	76.7	1594	84.8	239	90.4	85
Normal Delivery Center	1.4	7	0.2	4	0	0	0	0
Other hospitals	2.8	14	4.2	87	12.1	34	8.5	8
Emergency units	3.4	17	0.4	8	0.4	1	1.1	1
Other facilities	48.8	245	18.6	386	2.8	8	0	0
Type of care:								
Outpatient	26.3	132	0.3	6	0	0	0	0
Inpatient	73.7	370	99.7	2073	100	282	100	94
Complexity of inpatient care:								
Low	19.4	74	6.8	141	0.7	2	0	0
Medium	66.1	252	72.6	1506	36.9	104	0	0
Medium + Diagnostics	6.6	25	10.9	225	20.9	59	18.1	17
High	7.9	30	9.7	201	41.5	117	81.9	77
Patient volume (births):								
≤ 37	27.9	140	8.4	174	4.3	12	5.3	5
37-157	40.0	201	31.1	646	5.3	15	1.1	1
157-550	25.7	129	38.2	795	22.0	62	7.4	7
>550	6.4	32	22.3	464	68.4	193	86.2	81
Extremely preterm births:								
≤ 0	76.3	383	57.0	1186	23.4	66	8.5	8
0-2	18.5	93	28.3	588	18.4	52	6.4	6
>2	5.2	26	14.7	305	58.2	164	85.1	80
Very low birthweight:								
≤ 0	63.3	318	42.3	880	16.0	45	5.3	5
0-1	18.1	91	20.7	430	4.6	13	1.1	1
1-3	12.4	62	17.7	369	13.5	38	2.1	2
>3	6.2	31	19.2	400	66.0	186	91.5	86
Observations	502		2079		282		94	

Notes: Level I: A facility capable of assisting low-risk births. Level II: A facility capable of assisting high-risk births requiring obstetric surgical interventions and intermediate neonatal care. Level III: A facility capable of assisting high-risk births requiring obstetric or neonatal critical care. Level 0: Residual level, not satisfying any of the criteria above.

Complexity of inpatient care is the MOH's facility classification. Low-complexity facilities perform basic and first referral outpatient procedures, deliveries, pediatric hospitalizations, minor clinician and surgical procedures. Medium-complexity facilities perform first and second referral outpatient procedures and medium-complexity hospital procedures. All specialized hospitals belong in this category. Medium+Diagnostics facilities provide high complexity outpatient diagnostic services in addition to medium-complexity facilities' procedures. High-complexity facilities focus on inpatient and outpatient highly complex procedures (Brazil. Ministerio da Saúde, 2022a). Very preterm births are those with 22 weeks or less of gestational age. Very low birth weights are those with 1500 grams or less of weight at birth.

Table A.2: Number of SUS birth facilities by year and perinatal level of care (2007-2021)

	Level 0	Level I	Level II	Level III	Total
2007	502 (17.0)	2079 (70.3)	282 (9.5)	94 (3.2)	2957 (100.0)
2008	514 (17.4)	2044 (69.3)	291 (9.9)	101 (3.4)	2950 (100.0)
2009	499 (17.1)	1995 (68.2)	319 (10.9)	113 (3.9)	2926 (100.0)
2010	479 (16.3)	2018 (68.6)	321 (10.9)	124 (4.2)	2942 (100.0)
2011	450 (15.5)	1981 (68.4)	335 (11.6)	130 (4.5)	2896 (100.0)
2012	453 (15.7)	1959 (68.0)	337 (11.7)	133 (4.6)	2882 (100.0)
2013	453 (15.6)	1974 (68.1)	336 (11.6)	134 (4.6)	2897 (100.0)
2014	445 (15.4)	1983 (68.5)	328 (11.3)	137 (4.7)	2893 (100.0)
2015	448 (15.7)	1935 (67.9)	307 (10.8)	160 (5.6)	2850 (100.0)
2016	448 (15.8)	1930 (68.2)	291 (10.3)	159 (5.6)	2828 (100.0)
2017	448 (15.9)	1917 (67.9)	289 (10.2)	168 (6.0)	2822 (100.0)
2018	445 (15.8)	1909 (67.8)	296 (10.5)	167 (5.9)	2817 (100.0)
2019	439 (15.7)	1885 (67.4)	299 (10.7)	175 (6.3)	2798 (100.0)
2020	424 (14.9)	1917 (67.5)	320 (11.3)	181 (6.4)	2842 (100.0)
2021	415 (14.5)	1934 (67.5)	331 (11.6)	184 (6.4)	2864 (100.0)
Total	6862 (15.9)	29460 (68.3)	4682 (10.8)	2160 (5.0)	43164 (100.0)

