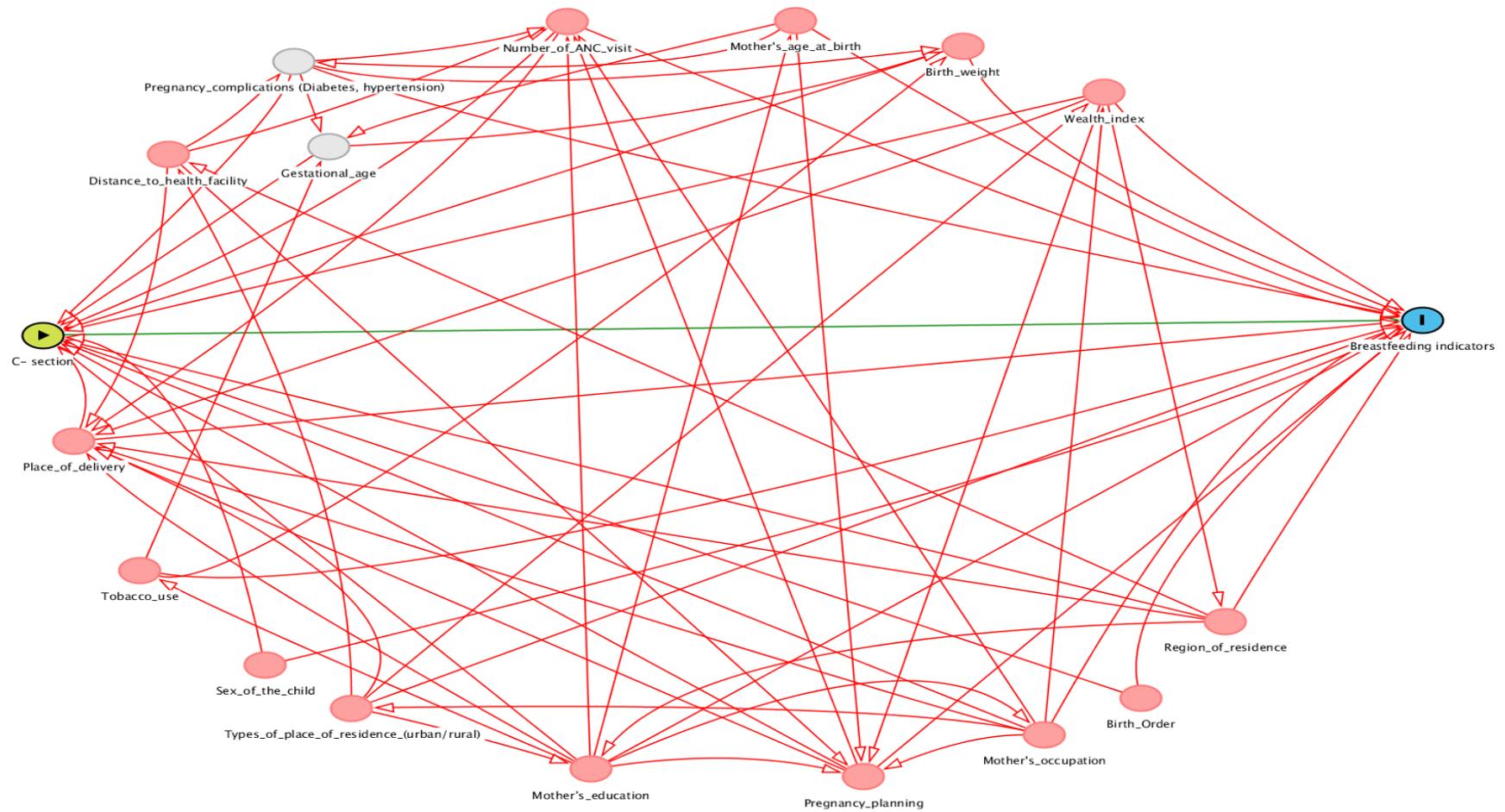


Web-appendix 1. Proposed Directed Acyclic Graphs (DAGs) describing the association between caesarean birth and breastfeeding

Web-appendix 2. DAGs model code

The following **DAGs code** can be used to generate the proposed DAGs in this study online at <http://www.dagitty.net/>.

