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Spatial dependence in fertility and related factors in Cote d'Ivoire: A cross national analysis of census data, 2014

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ABSTRACT: Diffusion of fertility control is recognized as one of the main factors that contribute to reduce fertility, particularly, in low-income countries. However, in Sub-Saharan Africa characterized by poverty and high fertility, little research has been conducted on this topic. This article contributes to improve the knowledge of the determinants of fertility by considering both structural factors and *aggregate pattern of spatial behaviour*. We measure spatial dependence in fertility and related factors, and then assess the diffusion effect of fertility behaviour across 518 administrative divisions based on Cote d'Ivoire census data conducted in 2014. We found out that spatial diffusion in fertility is statistically significant after controlling structural characteristics of women, which means that women shaped their demand for children based on their own characteristics and the influence of ideas, informations related to fertility control. By comparing areas of residence, we found that urbanization, employment and exposure of media (television/radio) were more significant in areas with the lowest child-woman ratio than in areas with the highest fertility rate. Considering spatial concentration of women's characteristics, the lowest cluster of female employment, educated women, women living in cities, household that owned radio/television were registered in areas with the highest child-woman ratio. However, these areas have the highest concentration of married women, who were likely to share conservative values of having many children.

KEYWORDS: Fertility diffusion, Spatial diffusion, Neighborhood effects, Child-woman ratio, Spatial dependence.

1 BACKGROUND

1.1 INTRODUCTION

In recent years, Cote d'Ivoire has experienced a (steady) fertility decline. This decline intensified after the implementation of family planning programs in the 1990s [1]. However, during the first decade of the twenty first century (2002-2011), political upheaval in Cote d'Ivoire resulted to a deterioration of socio-economic conditions of its population, most importantly, women. As consequence, women migrated massively to the capital city Abidjan, to the western areas of the country in cities such as Duekoue, Guiglo, Blolequin, Man, Touba, and to south-central (Yamoussoukro), east (Bondoukou) and east-central towns (Prikro) [2]. This decline in socioeconomic conditions affected health institutions widening further, economic development difference between high and low fertility areas. In Cote d'Ivoire, the northern region is considered as a low economic development area with the highest fertility rates compared to the more economically developed southern area with a low fertility rate.

Even though, Cote d'Ivoire has recorded good economic performance within west-Africa countries since years, its modern contraceptive prevalence estimated to 14% in 2012 [3] and 20,9% [4] was under the national target for contraceptive prevalence rate estimated to 36% in 2020 [5]. Limited services in the provision of family planning services, resulting in low availability of long-acting methods (female and male sterilisation, IUD, implant) and limited distribution of contraceptives at the community level may justify the low contraceptive rate in Cote d'Ivoire [5].

While fertility levels of most developing countries in Asia and Latin America have declined quickly, most Sub-Saharan African countries were characterized by a slow pace in fertility change [6]. In overall, the slow pace of fertility transition in Sub-Saharan Africa is linked to economic slowdown[1] [6]. At the national level, we assumed that regional variations in fertility could be attributed to the slowdown of development indicators, weight of cultural heritage, interest in family planning by political leaders as well as factors of diffusion of reproductive behavior [7]. In Cote d'Ivoire setting, regional variations related to factors of differentiation between the regions with high fertility and those with low fertility, were accessibility to education and health service, living conditions of the populations, availability of health and social infrastructures including communication infrastructure, transport infrastructure and job-providing infrastructures [3]. In addition, regional variations in fertility may be due to factors related to the rate at which fertility declines [8].

European research (Princeton European Fertility Project) [9] on fertility decline in Europe has proposed a conceptual framework for the research on the dissemination of reproductive behavior within communities or in a large scale within regions. This conceptual framework, which takes into account diffusion mechanisms including associated factors, is indicative of the rate at which fertility declines [8].

1.2 Spatial Diffusion Of Fertility Behavior

Diffusion process leads to answer two central questions: "How does diffusion occur or how do diffusion ideas or innovations reach individual" and what is spread? What is diffused refers to the content of innovations and ideas related to fertility control behavior. The following contents of fertility diffusion are contained in what Cleland [8] qualified as "key elements in diffusion theory" namely "Innovation diffusion" defined by behavioral innovation and ideational theories related to fertility regulation. Behavioral innovation is the adoption of new behavior based on the use of "innovative birth control techniques and technologies, (…) heretofore unknown or rare" [10]. While ideational theories go beyond the simple practice of modern contraceptive by focusing on acquiring new knowledge about "family limitation, knowledge/attitudes/values about modern contraception, and ideas about family behavior (the roles of women and children) " [11]. It has been called "innovative demographic behavior" generated by the Second Demographic Transition observed in many advances societies and referred to the spread of non-marital cohabitation, divorce, illegitimate childbearing, and single parenthood [12]. This innovative idea is also related to the value and cost of children ([12], p.2) affected by the modernization of the society.