Notes: Level I: A facility capable of assisting low-risk births. Level II: A facility capable of assisting high-risk births requiring obstetric surgical interventions and intermediate neonatal care. Level III: A facility capable of assisting high-risk births requiring obstetric or neonatal critical care. Level 0: Residual level, not satisfying any of the criteria above.

Table A.3: Number of SUS birth facilities by year and perinatal level of care (2012-2021)

	Level 0	Level I	Level II	Level III	Total
2012	468 (16.2)	2054 (71.3)	243 (8.4)	117 (4.1)	2882 (100.0)
2013	469 (16.2)	2057 (71.0)	247 (8.5)	124 (4.3)	2897 (100.0)
2014	464 (16.0)	2054 (71.0)	247 (8.5)	128 (4.4)	2893 (100.0)
2015	462 (16.2)	2008 (70.5)	234 (8.2)	146 (5.1)	2850 (100.0)
2016	461 (16.3)	1996 (70.6)	226 (8.0)	145 (5.1)	2828 (100.0)
2017	459 (16.3)	1983 (70.3)	227 (8.0)	153 (5.4)	2822 (100.0)
2018	457 (16.2)	1973 (70.0)	230 (8.2)	157 (5.6)	2817 (100.0)
2019	448 (16.0)	1954 (69.8)	233 (8.3)	163 (5.8)	2798 (100.0)
2020	433 (15.2)	1984 (69.8)	252 (8.9)	173 (6.1)	2842 (100.0)
2021	421 (14.7)	2001 (69.9)	265 (9.3)	177 (6.2)	2864 (100.0)
Total	4542 (15.9)	20064 (70.4)	2404 (8.4)	1483 (5.2)	28493 (100.0)

Notes: Level I: A facility capable of assisting low-risk births. Level II: A facility capable of assisting high-risk births requiring obstetric surgical interventions and intermediate neonatal care. Level III: A facility capable of assisting high-risk births requiring obstetric or neonatal critical care. Level 0: Residual level, not satisfying any of the criteria above.

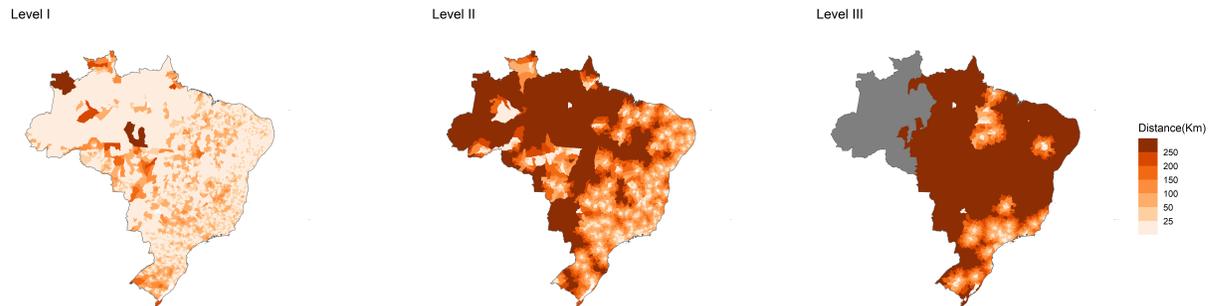
Table A.4: Regional distribution of extremely preterm births by perinatal level of care in 2007 and 2021

