Remittances and financial inclusion in municipalities of Northeast Mexico: A Bayesian spatiotemporal analysis

—

Gerardo Núñez Medina[1]
gnunez@colef.mx

César R. Pérez Marcial[2]
cesar.marcial@gmail.com

Jorge López Arévalo[3]
jalachis@hotmail.com

1 Colegio de la Frontera Norte COLEF-Sede Piedras Negras. Coahuila. México

2 Universidad Regional del Norte, Campus Chihuahua, Chihuahua. México

3 School of Social Sciences, Universidad Autónoma de Chiapas San Cristóbal de Las Casas. Chiapas. México

— Abstract—

This paper aims to analyze the spatiotemporal distribution of remittances in the municipalities of northeastern Mexico given the effect of financial services and therefore focuses on studying the relationship between the flow of remittances and financial inclusion, considering the existing infrastructure and network of banking services in the municipalities of the region, while arguing that financial inclusion can support the accumulation of resources through savings and allow access to credit, insurance and other types of financial products. The results show that the concentration of resources in institutions and municipalities with a greater presence of banking institutions can lead to the expansion of small businesses, the generation of income derived from the development of micro-businesses and productive investment, especially in low-income segments, and that this is associated with the receipt of remittances, as well as highlighting the importance of understanding the complex interactions between international migration, remittances, and the economy.

Keywords:

Financial inclusion; additive log-linear models; remittances.

This longitudinal cohort study aims to analyze the spatial distribution of remittances in the municipalities of northeastern Mexico conditioned by the effect of the levels of financial inclusion observed. Remittances were quantified by Banco de Mexico in the balance of payments based on the municipal distribution of income from family remittances in quarterly series estimated in millions of dollars. Financial inclusion was quantified from the total number of bank branches reported by the Economic Information System of Banco de Mexico within the operational information module of commercial banking for the municipalities of northeastern Mexico, a region made up of Tamaulipas, Nuevo León, and Coahuila. The analysis period covers the years 2015 to 2020.

Therefore, the relationship between remittance flows and financial inclusion was analyzed, considering the infrastructure and economic network present in the municipalities of the northeastern region of Mexico. It is, therefore, an analysis of the economic flows and how these financial resources transit, resources from the work of migrants that are sent to their places of origin, where they could have a family and/or consumption relationship in Mexico. Remittances can be understood as one more instrument that supports the financial inclusion of families receiving remittances. The integration into the banking or financial system of a part of the migratory circuits causes the concentration of resources in institutions and municipalities, where both the reception of remittances and bank branches are concentrated, with the reduction of the dispersive effects of resources in the municipalities with less presence of the banking system.

Financial inclusion makes it possible in principle, the opportunity to accumulate resources via savings, and secondarily allows making payments or receiving them with collateral, which would eventually lead to the possibility of accessing credits, insurance, and financial products of greater complexity (Buchenau, 2010). Experience and studies show the correlation between access to financial services and obtaining credit, associated with the expansion of small businesses, the generation of other income, and productive investment in low-income segments (Dittus and Klein, 2011).

BACKGROUND

Recognizing the complex relationships between international migration and its economic counterpart, the issuance of remittances leads to the analysis of the behavior that remittances describe in the spatial and temporal dimensions. Although the behavior of remittances at any scale is similar, of course with variations, one interpretation of remittances is to give them a role as an agent of dependence and motivator for international migration; from the explanation of the cyclical performance of the economy, in the

case of concrete of the Mexico-USA circuit, the flow of remittances has a dynamic behavior, dominated by defined cycles, which implies a certain vulnerability; this is by what has been expressed in recent years by the figures of Banco de Mexico.

The connection between migration and financial services is largely determined by remittances and the possibility of accessing these resources in a secure market with convenient conditions for those who send and those who receive. The flow of remittances is identified as a starting factor, within a particular vision of local development, capable of promoting the development of productive projects and of direct connection with consumption and indirect with the productive and commercial sectors. In particular, remittances have been identified as a support lever for reducing poverty and migration as a means of occupying surplus labor.

There are countless examples of actions undertaken such as the Tres por uno program (3X1 for migrants) and investment in family businesses; to some extent, collective remittances (intermittent and under-served) are connected to problems in planning and complications in their use; at the family level it is where subtle aspects such as banking and financial education (initial aspects of financial inclusion) play a role in the management of local businesses.

Access to remittances, from a broad and theoretical perspective, would reduce vulnerability and, in the long term, dependence on external resources, however, market conditions and low integration with the financial sector cause more complex problems for the management and use of remittances. One of the characteristics of Financial Inclusion (FI) is its use in economic theory and, of course, in public policies, where specific institutions of national governments seek to integrate migrants and their families into the management of financial instruments, specifically to access, knowledge, and management of technologies associated with banking, (cell phones, institutional apps among others).

Inclusive financial systems consider the user or potential user as a connoisseur of operations and the logic of financial transactions. They consider the user a central actor who intuits that approaching financial institutions and their services can be of benefit. On the other hand, there are the operators or financial intermediaries who do not stop to observe the client, nor their condition or situation their objective is to attract attention through efficiency in the use of products and services, while traditional banking systems act based on corporate interests so they avoid dealing with specific social strata, strata that are integrated into new models of the global market, through public or private financial actors that to consolidate themselves offer efficient, cheap, immediate, and safe financial products and services.

Despite being a widespread demographic component in much of the national territory, migration is selective due to economic (strategic definition) and family issues, and in turn, the economic response that is the counter-flow of resources is given using transfers within financial systems. With information from Banco de Mexico, we now know which municipalities receive remittances. Regardless of the amount, the disaggregated data are a source of direct and frequent information on the place "where the remittances arrive". The previous references were "*households that declared receiving remittances*" for 2000 and 2010 of the Migration Intensity Index (IIM-CONAPO) and the different INEGI household income surveys. Therefore, the opportunity of reference under another source that is opposed to what was established by initial sources provides a greater capacity for interpretation, allowing to detail the circuit that remittances follow in the country and, of course, the medium, to the levels of financial inclusion of the spaces associated with the counterflow that, together with the amount, frequency, and sequence of the information, will allow a greater analysis of the impact. Despite the above, it is recognized by different studies that their role is consumption and, to a lesser extent, investment (Canales, E. 2006).

In the consumption line, it is important to note that it is mostly generated in the same place of receipt of remittances, so the measurement of that economic impact is concentrated and decreases by distance and time from these points, but without distinguishing the exit or stay from the municipal demarcation. Specifically, the reception takes place in medium to larger localities where financial services are located (banks, remittances, exchange houses, among others) that are chosen by users to have this service (Pérez C., 2015).