The second point of our literature review will focus on how the innovation-diffusion ideas and behavior spread among the population. In diffusion modeling, Reference [13] identified different processes of diffusion, carriers which may carry easily information and barriers which are susceptible to retard the flow of information across space and time. Either within or across geographical areas, diffusion processes by spreading ideas or innovation through (i) interpersonal communication in which information comes from a person or group of person and then spread through the all population over the time (Expansion diffusion). It may processes through (ii) personal contacts and then widespread quickly among the population (Contagious diffusion), or through (iii) geographical hierarchy from larger to small area or social hierarchy from higher to low social class (Hierarchical diffusion). Ideas or innovations are also spread through the movement of people across space (relocation diffusion). These different types of diffusion are combined in the diffusion process [13]. For instance, relocation diffusion may proceed by contagious or hierarchical ways while expansion diffusion may deal with contagious or hierarchical type ([13], p. 6). Reference [14] combined these types of fertility diffusion in what they called social learning and social influence. Social learning is defined as "the process through which individuals gain knowledge from others (through informal or formal social interaction, and including the mass media); and Social influence, the process through which some individuals exert control over others, by virtue of their power or authority" ([10], p. 14). In addition, distance and time consuming by the diffusion mechanism may influence the strength of diffusion process through a wave of innovation that losing intensity as the distance increases between geographical areas ([13], p. 11).

1.3 Study Objectives

Considering geographic variation of factors related to fertility, this study aims to first test the diffusion effect in fertility variations across geographical space. The second purpose of this study is to assess the regional differences in fertility by

[1] Measured by the gross domestic product (GDP) per capita, the percentage of the population having completed at least primary school level, life expectancy at birth and the percentage of population living in urban areas [6].

comparing structural and diffusion related factors. Structural factors are defined as women's characteristics and considered as potential diffusion factors when considering the spatial proximity of the localities sharing these features.

2 Material And Methods

2.1 Spatial Correlation Method

Spatial dependence refers to the relationship between areas and their neighbors. In this research paper, we aim to understand the relationship between areas (sub-prefectures) with their neighbors regarding their fertility level. We describe fertility expansion across space through spatial autocorrelation analysis based on spatial contiguity methods. Based on the First Law of geography (nearby areas are likely to have similar values), spatial autocorrelation measures the strength and direction of the relationship between the distribution of areas and their features values. Spatial correlation between features is considered positive if nearby features share similar aggregate values. Conversely, its value is considered negative if nearby features share opposite aggregate values. Spatial autocorrelation varies between -1 and 1; if its value is 0 there no spatial association between nearby features. The global spatial autocorrelation is measured by Moran's Index I test calculated from:

$$I = \left[\frac{n}{\sum_{i=1}^{n} (y_i - \bar{y})^2}\right] * \left[\frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(y_i - \bar{y})(y_j - \bar{y})}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}}\right]$$

Where, y_i is the feature value at spatial unit i, $\bar{y}$ is the mean of y, and w_{ij} is the spatial weight matrix based on queen continuity weights based on boundaries of the census geographic units. According to reference [15], the features' weights by boundaries[2] instead of distances were more appropriate to measure "spatial influence" assimilated (in this study) to the effect of spatial proximity on observed fertility. In the definition of the spatial weight matrix, i represents the spatial unit of interest and j the spatial unit considered as neighbourhood to i if w_{ij}=1 or not if w_{ij}=0. The spatial weight is resumed as following, where bnd (i) represents boundary of spatial unit i and bnd (j) the boundary of spatial unit j:

$$w_{ij} = \begin{cases} 1, \text{bnd(i)} \cap bnd\ (j) \neq \emptyset \\ 0, \text{bnd(i)} \cap bnd\ (j) = \emptyset \end{cases}$$

In order to identify spatial concentrations in which high features values are likely to cluster together (hot spots) or low features values cluster together (cold spots), we use Getis-Ord Gi (G) at global and local level (Getis-Ord Gi*).

Global G is given by:

$$\text{G}(d) = \frac{\sum\sum w_{ij}(d) x_i x_j}{\sum\sum x_i x_j}$$

$$W_{ij} = \begin{cases} 1\ 0 \leq d_{ij} \leq d \\ \ 0\ d_{ij} > d \end{cases}$$

x_i and x_j are respectively attribute value of features i and j.*d* is neighbourhood distance within a cluster is expected to occur. W_{ij} represents spatial weight matrix holding value 1 if j is within *d* distance and 0 if *d* is beyond that distance.

Getis-Ord Gi (G) value is related to its expected value[3]. Thus, if G is larger than its expected value, then we expected potential hot spots, and if G is smaller than its expected value, then we expected cold spots (see web site page) [4]. Getis-Ord Gi* identifies local hotspots by including x_i and all its neighborhoods values.

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[2] According to our point of view, in human relations, the neighbor can be near or far regardless of the distance separating the two neighboring peoples.

[3] $Expected\ value\ of\ G = \frac{Number\ of\ points\ (xi,xj) within\ d: \sum_i \sum_j w_{ij}(d)}{Total\ number\ of\ points\ in\ region\ under\ study: n\ (n-1)}$

[4] http://www.utdallas.edu/~briggs/henan/10SAglobal.ppt

2.2 MODELLING OF SPATIAL DIFFUSION OF FERTILITY

Spatial model aims to take into account spatial parameters in demographic events measurement. It is used to overcome the problem of spatial dependence of disturbance term often registered in standard linear regression. In fact, geographical factors may influence known demographic events occurring in geographical units. This influence that ordinary least square does not take into account is termed as disturbance term, which may come from geographical scale influences or spatial autocorrelation of dependent or independent variables [16].