	Level 0		Level I		Level II		Level III		Total	
	%	N	%	N	%	N	%	N	%	N
Regions (2007):										
North	5.3	41	54.6	425	31.6	246	8.5	66	100.0	778
Northeast	4.5	146	53.6	1742	33.4	1086	8.5	277	100.0	3251
Southeast	2.4	75	28.2	870	31.7	976	37.7	1161	100.0	3082
South	0.3	2	43.8	330	26.3	198	29.6	223	100.0	753
Central-west	1.1	6	39.1	213	31.6	172	28.3	154	100.0	545
Total	3.2	270	42.6	3580	31.8	2678	22.4	1881	100.0	8409
Regions (2021):										
North	0.4	5	41.7	569	28.4	387	29.6	404	100.0	1365
Northeast	1.0	34	27.4	956	37.0	1292	34.6	1207	100.0	3489
Southeast	0.4	12	23.5	799	20.9	709	55.3	1877	100.0	3397
South	0.1	1	26.3	279	21.9	232	51.7	548	100.0	1060
Central-west	0.0	0	28.6	254	33.1	294	38.2	339	100.0	887
Total	0.5	52	28.0	2857	28.6	2914	42.9	4375	100.0	10198

Notes: Level I: A facility capable of assisting low-risk births. Level II: A facility capable of assisting high-risk births requiring obstetric surgical interventions and intermediate neonatal care. Level III: A facility capable of assisting high-risk births requiring obstetric or neonatal critical care. Level 0: Residual level, not satisfying any of the criteria above.

Odd columns (“%”) contain the percentage of births by perinatal level of care. Each row percentages should sum to 100%. Even columns (“N”) contain the number of births by perinatal level of care. The last two columns contain the total number of births of the row, expressed in percentage and number.

Figure A.1: Municipal maps of minimum distances to health facilities by perinatal level of care (2007)



Note: Figure shows the shortest traveling distance between one municipality and another containing a facility of a certain level of care. Level I: A facility capable of assisting low-risk births. Level II: A facility capable of assisting high-risk births requiring obstetric surgical interventions and intermediate neonatal care. Level III: A facility capable of assisting high-risk births requiring obstetric or neonatal critical care.

Table A.5: Average minimum distance to perinatal levels of care by year

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Level I	20.2	20.1	20.2	20.4	22.4	22.4	22.8	22.6	21.3	25.0	22.0	21.8	23.9	23.9	20.9
Level II	109.9	95.4	101.1	95.8	96.9	90.3	79.3	80.3	87.2	85.2	87.3	73.4	71.4	67.9	71.4
Level III	324.1	288.6	231.4	262.8	238.1	225.4	238.9	205.9	210.6	243.6	196.5	225.8	228.9	202.7	174.9
Infrastructure Level I	24.6	25.8	24.4	27.4	27.2	27.5	25.3	28.2	26.3	27.6	28.9	30.8	30.8	27.1	29.0
Infrastructure Level II	63.9	61.4	66.0	61.3	61.1	61.3	62.9	56.8	58.9	61.7	60.7	60.2	63.1	61.4	59.0
Infrastructure Level III	199.0	141.2	162.8	186.5	153.7	103.5	150.5	117.7	146.2	147.7	109.3	113.7	113.0	124.5	100.1
Equipment Level I	24.0	22.9	25.4	23.9	27.6	26.1	28.4	27.0	25.9	28.5	26.7	26.0	28.2	29.2	26.0
Equipment Level II	54.7	49.1	51.5	50.9	46.7	49.1	46.2	47.9	49.9	49.7	50.5	48.6	42.0	41.9	44.4
Equipment Level III	263.5	231.9	205.1	244.1	194.7	159.2	186.3	167.2	139.5	158.3	163.4	155.3	166.2	149.5	115.4
Human resources Level I	.	.	.	.	.	25.4	25.3	27.1	27.8	27.4	28.1	28.6	28.9	31.2	32.6
Human resources Level II	.	.	.	.	.	77.9	73.9	82.3	72.1	75.4	69.6	72.7	78.0	77.3	75.7
Human resources Level III	.	.	.	.	.	88.1	83.6	81.7	81.1	93.3	90.0	82.5	65.1	60.2	52.9

Notes: Averages are weighted by municipal births.

