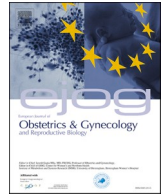Contents lists available at ScienceDirect

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Review article

Global inequities in cesarean section deliveries and required resources persist

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A B S T R A C T

Objective: The purpose of this study was to estimate the global distribution and financial cost associated with the inequities present in the use of cesarean sections (CS) worldwide.
Study Design: We used the latest estimates on CS rates published by WHO and we adopted 10–15 % as the range of CS rates that are considered optimal for adequate use. We calculated the cost (in USD) to achieve CS rates of 10–15 % for countries that reported rates below 10 %. We also calculated the cost of CS rates in excess (>15 % and > 20 %) by estimating how much it would cost to reduce the rates to 10–15 % for each of those countries.
Results: 137 countries are included in this analysis with updated data on CS rates between the years 2010 and 2018. Our analysis found that 36 countries reported CS rates < 10 %, whereas 91 countries reported CS rates > 15 % (a majority of which were > 20 %); only 10 countries reported CS rates between 10 and 15 %. The cost of CS exceeding a rate of 15 % is estimated to be $9,586,952,466 including inflation and exceeding 20 % is $7.169.248.033 (USD). The cost of achieving "needed" CS among countries with CS rates < 10 % is $612,609,418 (USD). The cost of cesarean sections exceeding 15 % has increased by 313 % between 2008 and more recent years, accruing $7 billion (USD) more in surplus since 2008. The reallocation of CS funding would save the global economy $9 billion (USD).
Conclusion: Global inequities in CS performed and associated costs have increased since 2008, resulting in a disproportionate number of resources allocated.

Introduction

A cesarean section (CS) is a surgical procedure carried out to deliver a baby in lieu of vaginal birth and has been deemed a lifesaving technological advance for both the mother and infant in the event of complications during pregnancy or childbirth. As with many other innovations, there has been a persistent global pattern of health inequity associated with the use of CS [1–3]. Although there has been a global rise in CS rates, there is still an unmet need for the procedure in low-income countries [4]. The underuse of this procedure stems from a lack of physical and financial resources needed to carry out the

intervention safely or lack of access [4].

Although CS has become a very safe procedure, as with any surgery, it is not without risks. When a CS is medically needed, the benefits outweigh the risks but there is currently no evidence of the health benefits of CS for women when a CS is not medically necessary. The prevalence of maternal mortality and maternal morbidity is higher after CS than after vaginal birth [5–8]. CS is associated with an increased short and long-term risk both in women and children such as uterine rupture, abnormal placentation, ectopic pregnancy, stillbirth, and preterm birth [9–11]. Recent studies averted that babies born by CS have different hormonal, physical, bacterial, and medical exposures, resulting

Table 1

Number and percentage of countries according to the cesarean section rate categories (n = 137 and n = 172).

Cesarean section deliveryrates, %	Countries (n = 137)[a]		Countries (n = 172)[b]	
	n	%	n	%
<5	18	13.1	26	15.1
5–9.9	18	13.1	23	13.4
<10	36	26.2	49	28.5
10–15	10	7.3	14	8.1
>15	91	66.4	109	63.4
>20	70	51.1	82	47.7

[a] Countries included in the current analysis.

[b] Total countries providing values of CS rates but some of them were excluded in the current analysis since no information on costs were available.

in higher risk of altered immune development, an increased likelihood of allergy, atopy, and asthma, and reduced intestinal gut microbiome diversity.

Although the debate over the appropriate use of CS continues and WHO does not recommend any specific CS rate to be achieved, it is generally accepted that, at the population level, CS rates of 10–15 % are necessary to achieve optimal outcomes [9–11,13].

In 2008, our team conducted a study aimed to examine the distribution of CS in the world and the resource-use implications [14]. Using nationally representative CS rates from 137 countries, we found that 54 countries had CS rates < 10 %, while 69 countries had rates > 15 %. Most of the countries with rates < 10 % were from low-income countries in Africa and Latin America, which confirmed the existing global inequities across income levels. Furthermore, the potential global saving associated with a reduction of CS rates to 15 % or below were estimated to be $2.32 billion (USD). Based on these findings, we recognized that CS

Table 2

Latest available cesarean section rates, additional cesarean sections required and cost per year to achieve a minimum of 10 % rate for countries with cesarean section rates < 10 %[4].

