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TESTS OF INTRAURBAN CENTRAL PLACE THEORIES*

Douglas S. West, Balder Von Hohenbalken, and Kenneth Kroner

For many years, economists have been interested in the reasons for the clustering of firms within cities. Early attempts to address this question seemed to focus primarily on the supply side of the market and revolved around the concept of 'agglomeration economies' (see Richardson (1978, pp. 41–2)). More recently, economists have sought an explanation for clustering of firms by addressing the demand side of the market. Most of this attention has been directed towards showing how search behaviour on the part of consumers can lead firms selling similar products to cluster (see Stahl (1982*a*, *b*); Stuart (1979) and Eaton and Lipsey (1979*b*)). While these *comparison shopping* models take us part of the way towards understanding the spatial distribution of retailing, they cannot explain why firms selling non-substitutes also cluster together in shopping centres and why shopping centres come in different sizes.

The classic model that was designed to explain these observations was the one proposed by Christaller (1966). He obtained a hierarchy of shopping centres (or *central places* in his terminology) wherein firms selling different goods locate together. His model inspired much empirical research into interurban and intraurban retail structures despite the fact that his model lacked a firm micro-economic foundation. An attempt to remedy some of the behavioural deficiencies of the Christaller model has recently been made by Eaton and Lipsey (1982). They wanted to show that a hierarchy of shopping centres could be derived from a model that allowed for *multipurpose shopping* on the part of consumers and profit maximising locational choice on the part of firms. The *hierarchy* that they derive has some characteristics in common with Christaller's, and some that are different, and their model also yields testable predictions and insights that Christaller's model cannot supply because of its weak behavioural base. In this paper, we wish to test the empirical implications of both the Eaton and Lipsey model and Christaller model using sequential shopping centre data from Edmonton, Alberta.

In the next section, we conduct a brief tour through the Eaton and Lipsey and Christaller theories of central places, and argue that it is the existence of demand externalities in the Eaton and Lipsey theory that enhances its predictive power over that of Christaller's. In Section II, we discuss how shopping centres are defined in this study, and how our shopping centre data are classified. Tests for a hierarchy of shopping centres are conducted in Section III. In the next two sections, we examine predictions that are made by the Eaton and Lipsey

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model, but not by Christaller's: Section IV tests for the differences between planned and unplanned shopping centres, and Section V contains a preliminary investigation into the causes of internal growth and decline of shopping centres. Concluding remarks and suggestions for future research are made in Section VI.

I. RECEIVED THEORIES

In their recent paper, Eaton and Lipsey (1982) set out to show that the clustering of firms selling heterogeneous goods can be derived from a model with profit maximising firms and cost minimising consumers. They assume that there are only two goods, *A* and *B*, which are consumed by households at constant rates of one unit each per period. Households purchase goods in indivisible bundles when their inventories are insufficient to support next period consumption, but they never buy more than one bundle of any good on a shopping trip. Shopping costs are an increasing function of distance travelled and the number of stops the shopper makes, and consumers are assumed to minimise transport costs on each shopping trip. These assumptions on the demand side are designed to allow for multipurpose shopping behaviour on the part of consumers. On the supply side, it is assumed that separate profit maximising firms sell goods *A* and *B* at parametric prices, that there are increasing returns to scale due to capital indivisibilities and that each firm, in choosing its location, assumes that all other firms will stay put. Eaton and Lipsey (henceforth referred to as E–L) confine their attention to a one-dimensional market of unit length and uniform density of households. Since there are only two goods in their model, at most a two-level hierarchy can exist in equilibrium. For such a hierarchy to exist, there must be central places or shopping centres in which only good *A* or good *B* is offered for sale (they term these $CP1As$ and $CP1Bs$, respectively) in addition to central places in which both good *A* and good *B* are sold ($CP2$s).

Under these assumptions, E–L show (among other results) that in market equilibrium, there must exist at least one $CP2$ and that $CP1As$ and $CP1Bs$ cannot be neighbours. They also show that more than one firm selling *A* and/or *B* may locate in a $CP2$ in equilibrium. It is this last result that is the key to understanding the substantial differences in empirical content of the Eaton and Lipsey model and the one proposed by Christaller (1966).

In Christaller's theory of central places, there are n goods, and each good is sold by a separate firm. These goods can be ranked by their 'threshold ranges', or the minimum market areas necessary for revenues to cover costs. At the highest level of the hierarchy of central places, all n goods are offered for sale with one firm supplying each good. These level-n central places are located on a hexagonal lattice. The next level of the hierarchy is found by running down the ranking of the n goods until one is reached, good $n-i$, which can be offered without losses from the centroids of the triangles defined by three neighbouring level-n central places, in addition to being offered from level-n places. These lower level central places will then supply all goods up to and including good $n-i$, with one firm supplying each good. By repeating this procedure, the full central place hierarchy can be found.

Both E–L and Christaller obtain the result that a hierarchy of central places can exist in equilibrium, although whether a hierarchy exists in the E–L model depends on certain parameter values. Both theories indicate that centres at a higher level of the hierarchy will offer all of the goods sold at a lower level, plus additional goods as well. In terms of the locations of central places and their market areas, central places at a particular level of the hierarchy in Christaller's model are equi-distant from one another and lie on a regular lattice so that market areas are identical; lower level centres will have smaller market areas. In the E–L model, regularity of spacing is not necessarily a property of central place equilibrium but the market areas of lower level centres will again be smaller. It is at this point, however, that the similarity in the theories and their results ends. There are no demand externalities in the Christaller model, and hence no sales advantage to a firm locating at a higher rather than lower level place, provided both locations would permit the firm to cover its costs; if firms at a particular level of the central place hierarchy earn sufficient profits to induce entry, entry will occur, but at a lower level of the hierarchy. In the E–L model, depending on parameter values, there may exist many *A* and/or *B* firms in a *CP*2 in market equilibrium. (See Eaton and Lipsey (1979*a*) for a detailed derivation of the conditions.) Hence, we have here a major discrepancy in the predictions of the two models.

