EXTENDED ABSTRACT

Title: Economic and environmental effects of urban sprawl: A multisectoral analysis for the case of Spain

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Abstract:

Urban sprawl is a phenomenon which starts in the 50-60’s years of the past century in United States, but which has been globalized, affecting cities along all the planet. It consists of the generation of the residential model of single-family houses with low density of construction and extensive use of land.

Urban sprawl is recently also increasing in Europe and Spain, and the expectations after the health crisis of COVID19 are in the line of the acceleration of this process. The Spanish case is one of the most interesting in Europe because in several cities there is a pressure of the construction sector due to the large demand of holidays houses. The economic growth in Spain has been really intense in the last 60 years,

which has made a deep transformation of our society, our traditions and our cities. A concentration process of the population and of the urban growth has also taken place generating cities of a great dimension (Munoz, 2003).

Which consequences can have this phenomenon of the *urban sprawl* in Spain? International literature focuses on four main consequences: (i) immediate impact of *sprawl* on the environment or landscape; (ii) mobility, *sprawl*, and sustainability; (iii) social or economic effects of the *sprawl*; and (iv) *sprawl*, climate change, and energy efficiency (Langarita and Rubiera-Morollón, 2021). This last aspect, the relation between *sprawl* and energy efficiency, is the one where most scientific production is interested on in recent years. The tendency to intensify the usage of own vehicles in the *sprawled* cities drives to a non-sustainable mobility model. Zhao and Zhang (2018) study the impact of higher levels of *sprawl* on the fuel consumption for vehicles. The impact of the sprawl on energy efficiency of houses has also been explored (Estiri, 2014; Heinonen and Junnila, 2014; Huang, 2015; Wiesmann et al., 2011).

There are several papers evidencing the negative environmental consequences of this type of *sprawled cities*. In this work, we go one step further and we also analyze the effects of *sprawl* on the whole economy and in terms of environment from a multisectoral perspective.

Specifically, we evaluate how increases in *urban sprawl* affect the electricity consumption, and, through this, we analyze the economic and environmental effects on the whole economy. First, we make use of Cartone et al. (2021), to see the impact on electricity consumption and, then, we apply the input-output model to see the effects on the rest of the economy.

The input-output (IO) model, developed by Leontief (Leontief, 1941), is a useful tool to analyze the links between economic sectors and, among other applications, to study the impacts on the value chains of reallocations of production. Their extensions to have the environmental flows into account let complement the economic analysis with the study of environmental impacts, which has lets several contributions from several perspectives[1].

[1] As an example, we can see Lenzen et al. (2003), who evaluate the environmental impacts using IO, Wiedmann et al. (2007), where the environmental impact of regional consumption activities is evaluated. Other previous studies have also analyzed the Spanish electricity system using IO, as Duarte et al. (2017),

An input-output table presents a structure similar to the one shown in Table 1, where rows indicate supplies to the different sectors and to the components of final demand and columns show the demands that each of the sectors makes both to the rest of the sectors and to the value added and imports. Each X_i represents the total output of each sector (coinciding the "total resources" with the "total employments"); being each x_{ij} the quantity that the branch *j* demands from sector *i* as input to be incorporated in the productive process to produce X_j; for example, x_{23} represents the quantity that sector 3 demands from sector 2.

Table 1. Schedule of an input-output table

Activity braches	1	2	3	...	n	Intermediate demand	Final demand	Total employments
1	x_{11}	x_{12}	x_{13}	...	x_{1n}	Σx_{1j}	d_1	x_1
2	x_{21}	x_{22}	x_{23}	...	x_{2n}	Σx_{2j}	d_2	x_2
3	x_{31}	x_{32}	x_{33}	...	x_{3n}	Σx_{3j}	d_3	x_3
...					...	...	...	
n	x_{n1}	x_{n2}	x_{n3}	...	x_{nn}	Σx_{nj}	d_n	x_n
Intermediate consumption	Σx_{i1}	Σx_{i2}	Σx_{i3}	...	Σx_{in}	$\Sigma\Sigma x_{ij}$	Σd_i	Σx_i
Gross value added	V_1	V_2	V_3	...	V_n	ΣV_j		
Taxes	T_1	T_2	T_3	...	T_n	ΣT_j		
Gross production	P_1	P_2	P_3	...	P_n	ΣP_j		
Imports	M_1	M_2	M_3	...	M_n	ΣM_j		
Total resources	x_1	x_2	x_3	...	x_n	Σx_j		

Source: own elaboration. Spanish version in Langarita and Rubiera-Morollón (2021).

In matrix form, Table 1 can be expressed as:

$$\boldsymbol{x} - \boldsymbol{A}\boldsymbol{x} = \boldsymbol{d} \quad [1]$$

Being:

A: matrix *nxn* of techincal coefficients a_{ij}.[2]

x: vector of final production.

d: vector of final demand.

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where authors disaggregate the electricity sector in an input-output table (IOT) for Spain. Ramos et al. (2019a) analyze socio-economic impacts of changes in the sector using IO, Ramos et al. (2019b) analyze small scale renewables.