Country	Year	National cesarean section delivery rate, %	Additional number of cesarean sections needed to attain a 10 % rate per year, n[a]	Contribution to the total global number of additional needed cesarean sections, %	Cumulative percentage	Estimated cost per year of needed cesarean sections (USD)	Estimated cost per year with inflation (USD)
Nigeria	2018	2.7	542,609	28.0	28.0	74,880,042	230,201,000
Ethiopia	2018	1.9	286,497	14.8	42.7	37,817,604	122,098,102
Congo Democratic Republic	2014	5.1	155,428	8.0	50.7	20,361,068	30,025,848
United Republic of Tanzania	2016	5.9	85,567	4.4	55.2	11,893,813	25,656,654
Niger	2012	1.4	73,788	3.8	59.0	9,371,076	10,654,134
Madagascar	2018	2	68,800	3.5	62.5	8,806,400	18,294,248
Uganda	2016	6.2	65,170	3.4	65.9	9,188,970	18,248,366
Cameroon	2014	2.4	63,764	3.3	69.2	9,182,016	11,098,930
Mali	2018	2.5	59,625	3.1	72.2	7,989,750	9,157,164
Cote d'Lvoire	2016	3.3	57,486	3.0	75.2	8,795,358	10,153,332
Mozambique	2011	3.9	54,229	2.8	78.0	7,429,373	15,378,889
Chad	2015	1.4	54,180	2.8	80.8	7,585,200	9,708,076
Burkina Faso	2015	3.7	45,171	2.3	83.1	6,323,940	7,212,640
Yemen	2013	4.8	39,520	2.0	85.1	6,165,120	11,390,655
Guinea	2018	2.7	33,069	1.7	86.8	4,298,970	12,486,247
Zambia	2019	5	32,150	1.7	88.5	4,790,350	11,460,308
Senegal	2017	4.6	29,160	1.5	90.0	4,111,560	4,367,770
Malawi	2016	6.1	25,467	1.3	91.3	3,387,111	15,082,305
Benin	2018	5.1	20,433	1.1	92.4	2,901,486	3,335,213
Kenya	2009	8.7	19,890	1.0	93.4	2,764,710	5,664,360
Sierra Leone	2017	3	17,850	0.9	94.3	2,266,950	5,327,855
Eritrea[b]	2010	2.8	13,752	0.7	95.0	1,911,528	1,911,528
Cambodia	2014	6.3	13,579	0.7	95.7	2,009,692	2,649,139
Tajikistan	2017	5.3	12,925	0.7	96.4	1,731,950	2,914,697
Haiti	2012	5.4	12,190	0.6	97.0	1,877,260	3,543,081
Sudan[b]	2014	9.1	11,619	0.6	97.6	1,812,564	1,812,564
Liberia	2013	3.9	9,272	0.5	98.1	1,260,992	3,241,098
Central African Republic	2010	4.5	8,470	0.4	98.5	1,329,790	2,064,527
Mauritania	2015	4.9	6,834	0.4	98.9	1,100,274	1,578,654
Nepal	2016	9	5,730	0.3	99.2	555,810	1,207,519
Zimbabwe	2019	9	4,390	0.2	99.4	614,600	738,659
Libyan Arab Jamahiriya	2008	7.5	3,675	0.2	99.6	1,830,150	2,421,577
Togo	2017	8.6	3,668	0.2	99.8	484,176	573,366
Kyrgyzstan	2018	8.3	3,100	0.2	99.9	427,800	759,382
Turkmenistan[b]	2018	9.3	973	0.1	100.0	175,140	175,140
Comoros	2012	9.6	104	<0.01	100.0	14,664	16,388
Total	–	–	1,940,134	100.0	–	267,447,257	612,609,418

[a] Unknown annual number of births for 2014, 2017, and 2019 calculated from crude birth rate and population data from The World Bank.

[b] No data available on consumer price index (CPI) needed to calculate interest rate from 2008 to 2018.

Table 3
Countries with a cesarean section rate of 10–15%.

Country	Year	Cesarean section rate, %
Netherlands	2018	14.9
Namibia	2013	14.4
Uzbekistan	2015	13.6
Rwanda	2015	13
Philippines	2017	12.7
Indonesia	2012	12.3
Swaziland/Eswatini	2014	11.6
Kuwait	2008	11.2
Cape Verde	2008	10.7
Gabon	2012	10

conducted without medical necessity command a disproportionate share of global economic resources, such as medical services, medication, providers, and other resources that consume global monetary funds for health and can function as a barrier to universal health coverage with necessary health services [13,14].

In this manuscript, we aim to update previous estimates and determine the current global economic costs of both the underuse and overuse of CS using current CS estimates published by WHO [4]. We also update the distribution of inequities between countries.

Materials and methods

Source of data and estimation of national CS rates

In our analysis, we defined the rate of CS as a percentage calculated by dividing the number of cesarean births over the total number of live births each year or period of years. We obtained national CS rates from the latest WHO estimates, trends, and projections [4]. The detailed methodology for inclusion of nationally representative CS rates has been published elsewhere [4]. In brief, the latest available nationally representative data on CS rates from countries worldwide were included. Data before 2010 was excluded because it was considered too old to present a current estimate. The sources of data used were routine health information systems reports and population-based household surveys. Worldwide, data was available for 172 countries covering 94 % of world live births. For our cost savings analysis and in order to maximize comparability in estimates, we used data from the same 137 countries included in our previous analysis [13,14].

Estimates for the number of CS in countries with low and high CS rates

For this analysis, at a national level, we adopted 10–15 % as the range for appropriate CS rates. As in previously published analyses, we considered that populations with CS rates of<10 % are at a higher risk of underuse while populations with rates of>15 % are at a higher risk of overuse [14]. Two assumptions underpin this decision: (1) The recommended minimum CS rate at the population level to avoid death and severe morbidity of the mother lies around 5 %, according to the WHO and other researchers [3,15,16]. In addition, studies that have evaluated the association of CS rates with neonatal death have shown outcome improvements in CS rates up to 10 % [1,17]. Although traditionally 15 % has been used as the upper limit which was proposed by the WHO in 1985, more recent research suggests that CS rates higher than 10 % are not associated with reductions in maternal and newborn mortality rates [13]. However, these studies only include mortality indicators while maternal and newborn morbidity indicators at are not considered constituting a limitation. In addition, it should be noted that the upper threshold for the optimal CS rate in a country remains a matter of debate with recent studies showing that CS rates of up to 19 % are associated with lower mortality [18]. Considering all the available evidence, we conducted this analysis using 10–15 % as the range for the appropriate

CS rate at population level and to allow for comparison with our previous analysis. Additionally, to account for the controversy, we also conducted an analysis using 10–20 % as a range for the appropriate CS rate. Thus, we present four groups of countries according to their national rates of CS: (1) countries with CS rates < 10 %, (2) countries with rates of 10–15 %, (3) countries with CS rates above 15 % and (4) countries with CS rates above 20 %. Our fourth group will represent countries with "excess" cesarean sections in recognition of the most recent proposals supporting CS rates up to 19 %.

