Regional Science and Urban Economics 58 (2016) 13–25

Contents lists available at ScienceDirect

Regional Science and Urban Economics

journal homepage: www.elsevier.com/locate/regec

Will skyscrapers save the planet? Building height limits and urban greenhouse gas emissions☆

Rainald Borck

University of Potsdam, CESifo and DIW Berlin, Germany

ARTICLE INFO

Article history:
Received 24 March 2015
Received in revised form 22 January 2016
Accepted 25 January 2016
Available online 2 February 2016

JEL classification:
Q54
R11
R14

Keywords:
Greenhouse gas emissions
City structure
Building height limits

ABSTRACT

This paper studies the effectiveness of building height limits as a policy to limit greenhouse gas (GHG) emissions. It shows that building height limits lead to urban sprawl and higher emissions from commuting. On the other hand, aggregate housing consumption may decrease, which reduces emissions from residential energy use. A numerical model is used to evaluate whether total GHG emissions may be lower under building height restrictions. Welfare is not concave in the strictness of building height limits, so either no limit or a very strict one (depending on the strength of the externality) might maximize welfare. The paper discusses several extensions, such as congestion, endogenous transport mode choice, migration, and urban heat island effect.

1. Introduction

Can skyscrapers save the planet? Are densely populated cities with high-rise buildings good or bad for the environment? This paper sets out to analyze this question in an urban land use model with commuting and housing as sources of greenhouse gas (GHG) emissions.

Some analysts and commentators are afraid of the environmental consequences of urbanization. For instance, Seto et al. (2012) argue that the projected urbanization until 2030 leads to significant loss of biodiversity and increased CO_2 emissions due to deforestation and land use changes. Intuitively, cities use up land, which cannot be used for forests and other green vegetation areas, with concomitant negative effects for the environment.

On the other hand, there are also those who claim that densely populated cities produce lower per capita emissions. For instance, Glaeser and Kahn (2010) show that in the US, inhabitants of densely populated cities such as New York City and San Francisco tend to produce lower CO_2 emissions from transport and residential energy use than those living in less densely populated cities such as Houston, controlling for factors such as local weather. This line of reasoning has prompted organizations such as the OECD and the World Bank to advocate high density urban development to mitigate environmental pollution. In this spirit, Glaeser (2009) writes: “To save the planet, build more skyscrapers”.

This paper analyzes whether limiting building heights is good or bad for the environment. So why would dense high-rise buildings be good for the environment? There are two main effects to consider. First, when buildings are tall and population density is high, households tend to live close to their work, which reduces the need to commute. Since commuting is one of the largest drivers of GHG emissions, artificially limiting population density by reducing building heights would tend to increase GHG emissions (Glaeser and Kahn, 2010). The second effect is on housing. Intuitively, one might think that the effect is similar. When population is large, land is scarce, developers build high-rise buildings and dwellings are small. However, limiting building heights restricts the supply of housing, which drives up housing prices and leads to smaller dwellings. I show that GHG emissions from residential electricity and energy use may fall as a result of building height restrictions.

☆ I would like to thank Jan Brueckner, Kristof Dascher, Tatsuhito Kono, Will Larson, two referees, and seminar participants at Tohoku University, ADBI Tokyo, the UEA meeting in St. Petersburg and the Verein für Socialpolitik conference in Hamburg for their helpful comments, and Marie Bessec for the kind provision of data.

E-mail address: rainald.borck@uni-potsdam.de.

http://dx.doi.org/10.1016/j.regsciurbeco.2016.01.004
0166-0462/

The economic literature on urban structure and the environment is relatively small. Glaeser and Kahn (2010) use US data to study GHG emissions by residents of different cities. The focus of the study is on emissions from urban transport and residential energy use, and how these are shaped by urban structure, such as the density of housing development.

Gaigné et al. (2012) study environmental externalities in a new economic geography framework, pointing to the importance of the urban system as well as the structure of single cities. They analyze emissions from commuting and goods transport. Borck and Pflüger (2015) extend this framework to include emissions from industrial and agricultural production and housing. Legras and Cavailhès (2012) introduce land use as a source of GHG emissions into the same kind of model. Larson et al. (2012) use an urban model similar to the present one and study how energy use from commuting and housing changes with various policies, including building height restrictions. They find that such restrictions increase total emissions with the parameters they use for their quantitative model. This paper uses a standard urban model and studies building height restrictions as introduced by Bertaud and Brueckner (2005). In contrast to Larson et al. (2012), I analyze under what conditions building height restrictions are harmful or not for the environment. In fact, I find that for certain constellations, such restrictions may be good for the environment. The stricter the restriction on building height, the more likely it is that total energy use from residential housing decreases and hence total emissions fall. Larson and Yezer (2014) analyze the effects of city size and density on emissions from commuting, housing and consumption of a numeraire good. Dascher (2013) also analyzes the effect on urban structure on the environment. However, he focuses on how the exogenous 'city silhouette' affects residents' desire to increase carbon taxes. Also, he does not explicitly consider the equilibrium urban structure, nor are there externalities in his model. Tscharaktschiew and Hirte (2010) and Borck and Brueckner (2016) study the effects of carbon taxes in urban economic models.

