Motivations

“given the role that transport plays in causing greenhouse gas emissions, any serious action on climate change will zoom in on the transport sector”

(Yvo de Boer, Former Executive Secretary of the United Nations, 2009).

(1) Transport of commodities and people is a big and growing emitter of GHG

- 30% (resp., 20%) of total GHG emissions in the USA (resp., the EU-15)
- has increased by 28% over the period 1990-2006
- road-based transport accounts for approximately 80% of transport sector GHG emissions, of which two-thirds are attributable to private cars

=> The GHG emissions are mainly generated by the transport of commuters and the shipping of goods between cities
Motivations

(2) **Urban-containment policies** neglect their impact on the spatial organization of the economy and, in turn, on transport demand and the resulting GHG emissions.

The objective:

=> to restrict **urban sprawl** by increasing **population density** (in Barcelona, from 1986 to 1996, the level of per capita emissions has doubled, the average trip distance has increased by 45%, and the proportion of trips made by car has increased by 62%)
Motivations

However, when assessing the ecological impact of urban-containment policies, the existing literature fails to address **two major issues:**

1. **The locations of firms and households are given.**
2. **Most studies focus on individual cities instead of the urban system.**

Because of the intercity relocation of firms and households, ecological gains within a city may induce ecological losses in other cities.

**Example:** *by controlling its population growth, California has become the least emissions intensive area in the United States. However, a large number of households have to set up in other states, thus making these places less environmentally friendly*
Objective

To assess the ecological effects of higher population density when both firms and households are free to relocate between and within cities.

Our analysis relies on the following trade-off:

- on the one hand: the agglomeration of activities decreases the polluting emissions stemming from commodity shipping between cities.
- on the other hand: agglomerating activities increases GHG emissions by making worktrips longer.
what matters for our purpose are both the level of population density and the spatial pattern of activities
Results

► An increasing-density policy favors the agglomeration of activities, which *may* generate an upward jump in the level of global pollution.

► A higher population density *may* also be detrimental to welfare.

► An increasing-density policy favors the development of the central business district at the expense of secondary business centers, which leads to longer commuting trips.

► Favoring the decentralization of jobs in big cities may reduce the amount of commuting and improve global welfare.
I – A model with two monocentric cities

II – The ecological and market outcomes

III – A model with polycentric cities

IV – A model in which the intra-city and the intercity distribution of activities are determined endogenously

V – Conclusion
A simple model of trade and location with two monocentric cities

Each city is described by a one-dimensional space with a central business district (CBD) located at $x = 0$ where firms are set up.

There are $n$ Cournotian firms. The manufactured good can be shipped at the cost of $\tau > 0$ units of the numéraire.

Workers consume a residential plot of fixed size $1/\delta > 0$ regardless of their locations $\Rightarrow \delta$ is the population density

$$\text{Max } U_r = a q_r - q_r^2/2 + q_0$$

s.t. $q_r p_r + R_r(x)/\delta + t x = w_r + q_0$
Market outcome

Equilibrium land rent: \[ R_r(x) = \delta \left( \frac{tl_r}{2\delta} - tx \right) \]

\[ \Rightarrow \text{urban costs:} \quad UC_r = \frac{R_r(x)}{\delta} + tx = \frac{tl_r}{2\delta} \]

Equilibrium wage rate: \[ w_r = p_r^2 l_r + (p_s - \tau)^2 l_s \]

Surplus: \[ S_r = \frac{(a - p_r)^2}{2} \]

Indirect utility of a worker: \[ W_r = S_r + w_r - UC_r + \bar{q}_0 \]
The ecological outcome:

\[ E_m(\lambda) = e_C C_m(\lambda) + e_T T(\lambda) \]

where \( \lambda \in [1/2, 1] \) is the share of workers residing in city 1

\[ C_m = (L^2 / 4 \delta^2) (2 \lambda^2 - 2 \lambda + 1) \] is the total distance travelled by commuters

\[ T = \{ [2 - \tau (L + 2)] L^2 / (L + 1) \} (-\lambda^2 + \lambda) \] is the total quantity of the manufactured good shipped between cities

\( \Rightarrow \) a more agglomerated pattern of activity reduces pollution arising from commodity shipping, but increases pollution stemming from a longer average commuting
Spatial equilibrium

