Geographic availability of perinatal services in Brazil

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Abstract

TBD

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 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 minimun distance from each municipality to all possible destinations 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

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

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 2007-2017. 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 the installed capabilities - infrastructure, equipment, and human resources - of all health facilities, 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 concentrate our attention on facilities that deliver at least one baby per year, 50 births at least one year throughout the decade, 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 3360 health facilities; approximately, 2500 facilities per year, with 1793 complete cases (53.4%), 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 of 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, and post-labor room or bed. The facility needs at least one health professional qualified to assist eutocic deliveries and one nurse technician (*human resources*). Finally, the facility should have basic life support *equipment*

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

- **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 beds and neonatal intermediate care beds. Incubators, ultrasound 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 include phonologists and physical therapists, among others.

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. There is a group of facilities that, despite providing delivery services, do not satisfy any of the three level of care criteria. We created a *Level 0* category for this group, indicating they are not able to satisfy any of the previous standards. 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 uses the information available between 2007 and 2017, which is more limited because the human resources information is incomplete. The second indicator is available for 2012-2017 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 birth weights, by perinatal level 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). Very preterm births are those with 22 weeks or less of gestational age. Babies with very low birth weights are those with 1500 grams or less of weight at birth.

2.3 Geographic access measures

We estimate the minimum distance to health facilities, infrastructure, equipment and human resources by 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). Alternatively, we estimated the traveling distances using the package *OSM* from *OpenStreetMap* in R software and the latitude and longitude of each municipality's downtown neighborhood. Our results were similar in 99% of the cases.

The identification of 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 health system's referral norms. Finally, we calculate the minimum of the 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, region 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 developed in two parts. First, we validate the levels of care using auxiliary statistics and show the trends in number of facilities and births by 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 Perinatal levels of care trends

We classified SUS birth facilities by perinatal level of care between 2007 and 2017. This section presents the classification based on infrastructure and equipment criteria, which spans over the decade. In the Appendix, we present the classification that include human resources variables, only available for 2012 to 2017. Both classifications follow the 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] The purpose of this table is to show the validity of the level-of-care classification we have created.

[3]MOH's classification of the facilities' complexity of care is available only until 2015, which is why we cannot present 2017's statistics.

As we can see, the percentage of hospitals increased with the perinatal level of care; 57.6% of level 0 facilities are hospitals, and that percentage increases to 95.5% for level III facilities. Similarly, outpatient facilities were only allocated at 0 or I perinatal levels of care. The perinatal levels of care were correlated with the MoH classification of levels of care. For instance, 90% of the level III facilities provided high complexity inpatient care, whereas 66% 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: 86% of level III facilities assisted more than 656 births per year compared to only 17% of level I facilities with such patient volume. Likewise, we find that the number of very preterm and low-weight births assisted by a facility increased with the level of care. Ninety percent of level III facilities took care of more than four very low-weight births per year, while 50% of level I facilities did not assist with this type of birth. We observe similar differences for very 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).

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	57.6	186	83.2	1409	82.9	243	95.5	147
Normal Delivery Center	0.9	3	0.2	4	0	0	0	0
Other hospitals	1.9	6	3.7	63	15.4	45	4.5	7
Emergency units	3.1	10	0.4	7	1.4	4	0	0
Other facilities	36.5	118	12.5	211	0.3	1	0	0
Type of care:								
Outpatient	10.9	35	0.4	6	0	0	0	0
Inpatient	89.1	287	99.6	1673	100	292	100	154
Complexity of inpatient care:								
Low	12.5	36	8.2	138	1.4	4	0	0
Medium	71.1	204	66.3	1109	27.4	80	2.6	4
Medium + Diagnostics	9.4	27	15.2	255	29.5	86	7.1	11
High	7.0	20	10.2	171	41.8	122	90.3	139
Patient volume (births):								
≤ 75	57.9	187	31.6	536	4.4	13	5.8	9
75-209	22.9	74	28.4	481	7.8	23	0.6	1
209-656	14.2	46	23.2	393	19.5	57	7.1	11
>656	5.0	16	16.8	284	68.3	200	86.4	133
Very preterm births:								
≤ 0	76.2	246	60.2	1019	17.1	50	6.5	10
0-2	20.1	65	25.0	423	22.2	65	3.9	6
>2	3.7	12	14.9	252	60.8	178	89.6	138
Very low weight births								
≤ 0	66.9	216	50.6	858	13.0	38	5.2	8
0-1	17.0	55	20.2	342	10.2	30	1.3	2
1-4	12.7	41	16.8	285	15.0	44	0.6	1
>4	3.4	11	12.3	209	61.8	181	92.9	143
Observations	323		1694		293		154	

Source: PCDAS (Instituto de Comunicação e Informação Científica e Tecnológica em Saúde, Instituto de Comunicação e Informação Científica e Tecnológica em Saúde)

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.

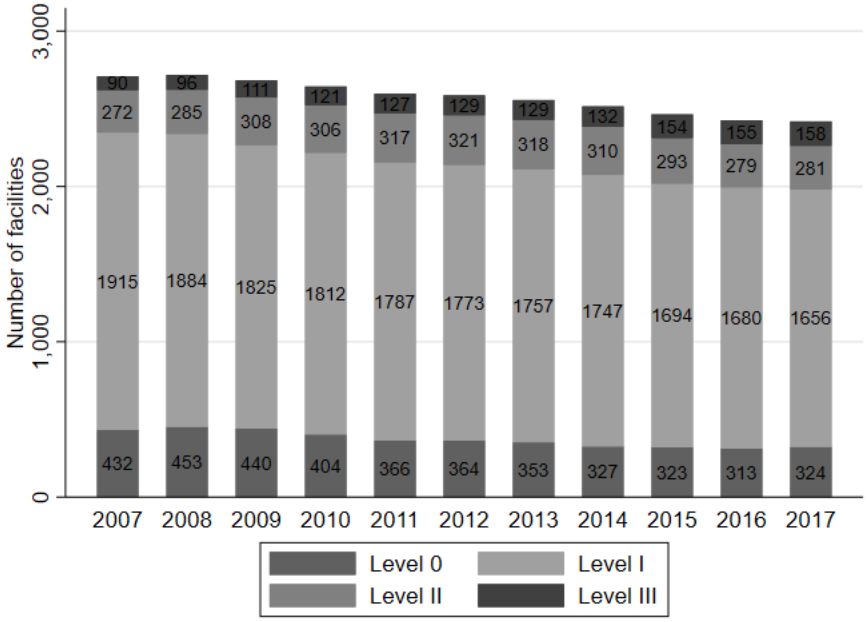
Complexity of inpatient care is the MOH's facility classification. Low-complexity facilities perform basic and first referral outpatient procedures, deliveries, pediatric hospitalizations, minor clinician and surgical procedures. Medium-complexity facilities perform first and second referral outpatient 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.

SUS birth facilities decreased over time, from 2709 to 2419 between 2007 and 2017 (Figure 1). In parallel, the number of level III and level II facilities increased. In 2007, there were 90 level III facilities, but in 2017 this quantity increased to 158. The rise in level II facilities was less salient, changing from 272 to 281. The overall reduction of facilities but the increase of level II and III facilities resulted in larger participation of these facilities in

2017 with respect to 2007.

In 2007, SUS birth facilities assisted 1.75 million births in Brazil, which reduced to 1.73 million by 2017 (Table 2). Throughout the decade, besides the slight 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 57 to 43, while the percentage at level-III facilities increased from 11 to 24. 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 the decade, from 6 to 3%.

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

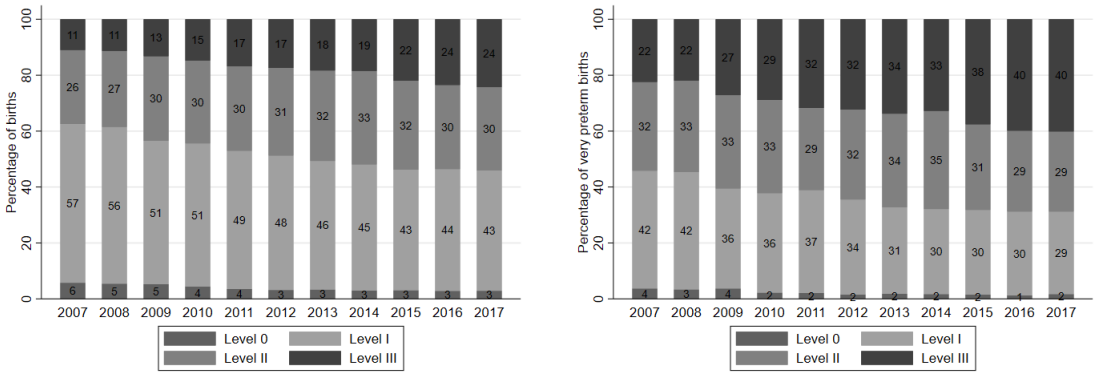


Note: Figure values can be found in Table A.2, with shares between parenthesis.