Communication-information technologies in this area, through cell phones, have taken two paths, their use as an element of economic potential for the traditional financial sector and, above all, for the characteristics of the inclusive financial and social system (BID, 2009). In addition to being a technological platform, it is an operational instrument of the market and the network through which monetary volumes flow. The World Bank identified the dimensions in Latin America where 98% of the territory has mobile signal reception, and 84% of households have mobile telephone service (Consultative Group to Assist the Poor, The World Bank Group, 2010).

Other existing elements for financial inclusion (FI) are defined by the political openness of governments to strengthen inclusive public policies; integrating specialized international organizations and an academic, theoretical, practical, and methodological debate on this issue in different public and private forums that acquires prominence. The FI is intended to have strategic nuances in national economies in times of digital services (Alfaro, 2010).

The distribution of the population in rural and/or remote areas increases the difficulties of relocation for simple financial transactions, such as receiving payments or subsidies. Reports show that access to Financial Services (FS) is a critical factor in increasing the quality of life, since they overcome contact barriers between people or microenterprises, strengthen their condition by reducing their vulnerability and directly reduce costs for procedures, add security and reduce cash handling times, facilitate the reception of remittances and transfers (BID, 2010b).

In some Latin American countries, programs were undertaken that promoted financial inclusion in a mandatory manner, which included actions at three levels: a) Change regulatory frameworks, b) Acquire resources for the supply of FS that include alternative products to traditional ones, adaptable to the needs of disadvantaged populations and c) Support and advise for the sustainability of financial companies. This means the application of subsidies intended to offset the costs of SF supply. It is about integrating new technologies that, in the form of channels and tools, allow us to support and provide efficient, fast, and low-cost services.

A developed financial system is crucial for economic growth; transaction costs, in addition to institutional weaknesses, restrict the integration, performance, and functionality of the finances of very low-income households, the microenterprise sector, and rural economies (Central Bank of Brazil, 2010). Access to financial services invigorates activities in local economies, generates new capacities that optimize resources, raise revenues, and integrate a greater number of actors, by eliminating imperfections in markets, from the local to the national level.

The above is marked by the positive correlation between access to financial services and economic growth (Levine, Loayza, and Beck, 2000). By the end of 2010, the G-20 promoted the Global Alliance for Financial Inclusion[1] with the formation of a group for FI and a subgroup for Innovation. Given the consensus on the importance of FI, there is talk of "banking the unbanked". Asmundson (2011) mentions that SFs comprise

---

1   Historical overview: informal savings and credit groups have antecedents in the 15th century. In Germany in the 1800s, a model of cooperative finance emerged, with adaptations that were replicated in the 20th century in rural areas of Latin America. In order to increase access to agricultural credit, state institutions were created (with losses due to subsidies and low recovery). By 1970 "microcredit" and the integration of small women's associations were created; by the 1980s, with greater methodological capacity, new models with sustainability were created and by the 1990s the concept of microcredit changed to microfinance. The transition to multi-product models took place, taking advantage of the unregulated market, reducing costs and expanding into the payment of remittances and the collection of savings. Geographic distribution and risk diversification took place, thus serving a group of strong potentials, increasing the number of clients (rural and urban), innovations and the beginning of regulation. The transition to inclusive financial systems is due to the need for access to quality instruments and fair costs, which reduced negative aspects.

significant components such as the transaction to obtain a financial good, with variations in transactions (real estate, consumer, insurance, and banking), and the intermediation that financial services make for the use of money in a productive way.

FI connects elements such as regulatory frameworks, adjusted product offerings (payments, savings, credit, insurance), coverage capacity, access to broad channels (traditional and modern), quality services at reasonable prices, safety, and efficiency potential, as well as the promotion of financial education and culture, along with information transparency formats (Pérez C., 2015).

The relationship between financial culture and technological exclusion are two important factors, given that the presence and distribution of formal banking institutions in the regions involved with SF and specifically with the payment of remittances is enhanced, in a market with low regulation, on the other hand, a high supply of SF increases the vulnerability of the plaintiffs, because the regulations that are fundamental in the action of small or informal financial institutions, increases the risks in the protection, execution of guarantees or tax burdens that distort the control of interest rates and directed loans (Gardev & Rhyne, 2011).

The lack of regulatory frameworks that prevent the risk of money laundering, known as "know your customer"[2], especially limits access to SF by the low-income population, and also by those who exercise informal productive activities, since they lack documents that prove their activity or their person to open an account. Another complication associated with the above is the reasonable and fair integration of costs to the provision of services to users.

The FI seen as a public policy that aims to shape an inclusive financial system that makes available to low-income people financial services (transactions, remittances, savings, microcredit, credit card, housing credit, and insurance) which implies changing the vision and management of financial institutions, regulators, supervisors and operators, it is about "restructuring" the idea of the financial services market towards simple models in technological conditions of broad support, developing institutions that allow the control and review of actors, generating levels of reliable and updated information, as well as with open regulatory frameworks that allow the connection of instruments and actors to improve and increase competition (Mas & Siedek 2008).

The target market of the FI should be the population with the lowest resources or income, the base of the social pyramid, which is looking for a

---

2   Know your client.

way to incorporate it into the benefits of economic growth through access to basic services, payments, and remittances. A public policy of FI must seek the arrival of more users and instruments to financial systems, and reduce their costs and limitations for households, people, and companies (Siedek, 2007, 2007b). On the other hand, according to Pérez (2015), remittances are the expression of contemporary international economic networks and their social relations, which are established between the places of origin and destination of migration. Its dynamics are associated with the objective of the initial migration, the number of people, the temporality of the process, and the spatial dispersion of migrants in the labor sectors and family consumption, among other elements.

At the national level and for income accounting in the banking sector, a significant growth in remittances is shown, which gives it an outstanding weight, due to its management at the local or regional level, it tends to be assumed that they affect the economies of the recipient countries, that there is a generalized impact, but this only occurs at the scale of the recipient households. In general, sending resources to migrant communities constitutes a family transfer wage fund, so its contribution to national economic growth and development is usually marginal.

The logic of sending remittances does not correspond to that of an investment or savings fund, but to a family income, which is usually destined to the satisfaction of basic needs, which contributes to reducing social vulnerability, to generating support during critical situations.