Birth_Order 1 @0.558,0.687
 Birth_weight 1 @0.490,0.099
 Breastfeeding%20indicators O @0.677,0.369
 C-%20section E @0.135,0.342
 Distance_to_health_facility 1 @0.187,0.197
 Gestational_age U @0.248,0.190
 Mother%E2%80%99s_education 1 @0.348,0.751
 Mother's_age_at_birth 1 @0.426,0.076
 Mother's_occupation 1 @0.521,0.720
 Number_of_ANC_visit 1 @0.339,0.077
 Place_of_delivery 1 @0.151,0.455
 Pregnancy_complications%20(Diabetes%2C%20hypertension) U @0.235,0.113
 Pregnancy_planning 1 @0.452,0.758
 Region_of_residence 1 @0.590,0.618
 Sex_of_the_child 1 @0.224,0.657
 Tobacco_use 1 @0.176,0.572
 Types_of_place_of_residence_(urban%2Frural) 1 @0.257,0.696
 Wealth_index 1 @0.544,0.141

Birth_Order Breastfeeding%20indicators @0.548,0.572 C-%20section
 Birth_weight Breastfeeding%20indicators @0.511,0.205 C-%20section
 C-%20section Breastfeeding%20indicators @0.667,0.361

Distance_to_health_facility Number_of_ANC_visit @0.251,0.161 Place_of_delivery @0.183,0.353
 Pregnancy_complications%20(Diabetes%2C%20hypertension) @0.211,0.169 Pregnancy_planning

Gestational_age Birth_weight @0.389,0.174 C-%20section

Mother%E2%80%99s_education Breastfeeding%20indicators C-%20section Mother's_age_at_birth
 Mother's_occupation @0.475,0.620 Number_of_ANC_visit Place_of_delivery @0.177,0.528
 Pregnancy_planning @0.404,0.732 Tobacco_use @0.208,0.612

Mother's_age_at_birth Breastfeeding%20indicators @0.581,0.298 Gestational_age @0.270,0.161
 Pregnancy_complications%20(Diabetes%2C%20hypertension) @0.393,0.130 Pregnancy_planning

Mother's_occupation Breastfeeding%20indicators @0.595,0.409 C-%20section Number_of_ANC_visit
 Place_of_delivery @0.473,0.694 Pregnancy_planning @0.490,0.720
 Types_of_place_of_residence_(urban%2Frural) @0.461,0.690 Wealth_index

Number_of_ANC_visit Breastfeeding%20indicators @0.584,0.316 C-%20section @0.269,0.235
Place_of_delivery @0.296,0.228

Place_of_delivery Breastfeeding%20indicators C-%20section @0.160,0.403

Pregnancy_complications%20(Diabetes%2C%20hypertension) Birth_weight @0.302,0.151
Breastfeeding%20indicators @0.315,0.182 C-%20section @0.229,0.168 Gestational_age
Number_of_ANC_visit @0.303,0.103

Pregnancy_planning Breastfeeding%20indicators C-%20section Number_of_ANC_visit Place_of_delivery

Region_of_residence Breastfeeding%20indicators @0.612,0.533 C-%20section Distance_to_health_facility
Mother%E2%80%99s_education @0.385,0.628 Place_of_delivery

Sex_of_the_child Breastfeeding%20indicators @0.567,0.461 C-%20section @0.198,0.372

Tobacco_use Birth_weight @0.220,0.603 Breastfeeding%20indicators @0.270,0.609 Gestational_age

Types_of_place_of_residence_(urban%2Frural) Breastfeeding%20indicators Distance_to_health_facility
@0.257,0.485 Mother%E2%80%99s_education @0.300,0.718 Place_of_delivery @0.294,0.602 Wealth_index

Wealth_index Breastfeeding%20indicators @0.572,0.218 C-%20section Place_of_delivery @0.519,0.167
Pregnancy_planning Region_of_residence

Sex_of_the_child Breastfeeding @0.635,0.256 C-%20section @0.198,0.372

Tobacco_use Birth_weight @0.220,0.603 Breastfeeding Gestational_age

Wealth_index Breastfeeding C-%20section Place_of_delivery Pregnancy_planning Region_of_residence

Web-appendix 3. Description of variables in Directed Acyclic Graphs (DAGs)—*a priori*

Pregnancy planning--- Women who are planning to conceive often take antenatal care and more likely to undergo C-section if pregnancy complication occurs. Besides, they may take better care of themselves and their newborns, which in turn may affect breastfeeding practice.