Considering the disturbance term in linear regression leads to spatial regression model (spatial effects of disturbance, spatial-effects model). When the spatial autocorrelation in dependent variable was concerned, spatial-effects model in which "the values of the dependent variable in one spatial unit are systematically related to values of this variable in adjacent units" ([17], p. 223) is more appropriate. In the reduced equation, spatial-effects is addressed by:

$$y = \rho W y + X\beta + \epsilon \text{ (1)}$$

Where the value of y at an area depends upon the values of X at the area and y at surrounding areas, plus unmeasured values (ϵ) related to y.

In spatial analysis, distance is often used to normalize the cumulative values of y at surrounding areas based on first geographical theory that stipule near areas share quite similar values of y and further areas different values of y. To determine the normalized value of y at surrounding areas, geographers often used spatial weight that is the inverse of the Euclidean or straight-line distance between the areas i and its neighbors j. Thus, the value of y at surrounding sites j can be written as

$$\sum_{j\#i}^{n} \left(\frac{yi}{dij} \right) \qquad \text{i = 1, ..., n, with } dij \neq 0$$

The above function is so-called Generalized Population Potential that originally had been used in migration for spatial analysis. The generalized population potential is defined as the cumulative population values of proximity areas surrounding a given area [17]. Later, this variable has been used in other disciplines. In social science research, reference [17] used population potential variable as spatial behavior variable in their research upon social network-effects analysis. Considering the child/women ratio (CWR) as variable to be explained.

Thus, if yi = CWRi for area i

Then generalized-potential variable in child/women ratio in area i can be defined as:

$$PCWRi = \sum_{j\#i}^{n} \left(\frac{CWRi}{dij} \right) \text{ i} = 1, \dots, \text{n with } dij \neq 0$$

Where 1/dij represents the spatial weight between areas i and its surrounding areas j. Spatial weight can be defined as bandwidth in which the spatial influence in area i is expected to come from areas j surrounding i.

In this research, we considered immediate neighbourhoods as first-order spatial influence space. We expected the share of fertility control among populations living in the same cultural borders as well as those who are not living in the same cultural borders. Considering the first-order queen approach, spatial weight value is equal to 1 if area j shares the same border with the reference area i.

Equation (1) can be written by:

$$CWRi = \rho \sum_{j\#i}^{n} \text{CWRi} + \text{Xi}\beta + \epsilon\text{i}, \text{i} = 1, \dots. \text{n} \qquad (2)$$

ρ represents spatial effect regression coefficient

Child Woman Ratio at area i depends on characteristics of women (Xi) located in area i (Table 1 et 2) as well as value of Child woman ratio at its surroundings areas j. In spatial process, the underlying mechanism that may explain the level of fertility in a given area is based on simultaneous actions of dependent variable (CWRi) in a reference area and dependent variables

($\sum_{?}^{n}$ CWRi) at surroundings areas [17]. This led to the correlation between the dependent variable (CWRi) and an exploratory variable ($\sum_{?}^{n}$ CWRi); and then, the nonzero correlation between the dependent variable (CWRi) and disturbance term (ϵi). In consequence, equation (2) may produce spurious statistical inferences because independence assumptions between equation variables are violated. In Two Least Square Regression modelling, in order to produce non spurious coefficient regression (known as ρ, β and ϵ), we have to construct a new variable ŷ ($\sum \widehat{CWRi}$) to replace the y ($\sum_{j}^{n}$ CWRi) and then getting better estimator of spatial effect (ᵞ), effect β of characteristics of women and effect π of unmeasured variables related to factors which may influence fertility behavior at geographical level.

Thus, spatial effect on observed fertility is expressed as follows:

$$y = \gamma\hat{y} + \beta X + \pi$$

Table 1. Description of independent variables

Variable	Description
Sociodemographic	
Married women	Percentage of women of childbearing aged 15-49, who are married or living with their partner
Socioeconomic	
Women's employment	Percentage of women of childbearing aged 15-49, who are working at the period of survey, no matter if the labour is paid or not.
Female urbanization	Percentage of women of childbearing aged 15-49, who are living in urban area
Sociocultural	
Education	Percentage of women of childbearing aged 15-49, who attended at least Secondary/High school or University
Christian women	Percentage of women of childbearing aged 15-49, who have either beliefs of catholic, methodist, evangelical, or other christian religions
Media	Percentage of households that own a radio or television, and both of them
Ethnic group Akan	Percentage of women of childbearing aged 15-49, whom ethnic group is Akan

Table 2. Abstract of child-woman ratio and explanatory variables for all subprefectures, subprefectures of high cwr and subprefectures of low cwr

Variables	*All subprectures*	*Subprefectures of high cwr*	*Subprefectures of low cwr*
Child Woman Ratio (**children under 5 per 1000 women**)			
Median	831	872	733
Mean	817	869	712
Minimum	140	483	236
Maximum	1613	1613	1166
Standard deviation	161	135	168
% Urban women			
Median	25.23	24.38	33.42
Mean	29.27	26.41	39.96
Minimum	0.00	0.00	0.00
Maximum	100.00	100.00	100.00
Standard deviation	26.34	24.01	30.25
% Women attended secondary/university			
Median	6.59	4.58	13.85
Mean	9.90	6.35	17.74
Minimum	0.48	0.56	3.15
Maximum	62.21	29.34	62.21
Standard deviation	9.32	5.38	11.92

