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Government expenditure on health and maternal mortality in México: A spatial-econometric analysis

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Summary

Objective: To assess the relationship between government expenditure on maternal health (GE) and maternal mortality (MM) in Mexican poor population between 2000 and 2015 in the 2457 Mexican municipalities.

Methods: Using administrative data, we performed the analysis in three stages: First, we tested the presence of selection bias in MM. Next, we assessed the presence of spatial dependence in the incidence and severity of MM. Finally, we estimated a spatial error model considering the correction of estimates for the spatial dependence and selection bias assessed before.

Results: MM and GE were not randomly distributed throughout the Mexican territory; the most socially vulnerable municipalities exhibited the highest levels of MM severity but the lowest levels of GE and available human and physical resources for maternal health; the incidence of MM was independent of GE; elasticity of GE-severity in MM was −4% ($P < 0.01$).

Conclusions: Resource allocation for maternal health must move towards a more comprehensive vision, and efforts to achieve an effective delivery of universal health services must improve, particularly regarding the most vulnerable municipalities.

KEYWORDS
government expenditure, maternal health, primary health care, spatial econometrics

These authors contributed equally to this work, and shared first authorship

1 | INTRODUCTION

Several studies have demonstrated that reducing maternal mortality (MM) depends largely of the reorientation and targeting of financial resources towards greater equality, accessibility, and quality in health services.[1-3] Most MM cases are preventable via effective access to health services before, during, and after childbirth.[4] Greater health expenditure—if it translates into greater resource availability—is expected to lower barriers to health services and, in turn, would have a favorable impact on health.[5-7] Increases in government expenditure have a greater impact on reducing child mortality and MM than the equivalent percentage increases in education, roads, and sanitation.[8] At a national level, health care expenditure per capita is a key factor in predicting MM[9,10]; however, studies assessing this association have not been performed in México and other middle-income and low-income countries.

Worldwide, numerous initiatives have been undertaken and considerable financial resources spent to reduce MM to its minimum. Nonetheless, it remains an unsolved and urgent task facing health care systems, particularly those of middle-income and low-income countries.[11,12] In México specifically, the System of Social Protection in Health (SPSS by its Spanish acronym), along with its main financial arm, the Seguro Popular de Salud or SP,[13] is the most important financing mechanism implemented in recent years for providing health care to the population without Social Security coverage[14] and their families representing around 45% of the total Mexican population[13] encompassing a broad range of populations mainly provided by the Ministry of Health services and covered by SP. The SP is a subsidy transfer instrument aimed at improving the accessibility, quality, and use of health services through a health service package free at the point of delivery.[15,16]

Since its inception, the SP has pursued improved maternal health as a top priority. Proof of this is the inclusion of MM interventions in its Universal Catalogue of Health Services or CAUSES by its Spanish initials,[14,17-19] which guarantees, among others, the antenatal and postnatal care, detection and referral of high-risk pregnancies, institutional childbirth services, diagnostic tests, medicine, and vitamin supplements.

The SP has sought close coordination with specific maternal health programs committed to reducing MM, namely the Fair Start in Life Program[20] and various inter-institutional agreements (ie, the Healthy Pregnancy Strategy, and the General Agreement on Inter-Institutional Collaboration for Emergency Obstetric Health Care, both established in 2008). Funds were allocated to finance these actions so maternal health expenditure increased 2.5 times between 2003 and 2014.[15] Notwithstanding the above, progress in reducing MM—particularly in the Mexican population without Social Security coverage—has been slow, and much remains to be done.[21] In México, seven out of every 10 women who die from MM-related causes lack Social Security coverage.[22] Furthermore, MM is a phenomenon concentrated in specific parts of the country and is closely associated with poverty.[23,24]

The relationship between government expenditure and MM has scarcely been studied owing mainly to the difficulty of identifying government expenditure on maternal health (GE) in a timely manner. While relevant literature indicates that such a relationship exists,[25] its magnitude is as yet uncertain.[9,26,27] In México, there is a dearth of literature dealing specifically with the relationship between maternal health indicators and the growth in public financial resources ensuing from the establishment of the SPSS. The one study published on the subject suggests an inverse association between government expenditure on health and the MM ratio.[28] However, this study was subject to several limitations: (1) it analyzed government expenditure on health in the 32 Mexican states in general; (2) it did not address intra-state heterogeneity in the pattern of expenditure, the spatial dependence of MM in the data analyzed, or the resulting bias in the reported relationships[29]; and (3) it did not consider the possibility of differential processes in MM incidence and severity (the distribution of the MM ratio among the geographical areas registering MM) because of the structural conditions mentioned above.[30]

Taking the foregoing into account, our study formulated its analytical strategy on the following bases: data were confined to GE for the population without Social Security coverage and were drawn from the Reproductive

Health and Gender Equality Accounts for the period 2003 to 2014[15]; the GE-MM relationship was estimated for the 2457 Mexican municipalities using Heckman self-selection bias correction[31] combined with spatial econometric analyses[29,32] that explicitly incorporated the aforementioned self-selection problem and non-random territoriality in the expenditure patterns, health investment, and MM in México.[20,30]