There are also a few papers that study building height restrictions as second-best policies in the presence of externalities. For instance, Joshi and Kono (2009) study floor-area ratio (FAR) limits in an urban model with population growth to address externalities. Kono et al. (2012) use a similar setup to study FAR limits as a second-best tool to mitigate traffic congestion. Neither paper, however, considers environmental externalities or, more particularly GHG emissions. Also, the current paper more explicitly looks at emissions from commuting and residential energy use in cities with different climates.

The paper proceeds as follows. The next section presents the model. Section 3 simulates the model numerically to gauge whether building height restrictions can reduce pollution using realistic parameters. In Section 4, I present four extensions: first, congestion, second, urban heat islands – that is, the fact that cities are hotter than rural areas and this effect may depend on urban structure –, third, transport mode choice, which affects the emissions from urban commuting, and fourth, an open city system where people can migrate between regulated and unregulated cities. Section 5 introduces pollution externalities into the utility function. This allows me to study the welfare effects from building height restrictions, which weigh the cost in terms of a distorted housing market against the possible benefit of reduced pollution. Section 6 conducts some sensitivity analysis by varying key parameters of the model. The last section concludes the paper.

2. The model

The model introduces environmental pollution into a standard monocentric city model with building height restrictions (Bertaud and Brueckner, 2005). Consider a closed circular city with a fixed number N of residents. Each household has a strictly increasing and quasiconcave utility function $v(c,q)$ defined over consumption c and housing space in square meters, q.[1] Housing is assumed to be a normal good. All households work in the Central Business District (CBD) and commute to work on a dense radial road system. A household living at r km from the CBD incurs two-way commuting costs of tr. The rent per square meter of housing is denoted by p.

Consumers maximize utility by choice of c and q, subject to the budget constraint

$$w - tr = c + pq. \tag{1}$$

All households are freely mobile within cities, and dwellings are allocated to the highest bidder, so households realize the same utility level u regardless of their location in the city. Together with household utility maximization, solving $v(c,q) = u$ gives the household's bid rent function $p(r,u)$ and the optimal dwelling size $q(r,u)$. These have well known properties, in particular, $p_r, p_u < 0, q_r, q_u > 0$ (see Brueckner, 1987).[2] Bid rent falls with distance from the CBD to compensate households for commuting costs. Bid rent also falls with an increase in u (ultimately, u is endogenously determined in the urban equilibrium). Mirroring this is the response of housing consumption, which rises with r and with u (if housing is a normal good) because of the lower price.

Housing is produced by profit maximizing firms, using capital and land under constant returns. The production function for floor space in intensive form is $h(S)$, where S is the capital–land ratio (structural density), and is increasing and concave. Since $h(S)$ gives housing per unit of land, it can be interpreted as floor–area ratio (FAR, see Bertaud and Brueckner, 2005). Firms maximize profits

$$\pi = p(r,u)h(S) - iS - R, \tag{2}$$

where i is the (spatially invariant) price of capital. Together with the zero profit condition for firms, profit maximization gives structural density $S(r,u)$ and land rent $R(r,u)$. It can be shown that $S_r, S_u < 0, R_r, R_u < 0$: since the price of housing falls with r and u, firms respond by using less capital per unit of land. Land rent must then also fall.

The city is circular and extends from 0 to the endogenous city border $\bar{r}$. At each distance r, the land available for housing is given by $\theta r \leq 2\pi r$. Without a building height restriction, the equilibrium in the city is given by the two conditions

$$\int_0^{\bar{r}} d(r,u)\theta r dr = N \tag{3}$$

$$R(\bar{r},u) = R_A, \tag{4}$$

where R_A is the agricultural land rent, and $d(r,u) \equiv h(S(r,u))/q(r,u)$ is population density at r. Eq. (3) states that the integral over all distances of the population density (total floor space h divided by dwelling size per household q) equals the (exogenous) number of residents.[3] Eq. (4) requires that the land rent paid by the housing construction firm at the endogenous city border $\bar{r}$ equals the agricultural land rent. These two equations determine the city border $\bar{r}$ and residents' utility level u as a function of the model's parameters.

[1] In Section 5, I introduce pollution externalities into the model to study the welfare effects of building height restrictions.

[2] Subscripts denote partial derivatives. To ease notation, the dependence of the $p(\cdot)$ and $q(\cdot)$ functions on other parameters is suppressed.

[3] In fact, h/q gives the number of households per square meter, which equals population density divided by the number of persons per household.