Birth order--- C-section rates are higher among the first births and breastfeeding practice is low among first births. Breastfeeding practice is high among second or more births because of previous infant feeding experiences among mothers.

Tobacco use--- Previous studies found that smokers are less likely to begin or persist with breastfeeding compared to non-smokers. Moreover, due to the greater dose of nicotine that will be delivered to the newborn through the breastmilk, the infant will spend less time in active sleep.¹ Tobacco smoking will also affect caesarean section mediated through birth weight and gestational age.

Place of delivery--- Antenatal care and place of delivery may contribute to mother's breastfeeding practice. Interventions about breastfeeding through health education will promote breastfeeding practice. On the hand, caesarean birth rates are higher in private health institutions than other health facilities.²

Number of antenatal care visits---Previous studies have demonstrated that antenatal care has an effect on women's breastfeeding practices. Women who had the recommended antenatal care visits during pregnancy might know signs of pregnancy complication and this may, in turn, affect caesarean section.

Mother's education--- Educated mothers are more likely to practice breastfeeding³ and also to undergo caesarean section if obstetric complications occur. On the other hand, previous studies showed that caesarean births are higher among educated women.

Region of residence---Both exposure (caesarean section) and outcome (breastfeeding indicators) may display geographic variations mediated through sociodemographic, socioeconomic, behavioural, ethnic, cultural, and other factors.

Sex of child--- Due to sex preferences, women may more likely undergo caesarean section to save the life of the newborn when pregnancy complication occurs. It has been shown that sex of child impacts breastfeeding as a result of different factors including, sex preference, and cultural beliefs surrounding gender.

Household wealth --- Both exposure and outcome may display household wealth variations not only directly but also mediated through other factors such as place of childbirth.

Birth weight--- Birth weight affects caesarean section rates. It is highly recommended that low birth weight infants should be put to the breast as soon as possible after birth and should be exclusively breastfed until six months of life. Birth weight is also affected by gestational age, pregnancy complications and maternal tobacco use.

Mother's age at birth---is a risk factor for some caesarean births, maternal age may also affect breastfeeding practice. For example, despite inconsistent findings, some studies found that early cessation of breastfeeding was common among younger mothers and another study concluded primiparous mothers in late child-bearing aged 35 years or older are at the greatest risk of exclusive breastfeeding.⁴

Pregnancy complications (Gestational diabetes mellitus, all types of hypertension in pregnancy and others) ---- Because of both exposure and outcome may display variations based on factors related to pregnancy complications directly or mediated through other factors like birth weight and gestational age, it can be assumed that these factors are important confounders of the association between caesarean section and breastfeeding.

Gestational age---It has been demonstrated that caesarean sections are usually performed at early term “37-39” and infants born at these period have lower odds of being breastfed compared to infants born after 40 weeks gestation.

Distance to health facility---Long distance to health facilities may delay access to emergency caesarean section and may also aggravate the obstetric complication encountered by mothers leading to bad outcome. On the other hand, severe obstetric complications may prevent mother from breastfeeding and healthcare providers should provide breastfeeding support (e.g., how to express breastmilk in order to initiate and maintain breastfeeding) to establish and maintain breastfeeding. Distance to health facility also affects number antenatal care visits, place of delivery, and pregnancy planning (because access to health services is limited for women who live far away from health facilities).

Web-appendix 4. Description of how variables in the current study are defined

Exposure

Delivery by caesarean section: Whether the singleton last born child was born by caesarean section.

Outcome

Breastfeeding indicators:-

- (1) **Early initiation of breastfeeding:** Proportion of children born in the past 2 years before the survey who were put to the breast within one hour of birth. “This indicator is based on historic recall and the numerator and denominator include both living and deceased children who were born within the past 2 years.”⁵
- (2) **Exclusive breastfeeding under 6 months:** Proportion of infants 0–5 months of age who are fed exclusively with breast milk. DHS use this definition to calculate exclusive breastfeeding under 6 months and the numerator in the calculation of ‘exclusive breastfeeding under 6 months’ involves “infants 0–5 months of age who received only breast milk during the previous day while the denominator is total number of ‘infants 0–5 months of age’. This indicator is based on ‘recall of the previous day’ and includes living infants who are residing with mothers.”⁵
- (3) **Children ever breastfed:** Proportion of children born in the last two years who reported to have been breastfed. “This indicator is based on historic recall. The numerator and denominator include both living and deceased children who were born within the past 2 years before the survey.”⁵

Variables used to eliminate or minimize confounding

Wealth quintiles: It was derived from an index (generated through principal component analysis) based on ownership of a range of assets (e.g., car, refrigerator and television), housing characteristics (e.g., material of dwelling floor and roof and main cooking fuel) and access to basic services (e.g., electricity supply, source of drinking water and sanitation facilities), etc. depending on the specific questions asked in each country. The index was standardized to a mean of 0 and a standard deviation of 1 and higher scores refer to greater wealth. DHS categorizes household wealth index into ‘wealth quintiles’.