The above discrepancy leads to other differences as well. Consider how the central place hierarchy in the two models might change if demand is growing over time: in the Christaller model, uniform demand growth would presumably lead to the replication of centres at each level of the hierarchy, but could not lead to more than one firm selling a particular good in each centre and it would certainly not lead to any firm's exit. In the E–L model, a much more interesting possibility arises: suppose that the urban economy is initially in central place equilibrium, and that it is served by *CP*2s. E–L argue that as demand grows, excess profits earned by firms in these *CP*2s will induce additional firms to enter the existing *CP*2s. At some point, however, demand growth will prompt a new *CP*2 to form between existing *CP*2s. The formation of new *CP*2s between adjacent *CP*2s will reduce the market areas of existing *CP*2s and consequently exit of *A* and/or *B* firms from old *CP*2s will occur until all remaining firms at least cover their costs. If demand growth continues, the process will repeat itself. We have here, then, divergent implications of the two models regarding changes in the central place system as demand grows over time.

In the E–L model, the absence of any restrictions on entry implies that there are conditions under which excessive entry of *A* and/or *B* firms into *CP*2s will occur, leading to rent dissipation. Extra *A* and/or *B* firms are induced to enter *CP*2s by the presence of excess profits, which leads to excess capacity (and rent dissipation) because E–L assume declining average costs and parametric prices. E–L argue that such rent dissipation may prompt the formation of planned shopping centres whereby developers restrict entry into *CP*2s to one *A* and one *B* firm, and capture all or part of the rent that would otherwise be dissipated.[1] Planned shopping centres cannot arise in this way in the Christaller

[1] It is clear that developers would restrict entry into CP2s to one *A* and one *B* firm only if comparison shopping behaviour is unimportant. If consumers could be expected to comparison shop for either *A*

model since rents are never dissipated through excess capacity of this sort. In the Christaller model, all centres at a given level of the hierarchy are identical in their makeup, whereas differences would exist in the E–L model if some centres were unplanned and others were planned.

It is clear that the E–L model yields a richer set of empirical implications than the Christaller model, due to the explicit modelling of consumer and firm behaviour. Because Christaller's '...pattern of central places and the hierarchical principle are simply products of Christaller's geometric argument' (Eaton and Lipsey (1982, p. 57)), the Christaller model cannot have firms (or individuals) responding to incentives in an economically interesting manner. This is why we do not view the tests that follow as pitting the E–L model against that of Christaller. Rather, we test the implications of both models; we find that the data fit the E–L model better than the Christaller model.

II. CLASSIFICATION AND DATA OF STORES AND CENTRES

The E–L hierarchy of central places is derived from a model which incorporates a number of important insights:

(1) cost-minimising consumers will wish to engage in multipurpose shopping,

(2) firms' location decisions will take into account the demand externalities which multipurpose shopping behaviour can produce,

(3) the importance of demand externalities to a particular firm will depend upon the nature of the goods which it sells,

(4) the size of the customer base necessary to support a particular firm's store will depend upon the location-specific demand for the store's products as well as costs of operation.

The predictions of the model are partially confirmed by the observation that a typical urban area contains many small shopping plazas, fewer large shopping centres, and a central business district that draws customers from all over the city. However, at issue is not simply whether shopping centres come in different sizes (they do), but rather whether shopping centres are arrayed in a hierarchy with properties specific to the E–L model. One method of addressing this issue is to use the E–L insights to define a number of shopping centre classes in terms of store variety and opportunities for multipurpose shopping, such that these classes exhibit the *minimal* characteristics of an E–L hierarchy. If the predictions of the E–L model are empirically correct we should be able to assign observed shopping centres to these classes so that *all* characteristics of the resulting allocation are reasonably consistent with the E–L hierarchy (i.e. the centre classes should be distinct and internally relatively homogeneous, with replicated store types, and with larger centres having the same store types as smaller centres, plus additional store types as well, etc.). This is the method we use in this paper, and in the remainder of this section we define our centre classes and discuss how we allocate shopping centres to them.

or *B*, then the developer would instead select the number of *A* and *B* firms to maximise profits. In Section IV, we discuss how planned centres would be expected to differ from unplanned centres in terms of the number and types of stores that each contains.

Shopping centre classes are defined in terms of store categories that differ in the customer base they require and by the extent they benefit from locating near other firms that sell the same or different goods. (Firms selling the same good would benefit from clustered locations if consumers engage in comparison shopping. While such behaviour is outside the E–L central place model, it is likely to be an empirically important phenomenon that can be allowed for by defining a suitable category. We also define a group of establishments that do not benefit from multipurpose or comparison shopping behaviour *per se*.) Store categories are defined below:

M1 stores are establishments that cluster together to attract mainly *multipurpose* shoppers; the patrons of these stores will not usually engage in search because expenditures on the goods involved, and quality and price variations between stores, tend to be insignificant compared to the associated search costs. *M*1 stores are viable with a relatively small clientele; examples are drug stores, groceries, gasoline stations, etc.