TABLE 1 Variables analyzed and sources of information

Variable	Operational Definition	Source	Year(s)
Endogenous			
Maternal mortality ratio	Total number of maternal mortality cases per 10 000 live births (population without Social Security coverage)	National Health Information System	2000-2015
Incidence of maternal mortality	Municipalities recording at least one maternal death	National Health Information System	2000-2015
Severity of maternal mortality	Maternal mortality ratio in those municipalities where such deaths occurred	National Health Information System	2000-2015
Exogenous			
Government expenditure on maternal health	Budget (accumulated 2003-2014) allotted by federal and state-level governments for activities supporting maternal health in the population without Social Security at the municipal level (per woman ages 10-54)	Reproductive health and gender equality accounts	2003-2014
Control			
Population without Social Security coverage	Percentage of Mexican population without Social Security coverage	Population and Housing Census	2000
Rurality	Average percentage of the total Mexican population living in rural areas		2000
Indigenous population	Percentage of population (men and women) five years old or older speaking an indigenous language		2000
Population without schooling	Percentage of the population (men and women) $\geq$5 years old without schooling or solely with pre-school education		2000
Marginalization index for population without Social Security coverage	Numeric value expressing the degree of overall marginalization in the municipalities	National Population Council	2000
Fertility	Average number of live births per woman $\geq$12 years old		2000
Affiliation with *Seguro Popular* (SP)	Percentage of women lacked social security enrolled in SP	System of Social Protection in Health	2003-2015
Health resources in terms of hospital facilities belonging to the Ministry of Health	Δ% 2001-2015 of the index of available hospital resources	National Health Information System	2001-2015
Health resources in terms of outpatient units belonging to the Ministry of Health	Δ% 2001-2015 of the resource index for outpatient care		2001-2015
Socio-demographic profile of women with live births, without Social Security coverage	Age and schooling		2015
Coverage for maternal health interventions (women without Social Security coverage)	Antenatal care, childbirths attended by medical staff, and health care provider		2015

2 | METHODS

2.1 | Settings

We performed an ecological analysis of the 2457 Mexican municipalities. The study population included women between ages 10 and 54 without Social Security coverage (either enrolled in SP or with no health insurance). Data analyzed were drawn from administrative sources and from official statistical records. Table 1 shows the definitions of the variables analyzed and their respective sources of information.

2.2 | Analytical variables

Following previous studies,[23,33] we calculated the annual municipal MM ratio and according to place of residence. Estimates were obtained by dividing the number of women (between ages 10 and 49) without social security coverage who died as a result of gestation by the number of live births. We took into account (1) deaths occurring during pregnancy, childbirth, or in the 42 days after delivery either for a reason related to or aggravated by pregnancy or as a result of the care received during that period; and (2) deaths occurring after childbirth, owing to sequelae or to other indirectly related causes. Because the MM ratio indicator was constructed at the municipal level, we rescaled the number of live births to 10 000. Based on this indicator, we defined two variables: the first, which identified the incidence of MM at the municipal level (N = 1957), was expressed in binary terms; the second, which identified the severity of MM, also at the municipal level, was defined as the distribution of the MM ratio among the municipalities presenting at least one case of MM (N = 301), and was expressed in terms of a natural logarithm.

The independent variable was GE earmarked for women without social security coverage between 2003 and 2014 (expressed in 2014 prices). This variable, operationalized by woman (between ages 10 and 49) without Social Security coverage, was obtained from the Reproductive Health and Gender Equity Accounts. As expenditure was originally reported in these sources at state level, we calculated the amounts to the municipal level (our analysis unit) using the SPSS regulatory approach, whereby the Federal Government transfers funds to the state-level Ministries of Health (SSA by its Spanish acronym) according to the number of their SP affiliates.[18,34,35]

Excluded from analysis were municipalities created after 2000 (n = 14) as well as those without full information in the indicators used to control for the relationship of interest (n = 185), such as rurality, marginalization, the presence of indigenous population[20,36]; female schooling[37]; fertility[38]; age structure of the female population; available human and material health care resources[39]; profile of women who died from maternal causes (socio-demographic characteristics and health care received); and timeliness and frequency of antenatal health care coverage at the municipal level (see details in Table 1). The final sample of municipalities analyzed came to 2258 (92% of the total number of municipalities in México).

To measure the availability of health care resources, we constructed a continuous index for the period 2001 to 2015 using a principal components analysis.[40] The index included resources in terms of hospital facilities and equipment (including the number of hospital facilities, physicians and nurses in contact with patients, hospital beds, operating rooms, and ultrasound equipment); and resources in terms of outpatient care (including the number of outpatient consultation units, physicians, nurses and medical students in contact with patients, and delivery rooms) in SSA health care facilities. The index was expressed as percent change (2015-2001).

2.3 | Exploratory analysis

First, we performed a non-spatial exploratory analysis of data using the Stata MP v13.1 statistical package.[41] We estimated the statistical dispersion and central tendency of the municipal variables considered. Analyses were complemented not only by an assessment of the bivariate correlation of the variables of interest but also by a description of the evolution of the probability of GE and of MM incidence and severity, from 2000 to 2015 at the municipal level.