In countries with CS rates of < 10 %, we calculated the number of additional CS that would be needed to increase the national rate up to 10 %; to calculate this number, we multiplied the annual number of births in each country by ten and then by the CS rate, which was then subtracted by the annual number of births. In countries with CS rates of > 15 %, we calculated the number of CS above this value by multiplying the annual number of births of each country by the CS rate minus the product of the annual number of births multiplied by 15 %. The annual number of births for the years 2010, 2011, 2013, 2015, 2016, and 2018 were obtained from the demographic data provided by UNICEF in the annual State of the World's Children (SOWC) reports [19]. The annual number of births for each country for the years 2012, 2014, and 2017 were identified by either Knoema Data, a repository that collects data from sources like the World Bank and United Nations, or calculated manually by multiplying the crude birth rate provided by The World Bank by the total population, as the SOWC reports did not publish the annual number of births for the years 2014 and 2017.

Estimating the cost

We estimated the cost of each CS per country based on data from our previous analysis, which utilized an "ingredients" approach [14]. This approach included gathering information on a standard set of physical inputs required to perform CS (not including antenatal care visits or services considered part of uncomplicated vaginal delivery) and finding their cost per unit by searching published and unpublished literature, as well as databases and consultation with costing experts. The standardized profile of CS inputs at point of care (i.e., the diagnosis of obstructed labor and referral, CS-associated devices and medicines, operative facility time, etc.), as well as the resources required to establish and maintain these services, were used for all countries but the costs were tailored for each country. Mark-ups, or increases in the price of products above the marginal cost of production, and other economic factors were not considered. The estimated costs should represent the costs of performance of the procedure according to recognized practice guidelines under idealized market conditions [14].

In this analysis and manuscript, the estimated costs of "needed" CS to reach 10 % and the cost of CS above the 15 % limit were calculated the same. First, we found the estimated cost of each CS procedure ("cost per procedure") according to each country by dividing the total cost of needed/excess cesarean sections (USD) from 2008 by the number (n) of needed/excess cesarean sections in 2008 [14].

After finding the "cost per procedure," we multiplied this value by the total number of needed/excess CS for each country according to the updated data collected from recent routine health information systems reports and population-based household surveys [4]. These calculations produced the estimated cost of "needed" CS to reach 10 % and the cost of CS above the 15 % limit according to the cost per procedure in 2008 [14].

To account for inflation from 2008 to 2018, we calculated the inflation rate using the consumer price indices (CPI) for each country in both years, 2008 and 2018. The CPIs for each country were obtained from The World Bank [20]. After obtaining the CPI for each country in both years, the following formula was used:

$$\text{(2018 CPI} - \text{2008 CPI)}/\text{2008 CP} = \text{Inflation Rate}$$

Then, we multiplied the inflation rate by the estimated cost

Table 4

Latest available cesarean section rates, excess cesarean sections and cost per year for countries with cesarean section rates of > 15 %[4,*].