M2 stores are similarly defined in that they cater to *multipurpose* shoppers, but they need a larger customer base, as for instance book stores, music stores, gift shops, etc.

C stores cater mainly to single-purpose *comparison* shoppers; consumers will perceive some net gains to search while acquiring the goods such stores sell. Examples are automobile dealerships and appliance stores.

MC stores rely on externalities created by a combination of *multipurpose* and *comparison* shopping. Shoe stores, clothing stores and camera stores belong to this category.

S stores, finally, are establishments that cater to *single* isolated purchases, i.e. neither multipurpose nor comparison shopping is important for their business. These firms locate in retail districts for extraneous reasons; movie theatres, for instance, take advantage of the ample parking facilities at night, arcades engage the children of shopping parents.

We come now to the classification of shopping centres in a city. The first five classes we view as hierarchical, with regional centres and malls being at the same level (distinguished here because we wish later to compare planned and unplanned centres). The last class is defined to capture centres which, because they rely mainly on comparison shopping, are likely to fall outside the hierarchy.

Neighbourhood centres cater mainly to convenience shoppers and thus contain mostly *M*1 stores.

Community centres also contain a variety of *M*1 stores, but their larger pool of customers attracts also those *M*2 and *MC* stores that tend to gain most from multipurpose shopping.

Regional centres (of the unplanned kind) show a composition of store categories similar to community centres, but with a larger variety. The number of different kinds of stores makes them comparable with planned malls. Due to their unplanned nature, and perhaps history or accident, some *C* or *S* stores might be found in these centres.

Malls are regional centres that are planned by a single owner or developer.

Entry into a centre and location within it are determined by the owner/developer so as to maximise (the present value of) profits; accordingly, such centres will contain few or no C and S stores since they derive little synergistic profits from being in a mall and thus cannot bid successfully for space.

Central retail districts contain a wide variety of stores from each category. Large cities with subcentres could conceivably have more than one central retail district.

Highway strips are highway-oriented centres, typically located on the low rent urban periphery, and contain C and S stores catering mainly to single-purpose comparison shoppers and single isolated purchases, respectively. (We expect a certain number of highway strips to show up in our data because of the empirical technique which we used to find shopping centres, and not because they are part of the hierarchy. For the same reason, highway strips will contain some $M1$ stores.)

Having defined the theoretical classes to which we shall allocate observed shopping centres, we must now set out the criteria that we used empirically to find shopping centres. First, to keep our investigation within bounds, we required that all shopping centres (initially) contain a supermarket or that they be malls (for our definition of a supermarket, see West and Von Hohenbalken (1984)). Once the locations of all supermarkets operating in a given period were found (using city directories and phone books), the member stores of an unplanned shopping centre were obtained by finding (using city directories) all the retail stores within two city blocks on the same street as the supermarket, and all the retail stores, for intersecting streets, within one city block on either side of the street where the supermarket is located (see Fig. 1).[1] These two criteria allowed us to gather a set of cross-section data on shopping centres. For our examination of shopping centre growth and decline, however, we require panel data. Hence, we track the changing internal structures of shopping centres, and we add new shopping centres to the data set whenever new supermarkets are opened in a time period after the initial period.

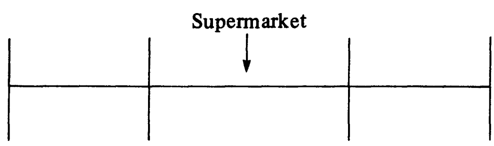

Fig. 1

Using these criteria, we collected shopping centre data for the City of Edmonton, Alberta, for the years 1962–77. We arrived at a count of 92 shopping centres, containing 2,200 stores, in Edmonton in 1977. To facilitate our allocation of shopping centres to the theoretical classes defined earlier, we used the 4-digit level of the U.S. SIC code to distinguish 77 types of stores, and these

[1] Several conventions employed by us were as follows: (i) the geographic bounds of a given centre were never allowed to extend beyond railroad tracks or the North Saskatchewan River that flows through the centre of Edmonton; (ii) when the geographic bounds of unplanned shopping centres overlap, the two centres are combined; (iii) malls are always treated as distinct from unplanned shopping centres, even if they lie within the latter's geographic bounds.

were put into categories on the basis of the definitions provided above and the authors' shopping experience. (See Table 2, first column, for the categorised store types. To save space, Table 2 also displays the distribution of store types across several hierarchical levels, which will be made precise in Section III.) We have excluded doctors, lawyers, accountants, real estate firms, and insurance companies because they are not retail firms in the narrow sense and are hard to classify from our data sources.

The completed set of raw panel data can be arranged in a three-dimensional *data matrix*, 77 store types high, 92 centres wide and 16 years deep. Its entries are nonnegative integers, representing the number of stores of type $i = 1, \ldots, 77$, residing in centre $j = 1, \ldots, 92$, during year $t = 1962, \ldots, 1977$. As is clear from their definition, all shopping centres are also explicitly located in geographic space; their coordinates are collected in a 2×92 *location matrix*. (Ancillary information about the city boundary is contained in a *city limit matrix*; see Section III and footnote 1 on p. 111.)

The allocation of shopping centres to classes proceeded in two steps: first, using the last year of our data set, we assigned each centre to a class by inspecting the types and variety of stores it contained. Second, we used the 'average centres' of the resulting groups in 1977 as seed points for a clustering operation of shopping centres in all 16 years of our data set; this was done to ensure that uniform criteria were used throughout.