[2] Each technical coefficient a_{ij} is obtained as $\frac{x_{ij}}{x_j}$. We divide by production without imports.

Starting from [1] we can get:

$$\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\, \boldsymbol{d} \qquad [2]$$

Where $(\boldsymbol{I} - \boldsymbol{A})^{-1} \geq 0$ represents the Leontief inverse. Each of the columns expresses the increases in production in each sector *i* after an increase of one unity in the demand of goods of sector *j*.

Thus, expression [2] shows which is the necessary production to satisfy final demand. Taking increments:

$$\Delta\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\, \Delta\boldsymbol{d} \qquad [3]$$

This lets us calculate which is the increment in production generated due to a variation in demand.

We can also see the effects on direct CO_2 emissions by sector making use of emissions coefficients divided by production without imports, obtained from INE (2018):

$$\Delta\boldsymbol{E} = \boldsymbol{e}'(\boldsymbol{I} - \boldsymbol{A})^{-1}\, \Delta\boldsymbol{d} \qquad [4]$$

Where $\Delta\boldsymbol{E}$ is the variation in emissions and ***e'*** represents the emissions vector.

Regarding the aim of the paper, on the evaluation of how increases in *urban sprawl* affect the electricity consumption, and, then, how this affects the economy and the environment, we plan three scenarios of change for the *Urban Sprawl Index (USI)*: (1) 25% increase, moderated scenario whose achievement is very realizable in the next decade; (2) 50% increase, scenario with a moderated increase with respect to the past trend; and, (3) 100% increase, situation which could be plausible due to the pandemic effects, which has changed the preferences of the people.

We particularize the analysis to the case of Madrid, since this is the most important city, together with Barcelona, of the Spanish urban system, and because Madrid is in transition from a traditional compact model to a sprawled model (Rubiera-Morollón et al., 2017).

First, we make use of Cartone et al. (2021), where we can find the relation between the level of *sprawl* and electricity consumption, where we can find de *beta* coefficient in logs. With this, we obtain the results shown in Table 2.

Table 2. Results on energy consumption under different scenarios of increase on the urban sprawl

	Moderated growth in line with the past tendency	**Similar growth to the one experimented by other Spanish cities**	**Strong growth possible if the pandemic implies a changes in the patters of residential decision**
Increase on the *urban sprawl index*	25%	50%	100%
Increase on the energy consumption	2,43%	4,85%	9,7%

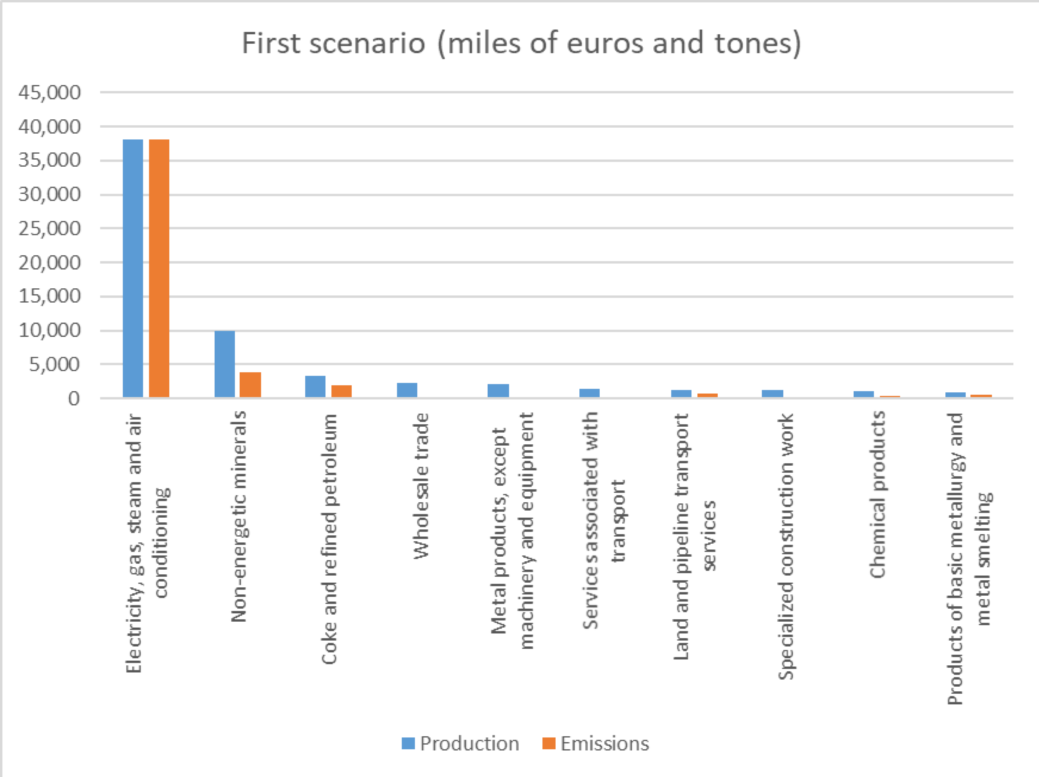
Source: Own elaboration.