The agglomeration of firms and workers within one monocentric city is the unique stable equilibrium iff $\delta > \delta_m$ and dispersion with two identical monocentric cities is the unique stable equilibrium iff $\delta < \delta_m$ with

$$\delta_m \equiv \frac{t}{[(\varepsilon_2 - \varepsilon_1 \tau) \tau] > 0 \quad (\varepsilon_1, \varepsilon_2 > 0)}$$

**Proposition 1:** Workers and firms are agglomerated into a monocentric city when the population density is high, commuting costs are low, and transport costs are high. Otherwise, they are evenly dispersed between cities.
The ecological assessment of the market outcome

\[ E_m (\lambda, \delta) = \{ e_T \left[ 2 - \tau (L + 2) \right] / (L + 1) - (e_C / 2 \delta^2) \} \times \]
\[ \lambda (1 - \lambda) L^2 + e_C L^2 / 4 \delta^2 \]

Agglomeration minimizes GHG emissions iff \( \delta > \delta^* = \sqrt{\frac{e_C (L + 1)}{2 \tau \left[ 2 - \tau (L + 2) \right]}} \)

Otherwise, dispersion is ecologically desirable.

**Proposition 2:** Assume that cities are monocentric. The pollution arising from transport is minimized under agglomeration (resp., dispersion) when population density is high (resp., low), transport costs are low (resp., high), or both.
Are big cities desirable?

Population density ($\delta$)

$\delta_m$

$\delta^c_m$

Commuting cost ($t$)

$\lambda^* = 1$

Win

$\lambda^* = 1/2$

Lost

Agglomeration minimizes GHG emissions

Dispersion minimizes GHG emissions

A

B

C

D
Are more compact cities desirable?

Figure 2a – Ecological and market outcomes when $t > \bar{t}$
Figure 2b – Ecological and market outcomes when $t < \tilde{t}$
Welfare

**global welfare**

\[ W_m (\lambda = 1) \]

\[ W_m (\lambda = 1/2) \]

Welfare losses due to market

\[ \delta_m \quad \delta^* \]

\[ \delta \]
Proposition 3: Assume that cities are monocentric. A higher population density reduces the pollution and raises welfare when commuting costs are high. Furthermore, when commuting costs are low, a higher density may be harmful to both the environment and social welfare.
The case of polycentric cities (with one CBD and two SBDs)

- Each firm set up in a SBD incurs a fixed communication cost $K > 0$

- Urban costs are now given by $UC_r = \frac{t_\theta l_r}{2\delta}$
Polycentric cities and the environment

- The total distance travelled by commuters in polycentric city $r$ is equal to

$$C_p(L_r, \theta_r) = \left( \frac{L_r^2}{4} \delta^2 \right) \left[ \theta_r^2 + \left(1 - \theta_r \right)^2/2 \right] \text{ with } \frac{dC_p}{d \theta_r} > 0$$

where $\theta_r$ is the equilibrium share of firms located in the CBD:

$$\theta_r = \frac{1}{3} + 4 \delta \frac{K}{3 t L_r} > \frac{1}{3} \text{ with } \theta_r < 1 \text{ iff } \delta < \frac{t L_r}{2 K}.$$
Proposition 4: Assume that the intercity distribution of the manufacturing sector and the population density are exogenous. Then, polycentricity generates ecological gains that decrease with the population density but increase with the population size.

Proposition 5: Agglomeration minimizes the pollution for a wider range of population density levels when cities are polycentric rather than monocentric.
The ecological impact of urban development when the size and spatial structure of each city are endogenously determined.
The ecological effects of compact cities

Total distance (commuters)

$C_{pp}$

$C_{pm}$

$C_{p0}$

$C_{mo}$

$\delta_m/3$

$\delta_{pm}$

$2\delta_p$

$\delta$
Welfare and the environment

**Proposition 6**: Starting from the market equilibrium, a coordinated decrease in the size of the CBD both raises welfare and decreases GHG emissions.
Conclusions

1. More compact cities need not be ecologically desirable

2. By lowering urban costs without reducing the benefits generated by large urban agglomerations, secondary business centers may allow large cities to reduce GHG emissions while maintaining their productivity

**BUT** we have left aside the role of density in the GHG emissions generated by

- modal changes leading workers to use mass transport systems
- home heating and air conditioning
- residential density preferences
It is our contention that our results are sufficiently convincing to invite city planners and policy-makers to pay more attention to the various implications of urban compactness.

Thank you for your attention.