Between 2007 and 2017, very preterm births assisted by facilities increased from 8.3 to 10.5 thousand (Table A.4). Combined with the decrease in births over the decade, this trend implies that facilities passed from assisting 4.76 to 6.04 very preterm births per thousand births by the end of 2017. 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 very preterm births assisted at level-III facilities was twice that of total births (22.4 versus 11%). In 2017, the odd ratio of very preterm births versus total births assisted at level-III facilities dropped to 1.65 (40.1 versus 24.3%), 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)



(a) Births

(b) Very preterm births

In spite of the improvements in the availability of level-III and level-II facilities, regional disparities in the facility of birth persisted along the decade. In 2007, 23% of Southeast's births happened in level-III facilities, the largest share of Brazil. In 2017, the Southeast region still held the largest share of births delivered in level III facilities, which are 39% 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 14 by 2017, but it is still the lowest share among the regions (Table 2).

Nevertheless, 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 3.5 higher than the share in the North. In 2017, this ratio reduced to 2.6, indicating some convergence between these regions. Another region that significantly improved the fraction of births at level-III facilities is the South region. The percentage of births that happened at level-III facilities in the South augmented from 13% in 2007 to 34% in 2017. Specific to very 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 out to another sign of convergence.

Table 2: Regional distribution of births by perinatal level of care in 2007 and 2017

	Level 0		Level I		Level II		Level III		Total	
	%	N	%	N	%	N	%	N	%	N
Regions (2007):										
North	7.0	14226	64.8	132384	21.9	44655	6.4	13078	100.0	204343
Northeast	8.0	57631	65.4	469532	23.9	171222	2.7	19212	100.0	717597
Southeast	3.8	20836	43.2	236766	30.3	166331	22.7	124449	100.0	548382
South	2.1	3176	57.5	87648	27.1	41279	13.4	20407	100.0	152510
Central-west	4.2	5468	52.6	68535	30.9	40202	12.3	15994	100.0	130199
Total	5.8	101337	56.8	994865	26.5	463689	11.0	193140	100.0	1753031
Regions (2017):										
North	2.2	5536	53.7	132686	29.5	72860	14.6	36124	100.0	247206
Northeast	4.9	31958	49.3	319249	31.8	205525	14.0	90388	100.0	647120
Southeast	1.5	8338	32.1	177674	27.5	152311	38.9	215543	100.0	553866
South	1.4	2110	36.5	56670	28.4	44131	33.8	52439	100.0	155350
Central-west	1.8	2350	45.7	58111	32.2	40971	20.3	25801	100.0	127233
Total	2.9	50292	43.0	744390	29.8	515798	24.3	420295	100.0	1730775

Source: PCDAS (Instituto de Comunicação e Informação Científica e Tecnológica em Saúde, Instituto de Comunicação e Informação Científica e Tecnológica em Saúde)

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.

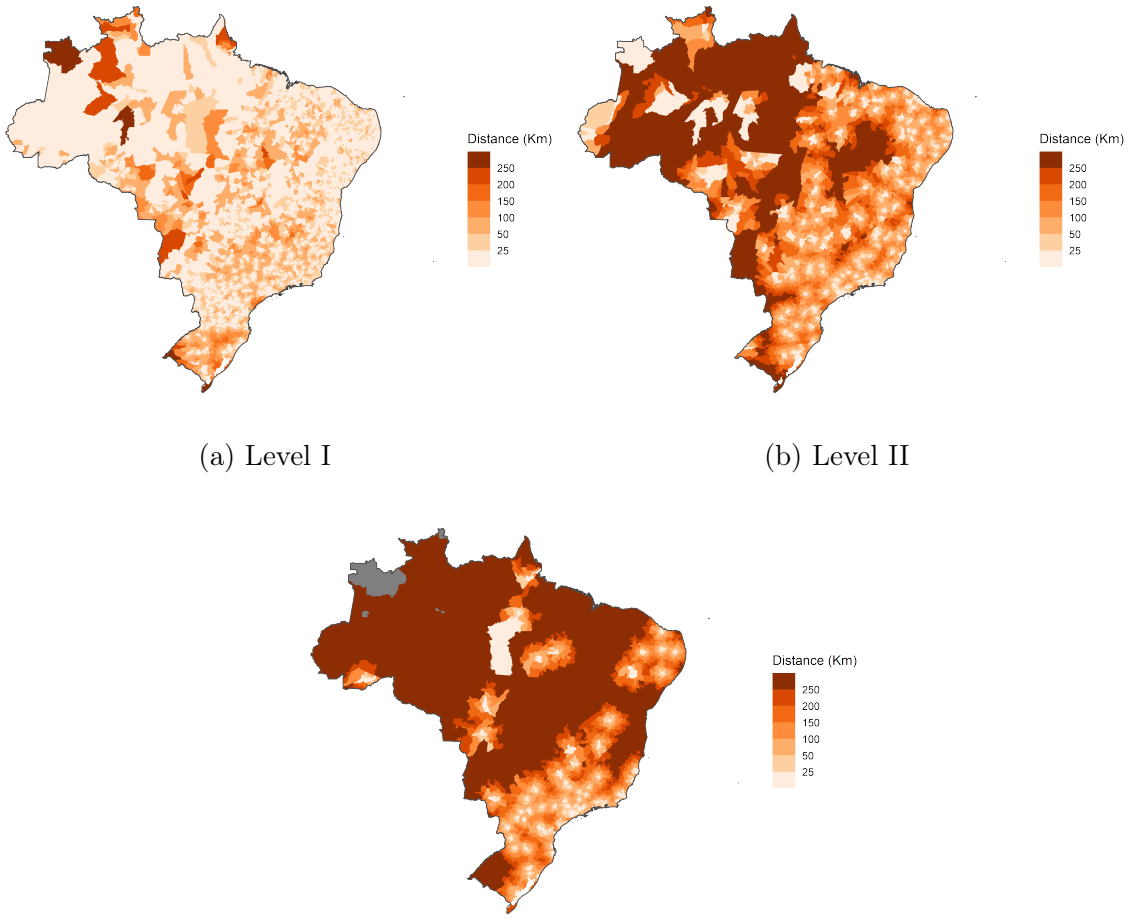
Odd columns ("%") contain the percentage of births by perinatal level of care. Each row percentages should sum to 100%. Even columns ("N") contain the number of births by perinatal level of care. The last two columns contain the total number of births of the row, expressed in percentage and number.

3.2 Geographic accessibility

The average minimum distance to SUS birth facilities increases with the perinatal level of care. In 2017, 22, 86, and 219 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 care. 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 2017, the average minimum distances to these facilities were 74 and 42 Km in the Northeast and Southeast regions, respectively (Table A.6). Nevertheless, the average minimum distances in the North region were 3 and 5 times greater than those. Regional differences for level-III facilities were more extreme, which were primarily concentrated in cities of the Southeast region.