Table A.6: Average minimum distance to perinatal levels of care by region and year

	North		Northeast		Southeast		South		Center-west	
	2007	2021	2007	2021	2007	2021	2007	2021	2007	2021
Level I	18.3	34.5	11.7	13.3	23.1	20.1	24.8	27.1	33.8	21.6
Level II	378.6	110.2	94.1	69.3	41.2	45.3	110.1	78.4	157.3	131.8
Level III	308.6	373.9	600.7	255.1	99.5	52.4	159.5	76.8	648.6	344.3
Infrastructure Level I	30.4	46.8	10.5	15.1	30.5	32.8	31.6	29.6	32.1	34.6
Infrastructure Level II	169.1	103.7	55.0	51.2	35.8	42.4	73.1	68.4	84.7	85.0
Infrastructure Level III	370.6	183.5	311.1	127.5	66.7	34.4	91.1	66.1	372.0	244.1
Equipment Level I	23.7	41.7	13.8	14.9	27.7	24.9	30.6	36.4	34.8	30.3
Equipment Level II	103.8	73.3	59.0	45.1	29.9	28.6	69.9	42.4	70.7	76.9
Equipment Level III	600.8	330.3	431.3	131.5	77.9	39.3	122.6	54.6	334.4	213.4
Human resources Level I	.	36.4	.	14.7	.	40.8	.	43.6	.	33.9
Human resources Level II	.	284.5	.	60.0	.	35.8	.	45.5	.	80.2
Human resources Level III	.	88.5	.	71.0	.	23.1	.	37.9	.	101.0

Notes: Averages are weighted by municipal births.

Table A.7: Average minimum distance to infrastructure by year

	Level	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Obstetric Center		9.3	9.0	9.9	10.5	10.3	10.9	10.6	10.3	11.3	10.9	10.5	10.3	11.6	9.8	9.8
Neonatal Unit		19.5	19.8	21.5	21.3	21.3	22.1	22.1	23.9	23.0	24.4	21.3	20.6	22.3	22.2	23.0
Rooms for normal delivery	I	10.6	9.8	11.4	12.1	11.4	12.0	11.9	11.4	12.6	11.8	11.5	11.6	12.7	12.0	11.8
Rooms for pre-labor	I	12.9	12.3	13.5	13.7	14.4	14.8	14.6	13.9	14.3	15.0	13.4	13.3	14.5	13.2	13.8
Beds for pre-labor	I	13.6	12.6	14.2	14.3	14.8	15.5	15.2	14.9	14.9	15.7	15.0	13.9	14.8	13.7	15.1
Mother-baby joint beds	I	20.8	20.3	22.1	23.3	22.2	24.1	23.8	25.9	24.9	26.3	23.5	23.9	24.6	24.2	26.1
Rooms for curettage (abortion)	I	43.6	47.4	48.0	48.5	47.7	49.0	51.1	45.5	50.7	52.8	48.4	46.3	47.6	47.2	44.8
Normal newborn beds	I	100.8	85.6	82.3	83.2	82.7	72.0	70.5	69.8	68.4	72.0	72.3	66.1	67.8	68.3	65.6
Bed for obstetric clinical attention	II	18.5	14.2	16.3	15.0	14.5	15.6	14.2	14.1	16.7	13.7	14.2	14.6	15.1	12.8	14.0
Bed for neonatal ITC - pre-RC	II	98.8	98.1	93.7	81.3	81.6	76.8	90.5	119.6	157.0	161.0	181.2	216.3	264.8	354.3	338.7
Bed for neonatal ITC - conventional	II	.	.	.	.	.	90.7	87.9	90.4	101.9	79.1	76.9	71.4	85.1	75.7	95.5
Bed for neonatal ITC - kangaroo	II	.	.	.	.	.	180.2	195.0	177.1	157.9	159.6	139.5	154.3	147.7	130.1	123.6
Bed for neonatal ITC - total	II	98.8	98.1	93.7	81.3	81.6	66.4	68.4	66.6	70.9	62.5	63.8	59.5	62.6	53.6	60.0
Bed for newborn clinical attention	II	94.1	83.8	104.1	96.4	88.4	106.8	92.6	89.4	118.0	115.1	104.3	100.6	103.9	110.4	107.7
Pathologic newborn beds	II	95.1	86.6	83.1	86.3	78.0	80.4	83.4	77.0	71.2	76.6	73.9	68.2	69.9	75.8	71.3
Obstetric surgical bed	III	16.8	18.4	17.3	17.0	17.7	16.7	19.4	16.4	19.5	16.5	16.4	16.1	18.7	16.6	19.1
Bed in ICU	III	122.9	125.5	100.8	107.6	104.1	79.8	109.7	99.8	81.4	108.5	86.7	80.6	77.9	95.9	67.7
Bed in NICU	III	145.0	145.9	134.6	128.1	133.1	92.0	126.4	112.5	108.2	118.6	107.2	104.4	99.2	116.6	103.6
Bed for pediatric surgery	III	156.3	134.1	105.2	95.9	91.7	79.5	79.7	77.0	79.1	74.5	67.3	69.1	70.0	67.8	65.1