% Employment			
Median	37.27035	37.34416	36.95334
Mean	39.09682	39.75034	37.58777
Minimum	16.77432	25.29167	16.77432
Maximum	78.31177	78.31177	55.00391
Standard deviation	7.917581	8.775089	5.370153
Media			
Median	58.05	54.90	76.27
Mean	61.90	56.03	78.43
Minimum	11.60	14.36	33.84
Maximum	147.64	120.34	147.64
Standard deviation	23.74	19.69	25.66
% Group ethnic "Akan"			
Median	18.20	2.50	53.70
Mean	28.95	14.40	54.91
Minimum	0.00	0.00	13.41
Maximum	98.18	98.18	98.12
Standard deviation	31.17	24.80	22.55

Variables	***All subprefectures (with low and high fertility)***	***Subprefectures with High fertility***	***Subprefectures with Low fertility***
% Christian			
Median	35.03	24.27	51.19
Mean	33.84	23.45	50.59
Minimum	0.08	0.08	23.58
Maximum	90.87	72.97	90.87
Standard deviation	21.13	17.79	13.78
% Married women			
Median	69.62	74.06	62.18
Mean	68.36	72.57	60.70
Minimum	25.42	44.04	25.42
Maximum	89.18	89.18	76.95
Standard deviation	10.68	8.71	10.13

3 RESULTS

3.1 SPATIAL CLUSTERS WITH DIFFERENT FERTILITY LEVEL

Based on 517 areas (defined as administrative boundary of Sub-prefecture[5]) we recorded 46.58 kilometers as threshold radius in which neighbors' influence in fertility behavior occurs. This threshold distance ensures that every feature (county characterized by its fertility level) has at least one neighbor. We calculated spatial autocorrelation (Moran's Index= 0.407299) based on the given threshold distance and zone of indifference (spatial relationship definition). For zone of indifference, features inside the given distance scale (46.58 km) were equally considered while features which were outside this given distance scale were discarded. Spatial proximity index (Moran's I) indicated that nearby areas were likely to share similar values of fertility so that fertility values decreased as distance increased. In order to identify the distance scale of our analysis we run Incremental spatial autocorrelation tool. As result, spatial processes promoting clustering were most pronounced around 173

[5] Fourth administrative boundary following District, Regions and Department administrative boundaries

km. Hotspot analysis based on this distance scale exhibited high net fertility registered north-west and western and patterns of low net fertility were found in central-east and in Abidjan and its surroundings areas (Figure 1). Higher sub-prefectures fertility rate included high, moderate and low clusters of child-woman ratio while lower sub-prefectures fertility rate were characterized by low, moderate and high cluster of low child-woman ratio. The national park, not inhabited by populations, was not considered for data analysis. These results were confirmed by recent national survey [18] which registered the highest total fertility rate in north-west (6.7) and western areas (6.2) and the lowest total fertility rate in Abidjan (2.8) and surroundings areas (4.4).

