Spatial Interaction Regional Model for the Mexican Economy (*SIRMME*): A Special Case for Mexico City Metropolitan Area

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Abstract: This paper analyzes empirically a macro model and a regional model to explain Mexico and Mexico City economies respectively. Typically, regional economic modeling considers either a top-down or bottom-up approach to model *regional difference* in economic growth. This paper shows results that explain regional difference in Mexico from the bottom-up through a special case that focuses on the spatial interaction between Mexico City -the main economic engine of Mexico- and the rest of the country during the period 2000-2010. Our results indicate that variables associated with human capital, internal migration, "creative class", micro-firms and spatial interaction among micro-regions were conditioning the differential growth between Mexico City and the whole country during the period 2000-2010. Likewise, we present econometric results of a typical macro model that explains economic growth in Mexico by different income effects on components of aggregate demand during the period 1993-2010. The purpose of both exercises is to motivate future research for the Mexican case to link macro components (such as export driven forces, Mexico´s dependency to the USA´s business cycle, loss of government spending, etc.) with their local counterparts such as agglomeration economies, human and creative capital stock, regional spillovers, natural resources, dynamic population, etc. to explain regional differential growth.

Keyword: Spatial regional model, differential regional growth, simulation forecasting, Mexican economy, Mexico City Metropolitan Area.

1. INTRODUCTION

This paper is implementing econometrically a strategy of modeling regional growth through a methodology that stresses top-down and bottom-up approaches. This type of strategy has been considered in the past years in the regional growth literature (Hewings, Nazara and Chokri, 2004; Capello, 2007; Capello and Fratesi, 2012) and it offers an interesting avenue to study the economic interaction between regions and their national or macro-regional counterpart economy. Even though these new approaches have been empirically implemented for the European region, they are practically absent for the case of leading Latin-American countries such as Brazil or Mexico. This paper contributes to overcome this lack of top-down *vs* bottom-up methodological strategies by studying the regional dynamics interaction between Mexico City, which is the second biggest city in the world and whose GDP represents 24.6% of Mexico's GDP, and the rest of the Mexican economy.

The rest of the paper contains five sections. In section 2 is discussed briefly the regional modeling strategies adopted in the literature. In section 3, we estimate a macro-national model that explains the role of each component of the aggregate demand on the Mexican economy growth during the period 1993-2010. In section 4, we propose a regional model that explains the differential growth between Mexico City economy and the rest of Mexican economy (2000-2010) through a spatial interaction model that takes into account the municipalities of Mexico City. In section 5, we present a simulation exercise that evaluates spillover effects of "human capital" on the differential growth among the micro/regions of Mexico City. Finally, we present some final remarks in section 6.

2. THEORETICAL BACKGROUND

Regional modeling, as a technique for structural analysis, policy impact assessment and forecasting, has several approaches; among them we can list the following: Economic base models, input-output models, social accounting matrix models (SAMs), Econometric models, Econometric and Input-Output Integrated models (EcIO), Computable General Equilibrium models, etc. (Loveridge, 2004). In this paper we restrict to the use of econometric models and their spatial version.

Regional econometric models have their antecedents in the pioneering workleaded in the sixties and seventies by Bell (1967), Klein (1969), Glickman

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(1971), and Adams, Brooking and Glickman (1975), among many others, for the case of the United States. The econometric methodology employed in these early works estimated -from a Keynesian perspective-the relations among macro variables throughout annual data. The specification of regional models was performed through a replica of the functional structure of national models, by doing this, the region was assumed as a "small country".

These mentioned models used a methodology called Top-Down, in which the regional model was a kind of satellite for the nation wide model, but the latter allowed the use of specific endogenous regional equations through macro variables at the national level. Bottom-up methodology was limited, to the extent that a regional economy only received shocks from the whole country, but there was no feedback process from regional economies to the national economy. Values of the national variables were simply distributed through the regions.

Over the years, the Top-Down methodology was substantially modified, allowing some sort of endogenization from national impacts, such as is the case of models in which regional equations are specified using a decomposition of impacts. Decomposition implies that regional growth of a variable in a specific sector is constructed from the sectorial growth and a spreading that represents the growth attributable to regional characteristics (Bassilière *et al*. 2008), which can be represented as:

$$y_{ir,t} = S_{i,t} + d_{ir,t} \tag{1}$$

where $S_{i,t} = \bar{y}_{ir,t}$ is the growth of the variable in the sector *i* in period t, $\bar{y}_{ir,t}$ is the national growth of sector *i* at time *t*, and $d_{ir,t}$ is the regional differential growth component in the region *r* in sector *i*, in period *t*. The regional difference can be expressed as follows:[1]

$$d_{ir,t} = y_{ir,t} - \bar{y}_{ir,t} \tag{2}$$

Endogenization of regional growth is achieved by specifying an econometric equation to explain the differential growth component $d_{ir,t}$, while the national share is determined exogenously in a nation wide model. Although Top-Down models can not account for regional effects, they were very popular because of the advantage of requiring little data and being able to model easily individual regions (Clifford, 1982). This last aspect is very relevant when the lack of regional data is common in many countries, especially in developing countries. The lack of information restricts the scope for disaggregation of the model, and usually leads to the use of regional variables constructed by the model´s author, a situation which necessarily implies a trade-off between disaggregation and data quality (Gustely and Ireland, 1980).

Bottom-up models assume that the national aggregate are an average of the regions (Capellini, *et al*. 1987). These models have the advantage of allowing endogenous estimates for regional variables, which in top-down modeling these are assumed as exogenous, and it ensures consistency between regional and national variables. In addition, it allows interaction between regions. These models are considered to be more consistent with the modern approach of regional growth because they incorporate endogenous and cumulative process from the bottom-up (Hewings, Nazara and Chokri, 2004; Capello, 2007; Capello and Fratesi. 2012). A breakthrough in regional modeling is achieved by considering hybrid models that combine both Top-Down and Bottom-Up approaches (Bolton, 1980; Glickman, 1982; Courbis, 1994).

Regardless of the methodological approach adopted, two problems in the regional models arise. First, the difficulties of highlighting inter-regional exchanges are difficult to take into account due to information gaps, lack of regional and multiregional I-O matrices, and scarcity of regional exports and imports statistics (Lemelin, 1980). Second, the appropriate incorporation of spatial spillover effects on growth, when agglomeration economies of some sort are strong, is not an easy task. The concentration of economic activity in space, considered by Krugman (1991), as the most prominent feature of the regional distribution of economic activity, necessarily leads to highlight the effects of spatial spillovers and the externalities involved in these processes.

In the specification and estimation of regional models, one can find an innovation in recent years, that consists in incorporating spatial effects to modeling either spatial dependence or spatial spillovers of economic activity. Spatial Econometrics allows working with spatial dependence through uni-equational models and more recently, through multi equation models (Rey and Boarnet, 2004). A variant of these models is the

[1]To separate national and regional effects, one can use a Shift and Share analysis of this variable, as Bassilière *et al.* (2008) suggest. Here we follow Capello (2007) who uses the difference of national and regional growth rates.

one proposed by Capello (2007) and Capello and Fratesi (2012), and it is used in this work, which allows for a multi equation model estimate, which combines both national and regional macroeconomic variables. The macro equations are estimated in the standard way, while regional equations incorporate spatial effects. The link among the equations is obtained by a simulation algorithm that allows the regional dynamics to play an active role in explaining the national dynamic. The result of these recent efforts, and upon which the model proposed in this paper is based on, is a combination of Top-Down and Bottom-Up approaches, multi equation systems using a mix of spatial and non-spatial specifications in the behavioral equations, and the use of a simulation algorithm to link the regions considered in the model with the national economy. In the next sections, the estimations of a macro and regional models are presented separately, and the developments of their linkages are left for future research.

3. THE MACRO-NATIONAL MODEL

The macroeconomic model advanced in this section runs along the lines of Roberta Capello (2007) and Capello and Fratesi (2012)'s regional model, where the economic growth in a country is explained in a "Keynesian fashion" by components of the aggregate demand (private consumption, private and public investment, exports and imports of goods and services). Likewise, these demand components display an endogenous system which is itself determined by economic policy instruments (interest rate, exchange rate and government spending) and economic policy targets (inflation and unemployment).