Then, we apply the input-output model, explained before, to identify the sectoral economic and environmental effects.

Since we have a linear model, most affected sectors are the same in the three scenarios analyzed both for the case of production and for the case of emissions.

We show results for scenario 1 in Figure 1, where we can see the increase in production of the ten most affected sectors in production and their related impact on emissions. As we can see, Electricity, gas, steam and air conditioning is the most affect sector, with a high difference, followed by Non-energetic minerals, Coke and refined petroleum, and Wholesale trade.

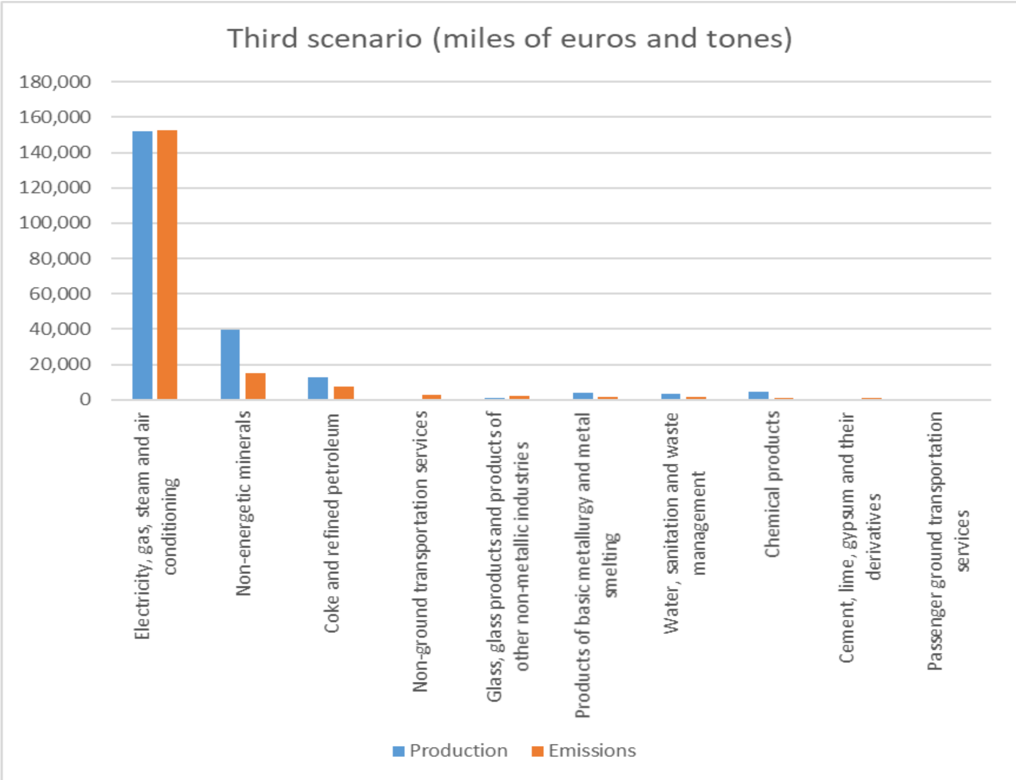
Figure 1. First scenario (top ten sectoral changes in production)



Source: Own elaboration.

If we order the sectors by those most affected on emissions, we have the results shown in Figure 2. The same as in the case of changes in production, most affected sector is Electricity, gas, steam and air conditioning, with a high difference again, and again followed by Non-energetic minerals, and Coke and refined petroleum. However, they are followed in the case of emissions by Non-ground transportation services. And we can also highlight here the presence of Water, sanitation and waste management as most affected in emissions.

Figure 2. Scenario 3 (top ten sectoral changes in emissions)



Source: Own elaboration.

With this IO simulation we confirm that a more sprawled model, as the one the pandemic seems to anticipate in the preferences of the families, will make an increase of the emissions making our cities less efficient. The effects are relevant if we take into account the simulations on Madrid city only. If this phenomenon occurs in general along our complete urban system, the economic and environmental impacts will be double.

In all the cases we will have a higher electricity consumption and a higher level of CO_2 emissions associated to the *sprawl* growth. In the most aggressive case the increase of the sprawl would cause an increase of the electricity consumption of almost 10%. If this process happens in a similar way in all the cities of the country the phenomenon can have relevant consequences in energy efficiency and CO_2 emissions. This supports that the urban form should be taken into account not only for territorial policies but also to improve energy efficiency. That is, our conclusions suggest the need of having this aspect into account. In this sense, General Urban Planning (PGOU in its Spanish acronym) can be an instrument of promotion and orientation of the city with an extraordinary potentiality.

This is a work in progress. The next step in the analysis is the comparison of these results with the case of Catalonia, as another representative case within Spain. Moreover, it would be interesting to see these effects for all the Spanish regions making use of a multiregional input-output (MRIO) model. In the case we want to see any fiscal measure, it would be interesting to apply a computable general equilibrium (CGE) model.

All in all, this paper constitutes a first step in the analysis of the effects of *urban sprawl* on a whole economy from a multisectoral perspective.

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