Figure 3: Municipal maps of minimum distances to health facilities by perinatal level of care (2017)



(a) Level I

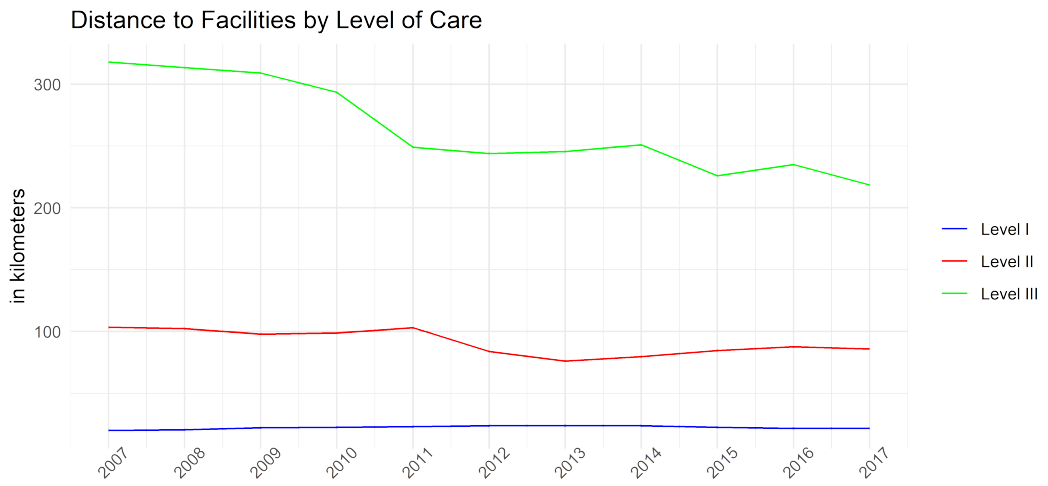
(b) Level II

(c) Level III

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 the number of level-III facilities between 2007 and 2017, the average minimum distance to these facilities reduced over time from 318 to 219 Km. The average minimum distance to level II facilities reduced from 103 to 86 Km, and the distance to level I facilities remained relatively constant (Figure 4). There were also regional improvements between 2007 and 2017, particularly in the access to level-III facilities that can be seen by contrasting 2007 and 2017 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 (2007-2017)



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.

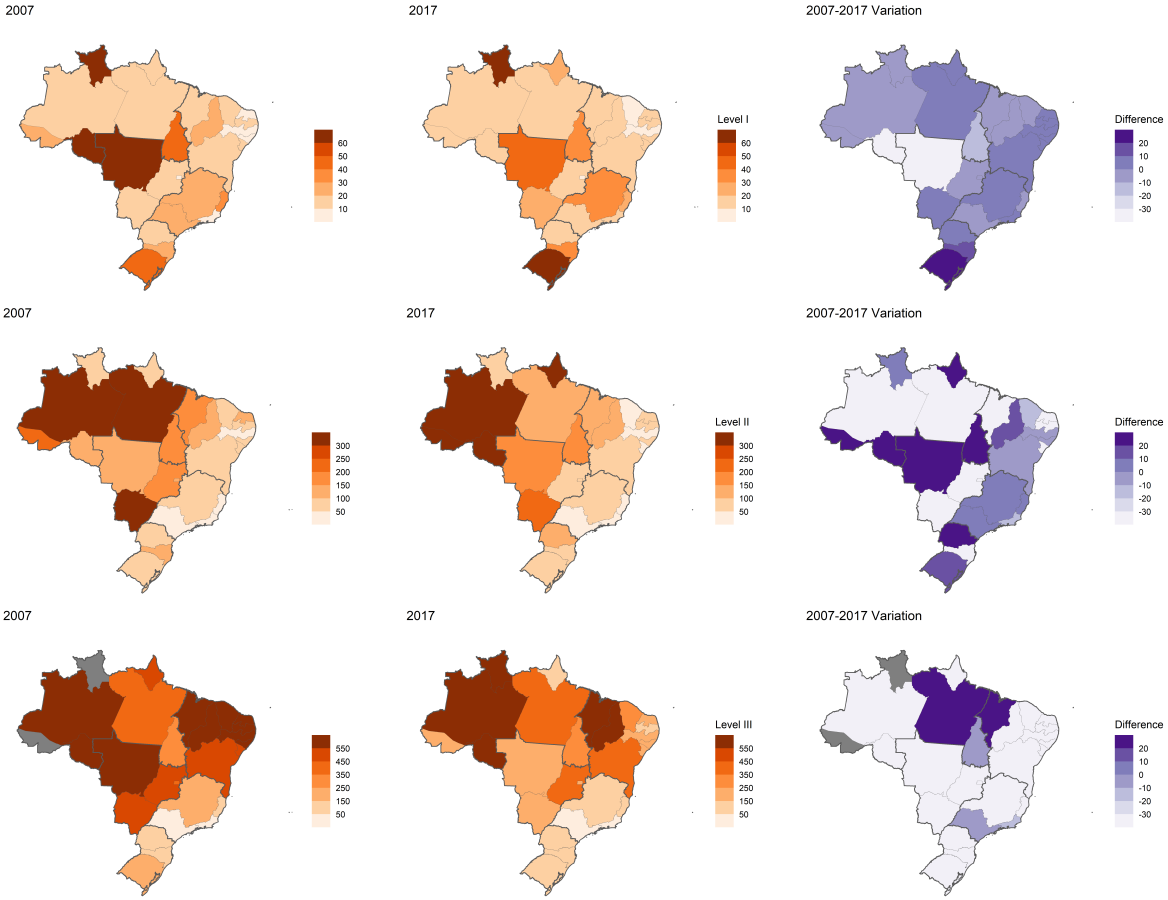
Figures 5-8 present a description of state's average minimum distances for the first and the last available year of our sample and the difference between them. Each row corresponds to a perinatal level of care: I, II or III. Excepting human resources component (Figure 8), whose time series begins in 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 magnitude for most states. Only Rio Grande do Sul recorded an increase surpassing 20 kilometers and, on the other extreme, Rondônia and Mato Grosso numbers fell more than 30 kilometers. Levels II and III had more significant variations: while the former has become closer and further depending on the state, the latter has become more reachable in the vast majority of the units. Nonetheless, Amazonas, Rondônia, Maranhão and Piaui endured at the highest bracket, with over 550 kilometers for both years. Acre and Roraima were assigned as missing due to distances peaking at least 2000 kilometers and were excluded from our procedure of assessment. 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.

Figure 6 depicts distances to perinatal levels of care based only on infrastructure criteria. Level I presents same stability as in the general classification, with no increases over 20 kilometers and one single reduction of more than 30 (Rondônia). In 2017, Amapá, Roraima

and Mato Grosso do Sul had on average at least 60 kilometers distance, same as 2007, while Rio Grande do Sul moved up one interval. Regarding level II care, Mato Grosso and Acre had more than 20 kilometers increase, but improved access in level III. Colors were overall the same or lighter, suggesting a better provision of infrastructure at this level.

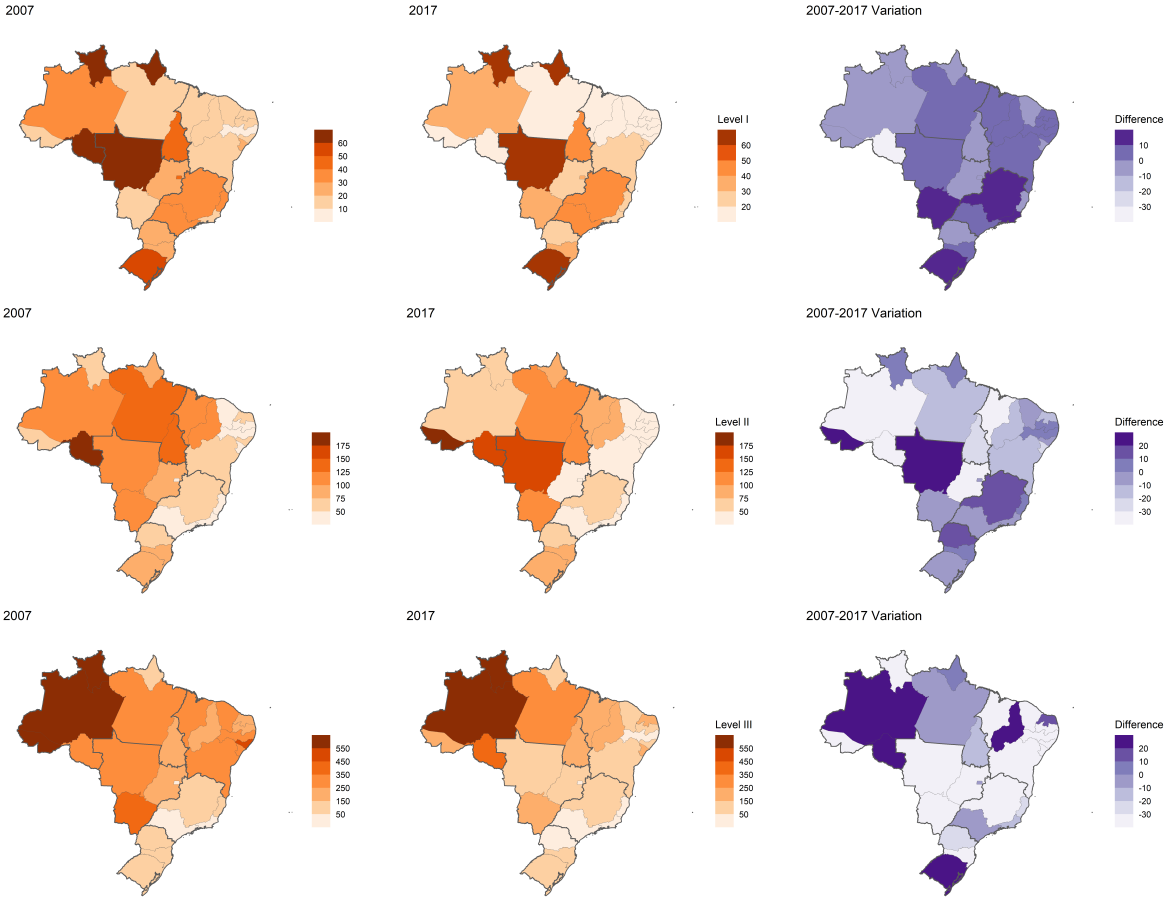
Figure 7 shows distances to levels of care based on the equipment component. Level I is still rapidly approachable and has less margin for variation. Level III has made significant progress reducing distances and Level II ranges in different directions all over the country. Figure 8 shows the third and final component, human resources. Compared to the others, one could hypothesize this to be the most flexible and mobile component. Repeating a pattern seen before, Level I does not vary too much in magnitude and no decreases are over 10 kilometers, for instance. Level II has similar range as previous components, but Level III offsets widespread reductions seen for equipment and infrastructure: here, there are more states that have faced a seclusion of its most specialized health sector workers.