In addition to the elements proposed by Capello (2007) and Capello *et al.* (2012), to build up the macro model, we consider specific structural conditions of Mexican economy in particular those emerged from the North American Free Trade Agreement (NAFTA) where Canada, USA and Mexico are the country members. One of these structural conditions is the new role of the public sector which was drastically modified since the early nineties (Mendoza, 2000); in particular, the public investment share in GDP declined from 10.4% in 1981 to 4.6% in 1988 and around 3.5% in recent years. For this reason, the Mexico´s macroeconomic model proposed in this paper considers private and public investment (consumption) in a separate way in order to evaluate the economic public instruments separately on growth.

Since NAFTA, the external sector of the Mexican economy has increased drastically its contribution to GDP: exports plus imports represented 35% of GDP in 1993 and 63% of GDP in 2010. Even though Mexican economy benefited at the beginning from NAFTA, the positive effects damped out because it was not possible to overcome the huge dependence that the Mexican economy has historically had on capital goods and raw materials imports. Therefore, NAFTA provoked a strong dependence of Mexican exports on USA economic cycle (Garcés, D., 2008; Gutiérrez *et al.*, 2005). For that reason, we decide to include the USA GDP in the export equation in the macro model and, in addition, we also modify the impact of foreign direct investment and its relationship with imports (see below).

In this macroeconomic model prevails a Keynesian approach that has been used elsewhere to study the Mexican economy (Castro, Loría y Mendoza, 1997; Urzúa, Esquivel, Lagunes y de la Cruz, 2000; Ruiz y Venegas, 2007; Quintana and Mendoza, 2008 and 2016), in where the economic growth is explained by different income effects on components of aggregate demand anda multiplier effect due to an expansionary fiscal policy. In addition, our model takes into account the strong dependence of the Mexican economy on USA economy.

National Growth Rate

The national growth rate is determined by a "pseudo" identity equation which is built up from national accounts: national income plus goods and services imports (Y+M) is equal to the sum of private consumption, private investment, government consumption and investment, and exports of goods and services (*Cp*+*Ip*+*Cg*+*Ig*+*X*).

After applying the total differentiation method to the accounting identity and doing some algebra, we get the following expressions:

$$Y = Cp + Ip + Cg + Ig + X - M$$

$$\Delta Y = \frac{\partial Y}{\partial Cp}\Delta Cp + \frac{\partial Y}{\partial Ip}\Delta Ip + \frac{\partial Y}{\partial Cg}\Delta Cg + \frac{\partial Y}{\partial Ig}\Delta Ig + \frac{\partial Y}{\partial X}\Delta X - \frac{\partial Y}{\partial M}\Delta M$$

$$\frac{\Delta Y}{Y} = \frac{\partial Y}{\partial Cp}\frac{Cp}{Y}\frac{\Delta Cp}{Cp} + \frac{\partial Y}{\partial Ip}\frac{Ip}{Y}\frac{\Delta Ip}{Ip} + \frac{\partial Y}{\partial Cg}\frac{Cg}{Y}\frac{\Delta Cg}{Cg} + \frac{\partial Y}{\partial Ig}\frac{Ig}{Y}\frac{\Delta Ig}{Ig} + \frac{\partial Y}{\partial X}\frac{X}{Y}\frac{\Delta X}{X} - \frac{\partial Y}{\partial M}\frac{M}{Y}\frac{\Delta M}{M}$$

$$\frac{\Delta Y}{Y}=\eta_{YCp}\frac{\Delta Cp}{Cp}+\eta_{YIp}\frac{\Delta Ip}{Ip}+\eta_{YCg}\frac{\Delta Cg}{Cg}+\eta_{YIg}\frac{\Delta Ig}{Ig}+ \eta_{YX}\frac{\Delta X}{X}-\eta_{YM}\frac{\Delta M}{M}$$

In order to simplify theexpression, the growth rates are identified with lower caps, for example $\Delta y_t=\frac{\Delta Y}{Y}$, such that the national growth equation is reduced to:

$$\Delta y_t=\eta_{Ycp}\Delta cp_t+\eta_{Yip}\Delta ip_t+\eta_{Ycg}\Delta cg_t+\eta_{Yig}\Delta ig_t+ \eta_{Yx}\Delta x_t-\eta_{Ym}\Delta M_t+u_{y,t} \quad (3)$$

Equation [3] establishes that the national income growth is equal to the weighted sum of the components of the aggregate demand in where we also find the income elasticity of each demand component $(\eta_{Yj}, j=cp,ip,cg,ig,x,m)$ at time *t*.

Private Consumption Growth

From a Keynesian framework, the private consumption growth rate depends positively on income growth:

$$\Delta cp_t=\alpha_0+\alpha_1\Delta y_{t-1}+uc_{p,t} \quad (4)$$

Where α_0 is the autonomous income growth component and α_1 is the income elasticity of consumption, i.e. marginal propensity to consume times the inverse of mean consumption, which measures how much the private consumption raises when the income growth is increased (with a temporal lag).

Private Investment Growth

The private investment growth equation has a traditional structure, it depends positively on income growth rate, negatively on interest growth rate (Δi_{t-1}), negatively on a competitive indicator such as the labour cost growth rate (Δulc_{t-1}) and positively on foreign direct investment measured as proportion of domestic investment (Δfdi_{t-1}):

$$\Delta ip_t=\beta_1\Delta y_{t-1}-\beta_2\Delta i_{t-1}-\beta_3 ulc_{t-1}+\beta_4\Delta fdi_{t-1}+u_{ip,t} \quad (5)$$

Exports Growth

In the export growth equation, we consider a positive relationship with the external income $(\Delta yusa_{t-1})$, negative with the labour cost growth rate (Δulc_{t-1}) and positive with the nominal exchange growth rate (Δe_{t-1}):

$$\Delta x_t=\gamma_1\Delta yusa_{t-1}-\gamma_2\Delta ulc_{t-1}+\gamma_3\Delta e_{t-1}+u_{x,t} \quad (6)$$

Imports Growth

The import growth depends positively on demand or national income change, negatively on nominal exchange growth rate and positively on internal inflation (Π_{t-1}):

$$\Delta m_t=\delta_1\Delta y_{t-1}-\delta_2\Delta e_{t-1}+\delta_3\Pi_{t-1}+u_{m,t} \quad (7)$$

Methodology and Econometric Results

As we pointed out before, the macro model studied here is a dynamic system that has to be analyzed in its reduced form (see equation 3). In this equation, the aggregate components (consumption, investment, exports, imports) are resolved simultaneously by the lagged national income growth, which is conditioned on structural's parameters linked to endogenous and lagged endogenous variables, this is what typically is known as *simultaneous equation bias* (Hamilton, 1994).

To solve the problem of *simultaneous equation bias,* different estimation methods are proposed by the literature which basically can be classified in two groups: those dealing with *limited information* [two-stage least squares (*2SLS*) and instrumental variables (IV)] and those dealing with *complete information* [three-stage least squares (*3SLS)*, full information maximum likelihood (*FIML*) and generalized method of moments (*GMM*)], and according to the specific estimating process of each equation is included individual or whole system information. From our perspective, it is better working with complete information methods because it allows getting asymptotic conditions when the $\boldsymbol{n}\times\boldsymbol{m}$ degree of freedoms are increased (where ***n***'s are the number of observations and ***m*** the endogenous variables or system equations number). In this sense, it is more efficient to work with *FIML* rather instead of *3SLS* methods because both are equivalent when the *equation system* is exactly identified and it is asymptotically more *efficient* when the system is over identified. On the other hand, the *GMM* estimator is equivalent to *FIML* and *3SLS* when is assumed that innovations have homoscedastic variance and, it is more efficient when the variance is heteroscedastic (Green, 2003; Hamilton, 1994).