The clustering is done as follows: consider the columns of the $77 \times 92 \times 16$ data matrix as points in 77-dimensional Euclidean space. The hand-picked members of the shopping centre classes in 1977 clearly belong to this point set in 'store type' space, and so do their barycentres (their means) which we take as our 'seed points'. Each centre (in each year) is then assigned to that shopping centre class to whose seed point it is closest; this involves calculating and comparing six Euclidean distances per centre per year. The results are collected in a 92×16 *class matrix* that we need in the sequel; each cell contains the index (if any) of the class to which centre j belongs in year t.

III. TESTS FOR AN E–L OR CHRISTALLER-TYPE HIERARCHY

Given the procedure which we used to segregate our shopping centre data into classes, we expect the classification to conform to the minimal characteristics of an E–L or Christaller-type hierarchy: fewer higher than lower level centres, and higher level centres should contain more stores on average than lower level centres. To verify these predictions, it suffices to use the year 1977, the last and most complete period of our data set. The results are reported in Table 1. It shows that the data are consistent with neighbourhood centres being the lowest level of a hierarchy, and community centres being the next higher level. Regional (unplanned) centres and malls jointly are nicely consistent with this hierarchical pattern, yielding a third level with seventeen centres averaging 54 stores each. (It will be recalled that regional centres and malls were theoretically distinguished by their planning status, a distinction which is used later.) The central retail district clearly yields the fourth and highest level of this hierarchy, representing one centre with 327 stores. Finally, as expected, highway strips do not fit into this hierarchical pattern: in terms of mean number of stores, highway strips belong between neighbourhood centres and community centres, but in terms of number of highway strips, they come just below the central retail district. Given the above, it seems appropriate to

Table 1

Number of Stores and Centres by Shopping Centre Class, Edmonton 1977

Stores	Neighbour-hood centres	Community centres	Regional centres	Malls	Central retail district	Highway strips
1–10	37	1	—	—	—	3
11–20	8	7	—	—	—	5
21–30	—	10	—	—	—	—
31–40	—	2	4	1	—	1
41–50	—	—	1	2	—	—
51–60	—	—	2	1	—	—
61–70	—	—	1	2	—	—
70+	—	—	—	3	1	—
Total number of centres	45	20	8	9	1	9
Mean number of stores (rounded)	8	23	46	61	327	16

Table 2

*Representation of Store Types at Hierarchical Levels, Edmonton 1977**

	Level 1		Level 2		Level 3*a*		Level 3*b*		Level 4		Level 0	
	30%	50%	30%	50%	30%	50%	30%	50%	30%	50%	30%	50%
Restaurant (*M*1)	x	X	x	X	x	X	x	X	x	X	x	X
Beauty shop (*M*1)	x	X	x	X	x	X	x	X	x	X	x	X
Drug (*M*1)	x	.	x	X	x	X	x	X	x	X	x	.
Barber shop (*M*1)	x	.	x	X	x	X	x	X	x	X	x	.
Dry cleaners (*M*1)	x	X	x	X	x	X	x	X	x	X	.	.
Supermarket (*M*1)	x	X	x	X	x	X	x	X	x	X	.	.
Bank (*M*2)	x	.	x	X	x	X	x	X	x	X	.	.
Petrol station (*M*1)	x	.	x	X	x	X	.	.	.	.	x	X
Grocer (*M*1)	.	.	x	X	x	X	x	X	x	X	x	X
Misc. retail	.	.	x	X	x	X	x	X	x	X	x	.
Music store (*M*2)	.	.	x	.	x	X	x	X	x	X	.	.
Book store (*M*2)	.	.	x	.	x	X	x	X	x	X	.	.
Florist (*M*2)	.	.	x	.	x	X	x	X	x	X	.	.
Household appliance (*C*)	.	.	x	.	x	X	x	.	x	X	.	.
Bakery (*M*1)	.	.	x	X	x	X	.	.	x	X	.	.
Radio & TV (*C*)	.	.	x	.	x	X	.	.	x	X	.	.
Used merchandise (*C*)	.	.	x	.	x	X	.	.	x	X	.	.
Meat & fish market (*M*2)	.	.	x	.	x	.	.	.	.	.	.	.
Liquor store (*M*2)	.	.	x	.	.	.	x	X	x	X	.	.
Shoe repair (*M*2)	.	.	x	.	.	.	.	.	x	X	.	.
Auto & home supply (*C*)	.	.	x	.	.	.	.	.	.	.	x	X
Hardware (*C*)	.	.	x	.	.	.	.	.	.	.	x	.

Table 2 (*Cont.*)