Number of antenatal visits: Women were asked whether they had received antenatal consultation from a health professional (doctor, nurse, or midwife) during the prenatal period. They were also asked the total number of antenatal visits during pregnancy. The variable used in this study reflects the number of visits reported by women who had received at least one antenatal consultation from a health professional. If women received antenatal care from a non-health professional, it was coded as zero in the ‘number of antenatal visits’ variable.

Birth order: The order in which a child was born.

Birth weight: All DHS in low-and middle-income countries collect information on baby’s size at birth based on mother’s perception by asking question, “was the newborn very large, larger than average, average, smaller than average or very small?” This is because the majority of births in these countries occur at home and birth weight is not available to be included. Previous studies conducted using DHS in low-and middle-income countries have shown that about 75% mothers are able to correctly report baby size at birth.⁶⁻⁹ In reference to these studies and due to lack of information on actual birthweight data, we used mother’s recall of baby’s size at birth as ‘proxy to

birth weight'.¹⁰ We then computed a categorical variable “low birth weight” (very small or smaller than average) and ‘normal birth weight’ (average, larger than average, very large).

Mother’s education: Mother’s highest education level attended which is standardized and categorized as: No education, Primary, Secondary, and Higher for each country in low-and middle-income countries.

Mother’s occupation: The standardized mother’s occupation groups (with some country-specific variations) include: professional, technical and managerial; clerical; sales or services; skilled manual; unskilled manual; household domestic; agricultural— own land; agricultural—family land; agricultural— rented land; agricultural—other; or other.

Distance to health facility: DHS collect information regarding problems faced by women of reproductive age (15-49 years) in accessing health care to obtain medical advice or treatment for themselves when they are sick were gathered. It consisted of four questions: distance to health facility (big problem/not big problem); getting money for treatment (big problem/not big problem); getting permission to go for treatment (big problem/not big problem); and not wanting to go alone (big problem/not big problem). Thus, we have used distance to health facility (big problem/not big problem) as a proxy to ‘actual distance’ in this study.

Other variables include: Pregnancy planning (yes/no), region of residence (categories include country-specific administrative areas/regions/provinces), sex of child (male/female), mother’s age at birth (in years), maternal tobacco use (yes/no), place of delivery (public sector, private sector, home, and other), and types of residence (urban/rural).

Web-appendix 5. Sample STATA code from Kenya DHS 2014 to generate 'exclusive breastfeeding under 6 months' variable.

Sample: Live singleton last-born children in the past 2 years and living with their mothers

```

* age in months (age)
gen age = v008-b3
* drop if too old or not alive
keep if age<24 & b5==1

* recode age into groups
recode age (0/1=1 "0-1")(2/3=2 "2-3")(4/5=3 "4-5")(6/8=4 "6-8")(9/11=5 "9-11")(12/17=6 "12-17")(18/23=7
"18-23")(24/59=.) , gen(child_age)

* tab all living children born in the last 2 years
tab child_age
tab child_age [iw=v005/1000000]

* keep only those children living with mother
keep if b9==0

* ... and keep the last born of those
drop if _n > 0 & caseid == caseid[_n-1]

* check the denominator
tab child_age
tab child_age [iw=v005/1000000]

* Breastfeeding status
gen water=0
gen liquids=0
gen milk=0
gen solids=0
gen breast=0

* Water
replace water=1 if (v409>=1 & v409<=7)

* Other non-milk liquids
replace liquids=1 if v410>=1 & v410<=7
replace liquids=1 if v412c>=1 & v412c<=7
replace liquids=1 if v413>=1 & v413<=7

* Powdered or tinned milk, formula, fresh milk
replace milk=1 if v411>=1 & v411<=7
replace milk=1 if v411a>=1 & v411a<=7

* Solid food
replace solids=1 if v412a>=1 & v412a<=7
replace solids=1 if v414e>=1 & v414e<=7
replace solids=1 if v414f>=1 & v414f<=7
replace solids=1 if v414g>=1 & v414g<=7
replace solids=1 if v414h>=1 & v414h<=7
replace solids=1 if v414i>=1 & v414i<=7
replace solids=1 if v414j>=1 & v414j<=7
replace solids=1 if v414k>=1 & v414k<=7
replace solids=1 if v414l>=1 & v414l<=7
replace solids=1 if v414m>=1 & v414m<=7
replace solids=1 if v414n>=1 & v414n<=7