In order to identify whether the incidence and severity of MM were spatially dependent on accumulated GE from 2013 to 2014, we performed an exploratory spatial data analysis (ESDA). We specifically estimated Moran's *I* global spatial correlation coefficient (univariate and bivariate).[42] The estimate, based on the location and values of the attribute in question (ie, maternal health expenditure), served to assess whether the resulting pattern was clustered territorially, scattered, or randomly distributed. Analyses considered a spatial weights matrix based on the five nearest neighbors ($k = 5$), as this was the number of neighbors that maximized spatial correlation. The *P* value used to assess Moran's *I* statistical significance was determined after performing 999 permutations with GeoDa statistical software.[32]

2.4 | Econometric analysis

We performed the econometric analysis in three stages. First, we tested the presence of selection bias in MM. Next, we assessed the presence of spatial dependence in the incidence and severity of MM. Finally, we estimated a spatial-econometric model considering the correction of estimates for the spatial dependence and selection bias characterizing the endogenous (in 2015) and exogenous (accumulated GE from 2003 to 2014) variables.

In the first stage, we followed the Heckman approach.[31] We began by estimating a probit model in order to calculate the adjusted probability of a municipality registering at least one case of MM. This equation is known as a selection equation. The model was constructed together with a maximum likelihood estimation and was adjusted for the characteristics of the municipality (in 2000) and of the socio-demographic profile (also at the municipal level) of the women who had registered at least one live birth (in 2015) (Table 1). We verified the presence (*rho* = −0.55, *P* = 0.01, results not shown) and estimated the magnitude of selection bias based on this model.

Having these results available, we turned to the second and third stages of analysis using a bottom-up approach, from the particular to the general, as proposed by Anselin.[32] We first estimated non-spatial models (for the incidence and severity of MM) using ordinary least squares, then we assessed the presence and type of spatial dependence in the data via Moran's *I*, Lagrange multipliers in spatial error and lag, and the Robust Lagrange Multiplier. We set out the following general specification for municipality *m*[43,44]:

$$Y_m = \rho W Y_m + \alpha i_m + X_m \beta + \theta W X_m + \mu_m \ \text{ with } \mu_m = \lambda W \mu_m + \varepsilon_m$$

where *W* represented, the spatial lag matrix was used to weight the estimates according to municipal proximity[43,44]; β was the vector of parameters associated with municipal characteristics; and ρ, θ, λ were the parameters tested in order to identify the type of spatial dependence existing among variables. Model selection was thus determined through hypothesis testing on ρ, θ, λ. In case $\rho = \theta = \lambda = 0$ became the non-spatial model. Appendix A shows the spatial autocorrelation test results: contrary to the severity (or outcome selection), the incidence (or selection equation) of MM presented non-spatial dependence. Furthermore, the best specification was the spatial error model ($\lambda \neq 0$ and $\rho = \theta = 0$). Hence, the severity model of MM was the following:

$$Y_m = \alpha i_m + X_m \beta + \lambda W \mu_m + \rho_m + \varepsilon_m$$

where Y_m and X_m represented MM severity and GE in municipality *m*; and ρ_m the selection statistical estimate obtained for municipality m in the first stage of the econometric analysis. To select the model, we used the *spatdiag* command in the Stata MP v13.1 statistical package.[41] The proposed model was estimated according to maximum likelihood using the *spmlreg* command in the aforementioned package. We analyzed the robustness of our estimates by varying the number of neighbors (k = 5, 8, 10, 12, and 15).