	Level 1		Level 2		Level 3*a*		Level 3*b*		Level 4		Level 0	
	30%	50%	30%	50%	30%	50%	30%	50%	30%	50%	30%	50%
Sporting goods (*MC*)	.	.	.	.	x	X	x	.	x	X	x	.
Gift & novelty (*M*2)	.	.	.	.	x	X	x	X	x	X	.	.
Jewelry (*MC*)	.	.	.	.	x	X	x	X	x	X	.	.
Travel agency (*MC*)	.	.	.	.	x	X	x	X	x	X	.	.
Men's clothing (*MC*)	.	.	.	.	x	.	x	X	x	X	.	.
Women's clothing (*MC*)	.	.	.	.	x	.	x	X	x	X	.	.
Shoes (*MC*)	.	.	.	.	x	.	x	X	x	X	.	.
Misc. apparel (*MC*)	.	.	.	.	x	.	x	X	x	X	.	.
Hotels & motels (*S*)	.	.	.	.	x	X	.	.	x	X	.	.
Movie theatres (*S*)	.	.	.	.	x	X	.	.	x	X	.	.
Photo studio (*S*)	.	.	.	.	x	.	.	.	x	X	.	.
Printers (*S*)	.	.	.	.	x	.	.	.	x	X	.	.
Billiards & pool hall (*S*)	.	.	.	.	x	.	.	.	x	X	.	.
Repair shop n.e.c.	.	.	.	.	x	.	.	.	x	X	.	.
Paint & wallpaper (*C*)	.	.	.	.	x	X	.	.	.	.	x	.
Furniture (*C*)	.	.	.	.	x	X	.	.	.	.	.	.
Candy & nut (*M*2)	.	.	.	.	.	.	x	X	x	X	.	.
Hobby, toys & games (*M*2)	.	.	.	.	.	.	x	X	x	X	.	.
Cigar (*M*2)	.	.	.	.	.	.	x	X	x	X	.	.
Department store (*MC*)	.	.	.	.	.	.	x	X	x	X	.	.
Family clothing (*MC*)	.	.	.	.	.	.	x	X	x	X	.	.
Camera (*MC*)	.	.	.	.	.	.	x	X	x	X	.	.
Sewing (*MC*)	.	.	.	.	.	.	x	X	x	X	.	.
Variety store (*MC*)	.	.	.	.	.	.	x	.	x	X	.	.
Luggage (*MC*)	.	.	.	.	.	.	x	.	x	X	.	.
Misc. food (*M*2)	.	.	.	.	.	.	x	X	.	.	.	.
Women's accessory (*MC*)	.	.	.	.	.	.	x	X	.	.	.	.
Children's clothes (*MC*)	.	.	.	.	.	.	x	X	.	.	.	.
Drapery & upholstery (*C*)	.	.	.	.	.	.	x	.	.	.	.	.
Car dealers – new & used (*C*)	.	.	.	.	.	.	.	.	x	X	x	X
Film developers (*M*2)	.	.	.	.	.	.	.	.	x	X	x	.
Stationery (*M*2)	.	.	.	.	.	.	.	.	x	X	.	.
News dealers (*M*2)	.	.	.	.	.	.	.	.	x	X	.	.
Furriers (*MC*)	.	.	.	.	.	.	.	.	x	X	.	.
Car dealers – used only (*C*)	.	.	.	.	.	.	.	.	x	X	.	.
Floor covering (*C*)	.	.	.	.	.	.	.	.	x	X	.	.
Misc. home furnishings (*C*)	.	.	.	.	.	.	.	.	x	X	.	.
Jewelry repair (*C*)	.	.	.	.	.	.	.	.	x	X	.	.
Drinking places (*S*)	.	.	.	.	.	.	.	.	x	X	.	.
Car rental (*S*)	.	.	.	.	.	.	.	.	x	X	.	.
Bowling alley (*S*)	.	.	.	.	.	.	.	.	x	X	.	.
Misc. personal services	.	.	.	.	.	.	.	.	x	X	.	.
General automotive repair (*C*)	.	.	.	.	.	.	.	.	x	X	.	.
Auto repair n.e.c. (*C*)	.	.	.	.	.	.	.	.	x	X	.	.
Top & body repair (*C*)	.	.	.	.	.	.	.	.	x	.	.	.
Car wash (*S*)	.	.	.	.	.	.	.	.	x	.	.	.
Building materials (*C*)	.	.	.	.	.	.	.	.	.	.	.	.
Garden supplies (*C*)	.	.	.	.	.	.	.	.	.	.	.	.
Auto dealers n.e.c. (*C*)	.	.	.	.	.	.	.	.	.	.	.	.
Radio & TV repair (*C*)	.	.	.	.	.	.	.	.	.	.	.	.
Electrical repairs (*C*)	.	.	.	.	.	.	.	.	.	.	.	.
Carpet & upholstery cleaning (*S*)	.	.	.	.	.	.	.	.	.	.	.	.
Dance halls (*S*)	.	.	.	.	.	.	.	.	.	.	.	.
Coin-op amusement devices (*S*)	.	.	.	.	.	.	.	.	.	.	.	.
Amusement services n.e.c. (*S*)	.	.	.	.	.	.	.	.	.	.	.	.

* An x (X) indicates that the store type appears in at least 30% (50%) of the centres at the given level.

label neighbourhood centres level 1, community centres level 2, regional centres and malls levels 3*a* and 3*b*, respectively, the central retail district level 4, and highway strips, for convenience, level 0.

According to E–L and Christaller, shopping centres on successively higher levels should contain the same variety of stores as the levels below, plus additional types of stores. Because incomes, population densities, consumer preferences, and distribution technologies are in reality not as uniformly distributed across a city as E–L and Christaller implicitly assume, centres on each level cannot be expected to contain precisely the same variety of stores. Therefore, we took store type i to be represented on hierarchy level l when at least 30% (or alternatively 50%) of the centres on this level contain store type i. In Table 2, store type i has an x for level l if its 'relative frequency' is 30% an X if it appears at least half the time (clearly large Xs are harder to achieve than small ones). It turns out that the rows in Table 2 can be arranged such that it closely approximates a block-triangular matrix. Since the columns represent the levels of the hierarchy in ascending order (excepting level 0, which does not belong), this verifies the prediction of E–L and Christaller that higher-level centres contain the same types of stores that are highly represented at lower levels plus additional stores as well. One expects (and hopes) that after this triangularisation the store categories associated with levels will be roughly the same as those associated with our theoretical shopping centre classes; scrutiny of the list of stores in Table 2 reveals that reasonable conformity indeed obtains.