```

```
replace solids=1 if v414o>=1 & v414o<=7
replace solids=1 if v414p>=1 & v414p<=7
replace solids=1 if v414s>=1 & v414s<=7
replace solids=1 if v414v>=1 & v414v<=7
```

*** Still breastfeeding**

```
replace breast=1 if m4==95
tab1 water liquids milk solids breast
```

*** Compute column variables used in DHS final reports**

```
gen feeding=1
replace feeding=2 if water==1
replace feeding=3 if liquids==1
replace feeding=4 if milk==1
replace feeding=5 if solids==1
replace feeding=0 if breast==0
tab feeding,m
```

```
label define feeding 0 "Not breastfeeding" 1 "Exclusive breastfeeding" 2 "+Water" 3 "+Liquids" 4 "+Other
Milk" 5 "+Solids"
label val feeding feeding
```

```
tab child_age feeding [iweight=v005/1000000], row
```

***Compute 'exclusive breastfeeding under 6 months' (exfeeding) variable**

```
gen exfeeding=.
replace exfeeding=1 if age<6 & feeding==1
replace exfeeding=0 if age<6 & feeding!=1
label define exfeeding 1 "Exclusive breastfeeding" 0 "no exclusive breastfeeding"
label val exfeeding exfeeding
lab var exfeeding "Exclusive breastfeeding under 6 months"
```

Web-appendix 6, Figures A-C. Subgroup analyses for the association between caesarean section and early initiation of breastfeeding in sub-Saharan Africa

We have conducted subgroup random-effects meta-analyses to explore potential sources of heterogeneity in the association between caesarean section and early initiation of breastfeeding in sub-Saharan Africa. For this purpose, we have defined the following subgroups *a priori*: (1) categorising the countries by region (according to United Nations geoscheme); (2) by rate of caesarean section categories (<5%, 5-15%, and >15%)¹¹; and (3) by prevalence of early initiation of breastfeeding categories ($\leq 50\%$ and $>50\%$). Although we have conducted the subgroup analyses, the source/s of the heterogeneity remains unclear. The forest plots from our subgroup investigations are displayed in **Figures A-C**.