The circulation and use of remittances have constituted a financial circuit, part of which is immersed in a rural context, with high rates of social deterioration and the productive fabric, while on the other hand, there is an economy that demands labor with higher wage conditions even in informal and/or irregular conditions. It is common that, since they are peasant economies, remittances impact production destined for self-consumption and the local market that has a different rationality, which by the exogenous injection of income generates new scales of polarization that transcend the spatiotemporal dimension. Therefore, the territorial scope and geographical scale are differentiating elements of the use and impact of remittances.
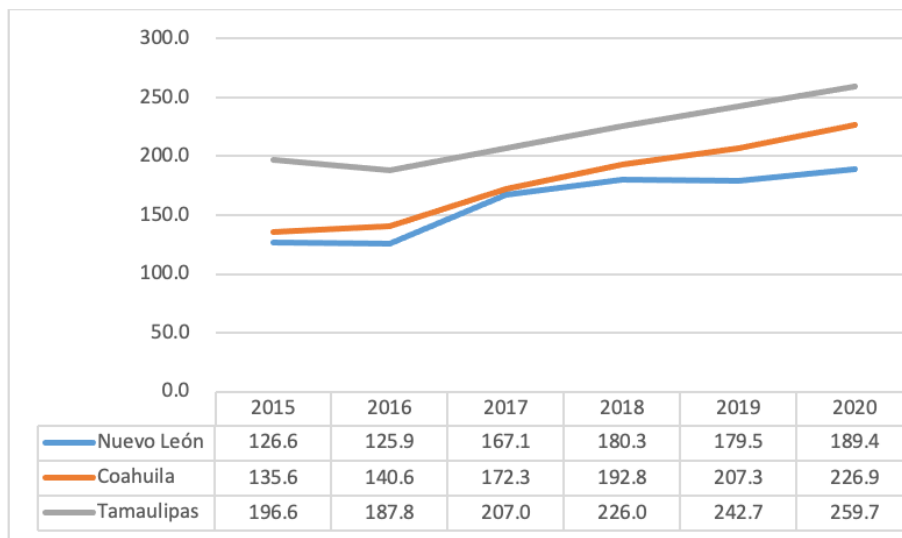
Another differentiating feature of remittances is the magnitude and impact they have in dispersed communities where this income, as well as its circulation, are fundamental for their survival. It is important to note that remittances have a sociocultural function to maintain and reinforce traditional practices and values, which strengthen the social cohesion, culture, and identity of the people in which they are inserted in the migratory circuits (collective remittances).

Sources of Information

The data used for the development of this research were obtained from the tabulations of the Economic Information System, published by Banco de Mexico and are available at https://www.banxico.org.mx/SieInternet/ In particular, the variables related to family remittance income and the total number of bank branches were processed, in both cases the variables are disaggregated at the municipal level.

REMITTANCE AND FINANCIAL INCLUSION IN MEXICO

According to the World Bank, the global flow of remittances in 2010 was 440 billion dollars, with Mexico in third place, surpassed only by India and China. In recent years, Banco de Mexico has recorded two important trends in the flow of remittances, one between 2004 and 2007, where the annual volume of remittances increased along with the number of transactions, however, as of 2008, these parameters fell to normal levels. The second trend began after 2014, when a sustained growth of remittances was observed until 2020, with an annual growth of 11.4%, marking a record growth for five consecutive years, its amount for that last year is equivalent to more than 875 billion pesos, which is higher than the federal budget of Mexico approved for 2021 by the Secretariats of Public Education, Health, Labor and Social Security, Welfare, and Culture as a whole. According to bank estimates, 0.7% of remittances arrive in cash or kind while 77.1% are collected in non-bank institutions (BBVA, 2021).

	2015	2016	2017	2018	2019	2020
Nuevo León	126.6	125.9	167.1	180.3	179.5	189.4
Coahuila	135.6	140.6	172.3	192.8	207.3	226.9
Tamaulipas	196.6	187.8	207.0	226.0	242.7	259.7

Graph 1. Evolution of remittances per capita in northeastern Mexico, 2015 to 2020. Source: Own elaboration with BANXICO information. Remittances per capita in annual dollars.

It should be noted that the average dollars per operation had a similar behavior during the years analyzed. In Mexico, the distribution by state shows unequal regional patterns, where only nine states concentrate more than 60% of remittances, a trend that is repeated within the states due to infrastructure conditions and connection with migratory circuits. In the case of the northeastern region of the country and only for the years 2019 and 2020, there was an increase in the amount received in Nuevo León of 6.7% (from 960 to 1,024 million dollars), Tamaulipas with an increase of 8.2% (from 873 to 945), as well as Coahuila, which showed a growth of 11.1% (from 640 to 711 million dollars) (BBVA, 2021).
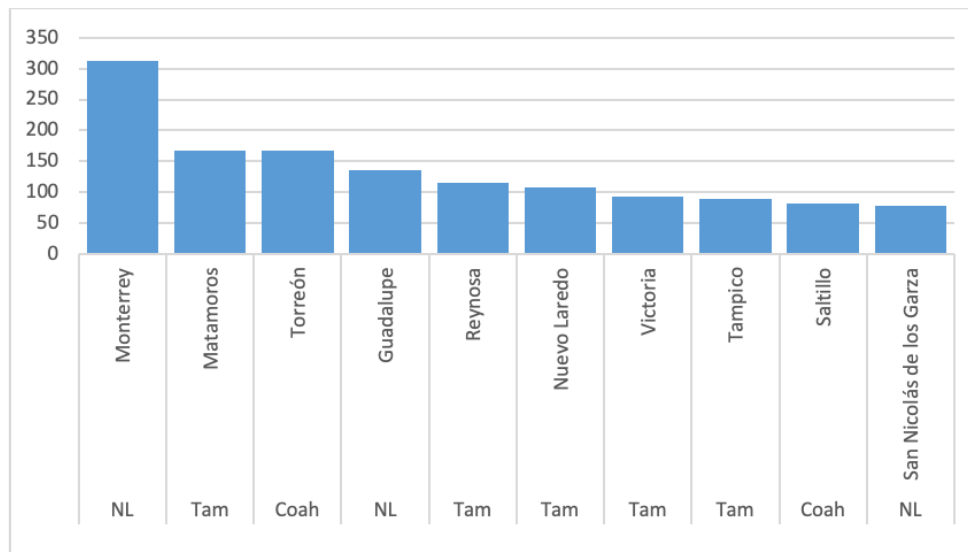
Graph 2. Municipal remittances in the northeastern region of Mexico in 2020. Source: own elaboration based on data from BANXICO and the Population and Housing Censuses, INEGI. Remittances per capita in dollars

Graph 1 shows the time evolution of remittance amounts per capita at the state level. The figures allow us to have an idea of the dispersion of the phenomenon among the entities of northeastern Mexico, where it is evident that over the period 2015-2020, remittances increased steadily, going from a regional average of 149 dollars per person-year to an average of 220 dollars per person-year. This increase in the number of remittances was also reflected in the number of receiving municipalities, while in 2015, a total of 23 municipalities of the 132 that make up the region did not receive remittances; for 2020, only one municipality, San Nicolás in Tamaulipas did not receive remittances, a municipality in which there are neither remittances nor ATMs, much fewer bank branches where the collection of remittances can be effective, so we assume that they are addressed to the surrounding municipalities (Banxico database, consulted on 02/20/2020).