Figure 5: State map of minimum distances to a facility by perinatal level of care: 2007-2017 comparison



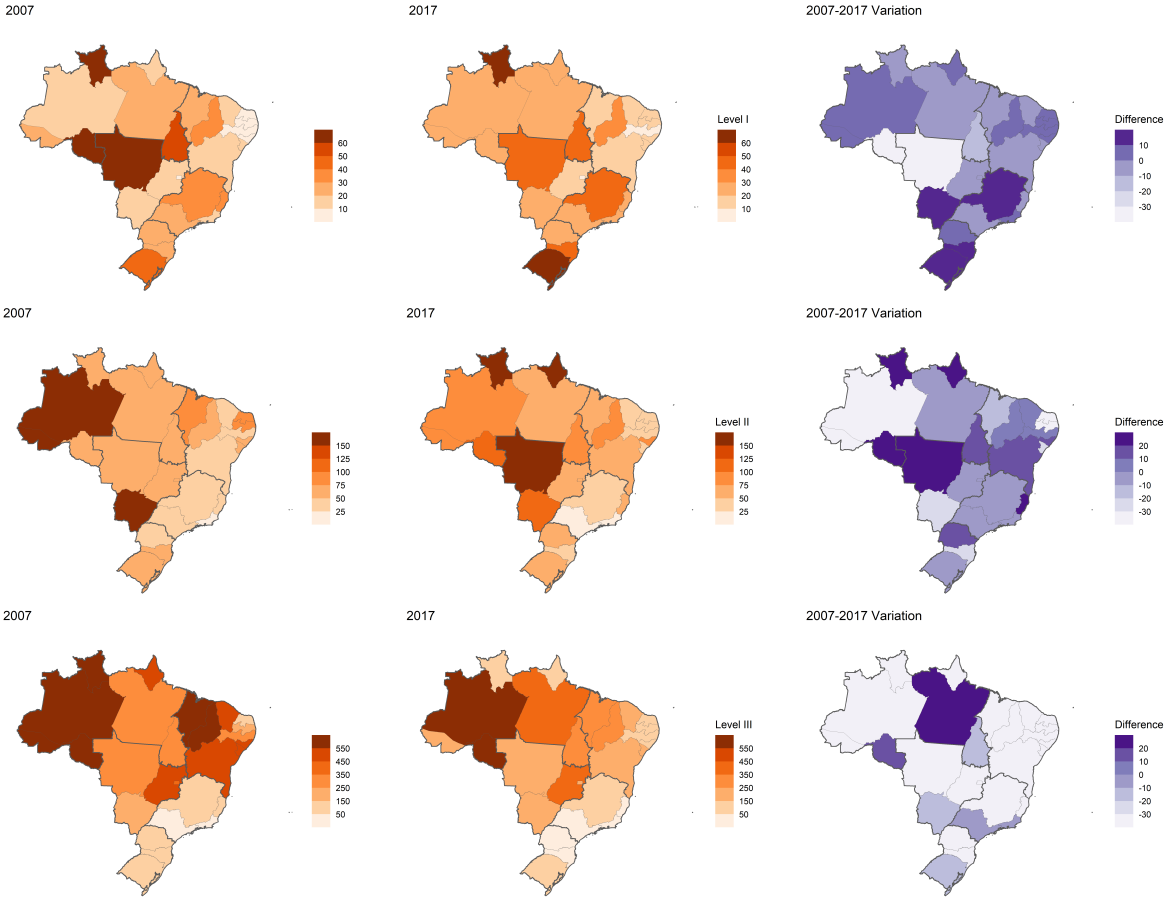
Note: Figure shows the state average minimum distance between one municipality and another containing a facility of a certain level of care. Level I: A facility capable of assisting low-risk births. Level II: A facility capable of assisting high-risk births requiring obstetric surgical interventions 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: 2007-2017 comparison



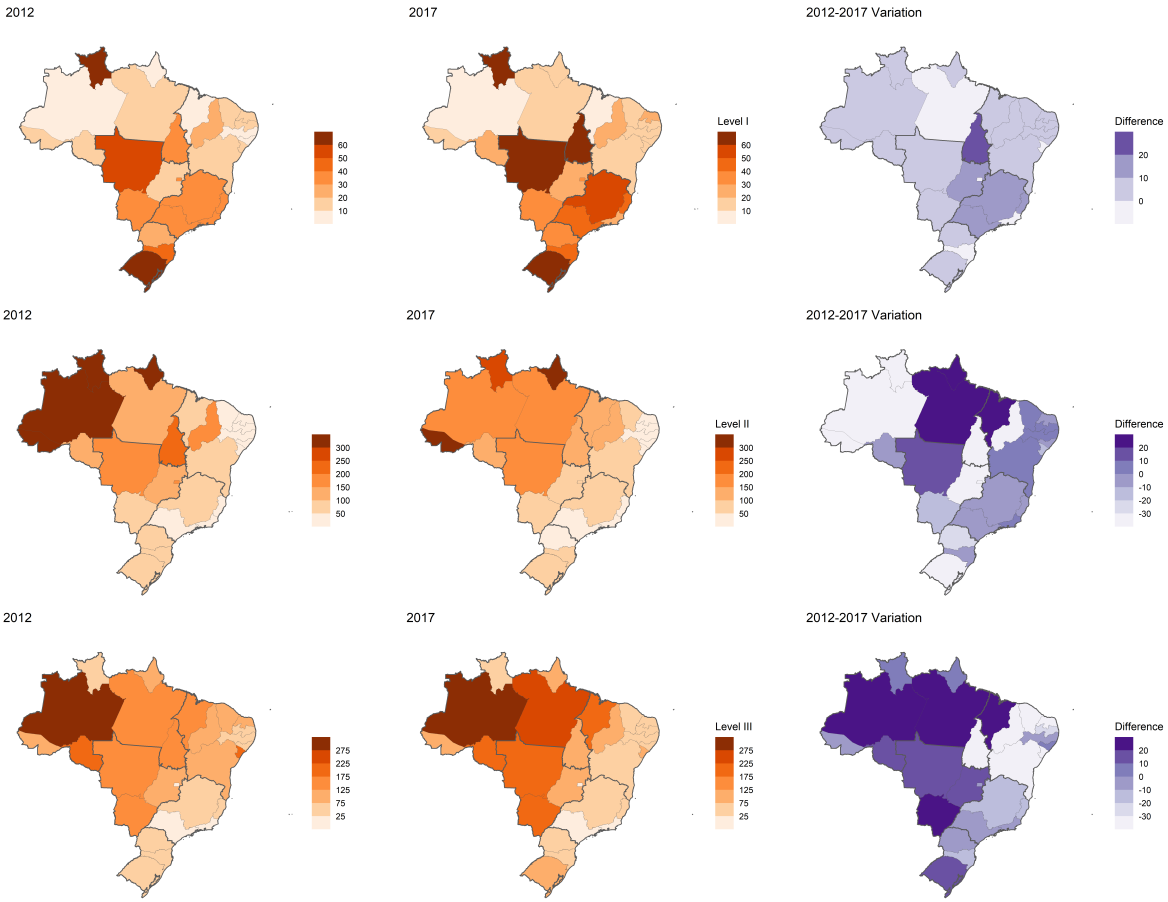
Note: Figure shows the state average minimum distance between one municipality and another containing a facility of a certain level of care, defined only by infrastructure requirements. Level I: A facility capable of assisting low-risk births. Level II: A facility capable of assisting high-risk births 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: 2007-2017 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: 2012-2017 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 Discussion