Country	Year	National cesarean section rate, %	Excess number of cesarean sections per year, n[a]	Contribution to the total global number of unnecessary cesarean sections, %	Cumulative percentage	Estimated cost of unnecessary cesarean sections per year (USD)	Estimated cost per year with inflation (USD)
China	2014	34.9	5,863,462	37.6	37.6	967,471,230	1,205,373,991
Brazil	2017	55.7	1,194,703	7.7	45.3	281,949,908	501,175,277
Germany	2017	30.5	1,189,222	7.6	52.9	1,008,460,256	1,137,330,431
Egypt	2014	51.8	947,122	6.1	59.0	153,433,764	504,575,711
United States	2018	31.9	661,128	4.2	63.3	675,011,688	787,855,587
Mexico	2015	40.7	602,922	3.9	67.1	158,568,486	237,504,991
India	2016	17.2	555,368	3.6	70.7	58,313,640	120,756,320
Bangladesh	2018	32.7	519,495	3.3	74.0	50,910,510	98,802,381
Turkey	2014	50.8	469,070	3.0	77.1	99,442,840	233,409,665
Pakistan	2018	22.3	437,927	2.8	79.9	67,440,758	142,759,705
Iran	2010	45.6	387,702	2.5	82.4	112,821,282	555,362,761
Venezuela	2013	52.4	224,774	1.4	83.8	57,092,596	2,548,059,297
Colombia	2018	44.4	216,384	1.4	85.2	46,306,176	67,237,752
Vietnam	2014	27.5	198,644	1.3	86.5	29,597,956	54,883,855
Thailand	2016	32.7	128,502	0.8	87.3	21,588,336	24,858,626
Republic of Korea	2015	39.1	110,137	0.7	88.0	32,600,552	39,569,136
Russian Federation	2017	20.8	108,462	0.7	88.7	75,381,090	155,619,673
South Africa	2016	24.2	108,192	0.7	89.4	21,638,400	36,852,900
Peru	2019	33.7	107,461	0.7	90.1	21,814,583	28,972,137
United Kingdom	2016	28.2	106,260	0.7	90.8	79,269,960	97,410,108
Ecuador	2016	46.2	103,272	0.7	91.4	23,752,560	32,032,319
Argentina[b]	2011	29.1	97,713	0.6	92.0	22,962,555	22,962,555
Dominican Republic	2012	58.1	93,958	0.6	92.6	25,180,744	35,258,474
Italy	2016	33.7	92,565	0.6	93.2	75,625,605	85,146,536
Chile	2012	49.6	85,116	0.5	93.8	24,002,712	31,401,310
Poland	2014	35.6	77,095	0.5	94.3	19,427,940	23,090,076
Australia	2017	34.6	62,259	0.4	94.7	57,900,870	71,481,807
Tunisia	2018	43.2	57,246	0.4	95.0	20,036,100	31,246,008
Romania	2015	46.9	57,101	0.4	95.4	14,103,947	18,826,321
Canada	2017	28.8	53,273	0.3	95.8	63,554,689	74,255,223
Japan	2014	19.7	48,957	0.3	96.1	55,615,152	57,194,818
Spain	2015	26.7	48,321	0.3	96.4	36,047,466	40,329,246
Morocco	2018	21.2	42,284	0.3	96.7	7,145,996	8,063,830
Lebanon	2018	47.8	38,376	0.2	96.9	15,657,408	20,799,630
France	2016	19.6	35,236	0.2	97.1	28,505,924	31,518,745
Azerbaijan	2017	33.5	31,736	0.2	97.3	4,760,400	7,809,712
Cuba[b]	2014	40.4	31,534	0.2	97.5	30,430,310	30,430,310
Bolivia	2017	26.7	28,916	0.2	97.7	4,800,056	7,403,476
Jordan	2018	25.8	23,328	0.1	97.9	7,161,696	9,293,064
Hungary	2015	39	22,080	0.1	98.0	44,314,560	57,003,538
Paraguay	2016	48.5	21,000	0.1	98.1	4,515,000	6,789,474
Nicaragua	2012	29.7	20,433	0.1	98.3	3,861,837	6,516,586
Bulgaria	2015	43	19,040	0.1	98.4	5,083,680	5,939,879
El Salvador	2018	29.8	17,316	0.1	98.5	4,225,104	4,799,684
Georgia	2018	46.6	17,064	0.1	98.6	3,156,840	4,381,061
Belarus	2017	29.6	16,477	0.1	98.7	9,342,459	54,713,622
Portugal	2018	34.1	15,280	0.1	98.8	18,290,160	20,295,821
Switzerland	2018	32.1	15,048	0.1	98.9	30,065,904	29,885,147
Czech Republi8c	2015	26.9	12,733	0.1	99.0	9,460,619	10,982,460
Austria	2018	29.4	12,672	0.1	99.1	14,103,936	16,789,025
Ireland	2016	32.6	12,144	0.1	99.2	23,450,064	23,427,879
Uruguay	2015	39.4	11,956	0.1	99.2	4,686,752	10,075,178
Serbia	2014	28.8	11,902	0.1	99.3	6,772,238	10,994,196
Panama	2013	27.7	9,525	0.1	99.4	2,924,175	3,794,613
Algeria	2013	16	9,460	0.1	99.4	1,892,000	3,087,495
Slovakia	2015	31.1	9,177	0.1	99.5	2,826,516	3,255,567
Ghana	2017	16	8,694	0.1	99.6	1,182,384	3,620,563
Mongolia	2018	26.2	8,512	0.1	99.6	1,591,744	3,439,978
Belgium	2015	21.3	8,190	0.1	99.7	6,592,950	7,778,199
New Zealand	2017	27.9	7,719	<0.01	99.7	14,179,803	16,654,230
Costa Rica	2017	24.3	6,555	<0.01	99.7	1,730,520	2,487,376
Albania	2018	31	5,440	<0.01	99.8	1,180,480	1,356,050

Table 4 (*continued*)

Country	Year	National cesarean section rate, %	Excess number of cesarean sections per year, n[a]	Contribution to the total global number of unnecessary cesarean sections, %	Cumulative percentage	Estimated cost of unnecessary cesarean sections per year (USD)	Estimated cost per year with inflation (USD)
Oman	2018	19.4	4,004	<0.01	99.8	2,438,436	2,954,259
FYR of Macedonia	2014	28.9	3,238	<0.01	99.8	3,791,698	4,300,061
Croatia	2016	23	3,120	<0.01	99.9	3,909,360	4,406,621
Bahrain	2017	29	3,052	<0.01	99.9	1,669,444	2,057,931
Sweden	2018	17.3	2,737	<0.01	99.9	3,629,262	3,969,163
Denmark	2018	19.1	2,501	<0.01	99.9	3,849,039	4,367,562
Israel	2014	16.1	1,834	<0.01	99.9	1,166,424	1,328,634
Latvia	2017	22.7	1,598	<0.01	99.9	9,199,686	10,717,257
Lithuania	2017	20.2	1,539	<0.01	99.9	3,338,091	4,086,954
Slovenia	2015	21.2	1,364	<0.01	99.9	2,586,144	2,902,110
Lesotho	2018	17.4	1,344	<0.01	100	271,488	446,554
Luxemburg	2015	32.7	1,062	<0.01	100	3,834,882	4,453,030
Saudi Arabia	2018	32	1,017	<0.01	100	379,192	507,127
Qatar	2012	19.5	990	<0.01	100	4,135,230	4,461,594
Malta	2017	30.9	680	<0.01	100	570,520	659,793
Syrian Arab Republic	2009	26	656	<0.01	100	244,539	376,133
Finland	2014	16.1	621	<0.01	100	656,397	738,779
Estonia	2018	19.1	574	<0.01	100	3,826,284	4,700,188
Norway	2018	15.9	531	<0.01	100	1,096,515	1,351,412
Guatemala	2015	26.3	495	<0.01	100	184,613	269,202
Ukraine	2015	17.9	140	<0.01	100	52,354	173,254
Kazakhstan	2017	18	119	<0.01	100	44,424	91,664
United Arab Emirates	2013	23.9	117	<0.01	100	43,820	52,440
Iceland	2018	17.2	88	<0.01	100	1,587,520	2,346,606
Andorra	2008	23.7	75	<0.01	100	189,375	189,375
Honduras	2012	18.6	75	<0.01	100	27,930	44,472
Republic of Moldova	2015	18.5	15	<0.01	100	5,614	9,557
Armenia	2016	18	12	<0.01	100	4,476	6,374
Montenegro	2018	24.4	7	<0.01	100	2,454	2,973
Total	–	–	15,577,245	100.0	–	4,823,951,077	9,586,952,466