Notes: Averages are weighted by municipal births.

Table A.8: Average minimum distance to infrastructure by region and year

	Level	North		Northeast		Southeast		South		Center-west	
		2007	2021	2007	2021	2007	2021	2007	2021	2007	2021
Obstetric Center		5.9	5.8	5.0	5.6	8.8	10.3	18.3	15.6	18.6	17.2
Neonatal Unit		42.5	31.8	13.0	18.5	13.0	19.4	26.3	27.5	35.1	34.8
Rooms for normal delivery	I	10.3	7.7	5.5	6.5	9.5	13.1	19.9	17.3	22.3	20.0
Rooms for pre-labor	I	14.6	12.0	7.5	8.4	10.7	12.6	22.2	18.8	28.2	31.4
Beds for pre-labor	I	17.7	13.0	8.0	8.8	10.9	15.0	22.6	19.6	29.1	32.4
Mother-baby joint beds	I	42.8	44.3	12.8	18.6	15.7	21.5	27.2	30.0	38.3	41.1
Rooms for curettage (abortion)	I	46.7	65.8	45.0	35.8	32.9	36.4	49.0	43.8	79.7	86.2
Normal newborn beds	I	311.3	148.0	71.6	54.3	51.8	43.7	140.6	58.3	114.1	104.1
Bed for obstetric clinical attention	II	11.5	9.6	11.6	8.5	20.5	15.0	26.1	20.5	32.2	22.9
Bed for neonatal ITC - pre-RC	II	252.8	615.7	108.3	353.0	45.0	232.4	94.0	330.1	132.6	428.5
Bed for neonatal ITC - conventional	II	.	116.8	.	86.8	.	54.4	.	105.9	.	261.8
Bed for neonatal ITC - kangaroo	II	.	229.0	.	128.8	.	69.0	.	160.1	.	152.4
Bed for neonatal ITC - total	II	252.8	69.4	108.3	60.5	45.0	42.2	94.0	70.1	132.6	109.2
Bed for newborn clinical attention	II	288.6	285.5	96.8	100.2	37.1	48.1	81.2	83.8	130.4	202.1
Pathologic newborn beds	II	288.7	167.9	83.0	67.4	40.0	42.0	118.9	64.2	120.7	99.1
Obstetric surgical bed	III	28.9	23.6	13.4	14.9	12.8	17.0	23.9	21.6	21.9	32.3
Bed in ICU	III	354.7	172.9	156.9	80.8	42.7	26.0	60.9	49.5	183.8	100.3
Bed in NICU	III	283.8	147.7	199.8	120.8	42.4	40.4	76.5	64.6	375.0	329.9
Bed for pediatric surgery	III	261.8	147.8	140.3	62.9	109.0	31.2	187.2	61.6	266.6	120.5

Notes: Averages are weighted by municipal births.