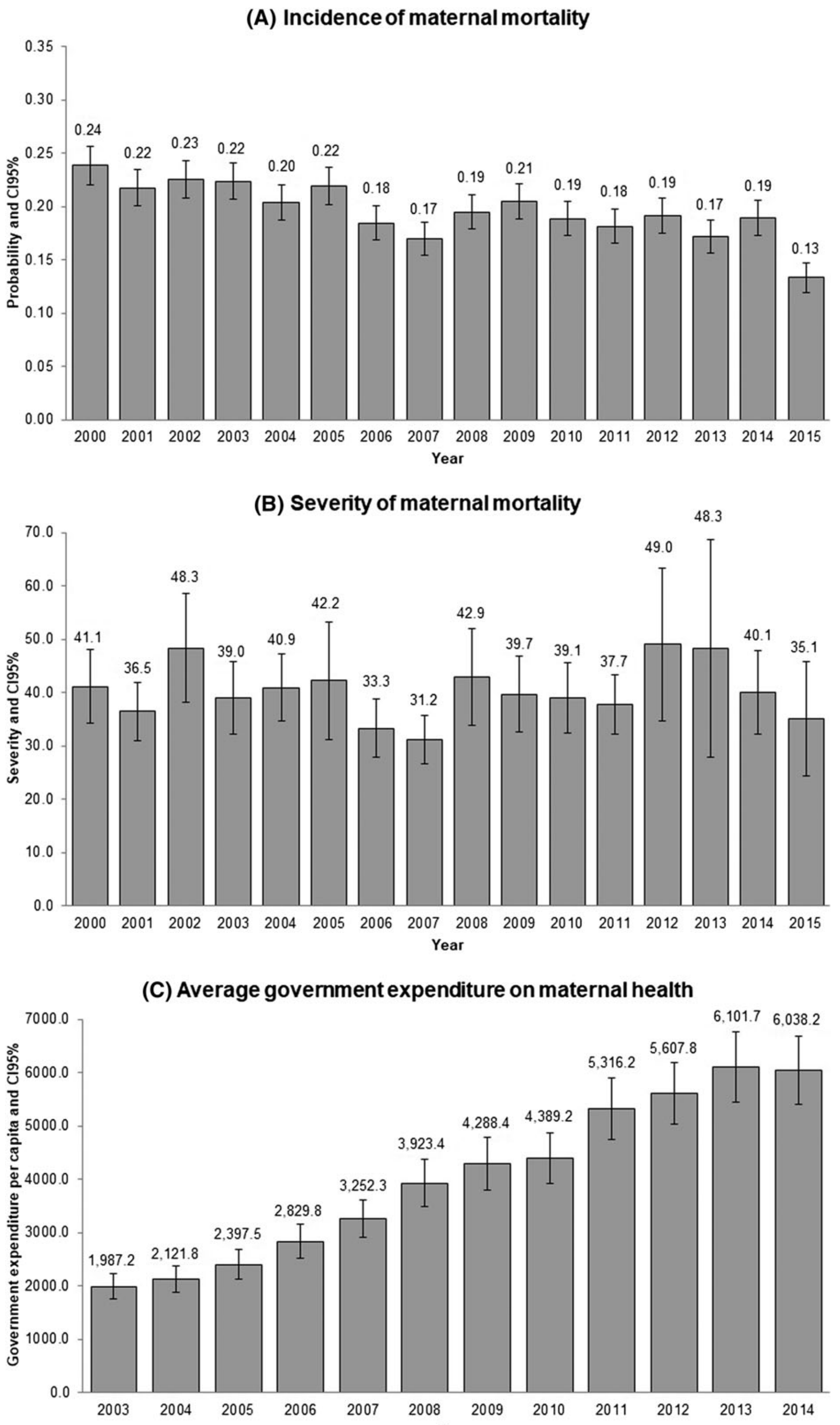

FIGURE 1 Evolution of the incidence and severity of maternal mortality at the municipality level, 2000 to 2015

TABLE 2 Principal characteristics of municipalities analyzed

N = 2258	Mean [Standard Error]
Characteristics in 2000	
Population without Social Security coverage[a] (%)	75.07 [0.39]
Rurality[b] (%)	60.98 [0.75]
Marginalization index (%)	41.70 [0.36]
Fertility[c]	3.14 [0.01]
Indigenous population[d] (%)	19.87 [0.67]
Affiliation with *Seguro Popular* health insurance (SP)[e] (%)	
2003	3.06 [0.24]
2006	31.11 [0.55]
2009	60.84 [0.51]
2012	87.22 [0.27]
2015	87.22 [0.31]
Available health resources[f]	
Δ% 2015-2001 of the index of available hospital resources	37.31 [2.90]
Δ% 2015-2001 of the index of available outpatient care resources	94.71 [12.85]
Socio-demographic profile of women with live births in 2015	
<20 years	22.85 [0.15]
20-29 years old	54.44 [0.16]
30-39 years old	20.82 [0.14]
≥40 years old	1.89 [0.04]
Without schooling	3.67 [0.12]
Elementary school	23.86 [0.27]
Junior high School	42.03 [0.24]
High school or higher	30.43 [0.29]
Coverage for maternal health interventions in 2015	
Antenatal care[g] (%)	97.88 [0.06]
Frequent antenatal care (≥4 antenatal consultations)[h] (%)	74.11 [0.24]
Timely antenatal care[i] (%)	90.33 [0.14]
Childbirths attended by medical staff (%)	84.19 [0.37]
Childbirths in Ministry of Health facilities (%)	82.65 [0.33]
Childbirths in other public health facilities (%)	0.94 [0.08]
Childbirths in a private health facility	14.06 [0.31]
Childbirths in other locations: at home/in public/other (%)	2.34 [0.13]

Notes

[a]percentage of the population without Social Security coverage.

[b]percentage of the population living in rural areas.

[c]number of children born to women >12 years old.

[d]percentage of the population > 5 years old speaking an indigenous language.

[e]resources in terms of hospital facilities and equipment include number of hospital facilities; physicians and nurses in contact with patients; hospital beds; operating rooms; and ultrasound equipment; resources in terms of outpatient care include number of outpatient consultation units, physicians, nurses and medical students in contact with patients, and delivery rooms.

[f]percentage of women lacked social security enrolled in SP.

[g]percentage of women who attended at least one antenatal consultation during pregnancy.

[h]percentage of women who attended at least four antenatal consultations during pregnancy.

[i]percentage of women who attended their first antenatal consultation during the first trimester of pregnancy.

This study was approved by the Committees of Research, Biosafety and Ethics of the INSP, Mexico (ID: 1649-7151) in 2016 and was made possible with the support of the National Council of Science and Technology (ID: 261535).

3 | RESULTS

Figure 1 charts the trends in the incidence and severity of MM between 2000 and 2015, and in GE per capita between 2003 and 2014. It can be seen that the probability of MM incidence dropped by 46%, while the severity of MM remained statistically unchanged, with GE per capita growing by more than 200%.