We next wish to examine some *market area implications* of the Christaller and E–L theories. Christaller and E–L predict that the market areas of higher level centres will be larger than those of lower level centres. Christaller's theory is designed so that the market areas of centres at a given level of the hierarchy must be identical; equal market areas do not necessarily constitute a property of equilibrium in the E–L model.

To test these predictions requires that we first specify how the market areas of shopping centres at different levels of the hierarchy are conceptually to be determined. We follow E–L in viewing the market area of a shopping centre at a given level of the hierarchy as containing all those consumers who, on a multipurpose shopping trip for the goods sold for the first time at that level, find it least costly to patronise. This implies that when calculating the market area of a shopping centre at a particular level of the hierarchy, the locations of all shopping centres at the same level *and above* must be considered since they are all potential neighbour-competitors. Shopping centres at lower levels cannot infringe on the market area of a higher level centre.

To find the market areas of centres at level l of the hierarchy, we assume that distances are Euclidean, transport costs are linear and uniform and that all stores of a given type charge the same vector of prices. Given the locations of centres at level l and higher levels, as well as a city boundary specification, this leads to market areas (or nearest point sets) of shopping centres that are contiguous convex polygons (that tile the city and form a so-called Voronoi diagram).

In practice our shopping centre Voronoi diagrams are found by an algorithm developed in Von Hohenbalken and West (1984). To find the market areas of shopping centres on every level, the method needs as inputs the locations of all centres (given in the location matrix), the level designations of all centres (from the class matrix), and information on the city boundary (given in the city limits matrix[1]). For example, the market area of a given centre opposite only one other centre is the halfplane in which it lies and which is bounded by the bisector between the centres. When several other centres (and dummy centres) are present, the market area is the intersection of all corresponding halfplanes. Our algorithm finds, in a cyclical and efficient way, the vertices of the intersection polygon. The size of any polygonal market area is easily computed by a discrete implementation of Green's theorem on line integrals (see Buck (1978, p. 478)): if $\{v^1, \ldots, v^m\}$ is the counter-clockwise ordered vertex set of a polygon, then its area is obtained by summing m determinants associated with the m boundary segments, i.e. area of polygon $= \frac{1}{2}\{\det [v^1, v^2] + \det [v^2, v^3] + \ldots + \det [v^m, v^1]\}$. Having computed the market areas for all levels of the hierarchy and for all years, we collect them in a 92×16 *market area matrix*, which is used in its entirety in Section V to examine growth and decline of shopping centres.

Table 3

*Average Market Area by Level, Edmonton 1977**

	Level 1	Level 2	Level 3*a* + Level 3*b*	Level 4	Level 0
Average market area	242·8	436·3	696·6	6246·0	189·0
Standard deviation	(171·2)	(247·1)	(570·8)	(0)	(105·5)

* Market areas are expressed in units that correspond to the grid in the original city map we used; one such unit equals 1·8 acres; Edmonton comprises about 35,000 units $\cong$ 100 square miles $\cong$ 260 km^2.

For 1977, we test the E–L and Christaller market area implications by computing mean market areas and standard deviations for the centres at each level of the hierarchy; these appear in Table 3. As predicted, higher level centres do have average market areas that are larger than lower level centres. However, contrary to Christaller's geographical constructs, market area sizes within levels are by no means the same. Market area sizes even overlap across levels, suggesting that regularity of spacing is not a property of our shopping centre hierarchy. This outcome is not surprising given that population in Edmonton is not uniformly distributed and given the presence of parks, creeks, zoning restrictions, etc.

[1] To bound the city, we use dummy centres placed along the city limits; these dummy centres will act as neighbours to real shopping centres but their nearest point sets will not be computed. We use dummy centres, instead of a fixed polygonal boundary, to model the city boundary because the city boundary will then be sensitive to shopping centre locations, and significant portions of peripheral centres' market areas that would be virtually empty of customers will be eliminated. Except for the calculation of the market area of the one level 4 centre, we also place dummy stores along the North Saskatchewan River that flows through the centre of Edmonton.

Table 4
Number of Shopping Centres Containing Replicated Stores, by Level, Edmonton 1977

Number of store types repeated within a shopping centre	Level 1	Level 2	Level 3a	Level 3b	Level 4	Level 0
1	20	2	0	0	0	2
2	3	3	0	0	0	2
3	0	2	0	0	0	2
4	0	7	0	0	0	2
5+	0	6	8	9	1	1
	23	20	8	9	1	9
0 (no replications)	22	0	0	0	0	0
Total number of centres	45	20	8	9	1	9

To complete our investigation into whether our shopping centre classes have properties consistent with the E–L or Christaller-type hierarchy, we wish to examine to what extent shopping centres at various levels tend to contain multiple stores of a given type. One recalls that in the Christaller model, shopping centres contain at most one store of each type, while in market equilibrium in the E–L model several firms selling the same good may locate in the same shopping centre. The 92×77 slice for 1977, from the $92 \times 77 \times 16$ data matrix, contains the information relevant for testing this prediction. Each element of this matrix gives the number of stores of each type in a centre. Table 4 condenses this information by showing the number of centres (at each level) that contain singly or multiply replicated store types. There clearly are many store types replicated within centres, a finding which falsifies Christaller's prediction; it is also evident that higher up in the hierarchy replications are more frequent. Indeed, multiple firms selling similar goods seem to be the rule rather than the exception for all levels except level 1.

We conclude from our examination that our shopping centre assignment for 1977 is consistent with the characteristics of the E–L hierarchy and all but two of the characteristics of the Christaller hierarchy. We thus proceed to test the predictions of the E–L model that depend on the possibility of several stores of the same type locating in shopping centres in market equilibrium.