[a] Additional sources: Knoema Data and Boerma T, Ronsmans C, Melesse DY, et al. Global epidemiology of use of and disparities in caesarean sections. *The Lancet*. 2018;392(10155):1341–1348. https://doi.org/10.1016/s0140-6736(18)31928–7.

[b] No data available on consumer price index (CPI) needed to calculate interest rate from 2008 to 2018.

[*] Number of deliveries can be seen in Annex. Table 1.

calculated prior. This gives a cost estimate that considers the inflation rate from 2008 to 2018, which accounts for the time that passed from the reporting of the original cost estimates and the recent cesarean delivery rate data now available. It is important to reiterate that we used the most recent CS rates of each country published in the latest WHO update on CS estimates [4]. Thus, we are assuming that the most recent rates available are like what occurred in 2018. Additionally, CPI data was not available for six countries: Eritrea, Sudan, Turkmenistan, Andorra, Argentina, and Cuba. For those countries, we kept the original cost calculated according to the cost per procedure in 2008.

Ethical approval for this analysis was not required.

Results

Using the most recent CS rates published between 2010 and 2018 for 137 countries, we found 18 countries with nationally-representative CS rates < 5 %, 36 countries with CS rates below 10 %, 10 countries with CS rates between 10 and 15 % (Table 1), 91 countries with CS rates > 15 %, and 70 countries with CS rates > 20 %.

Tables 2–5 list CS rates < 10 %, 10–15 %, >15 %, and > 20 % and associated costs by country, respectively. Within countries with CS rates < 10 %, 80.6 % are in Africa. Worldwide, an additional 1,940,134 cesarean sections would be needed to meet the 10 % threshold. Nigeria is the country with the largest unmet need for CS (comprising 28 % of

needed CS worldwide), followed by Ethiopia (14.8 %) and the Democratic Republic of the Congo (8 %). Within countries with CS rates > 15 %, 15,577,245 cesarean sections are performed in excess annually. China contributes the most to this excess (37.6 %), followed by Brazil (7.7 %) and Germany (7.6 %).

For countries with CS rates < 10 %, the cost of financing the additional cesarean sections needed to meet a rate of 10 % globally was $267,447,257 ($612,609,418 with inflation). The cost of cesarean deliveries that exceed the 15 % limit was estimated at $4,823,951,077. However, when considering the inflation rate between 2008 and 2018, this amount jumps to $9,586,952,466.

Within countries with CS rates > 20 %, 11,090,725 cesarean sections are performed in excess annually. China, Brazil, and Egypt contribute the most to this excess (39.6 %, 9.4 %, and 7.4 %, respectively). The costs of cesarean deliveries exceeding a rate of 20 % was $3.348.614.079 ($7.169.248.033 with inflation) globally. This number comprises 96.5 % of the cost of CS at rates > 15 % without inflation and 97 % of the cost with inflation. Furthermore, a majority of cesarean sections are performed at rates > 20 % globally which, consequently, demands a considerable number of global resources.

Comparisons between summary data on CS rates and associated costs from 2008 [13] and current data are provided in Table 6, indicating a clear widening of inequity. The number of countries with CS rates between 10 % and 15 % has constricted, with fewer countries reporting CS

Table 5

Latest available cesarean section rates, excess cesarean sections and cost per year for countries with cesarean section rates of > 20 %[4.]