Table 2 shows the main socio-demographic characteristics as well as the available health resources and levels of coverage for maternal health interventions in the 2258 municipalities analyzed. On average, prior to the creation of the SP (2000), these municipalities were characterized by a large proportion of population without Social Security coverage (75%), high rurality (61%), an indigenous population comprising 20% or more of the total, and a high fertility rate (3.1 children per woman 12 years of age or older).

México saw a notable expansion of SP affiliates from 2003 to 2015, with rates rising from 3% to 87%, and an increase in available health resources between 2001 and 2015. Hospital resources grew by 37%, while resources for outpatient care units rose by 95% (Table 2). In 2015, out of the total number of women reporting at least one live birth, 23% were less than 20 years old, 27% had completed only elementary school or no school at all, 98% had received antenatal care—with 74% having attended four or more antenatal consultations, and 90% having presented to their first antenatal consultation during the first trimester of pregnancy; and 84% of deliveries were attended by medical personnel, with 82% of these taking place in SSA facilities, and 14% in private facilities.

The territorial description of MM and GE mentioned above revealed that the indicators analyzed for 2015 and the years between 2003 and 2014, respectively, were far from randomly distributed, exhibiting marked territorial patterns: regions in the Southern and parts of central México recorded the highest incidence and severity of MM, a pattern which did not align with GE (see appendix B).

Table 3 shows the results of the analysis of the bivariate correlation between MM (incidence and severity) in 2015, on one hand, and on the other, accumulated GE between 2003 and 2014 and the contextual indicators described above. The following can be observed: (1) The incidence of MM (in 2015) was lower in those municipalities with the lowest quality of life indicators (ie, higher levels of marginalization and rurality, a greater proportion of the population without Social Security coverage, etc.) prior to the creation of the SP, and in those municipalities with the highest levels of coverage for maternal health interventions. (2) The municipalities suffering from the highest levels of MM in 2015 were those which in 2000 had exhibited the highest levels of fertility and marginalization, had a large indigenous population, and were classified as highly rural. The severity of MM was greatest in those municipalities with the highest proportion of people affiliated with the SP, but was unrelated to increased availability of health resources (hospitals, equipment, and primary health care services), and access to timely and frequent antenatal care; these municipalities were also marked by a higher proportion of births attended at SSA facilities. The severity of MM was lower in municipalities where childbirth was attended mostly by medical staff, as well as in those where private care for childbirth was more common. (3) Accumulated GE per woman (between ages 10 and 49) without Social Security coverage in the years 2003 to 2014 was higher in municipalities enjoying better living conditions in 2000, and in those which registered the greatest change in available hospital resources. In contrast, GE accumulated in 2003 to 2014 per woman without Social Security coverage was less in those municipalities showing the greatest change in available outpatient care, and in those registering the lowest levels of coverage for maternal care interventions.

Table 4 presents the aforementioned matrix of univariate and bivariate spatial correlation between MM (incidence and severity) and GE. This table demonstrates the extent to which the incidence and severity of MM, as well as the levels of GE, far from being randomly distributed throughout the country, exhibited marked territorial patterns

TABLE 3 Correlation among the endogenous, exogenous, and control variables analyzed

	Incidence of Maternal Mortality in 2015	Severity of Maternal Mortality in 2015	Government Expenditure on Maternal Health[j]
Characteristics in 2000			
Population without Social Security coverage[a] (%)	−0.18***	0.42***	−0.29***
Rurality[b] (%)	−0.23***	0.52***	−0.52***
Marginalization index (%)	−0.17***	0.47***	−0.28***
Fertility[c]	−0.24***	0.56***	−0.46***
Indigenous population[d] (%)	−0.08***	0.16***	−0.17***
Affiliation with Seguro Popular insurance (SP)[e] (%)			
2003	0.03	−0.09	0.11***
2006	0.01	0.11**	−0.002
2009	−0.06***	0.30***	−0.05**
2012	−0.09***	0.33***	−0.19***
2015	−0.03	0.12**	−0.09***
Δ% 2015–2001 of available health resources[f]			
Hospital resources	0.02	−0.05	0.07***
Resources for outpatient care	−0.03	0.08	−0.14***
Socio-demographic profile of women with live births in 2015			
<20 years old	0.07***	−0.10	0.14***
20-29 years old	−0.02	−0.02	−0.01
30–39 years old	−0.05**	0.11	−0.11***
40 years old or more	−0.005	0.16***	−0.05**
Without schooling	0.03	0.15***	0.05**
Elementary school	−0.06***	0.26***	−0.10***
Junior high school	−0.01	0.04	−0.02
High school or beyond	0.06***	−0.34***	0.09***
Coverage for maternal health interventions in 2015			
Antenatal care[g] (%)	−0.15***%	0.07	−0.15***
Frequent antenatal care (≥4 antenatal consultations)[h] (%)	−0.12***	−0.05	−0.12***
Timely antenatal care[i] (%)	−0.17***	0.05	−0.15***
Childbirths attended by medical staff (%)	−0.04	−0.11**	−0.08***
Childbirths in Ministry of Health facilities (%)	−0.16***	0.15***	−0.26***
Childbirths in other public health facilities (%)	0.11***	−0.10	0.11***
Childbirths in private health facilities (%)	0.11***	−0.20***	0.23***
Childbirths in other locations: at home/in public/other (%)	0.06***	0.14**	0.04**

Note:

[a]percentage of the population without Social Security coverage.