IV. PLANNED VERSUS UNPLANNED SHOPPING CENTRES

Eaton and Lipsey have argued that unplanned shopping centres are like common property resources in that unrestricted entry can lead to excessive entry, excess capacity, and rent dissipation. To prevent the dissipation of rents, planned shopping centres might be formed in an urban economy whereby owner/developers select the optimal numbers and types of stores, as well as their locations within centres. We would expect planned and unplanned centres to differ in two important respects:

(i) Planned centres should contain no more than one of each type of $M1$ and $M2$ stores since these stores do not tend to be patronised in conjunction with stores selling the same types of goods. In other words, demand externalities arising from comparison shopping are likely to be unimportant for $M1$ and $M2$ stores, and more than one of each type of them in a centre could lead to rent dissipation. In unplanned centres, we expect $M1$ stores to be replicated for the reasons advanced by E–L. However, we expect unplanned centres to be deficient in $M2$ stores because firms would prefer locating $M2$ stores in planned rather than unplanned centres. Recall that $M2$ stores require a larger customer base for their support than do $M1$ stores, and the size of the customer base will be a function of the variety of stores in the centre and opportunities for multipurpose and comparison shopping. The customer base for planned centres is more certain than for unplanned centres because the centre composition is more certain, and hence locating in a planned centre is less likely to result in unanticipated losses.

(ii) Planned shopping centres at a given level of the hierarchy should contain on average more of any type of MC store and a larger variety of $M2$ stores than unplanned centres at the same level because we would expect the demand faced by these kinds of stores to be higher in planned than in unplanned centres. This higher demand would arise from consumer beliefs, based on shopping experience, exposure to planned centre advertising and access to relatively low cost information on the internal structures of planned centres (i.e. word of mouth, the Yellow Pages, etc.), that the probability of finding their most preferred goods is higher if they patronise a planned rather than an unplanned shopping centre. Unplanned centres, because they are not designed by an owner/developer to maximise joint profits, are unlikely to contain the optimal mix of stores, will not necessarily have stores positioned in the optimal configurations, and are unlikely to provide consumers with the amount and quality of information that planned centres would.

To check the empirical validity of our expectations, Table 5 has been constructed to compare the mean numbers of different $M1$, $M2$ and MC stores in regional unplanned centres (level 3*a*) and malls (level 3*b*) in Edmonton in 1977. We find that seven out of nine kinds of $M1$ stores have means that are higher for regional centres than for malls, and only one kind of $M1$ store, restaurants (including take-out food concessions), appears on average to be replicated within malls. $M2$ stores had eleven out of fifteen means that were higher for malls than for regional centres, while MC stores had twelve out of sixteen means that were higher. The largest discrepancies occur for men's clothing, women's clothing, shoes, jewelry, department stores, family clothing, and gift and novelty stores. These stores tend to be the ones for which comparison shopping is relatively important.

To establish the statistical significance of our results, we performed a Wilcoxon rank-sum test for two matched samples (see Chou (1969, p. 472)). In our case, the two populations are malls and regional shopping centres, and the two paired sample points are the total (normalised) numbers of each kind of $M1$, $M2$ and MC stores in the two classes of centres. With the number of matched

Table 5

Average Numbers of M1, M2, and MC Stores in Malls and Unplanned Regional Shopping Centres, Edmonton 1977

M1 stores	(Planned) mall	Unplanned regional	M2 stores	(Planned) mall	Unplanned regional	MC stores	(Planned) mall	Unplanned regional
Restaurants	6·00	5·00	Bank	2·11	2·75	Sporting goods	0·67	1·37
Drug	0·89	1·12	Music store	1·44	1·25	Men's clothing	3·44	0·38
Beauty shop	1·33	2·37	Book store	1·11	1·00	Women's clothing	7·89	0·50
Barber shop	0·78	2·00	Florist	0·89	0·88	Shoes	4·22	0·63
Dry cleaners	0·78	1·00	Liquor store	0·67	0·13	Misc. apparel	1·00	0·38
Supermarket	0·89	0·63	Shoe repair	0·22	0·25	Jewelry	2·78	0·50
Petrol station	0·22	0·63	Meat & fish market	0	0·50	Travel agency	0·67	0·88
Grocer	1·11	1·12	Gift & novelty	3·11	1·00	Department store	1·67	0
Bakery	0·22	1·25	Candy & nut	1·22	0	Variety store	0·44	0·25
—	—	—	Hobby, toy & game	1·22	0·38	Family clothing	2·00	0·13
—	—	—	Cigar	1·33	0	Camera	0·67	0·13
—	—	—	Misc. food	1·00	0·25	Luggage	0·33	0·38
—	—	—	Stationery	0·22	0·13	Sewing	1·00	0·38
—	—	—	News dealers	0	0·13	Women's accessory	0·67	0
—	—	—	Film developers	0·22	0·13	Children's clothes	0·78	0
—	—	—	—	—	—	Furriers	0·11	0·25

pairs equal to 40, the test statistic Z is approximately normally distributed, and since in our case $Z = -3{\cdot}6$, the differences between malls and regional centres are statistically significant on the 1 % level.