Table **1** shows the estimations of the macroeconomic model's structural parameters by *OLS*, *FIML* and *GMM* procedures. Most of the parameters

Table 1: Macroeconomic Model Estimation

Independent variables with one lag	Private consumption growth model			Private investment growth model			Exports growth model			Imports growth model		
Constant	0.52 (0.78)	1.59 (1.99)	0.54 (4.54)									
Real GDP growth	0.91 (6.79)	0.76 (2.06)	0.91 (35.3)	2.58 (6.27)	2.66 (2.32)	2.75 (42.1)				1.37 (5.37)	2.16 (2.03)	1.38 (41.37)
Interest rate growth				-0.11 (-3.68)	-0.05 (-1.41)	-0.10 (-21.03)						
Labour cost growth rate				-0.74 (-3.97)	-0.84 (-2.47)	-0.86 (-26.35)	-0.21 (-1.64)	-0.04 (-0.13)	-0.21 (-9.30)			
Log foreign direct investment (as proportion of domestic investment)				1.03 (3.33)	2.34 (1.94)	3.45 (34.62)						
Real GDP USA growth							2.37 (10.5)	2.51 (5.10)	2.38 (37.17)			
Nominal exchange growth							0.20 (3.8)	0.22 (1.76)	0.20 (14.29)	-0.42 (-4.44)	0.13 (0.88)	-0.41 (-46.91)
Inflation rate										0.82 (6.33)	0.32 (1.71)	0.81 (57.72)
Estimation method	OLS	FIML system	GMM system	OLS	FIML system	GMM system	OLS	FIML system	GMM system	OLS	FIML system	GMM system
Number of observations	55	275	275	55	275	275	55	275	275	55	275	275
R-squared	0.55	0.52	0.55	0.65	0.63	0.68	0.62	0.60	0.62	0.66	0.39	0.66

Pseudo identity: OLS

$\Delta y_t = 0.56\Delta cp_t + 0.10\Delta ip_t + 0.12\Delta cg_t + 0.02\Delta ig_t + 0.14\Delta x_t - 0.08\Delta m_t, \quad R^2 = 0.98$

Pseudo identity: FIML

$\Delta y_t = 0.55\Delta cp_t + 0.11\Delta ip_t + 0.13\Delta cg_t + 0.01\Delta ig_t + 0.16\Delta x_t - 0.10\Delta m_t, \quad R^2 = 0.97$

Pseudo identity: GMM

$\Delta y_t = 0.54\Delta cp_t + 0.13\Delta ip_t + 0.12\Delta cg_t + 0.03\Delta ig_t + 0.17\Delta x_t - 0.13\Delta m_t, \quad R^2 = 0.97$

Note: *t student in brackets; GGM instruments:* $\Delta cg_t, \Delta ig_t, \Delta y_{t-1}, \Delta i_{t-1}, \Delta ucl_{t-1}, fdi_{t-1} \Delta yusa_{t-1}, \Delta e_{t-1}$ and Π_{t-1} ; We use quarterly data to estimate the macroeconomic model, Period 1993-2010, Source: INEGI and BANXICO.

are significant at the 95% level, but the consumption equation's constant term and the labor cost growth coefficient in the exports function are both significant only at the 90% level (these statistical inferences were made by *OLS* estimations). The coefficient of determination is between 0.55 and 0.66 in the consumption, investment, exports and imports growth equations; and it is 0.95 for the pseudo identity equation. These results are in acceptable ranges for the case of models with stationary variables (Hendry, 1995). One might have been expected good results using a *FIML* procedure, however some variables are non-statistically significant under this estimation and in other variables the expected sign of the coefficient changed. In this sense, it must be emphasized that the labor cost and exchange rate variables have lost statistical significance and that the interest rate is just now significant at 85% level; in the same way, foreign direct investment (as proportion of the gross fixed capital formation) is at 95% significance level. Finally, in the imports function estimations, we find that under *FIML* procedures, the exchange rate devaluation and inflation are not significant at 95% level. The best econometrics results were obtained by using the GMM estimator; under this estimation, all system parameters were highly significant at 95% level and they have the expected sign.

Theoretical Results and Economic Policy Implications

Given the econometric results of the macroeconomic model under GMM method, we propose the following economic inferences about growth dynamics in Mexico and their economic policy implications.

Pseudo Identity Equation

The national income growth function estimation shows (see low panel of Table **1**), as expected, that the greatest elasticity comes from the private consumption (0.54%); moreover, if the government consumption is also considered, total consumption can explain 0.66% of the national income growth. The second best impact is the external sector component in where the exports and imports elasticity are 0.17% and 0.13% respectively. These results show the relevance of the exports function to the national income growth. But by the same token, it also shows the weakness of the external component due to the high imports dependence because the external sector net effect is highly reduced: the external sector elasticity or the net exports is hardly 0.04%. Finally, the main impact of government in generating economic growth comes from its consumption spending (0.12%) in contrast to its investment spending (0.03%).

Consumption Function

The Keynesian specification of the consumption function shows the existence of an autonomous part (0.54), nevertheless, the main element that explains consumption is the GDP growth (0.91). The income elasticity of consumption equation is pretty close to most of Mexican estimations found in the literature, but this result differs from Capello's (2007) and Capello *et al.* (2012) estimations for the European Community countries. The marginal propensity to consumption derived from the estimated elasticity is 0.65 in averages for all the period analyzed, which suggests that an important part of the economic agents are saving money.

Private Investment Function

The typical finding in the Keynesian private investment estimation is that the income accelerator is the most important component that explains investment decisions; however, for the Mexican case, foreign direct investment (as proportion of the gross fixed capital formation) is the main factor in explaining the private investment equation (3.45). The second one is the income accelerator (2.75) followed by competitiveness (-0.86) and interest rate (-0.10).

Exports Function

As expected, USA income is the most important variable in the Mexican exports equation. Its elasticity is 2.38 which is very similar to the found in other studies. We also see that competitiveness of Mexican goods is not affected by exchange rate devaluation or wage costs reduction because the elasticity in both cases is very small. In fact, these two last factors do not have any relevant impact on exports.

Imports Function

The income elasticity is the most important component in the imports equation which confirms that the Mexican economy has a strong dependence on imports. This also shows that import substitution depends more on internal price growth (inflation) than on exchange rate devaluation.

4. REGIONAL MODEL

In this section, we describe the regional model that explains the growth dynamics of Mexico City at

Municipality level. As we discussed before, and along the lines of Capello (2007) and Capello *et al.* (2012), the main task of the model is to explain, through regional factors associated to the metropolitan area, the growth differentials between the municipalities of the metropolitan area of Mexico City and the whole country. The regional factors considered in this study invoke modern theories of regional growth (Capello and Nijkamp, 2009), from which we specially pay attention to both endogenous growth determinants and interactive behavior and processes that take place in space. The regional model that we display below takes into account *structural resources* as quality of human capital and population dynamics, *sector activity resources* in manufacturing and services and self-employment activities, and finally *territorial structure resources* as roads density, distance to the center of the metropolitan area and spatial structure in the form of regional growth dependence among neighboring regions. This last component can be a good proxy of the role of agglomeration economies which is a central element in the literature of the New Economic Geography.

Descriptive Data

The regional area of study is the Metropolitan Area of Mexico City which has around 20 million inhabitants and it is among the top largest urban areas in the planet. The Metropolitan Area of Mexico City has a political-administrative division that consists of 75 municipalities spreading basically over two federal states (Mexico State and the Federal District).[2] As we can see in Table **2**, the population of Mexico City represents around 17.9% of the total population in the country but its demographic determinants (fertility, migration and mortality) are less dynamic to the displayed in other regions of the country, which translates in a relative loss of contribution of Mexico City population (as we can see in Table **2**, growth country population has been higher). The economic activity of Mexico City is very important for the country (see Table **2**), because its GDP covers almost the 24.6% of the country GDP (in 2010); however note also, as in the case of its population, that the contribution of Mexico City GDP has decreased since 1995 meaning that other regional areas (for instance, those closer to the USA border) have increased its share on GDP.