[b]percentage of the population living in rural areas.

[c]number of children born to women >12 years old.

[d]percentage of the population > 5 years old speaking an indigenous language.

[e]percentage of the population affiliated with the Seguro Popular.

[f]resources in terms of hospital facilities and equipment include number of hospital facilities; physicians and nurses in contact with patients; hospital beds; operating rooms; and ultrasound equipment; resources in terms of outpatient care include number of outpatient consultation units, physicians, nurses and medical students in contact with patients, and delivery rooms.

[g]gpercentage of women lacked social security enrolled in SP.

[h]percentage of women who attended at least one antenatal consultation during pregnancy.

[i]percentage of women who attended at least four antenatal consultations during pregnancy.

[j]Per woman between ages 10 and 54 without Social Security coverage.

***$P < 0.01$.

**$P < 0.05$.

TABLE 4 Univariate and bivariate spatial correlation matrix among endogenous and exogenous variables: Local Moran's I

	Incidence of Maternal Mortality in 2015	Severity of Maternal Mortality in 2015	Government Expenditure on Maternal Health[a]
Incidence of maternal mortality in 2015	0.147***	----	0.243***
Severity of maternal mortality in 2015	----	0.172***	−0.206***
Government expenditure on maternal health[a]	0.243***	−0.206***	0.549***

Note:

[a]Per woman between ages 10 and 54 without Social Security coverage.

***$P < 0.01$.

**$P < 0.05$; estimates with the five closest neighbors and 999 shocks; elaborated by the author on GeoDa.

(ie, with certain areas showing greater incidence and severity of MM coupled with higher levels of GE). In bivariate terms, this matrix also yielded a positive spatial correlation between the incidence of MM and GE; in other words, higher levels of MM concurred territorially with higher levels of GE. By contrast, the spatial correlation between the severity of MM and GE came out negative; that is, the municipalities with greatest severity of MM were not those showing the highest levels of accumulated GE in 2003 to 2014.

Finally, Table 5 shows the results of the estimated regression model used to assess the relationship between MM in 2015 and accumulated GE in 2003 to 2014. The incidence of MM was not linearly associated with GE, but was positively associated with the quadratic term for expenditure (marginal effect = 0.01, $P < 0.05$); the Heckman model with spatial error showed that elasticity of incidence-expenditure was −4.4, $P < 0.01$ for the linear term, and 0.17, $P < 0.01$ for the quadratic term. In addition, this model confirmed the importance of the previously estimated selection parameter. The sensitivity analysis carried out after varying the number of nearby neighbors confirmed the robustness of our estimations.

4 | DISCUSION AND CONCLUSION

We contributed to understand the relationship between government expenditure and MM in three ways: (1) we discovered two previously undocumented processes related to the behavior, incidence, and severity of MM resulting in self-selection bias; (2) we correct for self-selection bias in the incidence of MM with econometric spatial analysis, in order to incorporate into the estimates the effect of location on MM and GE; and (3) unlike other studies, which have focused on financial protection for affiliates,[17,36,45,46] we focused on estimating the effect of increased SP resources on both indicators for the use of health services and health outcomes.[47,48]

We specifically demonstrated that the incidence of MM is unrelated to GE, since there are stronger determinants such as poverty itself, as opposed to the severity indicator, which is negatively associated with GE. On average, the elasticity of MM severity-GE was −4% ($P < 0.01$). However, in those municipalities suffering from the worst structural conditions and from the highest levels of social vulnerability (ie, greater social marginalization, a higher proportion of indigenous people, and less availability of health resources and public services such as potable water and roads), this association was negligible, finding that is consistent with previous reports.[20,49-54] Our results therefore suggest a spatial misalignment between increased resources and maternal health care requirements in México at the municipal level.

Our analysis points to some policy implications. Although Seguro Popular is meant to allocate resources according to the volume of population affiliated, it has been demonstrated that the rationale of allocation rest also or completely in negotiations among the state incumbent actors, inducing the competition for resources among municipalities, since the allocation of resources to one municipality can limit the possibilities of the others, or vice versa, thus having an effect on the provision of maternal health services and, indirectly, limiting the reduction of MM.