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 health outcomes for mothers and newborns Pacagnella et al. (2014); Leal et al. (2020), since displacement 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 and, hence, have margin of choice between available

facilities Viellas et al. (2014), in spite of a structured public health system such as SUS in Brazil, our case of study.

Between years 2007 and 2017, the overall number of facilities has decreased, specially among Levels I and 0. These are, respectively, the most basic level of care for births and an inappropriate establishment for this procedure. On the other hand, Level III facilities have expanded both in count and in accomplished births. However, one must consider these establishments' location: average distance to Level I remained stable, low and equal throughout the country, while to Level III remains high and irregular across regions, even though in a descending trend. Policymakers should use this information to allocate correctly resources 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 human resources have offset some advances for equipment and infrastructure at the state-level: regarding Level III, they have become more distant, unlike equipment and infrastructure.

References

Almeida, W. d. S. d. and C. L. Szwarcwald (2012). Infant mortality and geographic access to childbirth in brazilian municipalities. *Revista de Saúde Pública 46*, 68–76.

Arruda, N. M., A. G. Maia, and L. C. Alves (2018). Desigualdade no acesso à saúde entre as áreas urbanas e rurais do brasil: uma decomposição de fatores entre 1998 a 2008. *Cadernos de Saúde Pública 34*.

Barfield, W. D., L.-A. Papile, J. E. Baley, W. Benitz, J. Cummings, W. A. Carlo, P. Kumar, R. A. Polin, R. C. Tan, K. S. Wang, and K. L. Watterberg (2012, sep). Levels of Neonatal Care. *Pediatrics 130*(3), 587–597.

Brazil. Ministerio da Saúde (2012). Portaria n° 930.

Brazil. Ministerio da Saúde (2015). Portaria n° 11.

Brazil. Ministerio da Saúde (2022a). Cadastro nacional de estabelecimentos de saúde - datasus.

Brazil. Ministerio da Saúde (2022b). Sistema de informaç$\tilde{\{o\}}$es sobre nascidos vivos (sinasc).

Brazil. Ministério da Saúde (2015). *Pnass: National Program for Health Services Evaluation*. Ministerio de Saúde.

Cristina da Silva, N., T. A. H. Rocha, P. V. Amaral, C. Elahi, E. Thumé, E. B. A. F. Thomaz, R. C. d. S. Queiroz, J. R. N. Vissoci, C. Staton, and L. A. Facchini (2020). Comprehending the lack of access to maternal and neonatal emergency care: Designing solutions based on a space-time approach. *PLoS One 15*(7), e0235954.

de Azevedo Bittencourt, S. D., R. Queiroz Gurgel, M. A. da Silva Menezes, L. S. Bastos, and M. d. Carmo Leal (2015). Neonatal care in brazil: hospital structure and adequacy according to newborn obstetric risk. *Paediatrics and International Child Health 35*(3), 206–212.

de Carvalho, L. R., P. V. M. do Amaral, and P. S. Mendes (2021). Matrizes de distâncias e tempo de deslocamento rodoviário entre os municípios brasileiros : uma atualização metodológica para 2020. Textos para Discussão Cedeplar-UFMG 630, Cedeplar, Universidade Federal de Minas Gerais.

Empresa Brasileira de Serviços Hospitalares (2021). *Manual de Pré-Requisitos para o Credenciamento e Habilitação SUS em Serviços de Saúde* (2nd ed.). Ebserh - Empresa Brasileira de Serviços Hospitalares.

Hart, J. T. (1971). The inverse care law. *The Lancet 297*(7696), 405–412.

Instituto de Comunicação e Informação Científica e Tecnológica em Saúde. Plataforma de Ciência de Dados aplicada à Saúde.

Leal, M. d. C., A. P. Esteves-Pereira, E. F. Viellas, R. M. S. M. Domingues, and S. G. N. d. Gama (2020). Assistência pré-natal na rede pública do brasil. *Revista de Saúde Pública 54*.

Lorch, S. A., J. Rogowski, J. Profit, and C. S. Phibbs (2021, 6). Access to risk-appropriate hospital care and disparities in neonatal outcomes in racial/ethnic groups and rural–urban populations. *Seminars in Perinatology 45*, 151409.

Menezes, M. A. S., R. Gurgel, S. D. A. Bittencourt, V. E. Pacheco, R. Cipolotti, and M. d. C. Leal (2018). Health facility structure and maternal characteristics related to essential newborn care in brazil: a cross-sectional study. *BMJ Open 8*(12).

Monteiro, C. N., M. A. Beenackers, M. Goldbaum, M. B. d. A. Barros, R. J. Gianini, C. L. G. Cesar, and J. P. Mackenbach (2017). Use, access, and equity in health care services in são paulo, brazil. *Cadernos de Saúde Pública 33*, e00078015.

Mújica-Mota, R. E., P. Landa, M. Pitt, M. Allen, and A. Spencer (2020, 1). The heterogeneous causal effects of neonatal care: a model of endogenous demand for multiple treatment options based on geographical access to care. *Health Economics 29*, 46–60.

Pacagnella, R. C., J. G. Cecatti, M. A. Parpinelli, and et al. (2014). Delays in receiving obstetric care and poor maternal outcomes: results from a national multicentre cross-sectional study. *BMC Pregnancy Childbirth 14 159*.

Phibbs, C. S., L. C. Baker, A. B. Caughey, B. Danielsen, S. K. Schmitt, and R. H. Phibbs (2007, 5). Level and volume of neonatal intensive care and mortality in very-low-birthweight infants. *New England Journal of Medicine 356*, 2165–2175.

Profit, J., J. B. Gould, M. Bennett, B. A. Goldstein, D. Draper, C. S. Phibbs, and H. C. Lee (2016, 3). The association of level of care with nicu quality. *Pediatrics 137*.

Rocha, T., N. da Silva, P. Amaral, A. Barbosa, J. Rocha, V. Alvares, D. de Almeida, E. Thume, E. Thomaz, R. de Sousa Queiroz, et al. (2017). Access to emergency care

services: a transversal ecological study about brazilian emergency health care network. *Public Health 153*, 9–15.

Souza, M. S. P. L., R. Aquino, S. M. Pereira, M. d. C. N. Costa, M. L. Barreto, M. Natividade, R. Ximenes, W. Souza, O. M. Dantas, and J. U. Braga (2015). Fatores associados ao acesso geográfico aos serviços de saúde por pessoas com tuberculose em três capitais do nordeste brasileiro. *Cadernos de Saúde Pública 31*, 111–120.

Thaddeus, S. and D. Maine (1994). Too far to walk: maternal mortality in context. *Social science & medicine 38*(8), 1091–1110.

Travassos, C., E. X. de Oliveira, and F. Viacava (2006). Desigualdades geográficas e sociais no acesso aos serviços de saúde no brasil: 1998 e 2003. *Ciência & Saúde Coletiva 11*, 975–986.

Viellas, E. F., R. M. S. M. Domingues, M. A. B. Dias, S. G. N. d. Gama, M. M. Theme Filha, J. V. d. Costa, M. H. Bastos, and M. d. C. Leal (2014). Prenatal care in brazil. *Cadernos de saude publica 30*, S85–S100.