Regarding the net flow of remittances at the municipal level, during 2020, it is observed that the most important municipalities in the region receive the highest amount of remittances, which may be an indicator of the existence of a greater proportion of their population working in the United States. Thus, the municipalities of Monterrey, Matamoros, Torreon, Guadalupe, and Reynosa receive the highest amounts of remittances (see graph 2); for example, Monterrey received 312 million dollars during 2020, the average for the region was 20.2 million dollars per municipality for the same year. Although remittances reach practically all municipalities, as can be seen in map 1, there are large differences in the spatial and temporal distribution of remittances between the municipalities of the region, although a spatial pattern in the distribution of these cannot be distinguished.

BAYESIAN SPATIAL ANALYSIS

The spatiotemporal modeling of municipal remittances is done through the adjustment of a series of latent Gaussian models that include the application of parametric, non-parametric models, and spatiotemporal interaction models. The linear predictor of the latent Gaussian model is defined from a link function:

$$\eta = g(E(Y \mid \eta))$$

where η represents the linear predictor, g is a binding function, and Y represents an indexed sequence of the formula:

$$Y(i,t) = \left\{ y(i,t) \mid (i,t) \in \mathfrak{R}^2 \times \mathfrak{R} \right\}$$

defined as a stochastic process, where each $y(i,t)$ represents the remittances captured by the municipality $i = 1,...,2\ 456$, at year $t = 1,...,6$ (Blangiardo & Cameletti, 2015: 235), which are modeled by a Gaussian distribution, $Y_{it} \sim N\ (\eta_{it}, \sigma^2_t)$ where η_{it} represents the expected value of remittances in the municipality i at year t and σ^2 the variance.

Under these criteria, the Bayesian model is defined by a hyperparameter layer, a latent Gaussian field, and a likelihood function that captures the marginal distribution defined through an exponential family. The formulation of spatiotemporal models comprises a classic parametric model, a non-parametric dynamic model, and four variations of the spatiotemporal interaction model with structured and unstructured effects. The classic parametric formulation of spatiotemporal models defines the linear predictor η_{it} as:

$$\eta_{it} = \beta_0 + u_i + v_i + (\beta + \delta_i)t \tag{1}$$

The non-parametric dynamic model uses a formulation that allows it to manipulate temporal trends through parameters that independently control the structured ρt and unstructured φt temporal effects (Bivand, Gómez-Rubio & Rue, 2015), so its linear predictor is given by:

$$\eta_{it} = \beta_0 + u_i + v_i + \rho_t + \varphi_t \tag{2}$$

Spatiotemporal interaction models expand parametric and non-parametric models by introducing a γ_{it} term, capable of capturing the interaction between space and time, whereby its linear predictor takes the form:

$$y_{it} = \eta_{it} = \beta_0 + u_i + v_i + \rho_t + \varphi_t + \gamma_{it} \tag{3}$$

In models (1) to (3), β_0 represents the average level of remittances received in the municipalities of northeastern Mexico, u_i represents the spatially structured random effects, and the parameter v_i the spatially unstructured effect.

In model (1), each spatial unit has a spatial intercept given by $(\beta_0 + u_s + v_s)$ and a slope $(\beta + \delta_s)$ representing the temporal trend (Blangiardo & Cameletti, 2015), while in model (2) the structured temporal trend ρt is modeled as a random walk (rw(1)) distributed as:

$$\rho_t \mid \rho_{t-1} \sim N(\rho_{t-1}, \sigma^2)$$

Whereas the unstructured temporal trend φt follows a previously interchangeable Gaussian distribution N(0, 1/τφ) (Schrödle & Held, 2011). Finally, in equation (3) the spatiotemporal interaction term γ_{st} follows a Gaussian distribution given by $\gamma_{it} \sim$ *Normal* (0, $1/\tau_\gamma$), with a precision matrix given by $\tau_\gamma R_\gamma$.

In model (3), the term γ_{it} specifies the interaction between spatial and temporal effects, structured and unstructured, with which type I to IV interaction models are defined. The type I interaction controls the unstructured spatial and temporal effect, vi and ρt, the type II interaction defines the variation between the unstructured spatial effect vi and the structured temporal effect φt, the so-called type III interaction between the structured spatial effect ui and the unstructured temporal effect ρt and finally, the type IV interaction controls the variation between the structured spatial effect ui and the structured temporal effect φt.

MODELS OF SPATIOTEMPORAL INTERACTION

The six competing models were evaluated based on a statistical selection criterion known as Akaike. The selection of the model, within the set of alternative models, was made based on the implementation of algorithms that allow discrimination between models. In this way, the Akaike information criterion (AIC) provided a measure of the goodness of fit of the model while penalizing the degree of complexity of the model (Akaike, 1974). The AIC selection criterion consisted of choosing from among the alternative models, the model that achieves the smallest AIC, which is estimated in terms of the likelihood function and the number of parameters estimated by the model.

Among the set of six adjusted alternative models, the Akaike criterion was estimated for each of them. The results are presented in Table 1 and show that the minimum AIC was reached by the type II spatiotemporal interaction model, with an advantage of more than a thousand points over its closest competitor, the classic parametric model, so that the type II model proved to be the best option to model the spatiotemporal evolution of per capita remittances in the municipalities of northeastern Mexico.