TABLE 5 Spatial-econometric model of the association between expenditure on maternal health and maternal mortality in the Mexican population without Social Security coverage, 2015

N = 2258	Incidence of Maternal Mortality (marginal effects, mfx)	Severity of Maternal Mortality (Elasticity)				
		K = 5	*K* = 8	*K* = 10	*K* = 12	*K* = 15
Accumulated expenditure (in natural logarithm)	−0.05	−4.44***	−4.45***	−4.46***	−4.48***	−4.46***
	[0.06]	[0.40]	[0.40]	[0.41]	[0.41]	[0.41]
Accumulated expenditure squared (LN)	0.01**	0.17***	0.16***	0.17***	0.17***	0.17***
	[0.002]	[0.02]	[0.02]	[0.02]	[0.02]	[0.02]
Mc Fadden's R2	0.32					
Hosmer-Lemeshow test						
Chi2	13.72	—	—	—	—	—
Prob > Chi2	0.09	—	—	—	—	—
Mean variance inflation factor (VIF)	1.45	—	—	—	—	—
Wald Chi2	400.4	957.5	961.3	947.4	943.6	947.2
Prob >Chi2	0.000	0.000	0.000	0.000	0.000	0.000
Lambda	—	0.19**	0.15	0.22*	0.28**	0.31**
	—	[0.09]	[0.11]	[0.12]	[0.13]	[0.14]

Note: Estimates performed under maximum likelihood; robust standard errors reported in brackets.

***$P < 0.01$.

**$P < 0.05$; estimates performed with the five nearest neighbors.

Similarly, health units in each municipality have heterogeneous managerial capacities producing important variations on efficiency in the management of resources,[55] possibly yielding heterogeneous results in MM. Such relationships suggest that we should avoid embracing the simplistic concept of an unequivocal causal relationship[56]; nonetheless, these remain a valid hypotheses worthy of further study. We should also mention our methodological approach and the robustness of our results. One of the principal strengths of our study is that we were able to draw on a large number of secondary sources available in México, allowing us to control the relationship of interest through other relevant variables in the model—fundamental for a spatial error model, as mentioned previously.[57]

Our study had several limitations. First, having focused our analysis on the population without access to social security coverage, our results cannot be generalized to the entire Mexican population. However, our study dealt with the SPSS target population, which represents 50% of the total Mexican population, including the poorest sectors, in which 70% of MM is concentrated. Moreover, public health expenditure earmarked for this population represented 45% of total public health expenditure for 2014.[58] Second, we encountered a problem of potential endogeneity between GE and MM, this because of the possibility that GE correlated with the error term due to modification of the response by MM results from previous years.[27] That is, the government might have increased its spending on public health owing to a rise in the level of MM.[59,60] However, we addressed the possible endogeneity by analyzing accumulated GE through 2014. Third, there may be problems of specificity regarding the omission of relevant variables in the estimated econometric models. For example, we have no information on the performance of public institutions (ie, productivity, corruption, and efficiency) at the municipal level[27]; neither do we have information regarding proximate determinants at the individual level (ie, the presence of complications, obesity, etc.).[61] Fourth, the spatial structure selected could have influenced the estimated impacts. Nevertheless, we analyzed the robustness of our estimates by modifying this parameter and found no variation. Finally, we analyzed data using an ecological cross-sectional design, which limited the causal inferences that can be drawn from the study. Ideally, analysis should follow an experimental design[62] at the individual level, introducing maternal near-miss determinants (ie, clinical indicators such as complications before, during, or after childbirth); however, this would lead to ethical debates beyond the scope of this study. Although previous ecological approaches to the understanding of mortality and its determinants[63,64] exist, we believe that our results should be considered an initial approximation of the impact of GE on MM.

In sum, our results suggest that the enhancement of SP coverage and ensuing financial resources has not been sufficient to reduce MM in México[30] calling for urgent policy adjustments that help to better allocate resources and improve services delivery. Standards and guidelines must be established not only to guide the expansion of resources for maternal health towards health units located in municipalities with the greatest severity of MM, but also to monitor their effective utilization. Allocation of resources at state level should leave behind a politically driven rationale to shift into the use of criteria based on guidelines already established since the inception of SP, in order to promote demand-side subsidies rationale. The federal level should lead this strategy towards the definite shifting of criteria. Accordingly, when endeavoring to improve welfare through the provision of health services, it is essential to consider not only who receives goods and services, and how, but also where they are received.[65] The efficient allocation of SP resources is a complex matter that should be grounded on effective mechanisms to induce the fulfillment of technical criteria and, consequently, to protect them from political and bureaucratic interests.[19] Thus, a more comprehensive vision of the way in which health resources are allocated is urgently needed.

AUTHORSHIP

E.P.P. and E.S.M. designed the study, outlined the idea for this paper, and wrote the first draft of the manuscript. E.P.P. and E.S.M. analyzed the data. G.N., D.M.F., and L.A.B. substantially revised the drafts. All authors were involved in the revision of the final version of the manuscript. All authors approved the final manuscript.

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CONFIRMATION OF COMPLIANCE WITH ANIMAL/HUMAN ETHICS GUIDELINES

The research is based on a publicly available data set of the Mexican Ministry of Health. Data do not contain identifying or sensitive subject information, and there are no ethical restrictions on requesting access to the data. If you wish to consult either the database developed for this study or the Stata syntax performed for original research purposes, please contact Edson Serván-Mori, corresponding author (servanmorie@gmail.com). This study was approved by the Committees of Research, Biosafety and Ethics of the INSP, Mexico (ID: 1649-7151) in 2016, and was made possible with the support of the National Council of Science and Technology (ID: 261535).

FINANCIAL DISCLOSURE

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no competing interests.

