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Second-best cost–benefit analysis in monopolistic competition models of urban agglomeration

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ABSTRACT

This paper examines the agglomeration benefits of a transportation improvement in a city by modeling the microstructure of urban agglomeration based on monopolistic competition of differentiated intermediate products. Properly extended to include variety distortion in addition to price distortion, Harberger's measure of excess burden yields the agglomeration benefits. The agglomeration benefits are positive if increasing the variety is procompetitive; however, in the anticompetitive case, we cannot exclude the possibility of negative additional benefits. If there are multiple cities, the net agglomeration benefits can be negative when other cities that experience a reduction in population have larger agglomeration economies.

1. Introduction

Transport investments often have nonnegligible impacts on urban agglomeration. It has been argued that the benefit evaluation of a transportation project must take into account agglomeration benefits along with conventional user benefits. A number of economists have studied this issue, and policy makers in some countries, such as the United Kingdom, have been attempting to include them in their project assessments as one of the "wider impacts".[1] A notable example is the economic evaluation of Crossrail in London (Colin Buchanan and Partners Limited, 2007). In addition to conventional user benefits and tax implications, it includes pure agglomeration benefits that amount to almost two-thirds of the user benefits. The inclusion of agglomeration benefits will have significant impacts on the evaluations of other urban transportation projects such as the Greater Paris public transport network designed by the Société du Grand Paris. Agglomeration benefits may also exist in smaller cities, which may be used to justify light rail transit (LRT) projects that are increasingly popular politically but tend to have low benefit–cost ratios.

Based on past empirical work, urban agglomeration economies are substantial. For instance, a review by Rosenthal and Strange (2004, p. 2133) summarizes the empirical findings as follows: "In sum, doubling city size seems to increase productivity by an amount that ranges from roughly 3–8%".[2] Agglomeration economies on the consumer side are also substantial, as argued by Glaeser et al. (2001), with estimates by Tabuchi and Yoshida (2000) suggesting economies in the order of 7–12%. The benefit estimates could exceed 10% after combining production and consumption agglomeration economies.

Although agglomeration economies certainly exist, they do not yield additional benefits or costs if markets are perfect. Recent developments in spatial economics, however, have shown that many of the sources of urban agglomeration, such as gains from variety, better matching, and knowledge creation and diffusion, involve departures from the first-best world.[3] By modeling the microstructure of agglomeration economies, this paper derives second-best benefit evaluation criteria for urban transportation improvements. Venables (2007) investigated the same problem but without

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[1] See, for example, Venables and Gasiorek (1999), Department for Transport (2005, 2008), Graham (2005, 2006), and Vickerman (2008). Arnott (2007) studied second-best congestion tolls in the presence of agglomeration externalities.

[2] See Puga (2010) for a more recent review.

[3] See Duranton and Puga (2004) for a review of the theoretical analysis of various sources of urban agglomeration, and Fujita and Thisse (2002) for the new economic geography approach, and Kanemoto (1990) for the welfare analysis of a nonmonocentric city model.

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modeling explicitly the sources of agglomeration economies. Accordingly, our analysis examines whether the results in this prior work remain valid when monopolistic competition with differentiated products provides the microfoundation of agglomeration economies. Furthermore, our analysis uses a general functional form that includes commonly used specific forms such as the constant elasticity of substitution (CES) and quadratic functions.

In yet another departure from Venables (2007), we introduce explicitly the rural sector and multiple cities, where the cities can be heterogeneous. The results hinge on whether the city in which a transportation improvement occurs has larger agglomeration economies than other cities. If other cities have larger agglomeration economies, the additional benefits can be negative. We also examine multicentric cities and show that similar results hold between a center and subcenters. For example, if a transport project reduces the commuting costs for a smaller subcenter, the net agglomeration benefits tend to be negative because workers move from a larger center to a smaller subcenter.

Extending the Henry George Theorem to a second-best setting with distorted prices, Behrens et al. (2010) showed that the optimality condition for the number of cities (or equivalently, the optimal size of a city) includes an extension of Harberger's excess burden; that is, the weighted sum of induced changes in consumption, with the weights being the price distortions. New economic geography (NEG)-type models of monopolistic competition contain distortions of two forms: a price distortion for each variety of the differentiated good, and a distortion associated with the number of available varieties consumed. Although the former is well known, the latter has largely escaped the attention of the existing literature. Importantly, because these two types of distortions work in opposite directions, the net effect is uncertain. In the CES case, the excess burden is zero, but in general, it can be positive or negative, depending on specific functional forms.[4]

This paper shows that the same technique is applicable to the benefits of transportation improvements, but the two types of distortions may not work in opposite directions. If an increase in variety is procompetitive in the sense that it makes the price elasticity of demand higher, both distortions work in the same direction to make the additional benefits positive. In the anticompetitive case, however, they work in opposite directions, and the additional benefits may become negative.