Table 1

Akaike information criteria, estimated models

	Model	AIC
PAR	$y_{it} = \beta_0 + u_i + v_i + (\beta + \delta_i)t$	2,780.18
NOP	$y_{it} = \beta_0 + u_i + v_i + \rho_t + \varphi_t$	3,224.90
Tipo I	$y_{it} = \beta_0 + u_i + v_i + \rho_t + \varphi_t + \gamma_{it}$	3,018.47
Tipo II	$y_{it} = \beta_0 + u_i + v_i + \rho_t + \varphi_t + \gamma_{it}$	1,724.09
Tipo III	$y_{it} = \beta_0 + u_i + v_i + \rho_t + \varphi_t + \gamma_{it}$	3,221.36
Tipo IV	$y_{it} = \beta_0 + u_i + v_i + \rho_t + \varphi_t + \gamma_{it}$	3,226.32

Source: Own elaboration based on R-INLA estimates

Table 2 presents the subsequent estimates of the type II spatiotemporal interaction model for the fixed effects and random effects, where it is observed that the fixed effect α=1.59 estimates the average of the logarithm of per capita remittances received by the municipalities of northeastern Mexico, which reached an average observed amount of 200 dollars per person per

year, throughout the entire period analyzed (see table 2), which is why α significantly underestimates the average of municipal per capita remittances. This underestimation effect can be attributed to the spatial weighting carried out to adjust the spatiotemporal effects observed between municipalities with high and low levels of remittance reception, which is associated with the model borrowing information from neighboring municipalities to reduce variance and improve the estimation of a specific municipality (see map 2), while the effect of the β parameter shows the existence of a positive relationship between per capita remittances received and municipal financial inclusion, the estimated value of β shows that the increase at one point in municipal financial inclusion would imply a growth of 0.22 points in municipal per capita remittances.

About the estimated random effects for the type II interaction model, the mean of the posterior density of the structured spatial effect u_i was found to be 60% larger than the estimated mean of the unstructured spatial effect v_i, showing that the effect of the spatial dispersion of remittances per capita between municipalities depends significantly on the spatial structure and the distance between municipalities. Regarding the average estimated value of the temporal effects, by the spatiotemporal interaction model type II, it is observed in Table 2 that the unstructured temporal effect reaches a value much higher than that presented by the rest of the estimated effects, both temporal and spatial, which indicates that the temporal evolution of remittances has a greater relative importance than that presented by the spatial variations and that these follow a temporal pattern not subject to the variations of the calendar.

Table 2

Subsequent estimates, type II spatiotemporal interaction model

Fixed effects	mean	sd	Q1	Q2	Q3
α	1.598	0.197	1.211	1.598	1.985
β	0.288	0.197	-0.098	0.288	0.675
Random effects	mean	sd	Q1	Q2	Q3
Structured spatial effect	2274.63	2285.92	209.51	1606.61	8295.67
Unstructured spatial effect	1857.59	1835.37	128.37	1316.22	6707.52
Structured temporal effect	7.46	4.65	1.83	6.40	19.44
Unstructured temporal effect	21157.93	21330.11	1690.21	14889.58	78121.28
Spatiotemporal interaction effect	0.65	0.07	0.52	0.65	0.79

Source: Own elaboration based on R-INLA estimates

The spatiotemporal distribution of remittances per capita received by the municipalities of northeastern Mexico, during the years 2015 to 2020, are

presented in map 1, while the estimates, obtained by the spatiotemporal interaction model type II, for municipal remittances per capita can be seen in map 2. Maps 1 and 2 present the contrast between observed and estimated per capita remittances, both on a logarithmic scale. Map 2 presents the estimates of the subsequent linear predictor of per capita remittances made by the type II spatiotemporal interaction model, given the observed level of municipal financial inclusion present in the municipalities of northeastern Mexico during the period studied, in the same map it is possible to observe the effect of the smoothing made by the model.
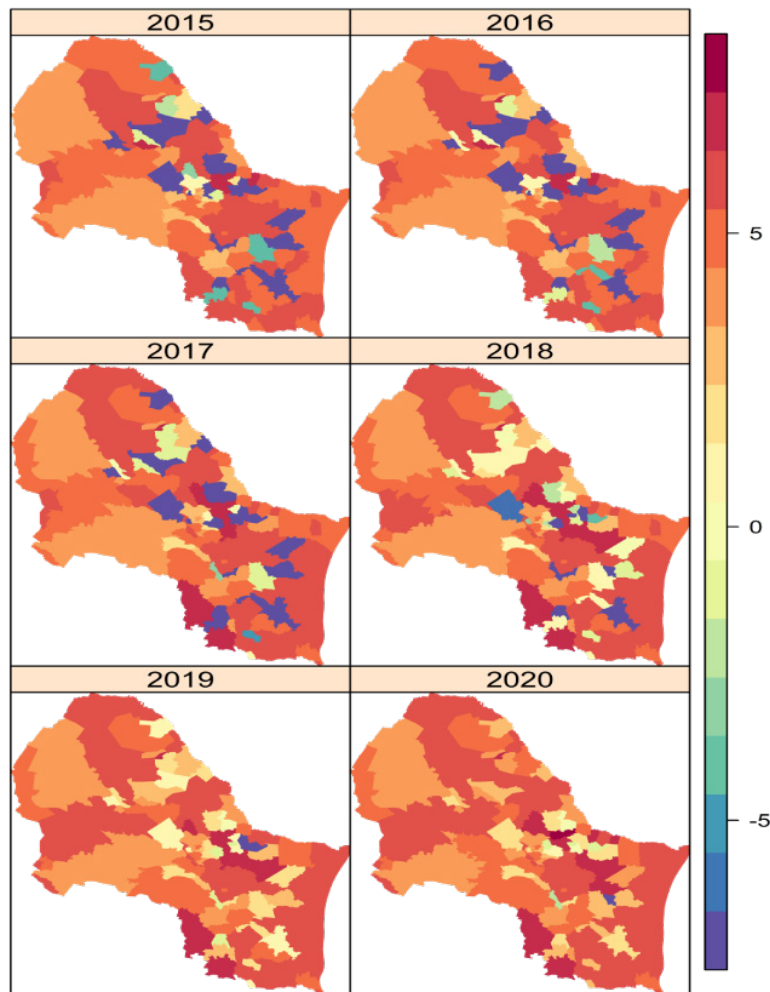
Map 1. Observed municipal remittances, northeastern region of Mexico 2015 to 2020. Source: Own elaboration based on R-INLA estimates. Logarithmic scale remittances