Country	Year	National cesarean section rate, %	Excess number of cesarean sections per year, n[a]	Contribution to the total global number of unnecessary cesarean sections, %	Cumulative percentage	Estimated cost of unnecessary cesarean sections per year (USD)	Estimated cost per year with inflation (USD)
China	2014	34.9	4.390.230	39,6	39,6	724.387.950	902.516.134
Brazil	2017	55.7	1.047.934	9,4	49	247.312.424	439.606.005
Germany	2017	30.5	805.602	7,3	56,3	683.150.496	770.449.647
Egypt	2014	51.8	818.437	7,4	63,7	132.586.794	436.019.257
United States	2018	31.9	465.528	4,2	67,9	475.304.088	554.762.218
Mexico	2015	40.7	485.622	4,4	72,3	127.718.586	191.297.794
Bangladesh	2018	32.7	372.745	3,4	75,7	36.529.010	70.892.104
Turkey	2014	50.8	403.557	3,6	79,3	85.554.084	200.810.336
Pakistan	2018	22.3	137.977	1,2	80,5	21.248.458	44.979.085
Iran	2010	45.6	324.352	2,9	83,4	94.386.432	464.617.212
Venezuela	2013	52.4	194.724	1,8	85,2	49.459.896	2.207.409.658
Colombia	2018	44.4	179.584	1,6	86,8	38.430.976	55.802.760
Vietnam	2014	27.5	119.186	1,1	87,9	17.758.714	32.930.202
Thailand	2016	32.7	92.202	0,8	88,7	15.489.936	17.836.415
Republic of Korea	2015	39.1	87.287	0,8	89,5	25.836.952	31.359.772
Russian Federation	2017	20.8	14.960	0,1	89,6	10.397.200	21.464.387
South Africa	2016	24.2	49.392	0,4	90	9.878.400	16.824.150
Peru	2019	33.7	78.728	0,7	90,7	15.981.784	21.225.546
United Kingdom	2016	28.2	66.010	0,6	91,3	49.243.460	60.512.340
Ecuador	2016	46.2	86.722	0,8	92,1	19.946.060	26.898.935
Argentina	2011	29.1	63.063	0,6	92,7	14.819.805	14.819.805
Dominican Republic	2012	58.1	83.058	0,7	93,4	22.259.544	31.168.164
Italy	2016	33.7	67.815	0,6	94	55.404.855	62.380.083
Chile	2012	49.6	72.816	0,7	94,7	20.534.112	26.863.548
Poland	2014	35.6	58.383	0,5	95,2	14.712.516	17.485.802
Australia	2017	34.6	46.377	0,4	95,6	43.130.610	53.247.109
Tunisia	2018	43.2	47.096	0,4	96	16.483.600	25.705.936
Romania	2015	46.9	48.151	0,4	96,4	11.893.297	15.875.487
Canada	2017	28.8	33.971	0,3	96,7	40.527.403	47.350.894
Spain	2015	26.7	27.671	0,2	96,9	20.642.566	23.094.525
Morocco	2018	21.2	8.184	0,1	97	1.383.096	1.560.741
Lebanon	2018	47.8	32.526	0,3	97,3	13.270.608	17.628.955
Azerbaijan	2017	33.5	23.159	0,2	97,5	3.473.850	5.699.052
Cuba	2014	40.4	25.327	0,2	97,7	24.440.555	24.440.555
Bolivia	2017	26.7	16.559	0,1	97,8	2.748.794	4.239.665
Jordan	2018	25.8	12.528	0,1	97,9	3.846.096	4.990.720
Hungary	2015	39	17.480	0,2	98,1	35.082.360	45.127.801
Paraguay	2016	48.5	17.866	0,2	98,3	3.841.190	5.776.226
Nicaragua	2012	29.7	13.483	0,1	98,4	2.548.287	4.300.060
Bulgaria	2015	43	15.640	0,1	98,5	4.175.880	4.879.186
El Salvador	2018	29.8	11.466	0,1	98,6	2.797.704	3.178.169
Georgia	2018	46.6	14.364	0,1	98,7	2.657.340	3.687.855
Belarus	2017	29.6	10.834	0,1	98,8	6.142.878	35.975.443
Portugal	2018	34.1	11.280	0,1	98,9	13.502.160	14.982.779
Switzerland	2018	32.1	10.648	0,1	99	21.274.704	21.146.800
Czech Republi8c	2015	26.9	7.383	0,1	99,1	5.485.569	6.367.981
Austria	2018	29.4	8.272	0,1	99,2	9.206.736	10.959.502
Ireland	2016	32.6	8.694	0,1	99,3	16.788.114	16.772.232
Uruguay	2015	39.4	9.506	0,1	99,4	3.726.352	8.010.592
Serbia	2014	28.8	7.590	0,1	99,5	4.318.710	7.011.086
Panama	2013	27.7	5.775	0,1	99,6	1.772.925	2.300.671
Slovakia	2015	31.1	6.327	0,1	99,7	1.948.716	2.244.521
Mongolia	2018	26.2	4.712	<0.01	99,7	3.793.160	8.197.541
Belgium	2015	21.3	1.690	<0.01	99,7	3.104.530	3.662.648
New Zealand	2017	27.9	4.727	<0.01	99,7	1.247.928	1.465.696
Costa Rica	2017	24.3	3.031	<0.01	99,7	657.727	945.389
Albania	2018	31	3.740	<0.01	99,7	2.277.660	2.616.411
FYR of Macedonia	2014	28.9	2.073	<0.01	99,7	2.597.469	2.945.719
Croatia	2016	23	1.170	<0.01	99,7	639.990	721.395
Bahrain	2017	29	1.962	<0.01	99,7	2.601.612	3.207.019
Latvia	2017	22.7	560	<0.01	99,7	1.214.640	1.415.006

(continued on next page)

Table 5 (*continued*)

Country	Year	National cesarean section rate, %	Excess number of cesarean sections per year, n[a]	Contribution to the total global number of unnecessary cesarean sections, %	Cumulative percentage	Estimated cost of unnecessary cesarean sections per year (USD)	Estimated cost per year with inflation (USD)
Lithuania	2017	20.2	59	<0.01	99,7	111.864	136.959
Slovenia	2015	21.2	264	<0.01	99,7	53.328	59.843
Luxemburg	2015	32.7	762	<0.01	99,7	284.114	329.911
Saudi Arabia	2018	32	718	<0.01	99,7	2.999.086	4.010.943
Malta	2017	30.9	466	<0.01	99,7	173.712	200.894
Syrian Arab Republic	2009	26	358	<0.01	99,7	378.406	582.038
Guatemala	2015	26.3	276	<0.01	99,7	103.212	150.503
United Arab Emirates	2013	23.9	51	<0.01	99,7	920.040	1.101.025
Andorra	2008	23.7	32	<0.01	99,7	11.917	11.917
Montenegro	2018	24.4	3	<0.01	99,7	1.052	1.274
Total	–	–	11.090.725			3.348.614.079	7.169.248.033

No data available on consumer price index (CPI) needed to calculate interest rate from 2008 to 2018.