V. GROWTH AND DECLINE OF SHOPPING CENTRES

We now come to the most difficult implication of the E–L model to test. As pointed out in Section I, E–L put forward a type of cycling hypothesis to explain the internal growth and decline of shopping centres. That is, if firms in an existing unplanned shopping centre are perceived to be earning excess profits sufficient to induce entry, new entry will occur into that centre. At some point, however, demand growth will prompt the creation of a new shopping centre in the neighbourhood of this existing centre. Because the existing centre's market area will now be reduced, some firms that had previously covered their costs will now be making losses, and will exit. If demand growth continues in the future, the process will repeat itself.

There are various ways of approaching this hypothesis empirically: taken literally the cycling hypothesis suggests that when a new entrant 'impinges upon' (= reduces the market area of) a shopping centre, the latter should experience a decline in its store membership; this decline would later be followed by increases in store membership up to the time when another entrant again brings about leaner times. An appropriate test might be to find whether, for each time period, the average elapsed time since declining centres were last impinged upon by a new centre is less than the average elapsed time since growing centres were last impinged upon. We did the calculations, but the results were inconclusive, with the elapsed times being of seemingly random lengths.

In a second test we try to escape the rigid timing of store entries and exits implied by the interpretation above. We simply prognosticate that increases and decreases in the number of stores within a shopping centre tend to follow the expansion and contraction of its market area. The market area of a centre at level l will expand if

(*a*) the centre moves up the hierarchy, to level $l+1$ or higher;
(*b*) a neighbouring centre moves down, to level $l-1$ or lower.

The market area of a centre at level l will shrink if

(*c*) the centre moves down the hierarchy, to level $l-1$ or lower;
(*d*) a neighbouring centre comes up the hierarchy, to level l or higher;
(*e*) a new centre, at level l or higher, is opened in the neighbourhood of the centre in question.

Table 6

Number of Shopping Centres Whose Store Count Moves With (+) or Against (−) Changes in Market Area, Edmonton 1963–1977

	Level 2		Level 3*a*+Level 3*b*		Sum of Levels 2, 3*a*, 3*b*	
	+	−	+	−	+	−
1963	3	1	1	2	4	3
1964	4	3	4	1	8	4
1965	3	1	0	0	3	1
1966	5	0	1	0	6	0
1967	8	7	2	1	10	8
1968	4	4	2	2	6	6
1969	11	1	1	1	12	2
1970	3	4	0	0	3	4
1971	11	6	6	1	17	7
1972	4	5	3	1	7	6
1973	2	4	3	0	5	4
1974	4	3	0	0	4	3
1975	7	0	0	1	7	1
1976	3	2	3	1	6	3
1977	2	1	3	1	5	2

From the data matrix, we know the number of stores in each centre in every year, and from the market area matrix we know their areas. Juxtaposing these two sets of time series, it is easy to extract the information in Table 6. It shows, by hierarchical level, the numbers of stores in each year that moved with (first column) and against (second column) market area changes. It is already clear by inspection that the hypothesis of parallel movement is strongly supported. We also ran a Wilcoxon rank-sum test on the last two columns of Table 6; it indicated statistical significance on the 1 % level.[1]

[1] Level 0 is excluded because it does not belong to the hierarchy *prima facie*; level 4's inclusion would be pointless since it contains only one centre with constant market area. Level 1 is omitted because its centres have only few repeated store types and hence few exits of redundant stores can occur.

VI. CONCLUSION

The purpose of this paper has been to establish in what ways the predictions of the Eaton and Lipsey model of central places differ from those of Christaller's classic model, and to test both sets of predictions using shopping centre panel data from Edmonton, Alberta. Our tests support the hypothesis of a hierarchy of shopping centres with properties that are more closely aligned to an E–L than a Christaller-type hierarchy. In particular, we found that our shopping centre hierarchy has one important characteristic that is consistent with the predictions of the Eaton and Lipsey model, but not Christaller's, namely the replication of stores of the same type in the same shopping centre. We would expect such replications to arise naturally from the profit maximising locational behaviour of firms confronted with comparison and multipurpose shopping behaviour on the part of consumers (behaviour that is outside the Christaller model, but within those developed by Eaton and Lipsey). It provides a basis for explaining the creation of planned shopping centres that, as we have shown, differ significantly from unplanned shopping centres (planned shopping centres should be designed to provide the optimal amount of replication).

The possibility of multiple stores of a given type in the same shopping centre is also the driving force behind the Eaton and Lipsey cycling hypothesis. Our tests of the cycling hypothesis do indicate support for it in that we show that the internal growth and decline of shopping centres are associated with the changes of their market areas, which in turn depend on the changing states of their neighbour relations. However, other variables might also be significant in explaining growth and decline. For example, our initial test of the cycling hypothesis compared the average elapsed time since declining and growing centres were last impinged upon by a new centre. We did not take into consideration the fact that planned centres might be more resilient to the encroachment of new centres, or that a new centre impinging on an established centre might do very little harm because of its distance from the existing centre, or that changing consumer preferences and distribution technologies might make older centres obsolete, hence contributing to their decline. The importance of such factors in explaining growth and decline of shopping centres can be explored within the context of a multinomial logit model, and we are currently pursuing this line of inquiry.

Future empirical studies would benefit from certain theoretical extensions. In particular, we would wish to know whether the Eaton and Lipsey hierarchy is robust with respect to an extension of the model to a two-dimensional world in which n goods are offered for sale. In addition, the possibility that consumers may wish to engage in multipurpose and comparison shopping on the same shopping trip should be formally modelled. Attention might also be given to investigating how the central place hierarchy will change in response to market growth and changing distribution technologies. And, of course, there are also strategic considerations. Our own empirical work leads us to believe that such theoretical extensions will have significant payoffs for understanding intra-urban retail structure.

University of Alberta, Canada

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