The main task of the regional model is to explain the regional differential growth component[3]:

$$y_{r,t} = \bar{y}_{r,t} + d_{r,t} \tag{8}$$

Where the $y_{r,t}$ and $\bar{y}_{r,t}$ denote the GDP growth of the *r* region and the whole country respectively, and $d_{r,t}$ is the regional differential component. Figure **1** shows the time series of the GDP growth rate in Mexico City and the whole country during the period 1994-2010. The figure depicts clearly that Mexico City, as indicated by the gray line in the Figure **1**, most of the time grew less than the country GDP during the last two decades: the average differential during the period was -0.82, that is, Mexico City increased around 0.82 percentage point less than the country. This poor performance of the city has been widely discussed in the literature, and several factors have been considered as explanations, among them, the relocation of the manufacturing activity from Mexico City toward the north of the country (see Hanson 1998). In this sense, note in Table **3** that the annual growth of the Gross Value Added during the period 1999-2010 in the country manufacturing sector was 10.24% more than two times that the registered in Mexico City (4.16%). Likewise, the decline in the growth of manufacturing firms has been faster in the case of the Metropolitan Area of Mexico City (-1.35%) than the country (-0.83%). As we can see below, one of the elements that might explain the poor performance of the Mexico City is its increasing loss of potential in the manufacturing activity.

It is interesting to point out some spatial dependence indicators of the economic activity in México City. Table **4** shows that the GDP growth in Mexico City –at municipality level– during the period 2000-2010 exhibits statistically significant spatial dependence (0.20), as measured by the Moran Index, which is very close to the calculated for the whole country (0.22). Nevertheless, note in Table **4** that the GDP per capita exhibits more spatial autocorrelation for the case of Mexico City in each of the years considered. These elements indicate that the spatial structure component could play an important role in the regional growth dynamics not only among regions (Federal States) but also inside the regions as in the case of the Metropolitan Area of Mexico City. We will see ahead that the spatial autocorrelation of GDP growth remains even when controlling for potential explanatory variables of growth.

[2]There is one municipality, Tizayuca, that is located in the federal state of Hidalgo. It is important to mention that we rely on the classification of CONAPO to delimit the metropolitan area of Mexico City.

[3]Which is similar to equation (1).

Table 2: Comparative Data between Mexico City Metropolitan Area and the Country

	Mexico City	Mexico	Differential
Avg annual GDP growth 2000-2010	1.33	2.15	-0.82
Ratio GDP Mexico city / GDP Mexico 1995	27.72		
Ratio GDP Mexico city / GDP Mexico 2000	26.93		
Ratio GDP Mexico city / GDP Mexico 2005	24.80		
Ratio GDP Mexico city / GDP Mexico 2010	24.60		
Population avg annual growth 2000-2010	0.94	1.52	-0.59
Ratio Population Mexico city / Pop. Mexico 1995	18.98		
Ratio Population Mexico city / Pop. Mexico 2000	18.87		
Ratio Population Mexico city / Pop. Mexico 2005	18.63		
Ratio Population Mexico city / Pop. Mexico 2010	17.91		

Source: prepared by authors based on data census gross value added economic census (INEGI) and GDP by state of German-Soto (2005 and 2015).

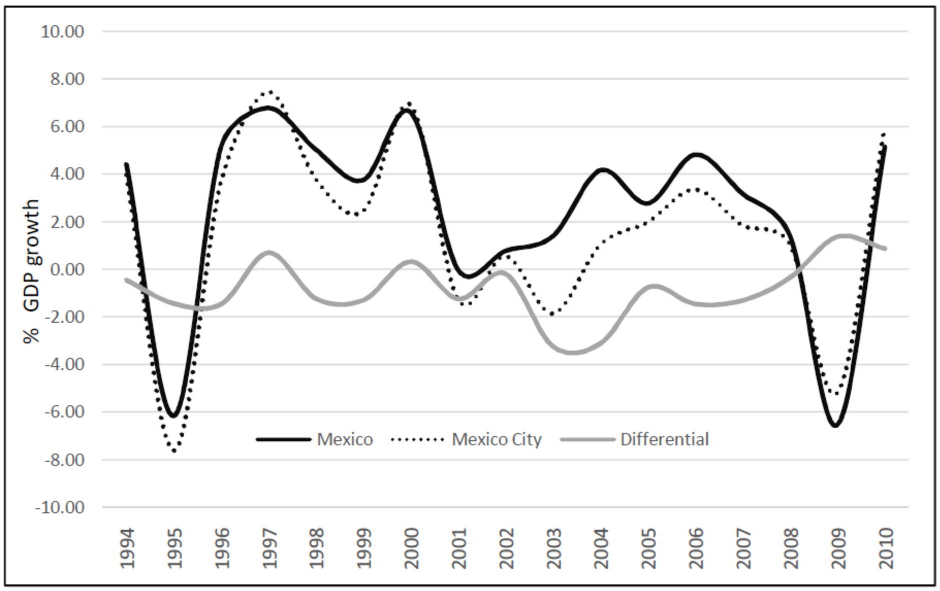


Figure 1: GDP growth and differential growth Mexico and Mexico City.

Source: prepared by authors based on data census gross value added economic census (INEGI) and GDP by state of German-Soto (2005 and 2015).

Table 3: Manufacturing and Service Activities

Annual growth of firms 1999-2010		
Sector	**Mexico City**	**México**
Manufacturing	-1.35%	-0.83%
Services	1.14%	1.58%
Annual Growth of Gross Value Added 1999-2010		
Sector	**Mexico City**	**México**
Manufacturing	4.16%	10.24%
Services	16.24%	16.30%

Source: prepared by authors based on data of economic census (INEGI).

Table 4: Spatial Dependence in Regional GDP Indicators

Spatial autocorrelation in log GDP per capita	Mexico City	Mexico
1995	0.3209	0.2692
2000	0.3750	0.2604
2005	0.3750	0.2811
2010	0.3674	0.2741
Spatial autocorrelation in GDP growth 2000-2010	0.2002	0.2148

Note: The Moran Index is used to calculate spatial dependence. All measures are statically significant at 99% by Monte Carlo procedures. A first order Queen contiguity matrix is used for calculations.

Specification of the Regional Model

The main purpose of this sub-section is to present the regional model that explains the differential growth between Mexico City and the rest of Mexico. The equation analyzed is the following:

$y_{r,t} - \bar{y}_{r,t} = d_{r,t}$ *f*(structural resources, territorial and spatial structure and economic activity sector) (9)

where $y_{r,t}$ is defined as the average annual growth of real GDP at municipality *r* during the period 2000-2010; likewise, $\bar{y}_{r,t}$ is defined as the average annual growth of real GDP in the country during the period 2000-2010. In equation 9, the explanatory variables considered in the *A) structural resources group* are growth of education years during 2000-2010 (*gHC*), population growth during 2000-2010 (*gPop*), an internal migration variable measured as the net immigration flow in 2000 (multiplied by 1000) divided by the mean population in the period 1995-2010 (*NI*), energy consumption per capita (kilowatts) in 2000 (*ECpc*), share of the employment in the professional-technical service sector that we call it "creative class" (*CClass*)[4]; the explanatory variables considered in the *B) territorial and spatial structure group* are Road Density (*RD*) measured as meters of roads per Km^2, the square of density roads (DR^2) as a variable that measures congestion effects, a *monocentric variable* defined as the euclidian distance in meters that separates each municipality from the center of the metropolitan area (*DistCenter*), a regional dummy variable that indicates whether the municipality is located at the Federal District (*FD*), *spatial spillovers* proxied through the differential annual growth of the neighboring municipalities (*WD*); and finally, the explanatory variables used in the *C) economic activity sector group* are the growth of manufacture firms during 1999-2010 (*gMF*), the growth of service firms during 1999-2010 (*gSF*), share of micro-firms (less than 10 employed persons)in the manufacturing sector in total firms *(micMF*), share of micro-firms (less than 10 employed persons) in the service sector *(micSF*) in total firms, self-employed population in the total occupied population *(SelfEmp)* –this is a proxy of *informality*.