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APPENDIX A

SPATIAL AUTOCORRELATION TESTS

	Two-step Heckman model			
	Incidence of maternal mortality		Severity of maternal mortality	
	Test statistics	*P*	Test statistics	*P*
PANEL A: *k* = 5				
Spatial error:				
Moran's I	0.11	0.11	2.57	0.01
Lagrange multiplier	2.07	0.15	3.83	0.05
Robust Lagrange multiplier	1.38	0.24	3.37	0.07
Spatial lag:				
Lagrange multiplier	0.95	0.33	0.56	0.45
Robust Lagrange multiplier	0.26	0.61	0.10	0.75
PANEL B: *k* = 8				
Spatial error:				
Moran's I	1.78	0.07	2.08	0.04
Lagrange multiplier	2.58	0.11	1.83	0.18
Robust Lagrange multiplier	0.71	0.40	1.27	0.26
Spatial lag:				
Lagrange multiplier	1.88	0.17	0.59	0.44
Robust Lagrange multiplier	0.01	0.92	0.02	0.87
PANEL C: *k* = 10				
Spatial error:				
Moran's I	1.73	0.08	2.75	0.01
Lagrange multiplier	2.35	0.12	3.54	0.06
Robust Lagrange multiplier	0.38	0.53	2.91	0.09
Spatial lag:				
Lagrange multiplier	2.11	0.15	0.64	0.42
Robust Lagrange multiplier	0.15	0.70	0.002	0.96
PANEL C: *k* = 12				
Spatial error:				
Moran's I	1.70	0.09	3.23	0.001
Lagrange multiplier	2.24	0.13	4.92	0.03
Robust Lagrange multiplier	0.13	0.72	4.94	0.03
Spatial lag:				
Lagrange multiplier	2.68	0.10	0.24	0.62
Robust Lagrange multiplier	0.57	0.45	0.26	0.61
PANEL C: *k* = 15				
Spatial error:				
Moran's I	2.35	0.02	3.27	0.001
Lagrange multiplier	4.45	0.03	4.58	0.03
Robust Lagrange multiplier	0.55	0.46	4.10	0.04
Spatial lag:				
Lagrange multiplier	4.64	0.03	0.51	0.47

(Continued)

	Two-step Heckman model			
	Incidence of maternal mortality		Severity of maternal mortality	
	Test statistics	P	Test statistics	P
Robust Lagrange multiplier	0.74	0.39	0.03	0.86

APPENDIX B

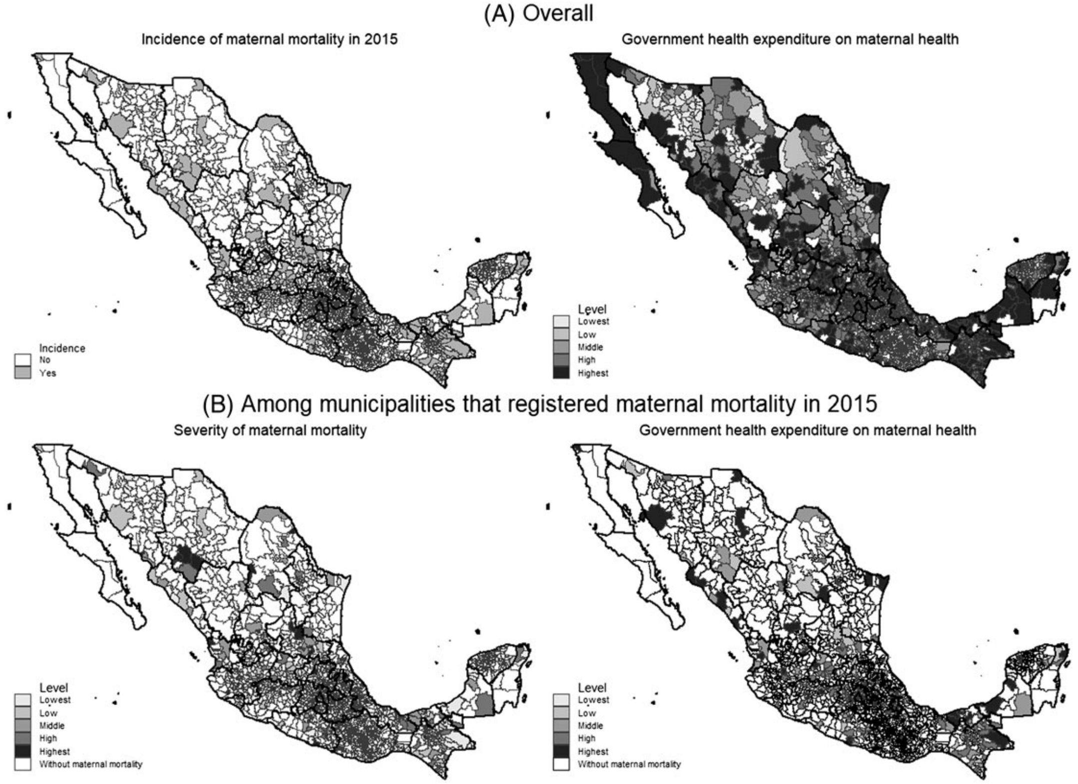

FIGURE A1 Municipality map of the incidence and severity of maternal moratlity in 2015, and public expenditure on maternal health