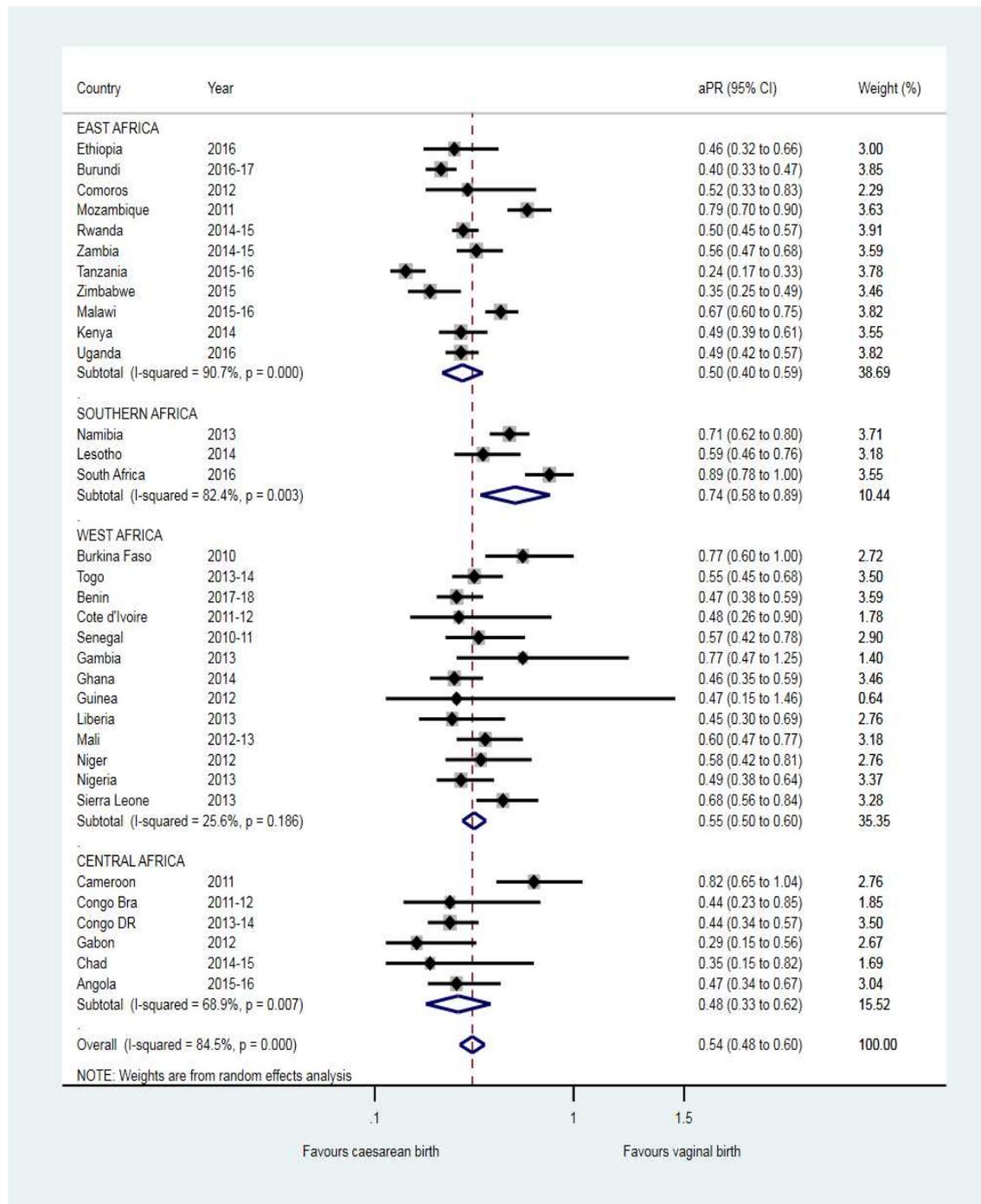


Figure A. Subgroup analyses for the association between caesarean section and early initiation of breastfeeding in sub-Saharan Africa stratified by geographic regions