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	50	216	77.2	1479	84.6	230	92.2	83
Normal Delivery Center	1.4	6	0.1	2	0	0	0	0
Other hospitals	2.1	9	4.2	80	12.1	33	6.7	6
Emergency units	1.4	6	0.3	6	0.4	1	1.1	1
Other facilities	45.1	195	18.2	348	2.9	8	0	0
Type of care:								
Outpatient	16.7	72	0.3	5	0	0	0	0
Inpatient	83.3	360	99.7	1910	100	272	100	90
Complexity of inpatient care:								
Low	19.0	70	6.3	120	0.7	2	0	0
Medium	67.5	249	73.4	1402	36.8	100	0	0
Medium + Diagnostics	7.9	29	10.8	206	21.3	58	18.9	17
High	5.7	21	9.5	182	41.2	112	81.1	73
Patient volume (births):								
≤ 75	32.9	142	14.8	284	2.2	6	1.1	1
75-209	34.7	150	30.5	585	7.0	19	0	0
209-656	24.8	107	35.2	675	23.5	64	8.9	8
>656	7.6	33	19.4	371	67.3	183	90	81
Very preterm births:								
≤ 0	68.5	296	54.6	1045	21.3	58	3.3	3
0-2	24.3	105	29.8	570	18.4	50	6.7	6
>2	7.2	31	15.7	300	60.3	164	90	81
Very low weight births								
≤ 0	51.9	224	39.1	749	13.2	36	0	0
0-1	22.7	98	21.9	419	4.8	13	1.1	1
1-4	18.1	78	22.9	439	17.6	48	3.3	3
>4	7.4	32	16.1	308	64.3	175	95.6	86
Observations	432		1915		272		90	

Source: PCDAS (Instituto de Comunicação e Informação Científica e Tecnológica em Saúde, Instituto de Comunicação e Informação Científica e Tecnológica em Saúde)

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 (2007-2017)

	Level 0	Level I	Level II	Level III	Total
2007	432	1915	272	90	2709
	(15.9)	(70.7)	(10.0)	(3.3)	(100.0)
2008	453	1884	285	96	2718
	(16.7)	(69.3)	(10.5)	(3.5)	(100.0)
2009	440	1825	308	111	2684
	(16.4)	(68.0)	(11.5)	(4.1)	(100.0)
2010	404	1812	306	121	2643
	(15.3)	(68.6)	(11.6)	(4.6)	(100.0)
2011	366	1787	317	127	2597
	(14.1)	(68.8)	(12.2)	(4.9)	(100.0)
2012	364	1773	321	129	2587
	(14.1)	(68.5)	(12.4)	(5.0)	(100.0)
2013	353	1757	318	129	2557
	(13.8)	(68.7)	(12.4)	(5.0)	(100.0)
2014	327	1747	310	132	2516
	(13.0)	(69.4)	(12.3)	(5.2)	(100.0)
2015	323	1694	293	154	2464
	(13.1)	(68.8)	(11.9)	(6.3)	(100.0)
2016	313	1680	279	155	2427
	(12.9)	(69.2)	(11.5)	(6.4)	(100.0)
2017	324	1656	281	158	2419
	(13.4)	(68.5)	(11.6)	(6.5)	(100.0)
Total	4099	19530	3290	1402	28321
	(14.5)	(69.0)	(11.6)	(5.0)	(100.0)

Source: PCDAS (Instituto de Comunicação e Informação Científica e Tecnológica em Saúde, Instituto de Comunicação e Informação Científica e Tecnológica em Saúde)

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 (2012-2017)

	Level 0	Level I	Level II	Level III	Total
2012	375	1873	226	113	2587
	(14.5)	(72.4)	(8.7)	(4.4)	(100.0)
2013	364	1848	227	118	2557
	(14.2)	(72.3)	(8.9)	(4.6)	(100.0)
2014	338	1825	230	123	2516
	(13.4)	(72.5)	(9.1)	(4.9)	(100.0)
2015	331	1768	224	141	2464
	(13.4)	(71.8)	(9.1)	(5.7)	(100.0)
2016	319	1750	217	141	2427
	(13.1)	(72.1)	(8.9)	(5.8)	(100.0)
2017	331	1721	220	147	2419
	(13.7)	(71.1)	(9.1)	(6.1)	(100.0)
Total	2058	10785	1344	783	14970
	(13.7)	(72.0)	(9.0)	(5.2)	(100.0)

Source: PCDAS (Instituto de Comunicação e Informação Científica e Tecnológica em Saúde, Instituto de Comunicação e Informação Científica e Tecnológica em Saúde)

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 very preterm births by perinatal level of care in 2007 and 2017

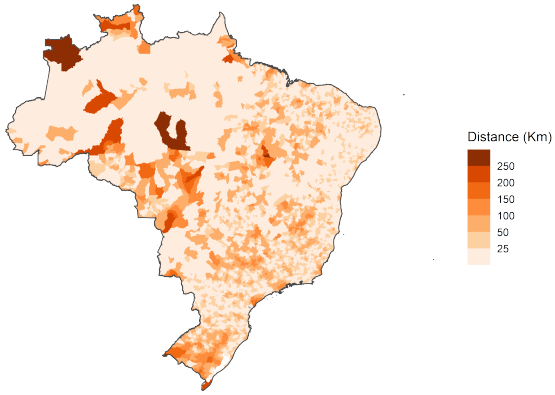
	Level 0		Level I		Level II		Level III		Total	
	%	N	%	N	%	N	%	N	%	N
Regions (2007):										
North	6.9	51	53.4	394	30.8	227	8.9	66	100.0	738
Northeast	4.8	156	53.3	1724	33.3	1077	8.6	277	100.0	3234
Southeast	2.6	79	28.2	865	31.7	972	37.5	1151	100.0	3067
South	0.4	3	43.8	330	26.3	198	29.6	223	100.0	754
Central-west	3.7	20	36.5	199	31.6	172	28.3	154	100.0	545
Total	3.7	309	42.1	3512	31.7	2646	22.4	1871	100.0	8338
Regions (2017):										
North	1.7	23	45.3	608	27.1	364	25.9	348	100.0	1343
Northeast	2.8	108	30.5	1162	34.7	1321	32.0	1217	100.0	3808
Southeast	0.9	33	24.3	879	23.1	835	51.8	1874	100.0	3621
South	1.2	11	25.2	240	25.7	245	48.0	458	100.0	954
Central-west	0.8	6	26.1	191	32.0	234	41.0	300	100.0	731
Total	1.7	181	29.5	3080	28.7	2999	40.1	4197	100.0	10457

Source: PCDAS (Instituto de Comunicação e Informação Científica e Tecnológica em Saúde, Instituto de Comunicação e Informação Científica e Tecnológica em Saúde)

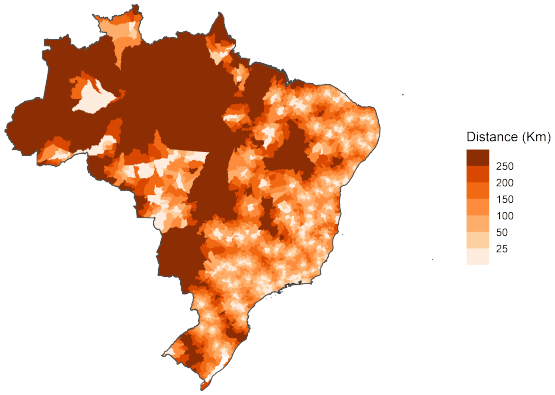
Notes: Level I: A facility capable of assisting low-risk births. Level II: A facility capable of assisting high-risk births requiring obstetric surgical interventions and intermediate neonatal care. Level III: A facility capable of assisting high-risk births requiring obstetric or neonatal critical care. 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.