Table **5** shows the descriptive data of the explanatory variables at municipality level. For example, despite the fact that the Metropolitan Area as a whole has a negative growth differential (see Figure **1**), the average growth differential among the municipalities is positive (0.02) but it exists important regional variations (i.e. the Federal District municipalities had in average a growth differential of -0.02 while the Mexico State municipalities had a positive growth differential of 0.03); likewise, the population grew in average 12% between 2000 y 2010 but in contrast the population increase in average in the municipalities that are located in the Federal District by a rate of only 3.4%; the average net immigration flow was positive in 2000 (16.4 immigrants per 1,000 persons); the manufacturing firms grew in average 30% between 1999 y 2008 but those firms located in the Federal District grew only 3.4%, in the same way the service firms grew in average 9.5% but its growth was negative among the municipalities of the Federal District (-6%). Finally, it is important to highlight from Table **3** that most of the firms in the Metropolitan Area are micro firms in the service sector (less than 10 employed persons) –note that in average 83% of the firms are in this category, while only 9.5% of the total firms are in average micro manufacturing firms. An interesting variable to mention is the so called "creative class" which, under our classification, represents in average 35% of the occupied persons that are considered professionals or technicians in the service sector.[5]

[4]We follow some of the guidelines of Fingleton *et al.* (2007) to build this variable. But, the meaning and relevance of the variable to understand the economics of the cities comes from the work of Richard Florida (2005).

[5]However, it is important to indicate that, in average, only 1.8% of the formal employment is considered to be employed in a professional or technical service sector.

Table 5: Descriptive Statistics for the Explanatory Variables

	Obs.	Mean	Standard deviation	Min value	Max value
Differential growth	76	0.02	0.06	-0.10	0.18
Annual GDP growth	76	0.04	0.06	-0.08	0.20
Growth of education years pop. over 15 years 2000-2010	76	0.09	0.03	0.04	0.17
Population growth during 2000-2010	76	0.12	0.19	-0.17	1.19
Energy Consumption - Kws per capita in 2000	76	327.41	496.88	4.05	2730.93
Road Density - Meters of roads per km^2	76	1397.55	1646.65	6.71	6343.55
Self-employmentshare	76	0.22	0.05	0.15	0.45
Growth of employment in the service sector 99-2008	76	11.02	74.24	-0.59	649.00
Growth of manufacturing sector firms 99-2008	76	0.30	0.65	-0.83	5.44
Growth of service sector firms 99-2008	76	0.10	0.30	-0.61	0.86
Micro manufacturing firms share	75	0.10	0.04	0.02	0.34
Micro service firms share	75	0.83	0.08	0.57	0.94
Net internal migration flow (migrants per 1000 persons)	76	16.41	40.59	-86.23	172.35
Percentage of the employment in professional-technical service sector that is part of the "*creative class*"	76	0.35	0.21	0.00	1.00
Monocentric variable. Meters from the center of the city	76	30789.09	15938.48	0.00	67682.80

Source: prepared by authors based on data of economic census (INEGI).

To study econometrically equation 9, we propose the following linear specification in a cross-section setting:

$$\begin{aligned} d_{r,2000-2010} = {} & \alpha + \beta_1 gHC_{r,2000-2010} + \beta_2 gPop_{r,2000-2010} + \beta_3 ECpc_{r,2000} + \\ & \beta_4 CClass'_{r,2004} + \beta_5 RD_{r,2000} + \beta_6 RD^2_{r,2000} + \beta_7 DisCenter_r + \\ & \beta_8 FD_r + gMF_{r,1999-2003} + \beta_9 gSF_{r,1999-2003} + \beta_{10} SelfEmp_{r,2000} + \\ & \beta_{11} gEmplServ_{r,1999-2004} + \beta_{12} micMF_{r,2004} + \beta_{13} micSF_{r,2004} + \varepsilon_r \end{aligned} \quad (10)$$

where ε is a random disturbance term.

In order to take into account spatial spillovers, the following specification is also estimated:

$$\begin{aligned} d_{r,2000-2010} = {} & \alpha + \rho Wd_{r,2000-2010} + \beta_1 gHC_{r,2000-2010} + \beta_2 gPop_{r,2000-2010} + \\ & \beta_3 ECpc_{r,2000} + \beta_4 CClass'_{r,2004} + \beta_5 RD_{r,2000} + \beta_6 RD^2_{r,2000} + \\ & \beta_7 DisCenter_r + \beta_8 FD_r + gMF_{r,1999-2003} + \beta_9 gSF_{r,1999-2003} + \\ & \beta_{10} SelfEmp_{r,2000} + \beta_{11} gEmplServ_{r,1999-2004} + \beta_{12} micMF_{r,2004} + \\ & \beta_{13} micSF_{r,2004} + \varepsilon_r \end{aligned} \quad (11)$$

To compare the performance among different specifications, we estimated also a slightly modified version of equation 10 and 11 in where the "creative class" is substituted by the "net immigration flow" variable and the population growth variable is dropped out because immigration flow explains it. Table **6** depicts the results for both models with their associated statistical tests. Model 1.A presents the estimations of equation (10) by OLS procedures, without the spatial spillover variable (Wd_r) and considering immigration variable instead of population growth. In this model, the growth of education years in the active population (*gHC)* and the net immigration flow (*NI*) are the only significant variables that are explaining the differential growth in the municipalities of the Metropolitan Area of Mexico City. Nevertheless, this model presents spatial autocorrelation in the error term (as indicated by the spatial dependence tests) and a spatial auto-regressive model is suggested as alternative; therefore, the spatial spillovers considered in equation (11) are well justified by the data used. Model 1.B presents the estimations with the spatial lag of the differential growth (Wd_r)[6], the results indicate that additionally to *gHC* and *NI,* the spatial lag variable and the share of micro manufacturing firms are also statically significant to the model.

In model 2. A of Table **6**, the *creative class* and *population growth* variables are introduced in the model, and the immigration variable is removed to avoid problems of endogeneity. The model seems to perform better than model 1.A as indicated by the log likelihood and the normality tests, and now the share of micro service firms and the "creative class" variables

[6]A first order queen contiguity weight matrix is used to calculate the differential growth of municipality neighbors.

Table 6: Regional Model Estimation for the Mexico City Economy

Variable	Model 1.A	Model 1.B	Model 2.A	Model 2.B
	Coefficient	Coefficient	Coefficient	Coefficient
*WDr,2*000-2010	-	0.2473	-	0.2596
	-	(0.1423)**	-	(0.1405)***
α	-0.0764	-0.0585	-0.0873	-0.0703
	(0.0771)	(0.0681)	(0.0785)	(0.0684)
gHCr, 2000-2010	0.7801	0.6697	0.8275	0.7021
	(0.3674)***	(0.3259)***	(0.4099)***	(0.3620)***
gPopr, 2000-2010	-	-	-0.0345	-0.0301
	-	-	(0.0440)	(0.0386)
*ECpcr,*2000	0.0000	0.0000	0.0000	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)*
Cclassr, 2004	-	-	0.0644	0.0602
	-	-	(0.0366)**	(0.0319)**
RDr, 2000	0.0000	0.0000	0.0000	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
(RDr)^2, 2000	0.0000	0.0000	0.0000	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
DistCenterr	0.0000	0.0000	0.0000	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)**
FDr	0.0115	0.0119	-0.0153	-0.0109
	(0.0275)	(0.0245)	(0.0234)	(0.0209)
gMFr, 1999-2003	0.0104	0.0095	0.0101	0.0095
	(0.0120)	(0.0106)	(0.0129)	(0.0113)
gSFr, 1999-2003	0.0346	0.0241	0.0285	0.0180
	(0.0266)	(0.0235)	(0.0268)	(0.0235)
SelfEmpr, 2000	0.0241	0.0247	-0.0773	-0.0659
	(0.1598)	(0.1411)	(0.1601)	(0.1398)
gEmplServr, 1999-2008	-0.0058	-0.0061	-0.0064	-0.0067
	(0.0047)	(0.0041)	(0.0048)	(0.0042)*
micMFr, 2004	0.1975	0.2522	0.1837	0.2438
	(0.1778)	(0.1574)*	(0.1783)	(0.1555)*
micSFr, 2004	0.0549	0.0380	0.1166	0.0941
	(0.0622)	(0.0552)	(0.0692)**	(0.0605)*
NI	0.0004	0.0003	-	-
	(0.0002)**	(0.0002)**	-	-
R2	0.35	0.38	0.36	0.39
R2 adjs	0.21		0.21	
Log Likelihood	116.799	118.077	117.369	118.815
	FD	p-value		
Jarque-Bera	2	0.024		
Breusch-Pagan test	13	0.565		
Koenker-Bassett test	13	0.907		
White	104	0.982		

(Table 6). Continued.