The remainder of the paper is as follows. In Section 2, we present a model of urban agglomeration economies based on monopolistic competition in differentiated intermediate products. Section 3 obtains second-best benefit measures of transportation investment. In Section 4, we examine specific functional forms frequently used in the literature of the new economic geography (NEG): additively separable and quadratic production functions and a translog cost function. Section 5 extends the model to multicentric cities. Section 6 concludes.

2. The model

2.1. Basic structure of the model

Our model adds three elements to Venables (2007): the microstructure of agglomeration, multiple cities that can be heterogeneous, and an explicit rural sector.[5] Agglomeration economies result from increased variety in the intermediate goods. We assume monopolistic competition for differentiated intermediate goods, and the differentiated goods are not transportable to outside a city.[6]

The economy contains n cities and a rural area, where all cities are monocentric; i.e., all workers commute to the central business district (CBD). Section 5 extends the analysis to a multicentric model. Cities may be heterogeneous with different technological conditions. Workers/consumers are, however, homogeneous. They are mobile and free to choose where (in the cities or in the rural area), to live and work. The total population in the economy is $\overline{N}$, divided into n areas with populations N^j, $j = 1, \ldots, n$. The first $n-1$ areas are cities with agglomeration economies in production, and the nth area is the rural area without them:

$$\overline{N} = \sum_{j=1}^{n} N^j = N^U + N^n, \tag{1}$$

where $N^U = \sum_{j=1}^{n-1} N^j$ is the total urban population. The number of areas n is assumed to be fixed. We assume that absentee landlords own land in both urban and rural areas.

2.2. Allocation within a city

This subsection characterizes the market equilibrium within a city. Although production functions are generally different across cities, we omit superscript j in this subsection. In order to avoid notational complexity, our model has only one factor of production, i.e., labor, but an extension to a multifactor model—for example, with capital and land—is straightforward.

2.2.1. Production of the final good

The production of the urban final good requires differentiated intermediate inputs only.[7] Unlike in typical NEG models, we do not assume specific functional forms for the production function. We only assume that the production function is symmetric in intermediate inputs and that it is well behaved, so profit maximization yields a unique interior solution. The production function is $y_0 = f(\{y_i\}_{i \in M})$, where y_0 and y_i denote the homogeneous final good and differentiated intermediate input i, respectively, and M is the set of available intermediate goods. The final good is homogeneous, and its transportation cost is zero. The mass of the set of intermediate goods that is actually used for production (i.e., $y_i > 0$) is denoted by m and is called the variety. An example of production functions satisfying these conditions is a separable function, which includes the CES form commonly used in NEG models. Other functional forms examined later are quadratic functions (Ottaviano et al. (2002) and Peng et al. (2006)) and a translog cost (expenditure) function (Feenstra (2003)).

The final-goods industry is competitive within a city, and we assume free entry. The profit of a producer is $\pi = y_0 - \int_0^m p_i y_i di$, where p_i is the price of intermediate good i, and we normalize the price of the final good to one (1). A producer takes the prices of intermediate goods, as well as that of the final good, as fixed. For the choice of y_i, profit maximization yields the usual first-order condition: $\partial f / \partial y_i = p_i$. The choice of variety m, however, is constrained by the entry decisions of intermediate-good producers. Even if adding another variety increases profit, it may not be available in the market. The first-order condition is therefore in an inequality form: $\partial f / \partial m \geqslant p_m y_m$. In fact, the inequality is strict in most cases.

[4] Zhelobodko et al. (2012) examined a monopolistic competition model with additively separable preferences and showed that the CES case yields another knife-edge result concerning procompetitive and anticompetitive effects.

[5] We ignore income tax distortions because Venables' analysis is applicable to our model without modification.

[6] See Kanemoto (2012) for the analysis of differentiated consumer goods. Although there are minor differences, most of the qualitative results are the same.

[7] Duranton and Puga (2004) distinguished three types of micro-foundations of urban agglomeration: sharing, matching and learning mechanisms. Our framework is an example of the sharing models in this classification. Specifically, it generalizes the differentiated intermediate-goods model of Abdel-Rahman and Fujita (1990) from its CES production function to a general functional form.