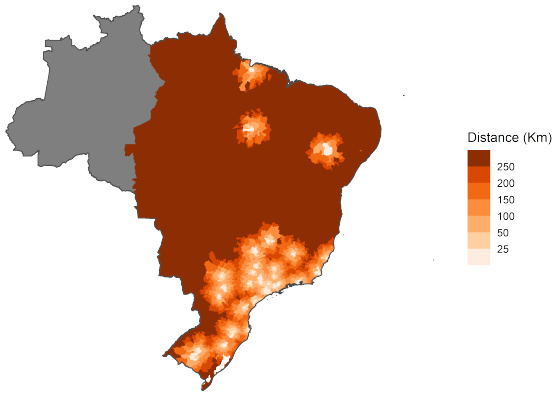
Figure A.1: Municipal maps of minimum distances to health facilities by perinatal level of care (2017)



(a) Level I



(b) Level II



(c) Level III

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

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Level I	19.9	20.6	22.2	22.6	23.1	23.8	24.0	23.7	22.6	21.6	21.7
Level II	103.4	102.4	97.8	98.7	103.1	83.8	76.0	79.7	84.6	87.7	85.8
Level III	318.0	313.5	309.1	293.4	249.1	243.9	245.5	251.0	225.9	235.1	218.5
Infrastructure Level I	25.4	25.7	27.0	27.1	28.6	28.9	30.0	30.5	32.3	32.5	32.6
Infrastructure Level II	62.3	64.0	70.9	65.4	62.9	60.6	57.4	60.0	57.4	58.2	58.3
Infrastructure Level III	184.1	139.4	139.0	130.5	131.1	120.0	146.5	128.8	125.5	127.1	125.8
Equipment Level I	24.2	25.1	26.7	26.8	28.6	29.5	30.3	30.1	27.7	26.2	26.2
Equipment Level II	51.9	51.2	51.5	54.8	53.0	50.3	48.1	51.5	52.0	51.9	53.5
Equipment Level III	264.2	268.5	245.6	221.8	183.0	183.5	164.8	144.0	166.9	164.8	158.0
Human resources Level I	.	.	.	.	.	26.8	27.3	30.9	31.5	32.0	33.5
Human resources Level II	.	.	.	.	.	85.7	79.9	86.4	76.6	78.9	72.1
Human resources Level III	.	.	.	.	.	82.0	86.7	78.6	81.1	88.5	89.4

Source: CNES
Notes:

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

	North		Northeast		Southeast		South		Center-west	
	2007	2017	2007	2017	2007	2017	2007	2017	2007	2017
Level I	24.5	20.5	12.3	12.3	20.7	22.5	28.0	40.3	27.0	21.3
Level II	320.8	227.8	93.8	74.1	42.2	42.3	93.2	102.0	175.8	121.8
Level III	406.6	689.8	601.4	322.4	74.7	52.5	147.3	79.4	638.2	282.4
Infrastructure Level I	33.9	32.3	12.5	16.5	28.2	39.6	35.1	42.4	35.6	37.6
Infrastructure Level II	130.5	111.4	60.6	48.7	35.1	38.2	76.3	79.0	92.8	83.3
Infrastructure Level III	480.9	551.0	282.5	122.9	53.3	35.3	78.9	69.8	228.6	112.0
Equipment Level I	34.8	30.3	15.2	13.7	24.0	27.7	32.6	44.8	33.5	24.8
Equipment Level II	96.4	124.0	56.2	51.3	30.3	28.0	55.9	53.3	78.4	91.3
Equipment Level III	652.4	531.7	433.8	184.0	61.9	44.9	117.5	68.2	363.5	272.5
Human resources Level I	.	19.9	.	16.0	.	42.6	.	49.8	.	39.5
Human resources Level II	.	230.8	.	65.0	.	36.3	.	51.8	.	94.4
Human resources Level III	.	368.1	.	74.2	.	27.1	.	58.0	.	128.4

Source: CNES
Notes:

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

	Level	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Obstetric Center		8.6	9.4	10.5	10.2	10.4	11.5	11.6	10.5	10.2	10.5	10.4
Neonatal Unit		18.6	20.4	21.6	23.1	22.4	22.8	24.2	23.6	23.9	23.6	23.6
Rooms for normal delivery	I	11.3	11.2	12.0	12.0	12.2	12.6	11.8	11.9	11.6	12.1	11.7
Rooms for pre-labor	I	12.3	12.6	13.4	13.7	13.8	14.8	14.4	14.0	13.6	13.8	13.5
Beds for pre-labor	I	13.9	13.4	14.3	14.6	14.4	15.9	15.7	15.3	15.8	15.9	15.5
Mother-baby joint beds	I	20.8	21.1	22.2	24.0	23.3	24.2	26.0	26.1	25.4	26.4	26.2
Rooms for curettage (abortion)	I	43.4	43.5	49.2	46.8	47.6	48.7	48.7	47.5	48.7	49.2	49.3
Normal newborn beds	I	105.7	91.6	89.6	86.6	73.7	69.5	70.8	69.0	69.6	68.9	67.5
Bed for obstetric clinical attention	II	15.7	15.2	15.6	14.1	13.7	14.3	13.9	13.4	14.2	14.0	14.0
Bed for neonatal ITC - pre-RC	II	98.7	103.3	93.6	76.4	74.2	75.8	80.7	107.5	152.7	166.7	204.6
Bed for neonatal ITC - conventional	II	.	.	.	.	.	89.1	84.1	82.5	77.8	76.9	77.8
Bed for neonatal ITC - kangaroo	II	.	.	.	.	.	190.7	188.6	158.2	157.5	157.5	158.5
Bed for neonatal ITC - total	II	98.7	103.3	93.6	76.4	74.2	64.3	67.0	64.7	65.3	64.7	64.1
Bed for newborn clinical attention	II	98.8	118.4	102.7	99.2	98.8	106.7	109.3	111.9	117.2	120.5	113.1
Pathologic newborn beds	II	104.0	89.6	87.8	91.0	83.8	78.2	79.3	74.1	72.1	75.5	70.2
Obstetric surgical bed	III	17.8	17.5	17.3	16.6	17.0	17.0	15.8	15.1	15.2	15.3	15.2
Bed in ICU	III	107.1	104.8	98.0	105.3	105.7	101.5	92.9	110.9	100.4	105.8	105.2
Bed in NICU	III	132.2	110.7	125.7	111.5	106.9	96.6	92.6	94.2	88.3	90.4	83.1
Bed for pediatric surgery	III	171.3	142.2	107.8	96.8	91.8	89.3	82.0	75.7	72.9	76.7	74.1

Source: CNES
Notes:

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

	Level	North		Northeast		Southeast		South		Center-west	
		2007	2017	2007	2017	2007	2017	2007	2017	2007	2017
Obstetric Center		7.5	5.9	4.5	5.4	9.3	11.3	17.7	20.7	8.3	11.8
Neonatal Unit		40.9	39.7	13.6	18.1	14.2	18.7	23.8	33.1	22.0	29.0
Rooms for normal delivery	I	10.2	9.2	4.9	5.9	12.2	12.0	18.8	23.3	21.6	14.7
Rooms for pre-labor	I	14.2	14.3	7.1	8.7	13.0	12.8	20.4	23.6	14.2	15.8
Beds for pre-labor	I	16.2	16.2	7.6	9.3	13.1	16.3	21.9	24.6	27.2	16.6
Mother-baby joint beds	I	41.1	47.2	14.0	19.6	17.1	19.7	24.7	33.2	33.0	40.4
Rooms for curettage (abortion)	I	53.4	75.7	37.2	35.2	37.3	39.0	50.1	56.5	74.5	99.4
Normal newborn beds	I	370.0	147.5	74.1	60.8	52.9	44.8	122.6	70.5	113.2	90.2
Bed for obstetric clinical attention	II	10.8	8.1	10.7	7.2	15.0	15.7	24.4	25.7	31.6	17.0
Bed for neonatal ITC - pre-RC	II	218.5	469.0	109.8	177.1	54.5	124.4	82.8	223.9	143.5	304.5
Bed for neonatal ITC - conventional	II	.	146.7	.	69.8	.	45.8	.	90.3	.	146.5
Bed for neonatal ITC - kangaroo	II	.	433.4	.	156.9	.	79.0	.	159.4	.	189.4
Bed for neonatal ITC - total	II	218.5	135.2	109.8	60.6	54.5	37.3	82.8	77.0	143.5	90.6
Bed for newborn clinical attention	II	317.0	324.6	96.5	95.2	40.7	44.5	81.3	146.4	136.9	171.4
Pathologic newborn beds	II	315.0	149.3	103.2	74.2	45.0	39.5	112.9	76.2	106.1	90.6
Obstetric surgical bed	III	33.8	21.7	14.1	11.9	15.8	12.6	23.2	22.4	11.1	18.8
Bed in ICU	III	371.9	469.0	119.7	98.9	38.9	29.2	57.4	58.4	126.3	97.0
Bed in NICU	III	384.1	223.4	171.7	92.8	44.9	35.3	71.2	66.3	178.1	123.6
Bed for pediatric surgery	III	303.7	203.1	188.7	65.5	81.5	37.5	239.8	72.8	268.3	112.8