B Levels of care and variable selection

The variable selection to create the level-of-care indicators for perinatal services happened in two stages. First, we examined the MoH perinatal care norms and searched specific references to equipment, infrastructure, and human resources by the level of care. Thus, we examined a compendium of the current maternal-infant facility qualifications, detailed in (Empresa Brasileira de Serviços Hospitalares, 2021), complementing our search by reviewing the qualification norms of neonatal units (Brazil. Ministerio da Saúde, 2012) and the national program for health services evaluation (Brazil. Ministério da Saúde, 2015). These documents were highly detailed; in some cases, specifying the required number of tensiometers and scales within a facility even. However, the CNES database contains more generic information, quantifying only more complex equipment and infrastructure. Hence, we filter the MoH requirements to only remain with the items available in the CNES database.

In a second step, we estimate the percentage of facilities with each of the selected items (infrastructure, equipment, and human resources variables) per year. We identified that not all the variables existed throughout the analysis period, and some specialized equipment, such as ECMO machines, were extremely scarce. The most critical case was that of human resources variables because the disaggregation of medical health personnel by specialty is only available after 2012. Consequently, we decided to create two sets of indicators of perinatal levels of care; one for 2007-2017, using a reduced group of variables (without human resources data), and another for 2012-2017 with a more extensive variable set.

In the following paragraphs, we describe the perinatal levels of care in terms of the infrastructure, equipment and human resources requirements.

Level I: A facility capable of assisting low-risk births, i.e., pregnancies with perinatal morbidity and mortality below or equal to the average population when an eutocic delivery is expected after an initial obstetric examination (Brazil. Ministerio da Saúde, 2015). In the Brazilian norms, this service is provided in facilities with normal delivery centers (Centro de Parto Normal or CPN in Portuguese). The CPNs are health units within hospitals or in proximity that aim to attend low-risk births (Brazil. Ministerio da Saúde, 2015). A delivery facility qualifies to provide these services if it possesses a pre-labor, labor, and post-labor room per 14 births/month and a minimum team of a coordinator, an obstetric nurse or midwife, a nursing technician, and a service auxiliary, available 24/7. The required equipment is the expected instruments for a normal delivery: gynecological instruments (e.g., stethoscope, portable fetal sonar, suction bulb), instruments to check vital signs, and basic life support equipment for transport to a referral hospital (e.g., heated crib or portable incubator, oxygen tank).

Considering the information in the CNES database, we classify a delivery facility with Level I infrastructure if it has at least one pre-labor, labor, and post-labor room, regardless of whether the rooms are for mother and baby jointly or apart. On the other hand, facilities with Level-I human resources possess at least one health professional qualified to assist eutocic deliveries, i.e., a nurse or doctor, and one nurse technician or auxiliary nurse available in the facility. Finally, the facility’s equipment for Level I care is measured by the availability of basic life support equipment, a heated crib, or vital signs equipment (ECG monitor, blood pressure manual equipment).⁴ The selected variables are summarized in Table B.1.

Level II: They are facilities that attend high-risk pregnancies. In the Brazilian norms, referral hospitals Type I and II receive high-risk pregnancies. Referral hospitals are high-volume facilities that should work at 85% capacity in obstetric care and 90% intermediate and intensive neonatal care capacity. In addition, they should be able to admit pregnant women and newborns for more extended periods than Level I facilities, supported by their physical and human resources (e.g., receive pregnant women in transitory shelters before delivery) (Empresa Brasileira de Serviços Hospitalares, 2021). The norms do not attribute hierarchy between these two types of hospitals. However, the main difference is that Type I hospitals do not require a 24/7 Intensive Care Unit (ICU) or a Neonatal Intensive Care Unit (NICU) in the facility, but Type II hospitals do (Empresa Brasileira de Serviços Hospitalares, 2021). All referral hospitals must have a unit of intermediate neonatal care. These units treat medium-risk newborns that require inpatient care but not as complex as intensive units could provide (Brazil. Ministerio da Saúde, 2012). Thus, in this study, we classify Level II facilities as Type I referral hospitals that at least are able to provide intermediate neonatal care.