The spatial dispersion of the natural logarithm of remittances per capita observed in the municipalities of northeastern Mexico, over the period studied, shows a sustained increase in the number of municipalities that received

remittances between 2015 and 2020. While in 2015 the total number of municipalities that received remittances reached 109 of the existing 132 by 2020 the number rose to 131. Growth in the number of remittance-receiving municipalities in the northeastern region increased as did the number of bank branches and the average per capita amount of remittances received by municipalities (see Chart 1).
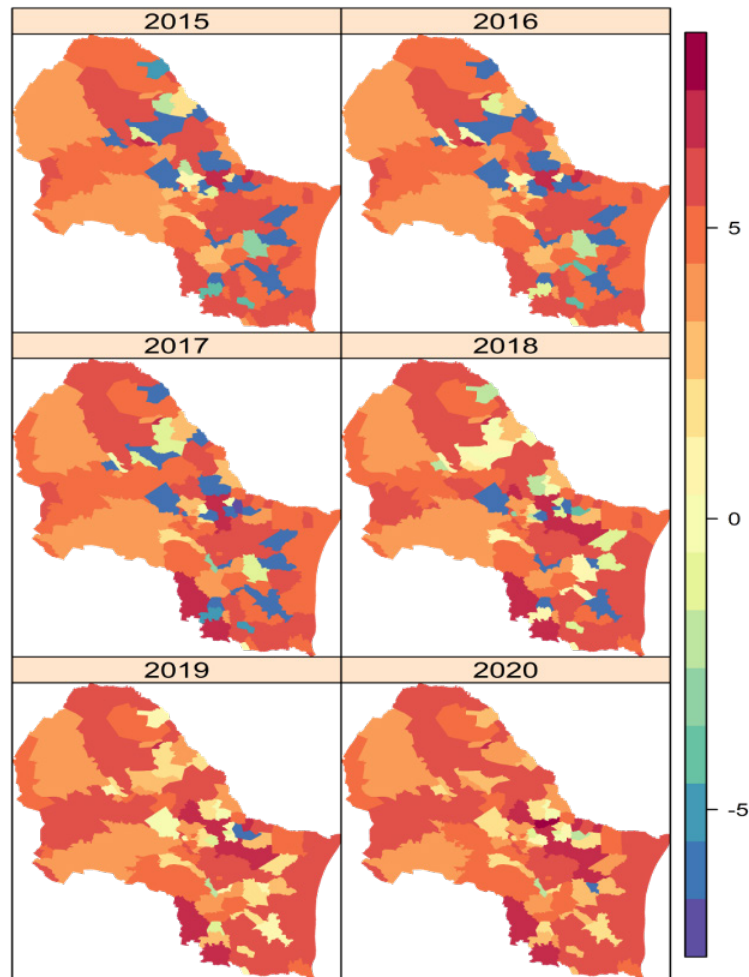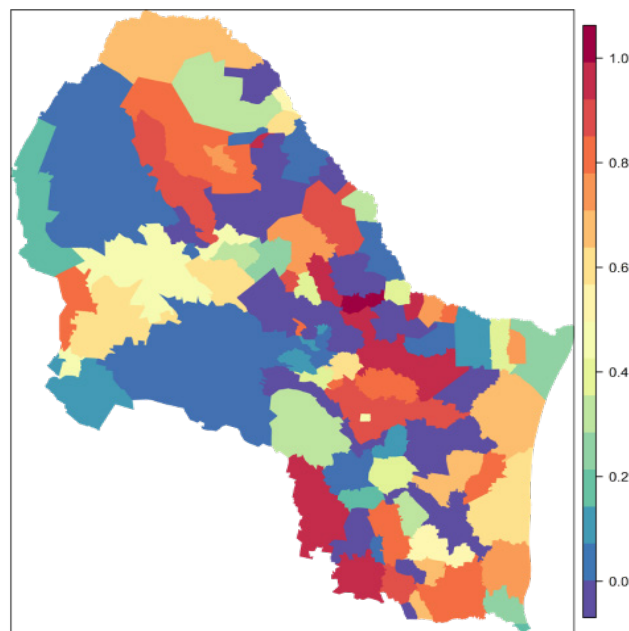

Map 2. Subsequent average estimate of municipal per capita remittances, according to type II interaction model. Source: Own elaboration based on R-INLA estimates. Logarithmic scale remittances

In general terms, a spatial pattern of concentration or dispersion of remittances between the analyzed municipalities cannot be distinguished (see maps 1 and 2), a situation that reveals a democratization in the reception of remittances for the northeastern region of the country, except perhaps a small region, of low reception formed by the municipalities of Dr. Coss, Los Aldama, General Treviño, and Melchor Ocampo (located in Nuevo León),

which seems to consolidate over the period analyzed. In any case, it is a set of basically rural municipalities with low population density, a situation that could somehow explain the behavior of remittances.

The type II spatiotemporal interaction model generates the subsequent distribution of municipal per capita remittances for the analyzed period, given the levels of financial inclusion observed so that it is possible to create a probability map in terms of the risk associated with the reception of a level of per capita remittances, defined from a given threshold. Map 3 presents the subsequent conditional probability that a municipality receives a level of remittances per capita higher than the regional average. Municipalities in red to orange shades show a high probability of receiving remittances above the region's average, while municipalities in blue to green shades have a low probability of obtaining remittances above the regional average, which draws a spatial pattern. In general, municipalities in blue are located in rural areas that are difficult to access, while municipalities in red, in general, correspond to urban areas.


Map 3. Probability. Source: Own elaboration based on R-INLA estimates

Graph 3 presents the estimates of the random spatial and temporal structured and unstructured effects of municipal per capita remittances for the analyzed period, for the type II interaction model. Graph 3.a shows the variations of the structured spatial effects that model the spatial dependence associated with the level of remittances received by the 132 municipalities that make up the northeastern region. In graph 3.b you can see the unstruc-

tured spatial effect, it is an interchangeable (unstructured) random effect that models the uncorrelated noise between geographical areas, that is, it models the random variations not captured by the spatial structure, for the 132 municipalities throughout the six years analyzed (i.e. 792 estimates).