Spatial dependence test						
	Model 1.A			**Model 2.A**		
TEST	**MI/DF**	**VALUE**	**PROB**	**MI/DF**	**VALUE**	**PROB**
Moran's I (error)	0.085	2.091	0.030	0.091	2.150	0.030
Lagrange Multiplier	1	2.462	0.110	1	2.832	0.090
Robust LM (lag)	1	2.720	0.090	1	3.030	0.080
Lagrange Multiplier	1	1.151	0.283	1	1.316	0.251
Robust LM (error)	1	1.409	0.235	1	1.515	0.218
Lagrange Multiplier	2	3.871	0.144	2	4.347	0.114
	Model 1.B			Model 2.B		
	MI/DF	VALUE	PROB	MI/DF	VALUE	PROB
Breusch-Pagan HETEROSKEDASTICITY	13	10.700	0.636	14	15.4136	0.350
Likelihood Ratio Test	1	2.555	0.110	1	2.89369	0.089

Note: ***Significant at 99% level, **Significant at 95%, *Significant at 90%.

emerge both significant to the model. But in spite of that, the model continues presenting spatial autocorrelation in the error term. The spatial dependence tests also suggest, and more clearly than in the case of model **1.A**, an auto-regressive model as alternative. The results of this model are showed in the last panel of Table **6**. As expected, the spatial spillover variable is significant and the *gHC* and *creative class* too, but also it is interesting to observe that there is now other block of variables that are contributing to the model with negative effects (the monocentric variable, the consumption of energy per capita and the growth of the occupied population in the service sector). As in the case of model **1.B**, the model **2.B** has a better performance that its counterpart model without spatial spillovers.

So far, we proposed in this section a regional model that explains the differential growth between GDP growth at municipality level and GDP growth at macro level (*i.e*. the country). The model relies on some theoretical elements that are considered in modern regional models (Capello and Nijkamp, 2009). In particular, we try to emphasize the role of spatial interaction among micro-regions as a mean to approximate either some of the forces that the New Economic Geography stresses (i.e. agglomeration economies) or some less mainstream components like no-pecuniary externalities (i.e. technological diffusion or/and human capital spillovers). We show that these elements could be important in the regional dynamics of Mexico City. Likewise, we put special attention in the regional model to the interplay between manufacturing and service sector activity, because there is a strong debate, at least for the Mexico City case, about whether the underperformance of Mexico City economy respect to the country is associated with the loss of dynamism in the manufacturing activity. In any case, our results indicate that manufacturing activity (in small enterprises) is also contributing to growth and, also the increase of employment in the whole service sector might affect negatively regional growth. Nevertheless, it would be erroneous to infer that all activity associated with the "service sector" is harmful to the Mexico City economy; in specific, our results indicate that the employment share in the professional-technical service sub-sector (that we called "*creative class*") is contributing positively to growth. This is important to highlight because it aims to a central element that is currently discussed in the modern economic city literature that emphasizes the role of location decisions of workers instead of location decisions of firms (Glaeser, 2007; Florida, 2005; Storper and Scott, 2009).

5. SIMULATION OF SPATIAL SPILLOVERS

In this section, we present a spatial simulation exercise using the regional model of the last section. The simulation consists in evaluating the effect of an increment in the "years of education" over the differential growth among the municipalities of Mexico City. In order to understand the spatial diffusion process, we use a reduced version of equation11that it only highlights the parameter associated with the spatial lag (ρ) nd the one linked to the education years (β); the rest is compacted to X_r .

$$d_r = \alpha + \rho W d_r + \beta gHC_r + X_r + \varepsilon_r$$

Simulation Scenarios

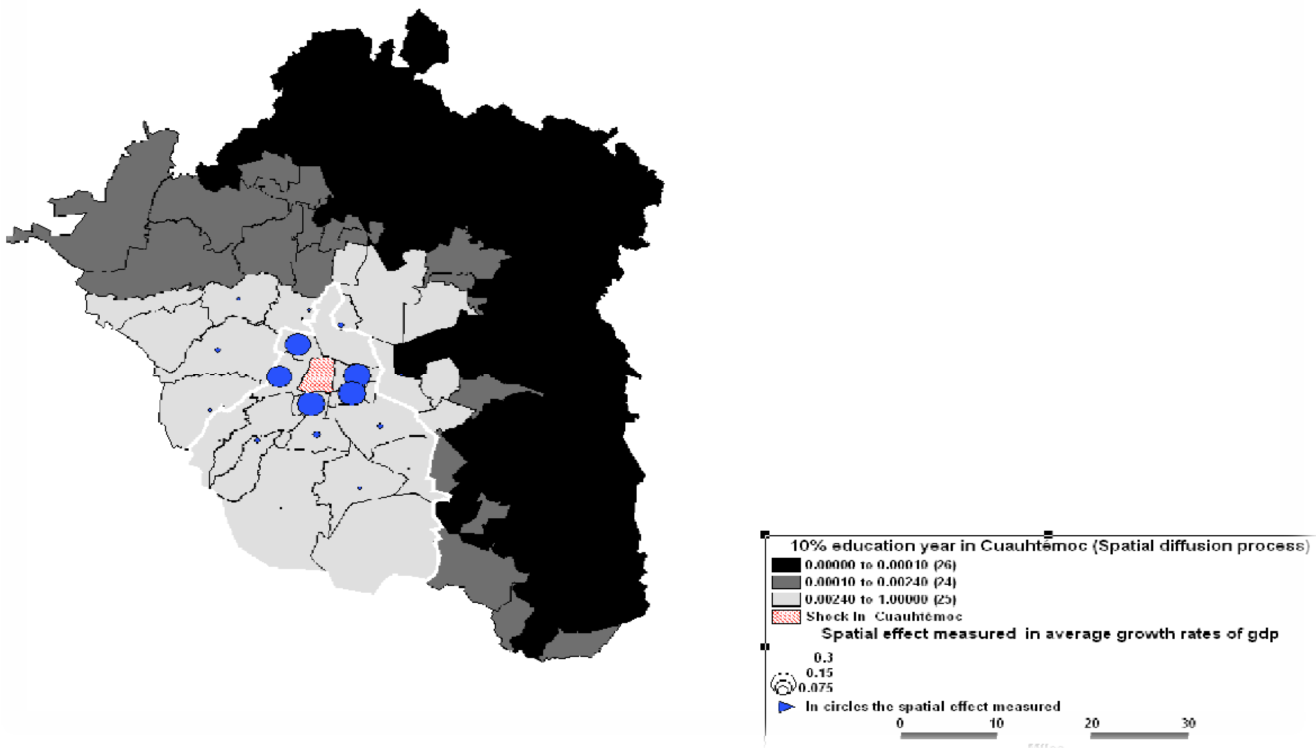
The solution of the regional model at equilibrium is used to measure the spatial effects and evaluate the spatial diffusion given by an increment of 10% in education years over the differential growth at both the municipality that receives the "shock" and the rest of municipalities in the Metropolitan Area.