The facility’s infrastructure should include obstetric and newborn beds for high-risk pregnancies, i.e., for inpatient care, and equipped for transport to ICU should mothers need it (Empresa Brasileira de Serviços Hospitalares, 2021). A neonatal unit requires two NICU beds, two conventional Intermediate Care beds, and one Kangaroo Intermediate Care bed per 1000 live births. Accordingly, Level II facilities require a minimum horizontal management team of an obstetrician, nurse, and pediatrician to provide maternal and neonatal care. These facilities also perform C-sections which need an anesthesiologist and a nursing technician. In addition, the health team should include a nutritionist, pharmacist, social worker and psychologist (Empresa Brasileira de Serviços Hospitalares, 2021). Finally, the minimum equipment should consist of all Level-I equipment and incubators, AMBU bags, and phototherapy equipment (Brazil. Ministerio da Saúde, 2012). Nevertheless, intermediate care

⁴The rest of the equipment available in the database belonged to higher levels of care, and smaller or less complex instruments were not in the database.

units may also require equipment for diagnostic services such as ultrasounds, blood tests, and radiographies available in the facility (Brazil. Ministerio da Saúde, 2012).

Given the information in CNES database, we consider the infrastructure of a Level II facility should have at least one inpatient bed for neonatal care (either any care or pathological babies care) or a intermediate neonatal care bed (conventional or kangaroo), and surgical or inpatient beds for obstetric care. We did not include shelters for mothers and babies at risk because less than 5% of the facilities in the database registered them. On the other hand, human resources would include a minimum team of a doctor (general physician or gynecologist), pediatrician, anesthesiologist, nurse, nursing technician, nutritionist and pharmacist. We did not include social workers and psychologists as human resource requirements because they were scarce in the database, particularly the latter. Finally, Level II equipment includes at least one incubator, AMBU bag, photo-therapy equipment, ultrasound and x-ray machines (See Table B.1).

Level III: As Level II facilities, these facilities assist high-risk pregnancies, but they differentiate from Level II facilities because they can provide intensive care for the mother and the baby. In the Brazilian norms, they are Type II hospitals with 24/7 ICU and NICU. These hospitals also require a phonologist, physical therapist, and a neonatologist or intensive care pediatrician. Likewise, besides Level II equipment, facilities must have a Doppler, an ECG, a cardiotocographic trace, and a human milk bank on the premises (Empresa Brasileira de Serviços Hospitalares, 2021).

We classify the infrastructure facilities as Level III in the CNES database if they have NICU or pediatric surgical and ICU beds. Accordingly, human resources at a Level III facility include a phonologist, physical therapist, and social worker and the personnel available in Level II facilities. However, we did not consider psychologists because they were very rare. Finally, the equipment that distinguishes a Level III facility from a Level II facility is the Doppler and the ECG. We could not find a cardiotocographic trace among the list of equipment in the database, and human milk banks were also very meager (See Table B.1).

Table B.1: Levels of Care Variables

	Level I	Level II	Level III
Infrastructure	Pre-labor, delivery and post-labor rooms or beds. Post-labor rooms or beds are for normal deliveries. They can be mother-baby joint rooms, normal newborn rooms.	Pathological newborn beds, inpatient neonatal beds or intermediate care beds, and surgical or inpatient obstetric beds	NICU or pediatric surgical and ICU beds
Human Resources ¹	At least one health professional among general physician, nurse, obstetric nurse, obstetrician or gynecologist, and a nursing technician. Administrative personnel was not included.	At least one doctor, pediatrician, anesthesiologist, nurse, nursing technician, nutritionist and pharmacist	Level II minimum team, phonologist, physical therapist and social worker.
Equipment	Basic life support equipment, vital signs equipment (ECG monitor or blood pressure manual equipment), or a heated crib.	Level I minimum equipment plus incubator, AMBU bag, phototherapy equipment, ultrasound and x-ray machines	Level II minimum equipment plus Doppler and ECG.

Notes:

¹ Data is only available from 2012 to 2021