Graph 3.c presents the structured temporal effect for the six years analyzed, while graph 3.d shows the unstructured temporal effect, which captures the random temporal variations that cannot be modeled by the calendar. The increase observed in Graph 3.c captures the temporal growth of the average value of remittances, while the value of the estimated parameter of unstructured temporal effects reflects the inability of the model to capture such effects.
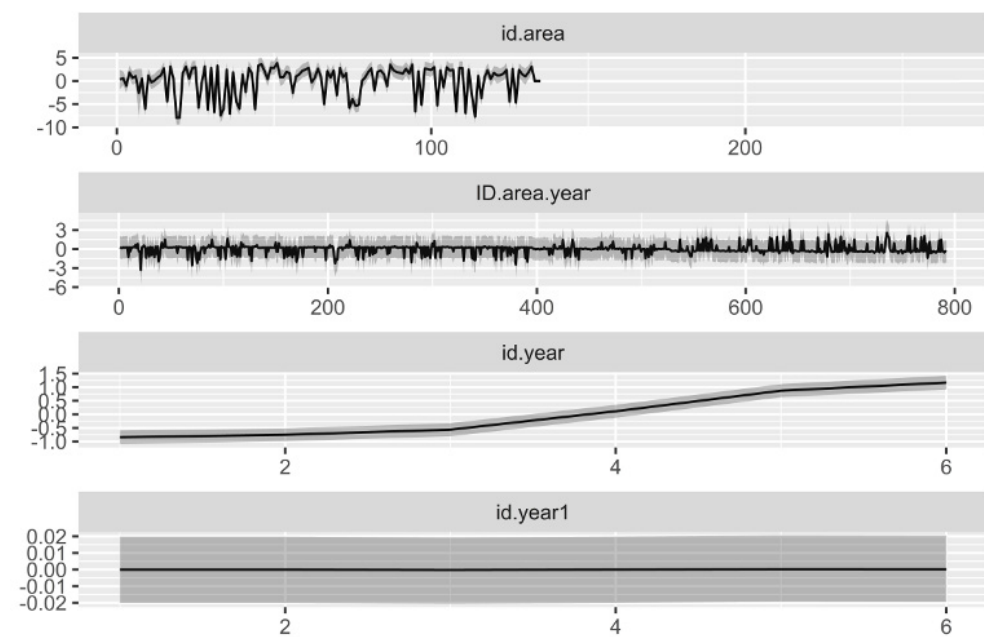
Graph 3. Spatial and temporal random effects of the type II interaction model. Source: Own elaboration based on R-INLA estimates

The reduction achieved in the AIC by the type II interaction model implies that the γit parameter efficiently captures the interaction between spatial and temporal effects (Schrödle & Held, 2011). When the variations between spatial effects and between temporal effects are relatively large (i.e. within each of them), compared to the estimated variation between the spatial and temporal effects (see Table 2), the estimate of the interaction term γit is of lower magnitude (Martins *et al.*, 2012) than that achieved by the temporal and spatial effects, so, the interaction term can adequately model the spatiotemporal dependence.

DISCUSSION

The contribution of this work revolves around the analysis of the spatio-temporal evolution of municipal remittances in the states of northeastern Mexico, and in a quantitative contribution to determine the importance of financial inclusion in the territorial dispersion of remittances. The analysis carried out through the above model allows us to recognize a specific behavior in the transmission of resources resulting from migration in that period, it is transcendental to recognize the capacity in the analysis of the past and to be able to recognize the conditions of the remittance market in the region, as well as the elements to be considered of the value of the information that Banco de México is now systematizing in the face of the relevance of the migration process in general and in a specific way of the transfer market from abroad.

The presence of bank branches and financial institutions, also called "dispersers" in the different municipalities will then have an impact on remittance recipients in municipalities without branches, as well as a potential increase in remittances in their regional total. Financial inclusion as a national policy responds to a need caused by migration (also created by structural deficiencies) for which it reproduces and uses the conditions established by the concentration market in cities with low investment for new branches and generates a transfer of costs for the use and management of certain associated technologies.

The integral process of inclusion also requires a greater development in communication infrastructure (digital channels), an expansion of tele-communication technologies, and a functional management for users that translates into a section of financial education that is not an issue present in most of the user population of some levels of financial services, although superficial management of a majority of users can be inferred.

The model shows the levels of concentration of the amounts in the institutions associated with the financial system, thinning remittances from other channels such as pocket money. It should be considered that in parallel there is an unregistered market for the transit of resources that may be temporary and others in kind, the former associated with collective or social expenses, for financing public works or festivities in migrant localities, which it does not define as current expenditure and the latter are gifts that are delivered directly to families that may include appliances, tools, cars, among other objects, without economic import registration, as well as payment of taxes.

CONCLUSIONS

The estimation of the spatiotemporal models was possible thanks to the use of Laplace's integrated nested approximation implemented in the INLA package and available in R language. The use of INLA provides significant computational advantages over other algorithm-based packages such as the Monte Carlo Markov chain (MCMC), that result in a significant reduction in processing time.

The interdisciplinary work between mathematics and social sciences, specifically between statistics and geo-demography, allows us to recognize the opportunity, and potential of the analysis beyond the numerical result of the model and the spatial expression, since the association was indispensable as the assimilation of terms of and in both areas to be able to coordinate the interpretations, so it was direct the adjustment of the process for the mathematical analysis in accessible variables, which closely express the selected conceptual elements, this as part of the recognition of a great context resulting from poverty and economic inequality in the country.

The model forms a robust basis for establishing a series of direct behaviors of the financial services infrastructure associated with transfers originating in another country and resulting from migration. The transit of remittances through these institutions has caused the concentration of these financial services in cities and in the banking sector by reducing their passage through other ways than transfers to commercial banking accounts. This concentration in cities and institutions occurs despite having large population segments to be served, especially low-income and in non-urban contexts as postulated by financial inclusion; the banking sector requires multiple elements for the installation and continuity of branches in medium or small cities, so the installation of new branches is an exercise that does not respond to the financial inclusion of the aforementioned groups but to a market vision of the demanders of these financial services.

Despite the concentration of remittances, the increase they have expressed does not fully respond to elements of inclusion or expansion of financial services, the dynamics of these respond more to a labor market in the destination of migration and to family economic behavior in the places of origin (consumption). The demand for financial services associated with remittances, such as bank accounts, has developed innovations and flexibilizations, to achieve positioning in the segment of families with migrants has allowed the integration of new banking actors and intermediaries in connection with remittances and through banking financial services manage to get these resources in a short time and advantages within the transfer market.

In the northeastern region, the weight of the metropolitan area of Monterrey, the major urban areas of Saltillo and Ciudad Victoria is evident,

following the border areas such as Matamoros, Reynosa, Nuevo Laredo, and Piedras Negras, in addition there is a trend that accompanies remittances together with bank branches in areas with rural and industrial profiles, where it can be the reason for subsequent research exercises on their population profile and especially migratory.

Finally, this type of research and the use of statistical and spatial tools can allow financial service providers to identify not only unattended population or territorial segments, but also specific profiles of the instruments demanded and the potential connection with other intermediaries to form a service and network costs and offer cross-products such as health insurance, credits, payments to third parties and other savings.

REFERENCES

Alfaro, N. (2010). *Principios para el Diseño de un Sistema Financiero Inclusivo*. Banco Internacional de Desarrollo. Foro Soluciones de Financiamiento Inclusivo. Panamá.