[a] Additional sources: Knoema Data and Boerma T, Ronsmans C, Melesse DY, et al. Global epidemiology of use of and disparities in caesarean sections. *The Lancet.* 2018;392(10155):1341–1348. https://doi.org/10.1016/s0140-6736(18)31928–7.

Table 6
Notable similarities and differences from 2008-present (n = 137).

2008[13]	Present
3.2 million additional CS per year are needed in 54 countries to attain a CS rate of 10 %	**1.9 million** additional CS per year are needed in **26 countries** to attain a CS rate of 10 %
39.4 % of countries (n = 54) have CS rates of < 10 %	**26.3 %** of countries (n = 36) have CS rates of < 10 %
10 % of countries (n = 14) have CS rates of 10–15 %	**7.3 %** of countries (n = 10) have CS rates of 10–15 %
68.5 % of countries (n = 37) with rates of < 10 % are in Africa	**80.6 %** of countries (n = 29) with rates of < 10 % are in Africa
6.2 million CS are performed each year in countries with CS rate > 15 %	**15.6 million** CS are performed each year in countries with CS rate > 15 %
50 % of countries (n = 69) have CS rates > 15 %	**66.4 %** of countries (n = 91) have CS rates > 15 %
35 % of countries (n = 48) have CS rates > 20 %	**51.8 %** of countries (n = 71) have CS rates > 20 %
Cost of additionally "needed" CS to reach 10 % is approx. US$432 million	Cost of additionally "needed" CS to reach 10 % is approx. **US$268million (US$612 million with inflation)**
Cost of CS conducted above the 15 % threshold is approx. US$2.32 billion	Cost of CS conducted above the 15 % threshold is approx. **US$4.82 billion (US$9.59 billion with inflation)**
Cost of CS conducted above the 20 % threshold is approx. US$2.27 billion	Cost of CS Conducted above the 20 % threshold is approx. **US$4.82 billion (US$9.59 billion with inflation)**

rates < 10 % and more countries reporting CS rates > 15 %. This disparity in CS rates has led to a 150 % increase in the number of countries with CS rates > 15 % since 2008. African countries, involved the majority of countries with CS rates < 10.

The cost of cesarean sections exceeding 15 % (including inflation) has increased by 313 % since 2008, accruing $7 billion more in surplus since 2008 (Table 6). Moreover, the cost of cesarean deliveries in excess was enough to cover the cost of "needed" cesarean deliveries in recent years by 18 times, or 15.6 times with inflation. In other words, if resources supporting cesarean deliveries performed at global rates > 15 % were reallocated to support the number of cesarean deliveries required to meet global rates of 10 %, there would still be $9 billion leftover (considering inflation).

Discussion

This study aimed to show global inequities in caesarean section rates, its financial implications and changes in the last decade using data from 137 countries. Acknowledging the existing controversy on the appropriate rate of CS at population level, we used population-based cut-off figures for CS from various recommendations [1,2,.13,16]. Our estimates show that in 36 countries the CS rate is below 10 % representing countries where there is a higher risk of underuse. These countries are mostly concentrated in sub-Saharan Africa. On the other hand, 91 and 71 countries show CS rates above 15 % and 20 %, respectively representing countries where there is a higher risk of overuse. We estimate that 6.2 million CS are conducted above 20 % rate, half of them (47.4 %) occur in Brazil and China alone. Caesarean section rates are rising unnecessary in many countries and are rising inequitably around the world. While LICs show figures that still fall short of minimum recommended rates, several MHICs are expected to reach unprecedentedly high CS rates by 2030 [4]. This inequity has relevant considerations for maternal and child health as very low rates mean women are dying due to lack of access to this lifesaving intervention while mortality and morbidity following CS is also rising simultaneously to the CS rise [21–23].

Inequities in the use of CS have resulted in a disproportionate allocation of resources across countries on unnecessary medical interventions, potentially costing the global economy billions of dollars annually.

A range of factors may have contributed to this increased disparity in CS rates and associated costs, which include, among others, the increasingly older age of mothers upon conception, reimbursement and financial incentives, gaps in wealth and education, and urbanization of the population [24,25]. The privatization of hospitals also remains a major challenge to lowering CS rates, as a 2017 *meta*-analysis found that privately-insured women were 1.13 times as likely to deliver via CS compared with publicly-insured women [26]. Efforts to optimize access of CS should (1) increase funding for resources required for performing CS in settings where CS are underutilized and (2) create guidelines for women decision-making with information on risks and benefits of both vaginal birth and CS, particularly in middle- and high-income countries where CS are overused [27]. WHO guidelines include recommendations for evidence-based interventions that help women prepare mentally and emotionally for childbirth, as well as helping them make more informed decisions about their birth options [28–30]. Indeed, based on results

Table A1

Number of births in countries with cesarean section rates >15%.