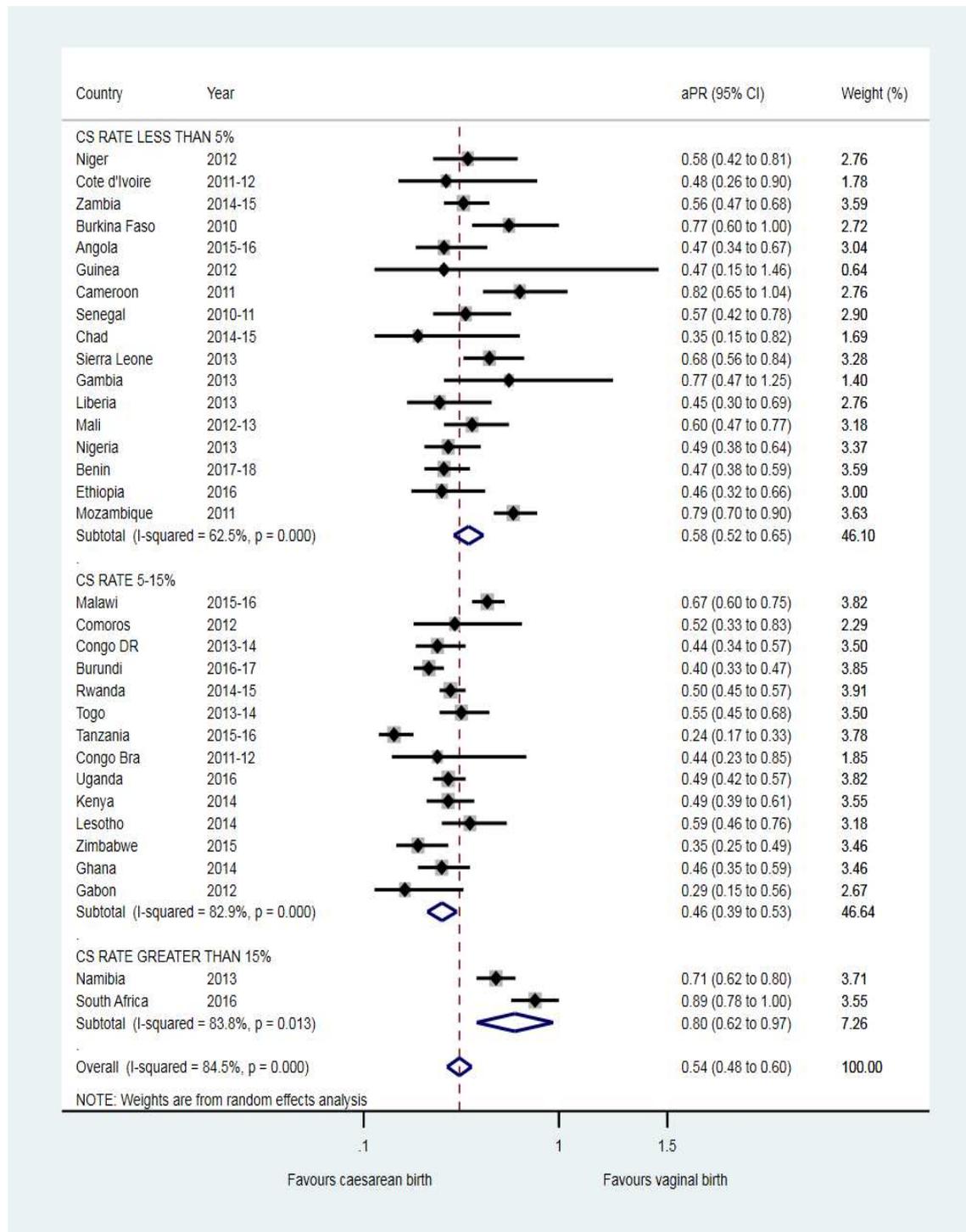


Figure B. Subgroup analyses for the association between caesarean section and early initiation of breastfeeding in sub-Saharan Africa stratified by caesarean section rates