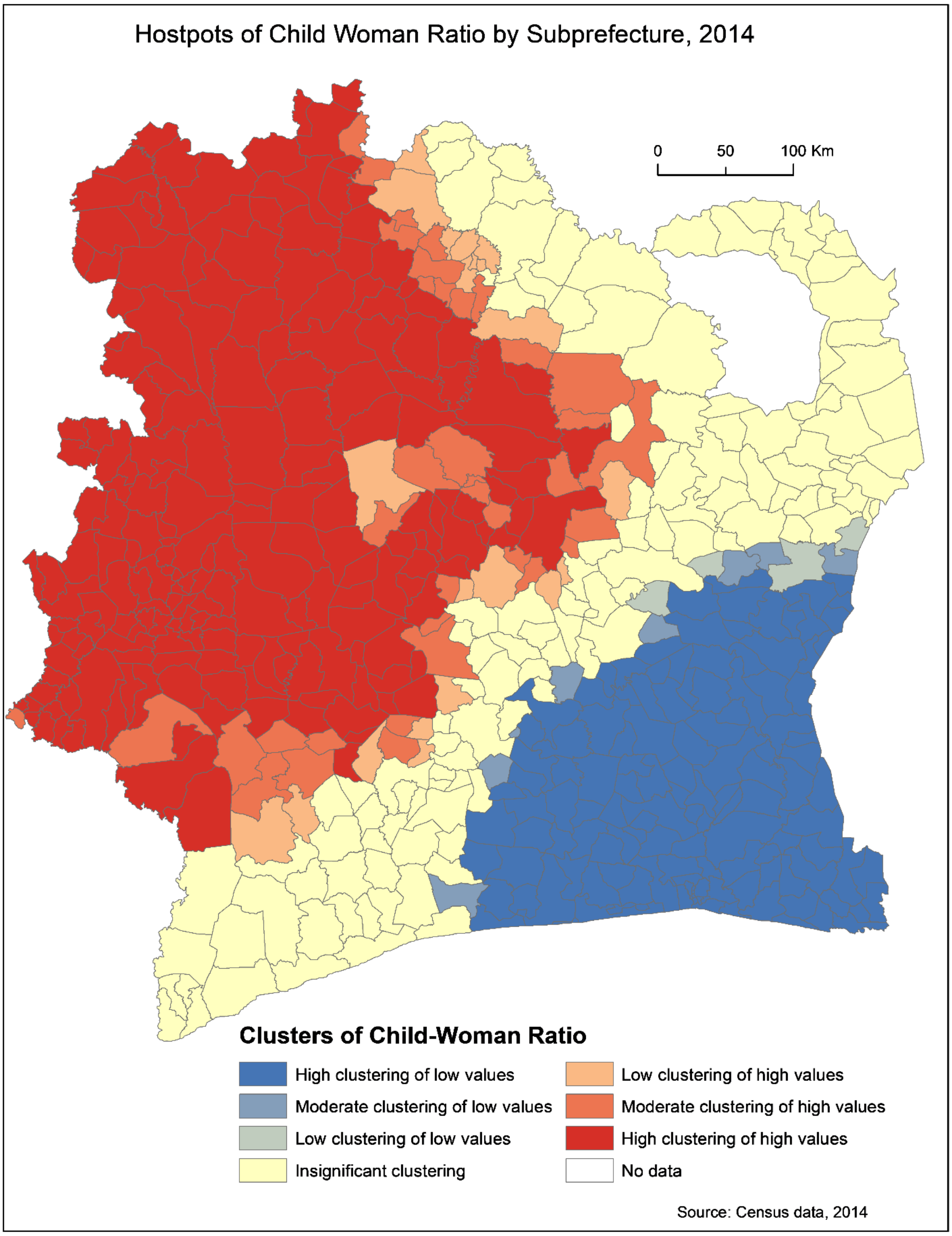

Fig. 1. Areas of high and low net fertility rate by hotspots analysis, 2014

3.2 Spatial Diffusion Of Fertility

The following analysis addresses issue of the relevance of fertility diffusion in Cote d'Ivoire. Diffusion effects were limited to neighbourhood, defined by first-order queen spatial contiguity. shows that the first stage equation has a better fit (Adjusted R^2 =.61) than the second stage equation (Adjusted R^2 =.59) indicating that exogenous variables explain 61% of the variability in net fertility potential. These results are consistent with the recommendations of Land and Deane [17]. The second stage equation exhibited diffusion effects throughout model 1 to 9 (Table 4).

The bivariate association between net fertility potential and net fertility was positive, strong and statistically significant, showing a given place and its surrounding neighbors tended to have similar fertility level. Location with high fertility level tend to be located in area where fertility level is high. Also, location with low fertility rate was located in area characterized by low fertility level. These results were consistent with fertility diffusion process by which fertility behavior was likely to spread across space independently other factors including economic development barriers. Fertility control behavior was expected to spread in areas with low fertility level. Non-birthcontrol behavior was not expected to diffuse but was considered as common habits acquired from the past. These habits may be viewed as traditional (versus modern) because they have been influenced by cultural conception of fertility and traditional methods of fertility regulation and may explain high fertility level in some sub-prefectures. The observed relation between net fertility potential and net fertility can be fallacious because this association may due to the effects of other variables. In the following models we controlled the effects of exogenous variables in relation to net fertility potential and net fertility to measure the diffusion effect.

After controlling all exogenous variables, net fertility potential remained positive and statistically significant, meaning that diffusion effect can be considered as a strong determinant of fertility (model 2). Model 2 indicated that education, female employment, ethnic group Akan and marriage as well as fertility diffusion effect were determinants of net fertility in Cote d'Ivoire. We were likely to find low net fertility in sub-prefectures characterized by great proportion of educated women, great proportion of women who are not married as well as in sub-prefecture that have high percentage of employed women. Woman urbanization was not a statistically significant determinant in net fertility unlike in other studies where authors have found out a significant contribution of urbanization to fertility decline ([19], [20]). Urban cities may have registered high proportion of mothers including their children during the period of political conflict. This situation could be explained by the numerous waves of population migrations [2] from rural areas to cities during the political crisis between 2002 and 2011 in Cote d'Ivoire. Consistent with diffusion process, low net fertility sub-prefectures such as big cities and urban sub-prefectures seemed to share fertility control ideas and behaviors with nearby neighbors (areas less hierarchical such as small cities, villages, countryside). High net fertility was likely to be found in sub-prefectures with less proportion of educated women, a great proportion of unemployment women and great proportion of married women. Sub-prefectures tended to have similar higher fertility level with their neighbors. Consistent with diffusion process, women living in those sub-prefectures seem to be less influenced by new ideas related to fertility control and associated advantages, and fertility control methods than their own preferences. Their fertility was more determined by their personal choice in accordance with their resources, economic, social and cultural conditions [21]. Contrary to our expectations, media (television, radio) penetration in household does not play a significant role in fertility regulation. Television and radio were expected to diffuse ideas related to new fertility behavior and its benefits. These messages in turn were expected to give more consistency to interpersonal exchanges and to influence personal fertility decision-making as well as community perception of fertility control. Ethnic group of "Akan" was a significant determinant of net fertility because most of this people were in the southern area where infant mortality was low. The number of surviving children under five increased the child-woman ratio among localities who registered high proportion of ethnic group "Akan".