Country	Year	Births
China	2014	29.464.633
Brazil	2017	2.935.388
Germany	2017	7.672.400
Egypt	2014	2.573.701
United States	2018	3.912.000
Mexico	2015	2.346.000
India	2016	25.244.000
Bangladesh	2018	2.935.000
Turkey	2014	1.310.251
Pakistan	2018	5.999.000
Iran	2010	1.267.000
Venezuela	2013	601.000
Colombia	2018	736.000
Vietnam	2014	1.589.152
Thailand	2016	726.000
Republic of Korea	2015	457.000
Russian Federation	2017	1.870.034
South Africa	2016	1.176.000
Peru	2019	574.658
United Kingdom	2016	805.000
Ecuador	2016	331.000
Argentina[b]	2011	693.000
Dominican Republic	2012	218.000
Italy	2016	495.000
Chile	2012	246.000
Poland	2014	374.248
Australia	2017	317.648
Tunisia	2018	203.000
Romania	2015	179.000
Canada	2017	386.036
Japan	2014	1.041.638
Spain	2015	413.000
Morocco	2018	682.000
Lebanon	2018	117.000
France	2016	766.000
Azerbaijan	2017	171.546
Cuba[b]	2014	124.150
Bolivia	2017	247.145
Jordan	2018	216.000
Hungary	2015	92.000
Paraguay	2016	62.687
Nicaragua	2012	139.000
Bulgaria	2015	68.000
El Salvador	2018	117.000
Georgia	2018	54.000
Belarus	2017	112.856
Portugal	2018	80.000
Switzerland	2018	88.000

Table A1 (*continued*)

Country	Year	Births
Czech Republic	2015	107.000
Austria	2018	88.000
Ireland	2016	69.000
Uruguay	2015	49.000
Serbia	2014	86.246
Panama	2013	75.000
Algeria	2013	946.000
Slovakia	2015	57.000
Ghana	2017	869.400
Mongolia	2018	76.000
Belgium	2015	130.000
New Zealand	2017	59.837
Costa Rica	2017	70.484
Albania	2018	34.000
Oman	2018	91.000
FYR of Macedonia	2014	23.295
Croatia	2016	39.000
Bahrain	2017	21.800
Sweden	2018	119.000
Denmark	2018	61.000
Israel	2014	166.727
Latvia	2017	20.753
Lithuania	2017	29.596
Slovenia	2015	22.000
Lesotho	2018	56.000
Luxemburg	2015	6.000
Saudi Arabia	2018	5.982
Qatar	2012	22.000
Malta	2017	4.277
Syrian Arab Republic	2009	5.964
Finland	2014	56.455
Estonia	2018	14.000
Norway	2018	59.000
Guatemala	2015	4.381
Ukraine	2015	4.828
Kazakhstan	2017	3.967
United Arab Emirates	2013	1.315
Iceland	2018	4.000
Andorra	2008	862
Honduras	2012	2.083
Republic of Moldova	2015	429
Armenia	2016	400
Montenegro	2018	74
Total	-	**105.792.326**

from a randomized controlled trial in Hamadan, Iran, women who received group counseling on birth delivery options during prenatal visits demonstrated a significantly increased preference for vaginal delivery [31].

Future efforts should also invest in improved data collection and surveillance of CS. Ours is a population-level analysis and thus we

cannot demonstrate that countries with CS rates of 10–15 % are performing CS for women truly *in need* of the procedure. Likewise, we also cannot conclude that all CS contributing to CS rates > 15 % and > 20 % are medically unnecessary.

Given the wide inequities described in the literature in many countries, a reliable and action-oriented monitoring of CS rates is recommended [32]. The use of the Robson classification can help identify groups of women more at risk of unnecessary CS and for monitoring, assessing, and comparing CS rates more accurately and meaningfully [32,33]. The causes of cesarean sections must be within acceptable values [34]. To this end, audit mechanisms must be put in place universally to ensure acceptable values of CS causes. For example, in places where the resources are available, WHO suggests that policies that require healthcare professionals to rely on a second opinion while weighing birthing options may be efficient to reduce intrapartum CS [29]. Efforts to integrate doulas and midwives in healthcare systems' models of care have also been shown to significantly reduce CS rates [28,35]. For example, collaborative midwifery-obstetrician model of care (i.e. a model of staffing based on care provided primarily by midwives, with 24-hour back-up from an obstetrician who provides in-house labour and delivery coverage without other competing clinical duties) have been suggested.

Left unaddressed, such inequities in CS rates and associated costs could largely increase in future years as population growth fluctuates. By 2050, the United Nations predicts that SSA's population will double, while regions like Northern America (USA and Canada), Latin America, and the Caribbean will experience lower rates of population growth [36]. Moreover, countries like those in SSA could experience a greater reduction of resources required to perform CS while countries with adequate financial and human resources available where CS rates are above 15–20 % could continue increasing the use of CS [4].

Strengths and limitations

A strength of this study is the fact that we used nationally-representative CS rates from the latest WHO effort to map worldwide rates [4]. We also utilized UNICEF's *State of the World's Children* (SOWC) reports in our calculations. SOWC is another comprehensive means of measuring global indicators related to children's health, which allows us to accurately quantify the burden of excessive cesarean deliveries based on the number of annual births per country [19].

Our analysis has some limitations. We were not able to differentiate between necessary and unnecessary CS due to lack of data at national level as to why these sections are being carried out. Another limitation is the lack of consensus on the appropriate or ideal CS rate at population level which results in lack of a recommendation to be used as a threshold. To palliate this challenge and for the purpose of our analysis, we have used a range where the appropriate CS rate us likely to fall in a large proportion of countries. Although we have used the most updated set of CS rates from the WHO, the latest estimates for some countries go a few years back. Moreover, we assumed that the cost of CS has not changed since 2008. To mitigate this limitation, we incorporated inflation rates in our calculations. In the case of rising costs, our findings will be conservative and may underestimate the breadth of this disparity in costs. Lastly, consensus still needs to be reached for the range of CS rates associated with a decrease in mortality, as this could affect our result's implications. We acknowledge such a range may be subject to variability, as there are persisting global resource differences across countries with varying income levels.

In conclusion, Results of this study show persistent inequities in the CS rates between countries worldwide resulting in an inequity allocation of economic resources.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

Table A1

Reference

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