With the purpose to evaluate some issues regarding with the advantages (disadvantages) of being economically located at the center (periphery) of Mexico City, we choose the municipalities of Cuauhtemoc (In the Federal District) and Tlalnepantla (State of Mexico) located close to the center, and the municipalities of Isidro Fabela (State of Mexico) and Magdalena Contreras (D.F) located at the periphery. The main results of the simulation exercise are the following: 1) An increment by 10% in education years in the municipalities chosen generate direct growth on the differential growth of the municipality receiving the shock between 6.9% and 7.5%. The municipality of Cuauhtemoc (at Federal District) has the greatest increment in its differential growth and, on the other side, the municipality of Magdalena Contreras (located toward the south of the city) receives the weakest impact (see Table **7**); 2) It is interesting to see that the municipality which is farthest from the center, Isidro Fabela, has not only the highest direct effect but also it develops the larger spatial diffusion effects (see blue circles in the Maps). Also it is important to point out that Isidro Fabela´s spatial diffusion effects impact heavily on municipalities located at the Federal District which are at the southwest part (Cuajimalpa and Magdalena Contreras) -see map **3**; 3) The municipality which is closest to the center (Cuauhtémoc) is the one that receives the higher direct impact of a 10% change in education years (7.5% increase in its differential growth), however it has the lowest spatial spillover effects on differential growth of other municipalities (see Table **7**). A similar situation occurs with Tlalnepantla which is located in an industrial area of the State of Mexico closer to the center; however, in contrast to Cuauhtemoc, Tlalnepantla has a higher degree of economic interdependence with their neighbors because of the industrial character of the area; and, 4) another interesting case is Magdalena Contreras which is located at the southwest side of the Federal District (map **4**), it has similar spatial spillover characteristics that Isidro Fabela; that is, its spillovers go beyond the neighboring municipalities (note in map **4** that the spillover effect from this municipality reaches the other extreme of the city in municipalities at southeast).

Table 7: Spatial Diffusion of the Effects of 10% Increase in Education Years on Differential Growth: the Case of Municipalities Located Either in the Center or the Periphery of the Metropolitan Area of Mexico City

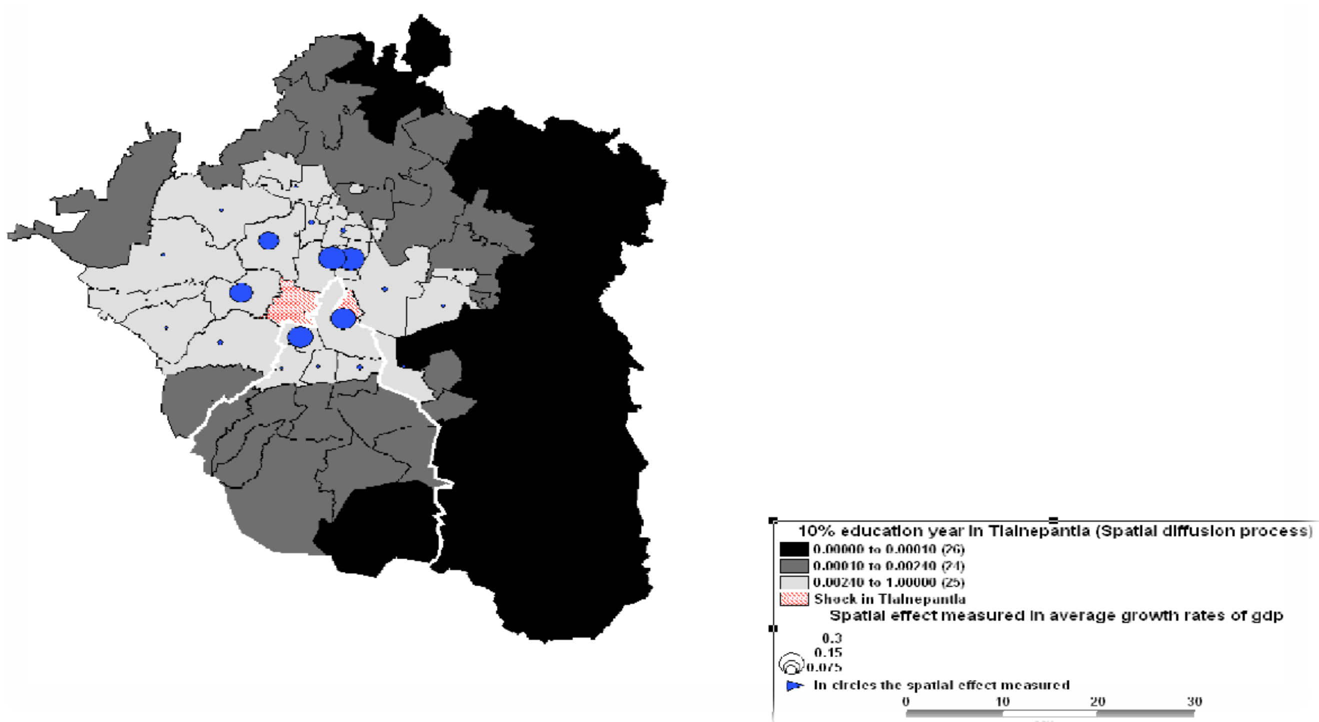
	Cuauhtemoc	Tlalnepantla	Isidro Fabela	Magdalena Contreras
Direct impact (inside the municipality)	7.5	7.3	7.3	6.9
Spatial diffusion impacts (over the rest of municipalities)	2.1	2.1	3.3	2.2
Total impact	9.6	9.3	10.6	9.1
Number of municipalities that concentrate more than 80% of impacts	5	6	7	6
Municipalities with higher spatial impacts	Benito Juárez	Tultitlán	Cuajimalpa de Morelos	Tlalpan
	Venustiano Carranza	Coacalco de Berriozábal	La Magdalena Contreras	Cuajimalpa de Morelos
	Iztacalco	Gustavo A. Madero	Nicolás Romero	Álvaro Obregón
	Miguel Hidalgo	Azcapotzalco	Atizapán de Zaragoza	Ecatzingo
	Azcapotzalco	Atizapán de Zaragoza	Jilotzingo	Tepetlixpa
		Cuautitlán Izcalli	Huixquilucan	Isidro Fabela
			Villa del Carbón	
			Naucalpan de Juárez	

Source: prepared by authors based on the regional model.



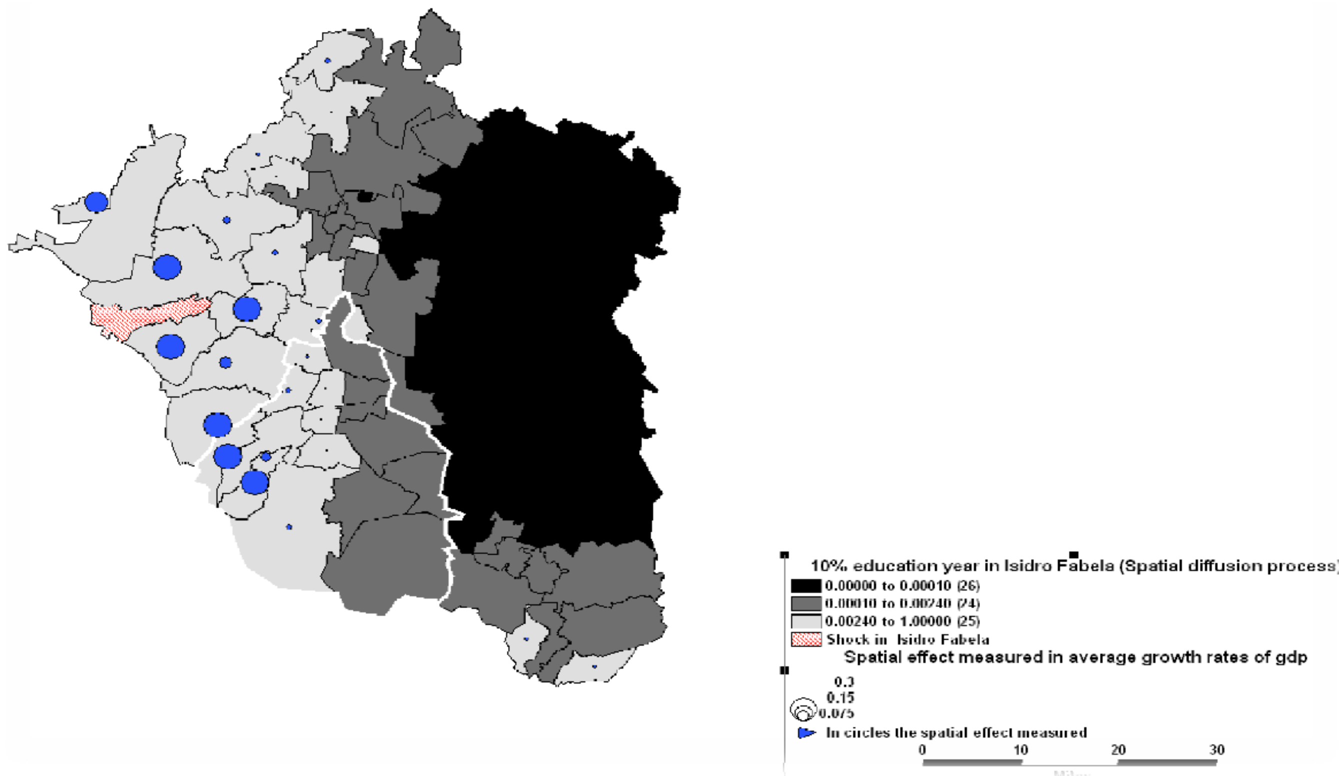
Map 1: Spatial spillover effects on differential growth among municipalities produced by an increase of 10% in education years in the municipality of Cuauhtemoc (Federal District).