Diffusion mechanisms were measured through model 3 to 9 after controlling for net fertility potential by each exogenous variable individually. We were interested to know which intermediate variable influence observed fertility. In general, partial effect of net fertility potential on observed fertility was observed. We expected media (television and radio) penetration in the household to have a significant influence on observed fertility, as informations related to fertility control spreading across space and time through media channels. However, the effect of the media was slight: (.869*** (model1) reduced to.756*** (model 6)) on the influence of net fertility potential on observed fertility (Model 6). We then assumed that in Cote d'Ivoire, the diffusion of fertility between areas (sub-prefecture boundaries) is more channeled through interpersonal exchanges through social networks rather than television and radio channels. Education and married status attenuated the influence of diffusion effect (Model 4 and Model 9) on observed fertility, while female urbanization, employment, ethnic group Akan and Christian religion (Models 3, 5,7) did not.

We concluded that in the particular context (Cote d'Ivoire) of "Africa effect" [6], diffusion process was relevant in fertility variations across space. Fertility variation was explained by both structural conditions and diffusion processes. In Cote d'Ivoire, women shaped their demand for children based on their own structural characteristics and the influence of ideas, information related to fertility control from surrounding local populations [22].

Table 3. Second-Stage (Weighted) Least Squares Unstandardized Coefficients for Regression of area-Level Net Fertility for all areas (517 subprefectures)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Net Fertility Potential	.869*** (.049)	.392*** (.076)	.824*** (.063)	.394*** (.077)	1.010*** (.065)	.756*** (.071)	1.026*** (.070)	1.000*** (.077)	.653*** (.074)
% Urban women		-.032ns (.022)	-.180*** (.021)						
% Women attended secondary/university		-.777*** (.112)		-.966*** (.073)					
% Employment		-.002*** (.001)			-.001ns (.001)				
Media		.010ns (.028)				-.191*** (.026)			
% ethnic Group "Akan"		.060*** (.021)					.015ns (.020)		
% Christians		.065* (.035)						-.017ns (.032)	
% Married women		.369*** (.072)							.581*** (.061)
Intercept	.119*** (.040)	.374*** (.089)	.208*** (.053)	.596*** (.068)	.049ns (.060)	.328*** (.067)	-.011ns (.059)	.020ns (.069)	-.14** (.046)
Adjusted R^2	0.377	0.598	0.400	0.557	0.32	0.396	0.317	0.33	0.472

*Significance Level: *** <.001 ** <.05 * < 0.1*

Table 4. First-Stage Least Squares Unstandardized Coefficients for Regression of area-Level Net Fertility for all areas (518 subprefectures) (Standard Error of Unstandardized Coefficients in parentheses)

Intercept	***-3.504*** (.426)***
% Urban women	.052*** (.016)
% Women attended secondary/university	-.284*** (.081)
% Employment	.000ns (000)
Media	.013ns (.023)
% Group ethinic "Akan"	-.013ns (.020)
% Christian	-.044ns (.030)
% Married women	.041ns (.058)
NorthWest[a]	-6.48*** (.625)
North[a]	-7.966*** (.761)
NorthEast[a]	-3.624*** (.338)
CentralEas[a]	-3.585*** (.334)
Center[a]	-3.716*** (.355)
CentralWes[a]	-.392*** (.038)
West[a]	-4.160*** (.400)
SouthWest[a]	-.087*** (.022)
Sud[a]	-1.766*** (.157)
infantmort	58.529*** (5.635)
logpop	.011ns (.011)
N	517
Adjusted R2	0.606

[a] The reference category for regional area variables is CentralNorth
*Significance Level: *** <.001 ** <.05 * < 0.1*

3.3 FACTORS RELATED TO HIGH FERTILITY

Education and marriage were two key determinants of observed fertility as they significantly decreased neighborhood effects in fertility diffusion (Table 4). Urbanization and media also contributed to the descrease of diffusion effect but not significantly. Education was a crucial determinant in the high fertility area as well as in the lower fertility area (see regression coefficient) (Table 5). It was the same case for marriage. Even though it was not statistically significant, female urbanization seemed to have more effect on fertility in sub-prefecture with low net fertility value (ß = -.029ns) than in areas with high net fertility value (ß = -.005ns). However, the later results remain to be verified with larger samples. Media penetration in the household appeared to have more impact on reproductive behavior in areas of low fertility (ß = -.012ns) than in high fertility areas (ß =.055ns). Larger samples may confirm this reality discover in other studies. Overall, Christian religion did not contribute to the decline in fertility in both regions. This result was less rigorous because individual data indicated that fertility was reduced among Christians compared to other religions in Cote d'Ivoire [20]. Employment contributed slightly (ß=-.003) fertility decrease in overall areas and especially in sub-prefecture with higher fertility (ß=-.004). In addition, all these variables were unable to explain observed fertility in sub-prefecture with higher fertility rate (adjusted R2 = 31.2%) while in sub-prefecture with low fertility they explained 76.1% of the variance in fertility. This suggests that specific factors, apart from those used in this study, underlie fertility behavior in subprefectures with high fertility.