Asmundson I. (2011). Back to Basics, what are Financial Services? *IMF Finance and Development Magazine*. https://www.imf.org/external/pubs/ft/fandd/2011/03/basics.htm

Banco de México (2020). *Sistema de Información Económica, Balanza de pagos; Ingresos por remesas, distribución por municipio - (CE166)*. https://www.banxico.org.mx/SieInternet/consultarDirectorioInternetAction.do?sector=1&accion=consultarCuadro&idCuadro=CE166&locale=es

------ (2020). *Sistema de Información Económica, Financiamiento e información financiera de intermediarios financieros, Información operativa de la banca comercial por entidad federativa y municipio - (CF660)*. https://www.banxico.org.mx/SieInternet/consultarDirectorioInternetAction.do?sector=19&accion=consultarCuadro&idCuadro=CF660&locale=es

Banco Interamericano de Desarrollo (2009). *Cooperación Técnica: "Canal Alternativo de Distribución de Remesas para Pequeños Intermediarios Financieros Ecuatorianos"*. Quito.

------ (2010). *Profundización de Servicios Financieros en zonas rurales*. Quito.

BBV Research (2021). Migración, México En 2020 crecieron las remesas 11.4%, pese a la crisis mundial por la pandemia. *Observatorio Migración México*. https://www.bbvaresearch.com/publicaciones/mexico-en-2020-crecieron-las-remesas-114-pese-a-la-crisis-mundial-por-la-pandemia/?cid=eml:oem:oth:----48030--:::lnkpubl:::20210202::oth:instant:

Bivand, Roger & Gómez Rubio, Virgilio & Rue, Håvard. (2015). Spatial Data Analysis with R-INLA with Some Extensions. *Journal of statistical software*. 63.1-31.

Blangiardo, M., Cameletti, M. (2013). *Bayesian Spatio and Spatio-Temporal Models with R-INLA*. Wiley.

Blangiardo, M., Cameletti, M., Baio, G., & Rue, H. (2013). Spatial and spatio-temporal models with R-INLA. *Spatial and spatio-temporal epidemiology, 4*, 33–49. https://doi.org/10.1016/j.sste.2012.12.001

Buchenau J. (2010). Nuevas tecnologías y canales para la Inclusión Financiera. En *Inclusión Financiera y desarrollo social: nuevos caminos para poner los servicios bancarios al alcance mundial de todos*. https://silo.tips/download/nuevas-tecnologias-y-canales-para-la-inclusion-financiera

Mendoza-Cota, J., & Calderón-Villarreal, C. (2006). Impactos Regionales De Las Remesas En el crecimiento económico de México. *Papeles De Población, 12*(50). Consultado de https://rppoblacion.uaemex.mx/article/view/8654

Central Bank of Brazil. (2010). *Relatório de Inclusão Financeira*. Brasilia: Central Bank of Brazil.

Consultative Group to Assist the Poor, World Bank Group. (2010). *Financial Access 2010: The state of financial Inclusion through the crisis*. Washington, EUA.

Consejo Nacional de Población. (2010). Monto de remesas familiares anuales, 1990-2006. *Índice de Intensidad Migratoria, Consejo Nacional de Población* (2010). http://www.conapo.gob.mx/mig_int/s2008/material/08_01_01.xls.

Dittus P Klein M. (2011). On harnessing the potential of financial inclusion, *BIS Working Papers* (347). www.bis.org/publ/work347.html

Fajury L. Gomez A. (2009). *Corresponsales no bancarios, manual genérico y mejores prácticas*. Bogota, Colombia. USAID / Programa midas- Acción social.

Fernández de lis S. (2011). Visión del desarrollo del sector Financiero y sus principales retos en América Latina y el Caribe. *Diálogo Regional de Política de la Red de Regulación Bancaria*. BID, ASBA y FELABAN, Washington, EUA.

Gardeva A., Rhyne E. (2011). *Oportunidades y obstáculos para la inclusión financiera*. Centro para la Inclusión Financiera, Acción Internacional. (12). https://content.centerforfinancialinclusion.org/wp-content/uploads/sites/2/2018/08/opportunities-and-obstacles-to-financial-inclusion_spanish.pdf

Levine, R., Loayza, N. Beck, T. (2000). Financial Intermediation and growth: causality and causes. *Journal of Monetary Economics, August 2000*(16), 1: 31-77.

Martino, S. and Rue, H. (2009) Implementing Approximate Bayesian Inference Using Integrated Nested Laplace Approximation: *A Manual for the Inla Program. Department of Mathematical Sciences*. Norway. http://www.math.ntnu.no/hrue/GMRFLib

Martins, T. G., Simpson, D., Lindgren, F., & Rue, H. (2013). Bayesian computing with INLA: New features. *Computational Statistics & Data Analysis, 67*, 68-83. https://doi.org/10.1016/j.csda.2013.04.014

Mas, I. Siedek H. (2008). *Banking through networks of retail agents. Focus Note 47*. Washington, D.C.: CGAP. https://www.cgap.org/sites/default/files/CGAP-Focus-Note-Banking-Through-Networks-of-Retail-Agents-May-2008.pdf

Pérez C. (2015). La inclusión financiera en las regiones migratorias de Hidalgo. En Hernández T, González A. estrada R. Moreno H. (Coord.) *Cambios e innovación: una visión estratégica para el desarrollo*. (2015). Universidad Autónoma de Tlaxcala, México.

Pérez C. (2014). Las remesas indígenas como complemento al ingreso y sus mecanismos de uso y recepción. en González J. Bernardino J. y Adán

B. (Coords.) *Hitos Demográficos del Siglo XXI: Migración Internacional.* México, Universidad Autónoma del Estado de México.

Rue, H., Martino, S., Chopin, N. (2009). Approximate Bayesian inference for latent Gaussian models by using integrated nested Laplace approximations. *Journal of the Royal Statistical Society Series B 71*(2), 1-35.

Rue, H., Held, L. (2005). *Gaussian Markov Random Fields. Theory and Applications.* Chapman & Hall.

Schrödle, B., Held L. (2011). Spatio-temporal disease mapping using INLA. *Environmetrics, 22*(6), 725-734.

Siedek, H. (2007). *Banking agents part III: Market reach.* http://www.cgap.org/gm/document-1.9.2115/agents_marketreach.pdf

Siedek, H. (2007b). *Banking agents to reach the unbanked.* http://acri-mena.org/Files/Banking%20agents%20to%20reach%20the%20unbanked%20-%2007.pdf

Tobler, W. R. (1970). A Computer Movie Simulating Urban Growth in the Detroit Region. *Economic Geography, 46,* 234–240. https://doi.org/10.2307/143141