Source: prepared by authors based simulation scenarios on regional model.



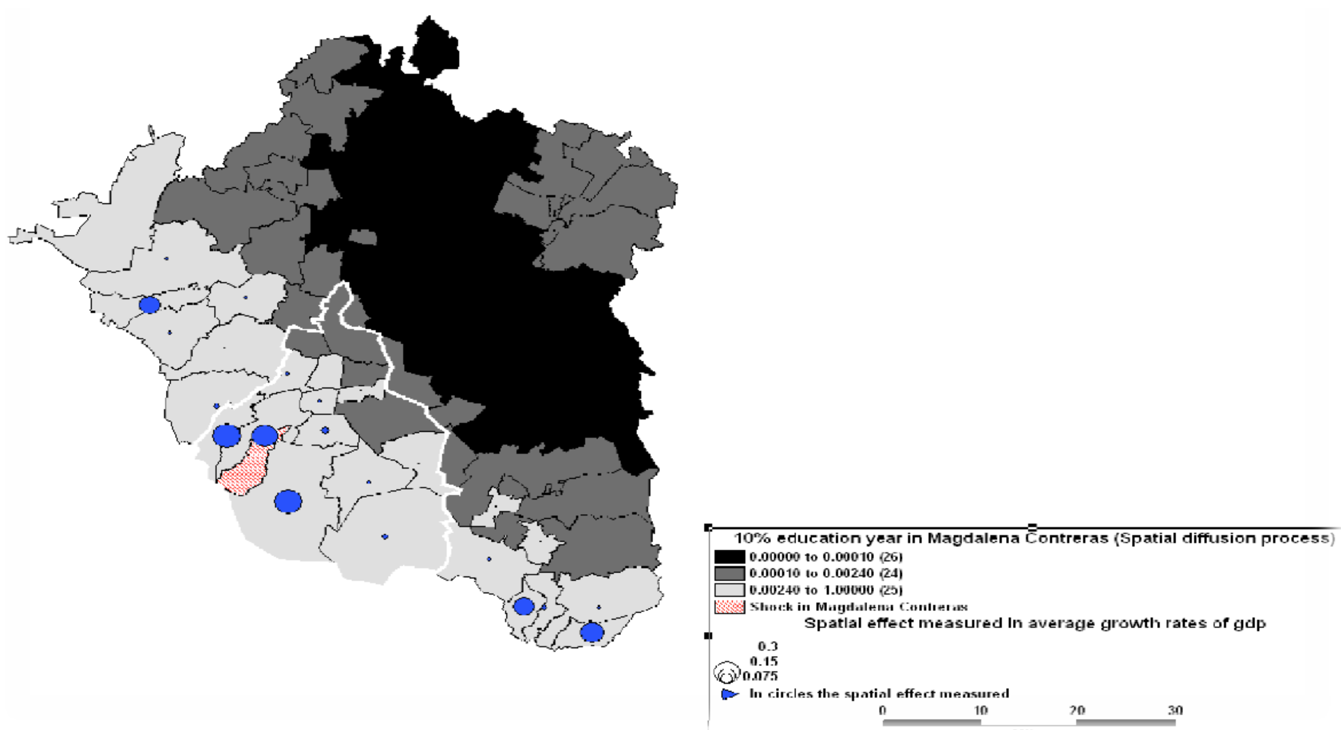
Map 2: Spatial spillover effects on differential growth among municipalities produced by an increase of 10% in education years in the municipality of Tlalnepantla (State of Mexico).

Source: prepared by authors based simulation scenarios on regional model.



Map 3: Spatial spillover effects on differential growth among municipalities produced by an increase of 10% in education years in the municipality of Isidro Fabela (State of Mexico).

Source: prepared by authors based simulation scenarios on regional model.



Map 4: Spatial spillover effects on differential growth among municipalities produced by an increase of 10% in education years in the municipality of Magdalena Contreras (Federal District).

Source: prepared by authors based simulation scenarios on regional model.

FINAL REMARKS

The model presented in this paper, called it *SIRMME*, is at initial stage of development. Because Mexico City continues being the main economic engine of Mexico, we decide to have a first top-down *vs* bottom up modeling of regional growth through the interaction between Mexico City and the whole country´s economy. But it remains for the next stages of modeling to take into account also the interaction between Mexico City and the other main metropolitan areas across the country.

Our results indicate that typical findings of traditional macro models applied to Mexico´s economy (such as the relevance of the export growth equation, the dependence in the USA business cycle, loss of government spending to promote growth, etc.) must be considered to model also local economic growth; and the methodological approach used in this paper can give some guidelines to have a first approximation with this regard. On the other hand, it is not a mystery that in order to have a better picture about regional dynamics is necessary to consider a modeling approach relying on "regional microfoundations" (such as agglomeration economies, human capital stock, no-pecuniary externalities, natural resources, dynamic population, etc.); and these elements can be appropriately studied in a wide range of econometric models among them the spatial econometric approach such the one used in this paper to model regional growth in Mexico City. Under this framework is possible to detect –as found in this research, that variables associated with "human capital", internal migration, the "creative class", micro-firms and spatial interaction among micro-regions are conditioning the differential growth between Mexico City and the whole country during the last ten years. Because there is a natural linkage between "regional microfoundations" and "the components of aggregate demand" (in a recursive way), our next step is to model growth-transmission effects from a process located at the top (bottom) of the system to the rest of the system and vice versa.

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APPENDIX 1: DATA

a. Macroeconomic Data

We use quarterly data to estimate the macroeconomic model (see Table **2**). The data comes from National Institute of Statistics and Geography (INEGI), the Central Bank (Banxico) and the Bureau of Economic Analysis (BEA). Nevertheless, not all series were available in quarterly frequency and, some aggregation data criteria (with available monthly information) were considered to build the complete quarterly series. Next, we present the main characteristics of the data used: aggregate demand data is in millions of constant pesos of 1993 and they are reported by INEGI; foreign direct investment is a quarterly series in millions of dollars (FDIdol) which have to be converted to constant pesos through the nominal exchange rate and the implicit gross fixed capital formation deflator; interest rate was proxied by CETES in 28 days (BANXICO); labor cost was measured through the index of unitary costs of the manufacturing sector working force; USA GDP is a quarterly series in constant millions of dollars (2005 base); the exchange rate (pesos to USA dollars) was used to consider foreign currency obligations; and finally, the monthly national consumer price index (BANXICO) with base june = 2002 was used to obtain the quarterly index price.

b. Estimations for Metropolitan Area and State GDP

The methodology used for the estimations considered: 1) Implementation of lineal interpolation methods using Gross Value Added of Economic Census (1994, 1998, 2004 y 2008) at municipality level from Federal District, Mexican and Hidalgo states, to estimate distributional series during the period 1994-2010. 2) Estimations from 1) were applied to the GDP State series estimations of German-Soto (2005 y 2015) to obtain GDP at municipality level that are equivalent to the GDP series at state level of German-Soto (2005 y 2015).

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