We assess the relevance of fertility diffusion by using bivariate instead multivariate analysis because the sample size of subprefectures (N=138) with low fertility was under the required sample size (200 and more) [17].The correlation between net fertility potential and observed fertility indicated that the relationship was stronger in regions of low net fertility values compared to those of high net fertility values (see regression coefficient in Table 5). This result suggested that the fertility control behavior may be spread easier within areas with low net fertility than in those with high net fertility, without controlling for other factors related to fertility. Considering spatial proximity of factors related to fertility behavior, we observed that spatial clustering of women's urbanization was more important in areas with low-fertility (Moran's I = 0.37) than in area with high fertility (Moran's I=.03ns) (Table 6). Clustering of education and media penetration were strong and statistically significant in subprefectures with low fertility than in other areas. These findings confirm that subprefectures with low fertility were most located in areas with high income most urbanized, registered a great concentration of secondary and high school as well as industrial factories, public services and Small and medium-sized enterprises (SMEs). However, married women were more clustered in subprefectures with high net fertility level than in sub-prefectures with low net fertility.

Table 5. Estimates of the regression of child-woman ratio, by subprefectures with high and low fertility, 2014

Characteristics of subprefectures	*All subprefectures (with low and high fertility)*	*Subprefectures with High fertility*	*Subprefectures with Low fertility*
% Urban women	-0.016ns	-.005ns	-.029ns
% Women attended secondary/university	-.968***	-1.282***	-.921***
% Employment	-.003***	-.004***	.000ns
Media	-.009ns	.055ns	-.012ns
% Group ethnic "Akan"	.066***	.056ns	.069ns
% Christian	.027ns	.153**	.170**
% Married women	.412***	.342***	.361***
Intercept	.715***	.785***	.553***
N	*517*	*253*	*138*
Adjusted R^2	.553	.312	.761
Correlation with Net Fertility Potential	.615***	.459***	.666***

*Significance Level: *** <.001 ** <.05 * < 0.1*

Table 6. Moran's Index of fertility related factors in subprefectures with high and low fertility

Variables	*Subprefectures with High fertility*	*Subprefectures with Low fertility*
Child Woman Ratio	.26***	.44***
% Urban women	.03ns	.37***
% Women attended secondary/University	.17***	.50***
% Employment	.16***	.27***
% Household own a Radio/Television	.35***	.65***
% Group ethnic "Akan"	.77***	.71***
% Christians	.78***	.37***
% Married women	.44***	.35***

*Significance Level: *** <.001*

4 DISCUSSION AND CONCLUSION

Spatial dependence decreased as distance increased. This is in line with fertility diffusion process [12]. Cross-sectional analysis of fertility at the sub regional level in Cote d'Ivoire confirmed the importance of the diffusion effect on fertility behavior among factors associated with fertility as has been observed not only in developed countries ([12], [22], [23], [24]), but also in developing countries ([25], [26], [27], [28]). In Cote d'Ivoire, the decrease in fertility in 2014 was probably due to (i) the decline in household income[6] [41] likely to increase the economic cost of children, (ii) increasing age at marriage [29], (iii) the (limited) offer in family planning [30] as well as (iv) the diffusion of family planning ideas, behavior and attitudes through the channel of social interaction between areas. Fertility control related ideas or information seemed to be spread across space by the means of interpersonal communication and less by radio or television channel. However, reference [22] in his research on fertility diffusion within counties in the American South, found that the media channel was the main driver of fertility diffusion among fertility associated factors. In Cote d'Ivoire, the role played by television and radio in promoting family planning practice had decreased in 2014 [3]. According to the national survey report [3], the percentage of women of childbearing age who had never heard of family planning was estimated to 73.2% for radio, television and newspapers. This means that much effort needs to be invested in family planning awareness through the media. As a result, this could result to the diffusion of ideas concerning fertility control in the country. Also, research concerning interpersonal relationships (included with the community interactions, institutions, etc) need to be carried out to highlight the diffusion of family planning ideas.

Structural factors associated with fertility at sub-regional level were education, female employment, ethnic group Akan and marriage. Studies using individual data have found these factors to be significant among socio-economic determinants of fertility in Cote d'Ivoire [20]. Regions with high fertility were less influenced by female urbanization, employment and penetration of media in household. In addition, factors such as spatial concentration of educated women, urban women, and household members of radio/television were found to be weak in areas of high fertility compared to those observed in areas of low fertility. However, high-fertility regions had a high concentration of married women who were likely to have conservative views of having many descendants.

However, we could not come to a conclusion whether diffusion effect or structural characteristics determined fertility decline in Cote d'Ivoire due to the kind of data we used. Indeed, cross-sectional data, even though reference [22] has argued that the data has shown some influence of diffusion factors to observed fertility change. Aggregate data could also produce results that do not match those given by individual data. Reference [13] warned that in the diffusion process, as the geographic scale increases, individual effects, often heterogeneous, are camouflaged by homogeneous group effects: "As we move further up the cone of resolution and examine diffusion processes at larger geographic scales, we tend to blur and smooth individual effects by lumping many human decisions together" ([13], p. 41).