Source: CNES
Notes:

Table A.9: Average minimum distance to equipment by year

	Level	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Life support equipment	I	9.2	9.3	9.7	9.6	9.9	10.9	10.7	10.6	9.9	9.7	9.7
Heated crib	I	17.4	16.9	15.7	15.9	16.1	16.5	16.3	15.6	15.5	15.3	15.1
ECG monitor	I	24.2	25.7	25.7	24.9	25.3	24.4	25.5	24.5	21.7	21.0	20.7
Blood pressure manual equipment	I	46.3	45.1	43.6	40.2	38.5	39.6	39.2	36.4	35.5	33.1	33.3
X-ray machines	II	12.8	12.2	12.4	12.6	12.6	13.7	11.8	12.0	12.2	11.8	12.1
Incubator	II	13.7	14.4	13.6	13.6	13.9	15.4	14.7	14.5	14.6	14.6	14.4
AMBU equipment	II	14.3	15.0	14.8	14.7	14.3	14.9	14.5	14.4	13.5	13.5	13.1
Ultrasound machine	II	21.5	18.7	17.1	18.2	18.4	17.9	16.7	17.1	16.9	16.4	17.0
Phototherapy equipment	II	21.7	21.6	22.9	21.7	22.0	22.4	22.2	22.2	22.2	21.6	20.9
ECG	III	19.8	16.6	16.3	15.7	15.3	14.7	13.1	12.9	13.1	12.3	12.6
Mechanical ventilator	III	24.5	22.6	23.8	22.9	22.0	22.5	23.0	22.0	21.0	19.9	19.4
Doppler ultrasound machine	III	62.9	56.4	60.4	51.4	52.7	50.1	48.3	48.6	47.6	48.5	45.4
Oxygen tube	III	74.7	73.6	73.8	67.0	64.1	59.1	61.7	62.1	60.4	57.4	53.1
Blood pressure invasive equipment	III	95.9	96.8	106.1	92.7	90.7	80.8	78.6	74.7	73.5	81.0	76.3

Source: CNES
Notes:

Table A.10: Average minimum distance to equipment by region and year

	Level	North		Northeast		Southeast		South		Center-west	
		2007	2017	2007	2017	2007	2017	2007	2017	2007	2017
Life support equipment	I	8.5	5.4	6.6	6.0	8.9	9.6	17.8	19.5	7.9	11.3
Heated crib	I	46.6	19.9	16.8	13.4	10.5	12.8	18.3	19.8	13.7	17.5
ECG monitor	I	53.3	49.2	28.3	19.2	12.7	11.4	23.4	24.6	28.0	25.9
Blood pressure manual equipment	I	129.6	79.8	45.1	31.2	22.6	15.5	42.2	38.5	65.8	56.0
X-ray machines	II	9.6	7.2	10.5	8.6	11.3	11.0	19.9	20.7	22.4	21.7
Incubator	II	26.2	13.7	12.4	13.4	9.5	12.9	21.2	20.8	10.9	15.3
AMBU equipment	II	16.7	9.9	14.6	12.8	9.7	10.1	19.1	20.0	25.9	21.7
Ultrasound machine	II	24.5	18.0	14.5	11.3	19.2	13.5	33.1	30.5	37.8	29.0
Phototherapy equipment	II	41.8	39.9	24.3	20.6	12.1	13.3	20.9	21.9	34.0	31.2
ECG	III	43.5	12.0	16.9	9.9	13.6	9.7	25.8	21.3	20.9	21.6
Mechanical ventilator	III	57.2	43.4	24.9	19.3	13.4	11.2	29.0	23.4	27.4	21.0
Doppler ultrasound machine	III	105.4	87.4	77.0	49.7	30.8	23.1	75.2	48.9	93.0	76.4
Oxygen tube	III	149.4	107.6	71.1	49.0	35.9	27.4	87.7	56.2	165.5	112.7
Blood pressure invasive equipment	III	251.2	289.4	120.7	66.8	35.2	26.6	62.6	51.8	150.5	109.9

Source: CNES
Notes:

Table A.11: Average minimum distance to human resources by year

	Level	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Auxiliary nurse	I	10.7	9.9	10.6	10.6	11.0	11.7	12.2	12.2	12.7	12.3	13.3
Nurse	I	10.1	9.5	10.0	9.5	9.6	9.5	9.1	9.1	9.2	9.1	9.0
Technician in nursery	I	16.1	13.8	13.1	11.9	11.9	11.5	10.4	10.2	9.9	9.7	9.4
Gynechologist or obstetrician	II	.	.	.	.	.	12.6	11.3	11.5	12.0	12.6	11.9
Pediatrician	II	.	.	.	.	.	14.6	14.4	14.8	15.3	15.9	14.8
Anaesthesiologist	II	.	.	.	.	.	16.5	15.3	15.1	15.3	15.3	15.3
Pharmacists	II	25.1	23.8	22.0	23.5	22.1	22.3	19.5	19.5	17.9	19.1	16.5
Nutricionist	II	36.3	29.1	22.6	21.2	21.1	23.1	20.4	20.1	18.1	18.5	17.4
General physician	III	.	.	.	.	.	9.7	9.8	9.6	9.9	9.5	9.5
Fisiotherapist	III	27.2	22.5	21.5	22.2	20.8	21.1	19.6	20.2	20.1	19.9	20.5
Social worker	III	38.7	36.0	31.5	29.3	27.2	28.1	25.3	25.5	24.3	25.4	22.7
Psychologist	III	48.4	44.8	39.5	40.1	37.4	37.6	34.1	34.7	32.9	31.7	31.3
Obstetric nurse	III	59.7	59.2	56.6	58.9	54.5	59.4	54.4	59.2	56.4	55.7	50.3
Fonoaudiologist	III	80.7	74.4	63.3	53.1	55.2	53.3	53.9	53.1	38.8	41.4	39.0

Source: CNES
Notes:

Table A.12: Average minimum distance to human resources by region and year

	Level	North		Northeast		Southeast		South		Center-west	
		2007	2017	2007	2017	2007	2017	2007	2017	2007	2017
Auxiliary nurse	I	11.6	16.8	4.5	6.0	11.2	12.1	18.2	23.5	19.6	22.1
Nurse	I	8.3	4.2	7.5	4.3	9.2	9.6	18.6	19.4	13.3	10.9
Technician in nursery	I	12.8	4.5	16.3	4.5	12.9	10.1	23.8	19.7	23.5	11.4
Gynechologist or obstetrician	II	.	9.7	.	10.2	.	10.3	.	20.5	.	14.0
Pediatrician	II	.	18.9	.	14.0	.	10.5	.	22.0	.	21.0
Anaesthesiologist	II	.	25.3	.	14.7	.	10.2	.	20.5	.	19.9
Pharmacists	II	53.5	29.6	23.9	16.2	14.5	10.4	29.0	22.8	39.6	19.5
Nutricionist	II	80.5	34.9	24.7	11.8	24.5	12.1	41.9	22.0	73.8	31.4
General physician	III	.	4.3	.	5.9	.	9.8	.	19.4	.	10.8
Fisiotherapist	III	38.6	27.8	26.7	17.5	18.8	13.3	34.6	27.8	45.0	43.6
Social worker	III	54.1	29.4	32.1	16.5	25.4	17.2	57.8	36.9	80.6	38.4
Psychologist	III	85.8	61.0	53.4	32.6	28.9	18.7	54.9	31.2	66.4	48.7
Obstetric nurse	III	79.8	78.3	46.3	32.1	47.0	33.8	74.4	66.1	127.9	128.0
Fonoaudiologist	III	189.8	71.2	91.9	41.6	36.5	20.3	73.1	36.4	126.7	81.9

Source: CNES
Notes:

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

[4] The 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.

Source: Own elaboration based on CNES dictionary
Notes:
[1] Data is only available from 2012 to 2017