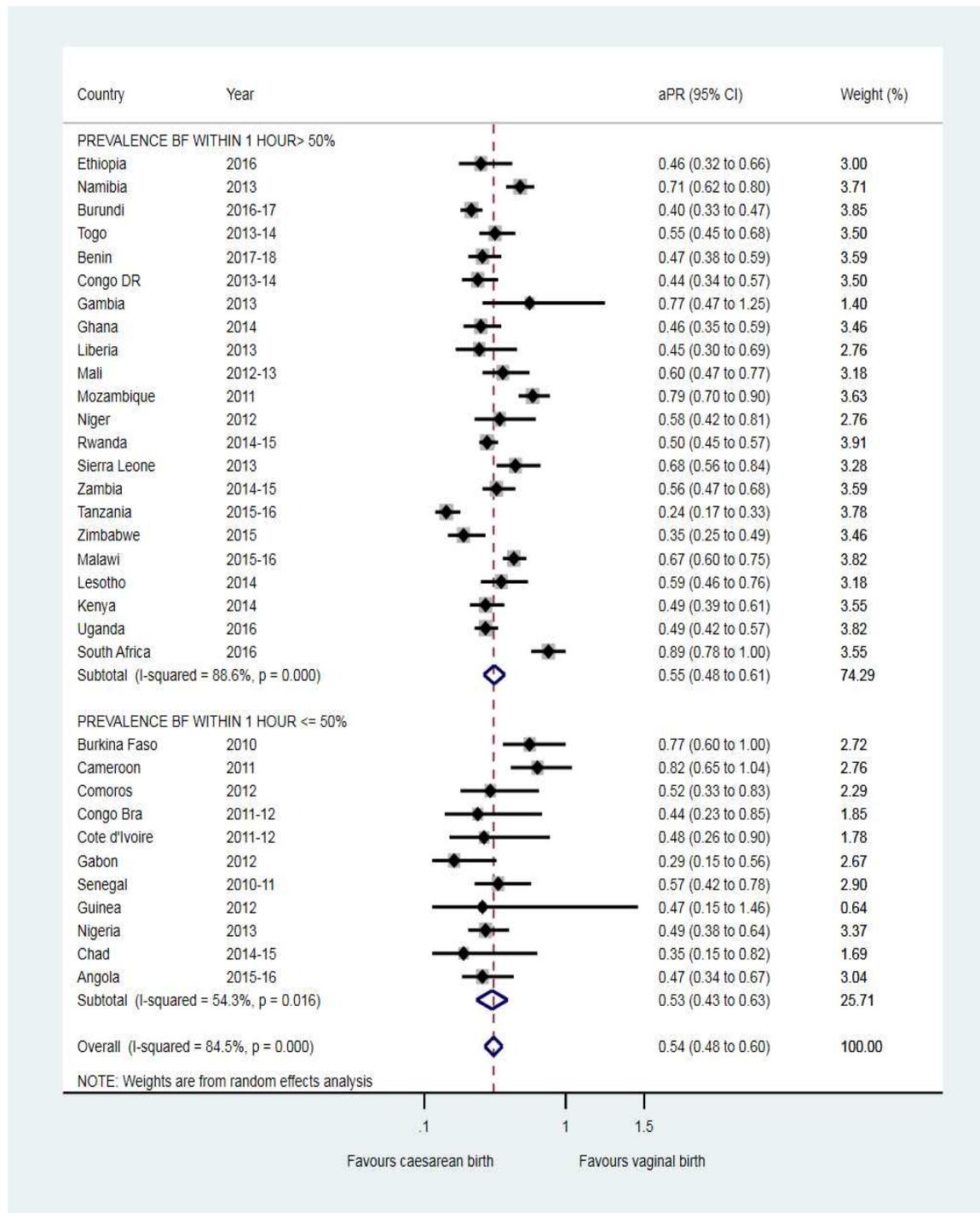


Figure C. Subgroup analyses for the association between caesarean section and early initiation of breastfeeding in sub-Saharan Africa stratified by prevalence of early initiation of breastfeeding

References

1. Mennella JA, Yourshaw LM, Morgan LK. Breastfeeding and smoking: short-term effects on infant feeding and sleep. *Pediatrics* 2007; **120**(3): 497-502.
2. Yisma E, Smithers LG, Lynch JW, Mol BW. Cesarean section in Ethiopia: prevalence and sociodemographic characteristics. *J Matern Fetal Neonatal Med* 2019; **32**(7): 1130-5.
3. Ekubay M, Berhe A, Yisma E. Initiation of breastfeeding within one hour of birth among mothers with infants younger than or equal to 6 months of age attending public health institutions in Addis Ababa, Ethiopia. *Int Breastfeed J* 2018; **13**: 4.
4. Kitano N, Nomura K, Kido M, et al. Combined effects of maternal age and parity on successful initiation of exclusive breastfeeding. *Prev Med Rep* 2016; **3**: 121-6.
5. World Health Organization. Indicators for assessing infant and young child feeding practices. Part I: Definitions. Conclusions of a consensus meeting held 6–8 November 2007 in Washington D.C., USA. Geneva: World Health Organization, 2008.
6. Rahman MS, Howlader T, Masud MS, Rahman ML. Association of Low-Birth Weight with Malnutrition in Children under Five Years in Bangladesh: Do Mother's Education, Socio-Economic Status, and Birth Interval Matter? *PLOS ONE* 2016; **11**(6): e0157814.
7. Sreeramareddy CT, Shidhaye RR, Sathiakumar N. Association between biomass fuel use and maternal report of child size at birth--an analysis of 2005-06 India Demographic Health Survey data. *BMC Public Health* 2011; **11**(1): 403.
8. Haque SR, Tisha S, Huq N. Poor Birth Size a Badge of Low Birth Weight Accompanying Less Antenatal Care in Bangladesh with Substantial Divisional Variation: Evidence from BDHS-2011. *Public Health Research* 2015; **5**(6): 184-91.
9. Khanal V, Sauer K, Karkee R, Zhao Y. Factors associated with small size at birth in Nepal: further analysis of Nepal Demographic and Health Survey 2011. *BMC Pregnancy Childbirth* 2014; **14**: 32.
10. Channon AA. Can mothers judge the size of their newborn? Assessing the determinants of a mother's perception of a baby's size at birth. *J Biosoc Sci* 2011; **43**(5): 555-73.
11. Kyu HH, Shannon HS, Georgiades K, Boyle MH. Caesarean delivery and neonatal mortality rates in 46 low- and middle-income countries: a propensity-score matching and meta-analysis of Demographic and Health Survey data. *Int J Epidemiol* 2013; **42**(3): 781-91.