[6] The average income of households decreased from 461,243 FCFA in 2002 to 386,215 FCFA in 2015 (Standard of living survey)

NOTES

TWO-STAGE LEAST SQUARE REGRESSION (2SLS)

The method of Two-Stage Least Square is derived from the Ordinary least square model and aims to highlight causal relationships (1) that can be observed in a unidirectional or multi-dimensional sense. This method has had many successes in psychology [31], econometrics [32], and Sociology ([33], [17]) and consists to determine non-biased coefficients regression in case of existing correlation between the independent variables. Two-stage least squares (2SLS) model holds under same statistical errors assumptions (normality[7], homoscedasticity[8] and independence[9]) as Ordinary least square regression. In 2SLS endogenous and exogenous variables are respectively defined as variables to be explained and causes of dependent variables. Exogenous variables can be measured based on current value (non-lagged) or past period value (lagged) [31]. Instrument variables (2) are considered as all potential variables able to control influence (on exogenous variable) due to disturbance term (i.e., omitted variables, measurement error, or other sources of simultaneity bias) in a regression model. Two-stage least square model is a simultaneous of two Ordinary Least Square (OLS) regressions. The first OLS is a linear function of the endogenous variable (correlated with other exogenous variable) and instrument variables including other exogenous variables. This equation produces structural estimated parameters often biased, plus a disturbance term. The second OLS is expressed by second endogenous variable (variable of interest) and exogenous variables excluded instrument variables. The latter model is defined as the best linear regression because it yields better-estimated parameters than the first OLS [32]. In addition, 2SLS estimated parameter even though may be biased under small sample data [17] had been proved better estimation than maximum likelihood (ML) estimators ([34], [17]) in spatial effect (3) analysis. This is why 2SLS model will be used to point out the influence of spatial effect in fertility variations.

STRUCTURAL EQUATION MODELLING CAUSAL RELATIONSHIP BETWEEN NET FERTILITY AND NET FERTILITY POTENTIAL

Spatial interaction of flow of fertility control information/methods between areas and within social framework consists of modeling causal relationship between net fertility (CWR) and net fertility potential. Theoretically, net fertility potential is suggested to be a causal effect of net fertility, and vice versa. Net fertility causing by net fertility potential shows how a given area may influence the level of fertility of its surrounding areas. Specifically, we can assume that big town may influence fertility level of small town or close villages through diffusion process of fertility control. On other hand, net fertility potential causing net fertility may influence fertility practices in the nearby area [35]. In our case, testing for these hypotheses was biased because the correlation estimator value, often used, could not confirm whether the causal relation was due to net fertility or net fertility potential. The causal relation between the two endogenous variables could provide reciprocal relation between net fertility and net fertility potential, or a false relationship (due to unmeasured variables) between net fertility and net fertility potential [31].

In order to understand the effect of net fertility potential, we considered one direction of the causal relation mentioned above. We assumed that net fertility potential was a spatial effect variable influencing net fertility at a given area. We found a positive statistically significant correlation[10] value (r=.61) between these two variables. In this causal relationship net fertility and net fertility potential represented endogenous variables and their respective covariates. These exogenous variables were urbanization, education, employment, ethnicity and mass media penetration ([36], [37], [38], [39], [20]). However, these endogenous variables may not be perfect measure given the nature of the data [40]. Thus, this leads to a measurement error in the sense that endogenous variable, may be correlated amongst themselves. In addition, net fertility measured at aggregate level may not be accounted for as well as unmeasured factors associated with fertility (e.g., family planning policies, family planning programs, health facilities, historical and geographic settings, and so on.). Measurement errors in aggregate characteristics (exogenous variables) of women and unmeasured variables associated with net fertility in a given area represented disturbance term associated with net fertility.

[7] Error terms values are expected to have a value of zero mean
[8] Errors terms should have the same variance
[9] Errors terms should be not correlated to the dependent and independent variables
[10] Pearson correlation at .01 level

Choice Of Instrument Variables

We select instrumental (region, population size, infant mortality) variables according to requirement set by reference [31] as basic assumptions of Two-stage least square. Instrument variables are expected to be correlated with net fertility potential but are simultaneously not associated with unmeasured causes of net fertility. In details,

The instrument variable is a significant direct or indirect cause of Net fertility potential: Net fertility potential can be considered as an "*aggregate pattern of spatial behavior*" [13]. It represents a regional level of fertility. Regional level of fertility may be linked to the multilevel of independent variables such as aggregate sub-national factors (region, population size, infant mortality) or individual factors.

The instrument variable does not affect net fertility directly. While region and population size do not affect net fertility directly, infant mortality measured at regional level does. Infant mortality is associated with fertility behavior but the strength of this relation varies by geographical level in which the relation is measured. Thus, regional infant mortality may have better significant coefficient correlation with net fertility potential than with net fertility observed at the area.

The instrument variable is unrelated to the unmeasured causes of net fertility: Region, population size and infant mortality do not meet this requirement. The fact that net fertility and net fertility potential are linearly correlated, it become difficult to separate unmeasured causes of net fertility to net fertility potential, and vice versa.

The instrument variable is not caused by either net fertility potential *and* net fertility: regional variable and population size do not result from fertility behavior. However, population size in each area does not only result from fertility level, but also from migration and mortality.

Variables of region and population size do not meet perfectly all the requirements mentioned above. However, in the case of spatial or network-effects, reference [17] stated that they are valuable instruments because: " The fact that potential variables will often capture regional or population size effects on generalized potential variables suggest that these (population size and belonging to region) are useful instrumental variables for entry in the first-stage regressions" ([17], p. 242). Infant mortality which is a regional variable may also capture regional effect of infant mortality on generalized potential variable (Net fertility potential). Thus, it can be also a great instrumental variable in the case of this research.

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