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Spatial Competition and the Structure of Retail Markets

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Abstract: Market definition and structure are central to the decision calculus of competition policy in Australia and other countries. The decision to allow firms to acquire the assets of another firm or to merge ownership often rests on how the acquisition or merger will change market structure and in turn may generate market power. In retailing, the spatial characteristics of markets are highly important.

A geographic market can be viewed analogously to a physical catchment - defined by a resident population and transport infrastructure. Unfortunately the tools generally used to define geographic market structure are quite primitive, for example, the number of competitors within a specified radius of a store location. Clearly such measures are biased by differences in population density and transport infrastructure and patterns. Bias corrections such as travel times are possible but complex.

An alternative approach is use the location of competitors, existing and under a proposed acquisition or merger, to define geographic markets. The definitions that are explored in this paper are based on the Delaunay tessellation and the construction of Voronoi polygons. These techniques are used to optimally locate network and public infrastructure and can be used to construct what is a relatively natural definition of market structure from a supplier's, as opposed to a consumer's, perspective. These measures include, for example:

- A franchise or chain catchment – that is, the area surrounding an individual store in which it is the closest outlet belonging to a particular franchise or chain. For example, amongst all Coles supermarkets, there is an area in which one particular Coles supermarket is the closest.
- A geographic market share – that is, the proportion of the population that is closest to a particular chain.
- Geographic diversity – a measure of the extent to which a geographic area is serviced by stores of one or more chains.

Voronoi polygons are also useful for exploring the impacts of site acquisition or mergers through counterfactual simulation. Site acquisition is particularly well suited as the vertices of the Voronoi polygons are natural candidate locations.

Measures were constructed for supermarkets in South East Queensland. The results suggest that retail competition is intense. There is a high level of geographic diversity considerably more than would be expected if store locations were randomly distributed in terms of ownership structure. Existing competitors would find it difficult to acquire or situate new assets in a way that would give them localised market power. Smaller chains can have a competitive advantage in that they are not often forced to compete with their own stores when establishing new sites. Larger chains are likely to need to consider sites that will limit losses as opposed to maximise gains in market share.

Keywords: *Voronoi areas, Delaunay triangles, spatial competition models, retail food markets.*

1. SUPPLY OF SUPERMARKET SERVICES

Market definition and structure are central considerations in determining whether mergers and acquisitions will be judged to be anticompetitive due to the creation of unwarranted market power. Spatial location is a major determinant of competitive structure in many markets. Where products are largely homogenous across competitors, accessibility can be seen as one of the main forms of product and service differentiation.

The analysis of geographic market structure is not well developed in theoretical models of competition or in its application in the context of competition policy. The former generally being limited to competition in very abstract geometries such as line or circle (Eaton and Wooders, 1985 and Maldonodado et al., 2005) and the latter usually being based on a fixed radial distance around store locations (Walker and Webber, 2004).

The natural evolution of existing store locations and patterns of location can provide a significant amount of information on consumer density, catchment size and other market structure variables. This information is derived from the supply side decision of where and when to locate a new supermarket, when to continue operations, and when to attempt to takeover a competitor's location. Competitors will not choose to locate in an area that is unprofitable, with a high density of other stores, and low density of consumers.

Voronoi polygons and their associated regions allow the construction of two dimensional metrics that more closely reflect geographic market structure. Voronoi areas define a catchment around a store where the population living within the catchment is closer to the nominated store than any other. Voronoi polygons can be used to exploit the relative location of retail stores to delineate a market and simulate the impact of a new entrant, expansion by an established chain or franchise, as well as an acquisition or a merger.

2. VORONOI AREAS

A Voronoi area is defined in terms of a set of reference points; in this case a reference point is the location of a supermarket. A Voronoi polygon then encloses a set of intermediate points that are closer to the given reference point, measured in this case as straight line distance, than to any other reference point. A Voronoi diagram is illustrated in Figure 1.

In practical terms, Voronoi areas define the catchment in which each point is closer to the nominated major supermarket chain than any other store of the same or other chain.

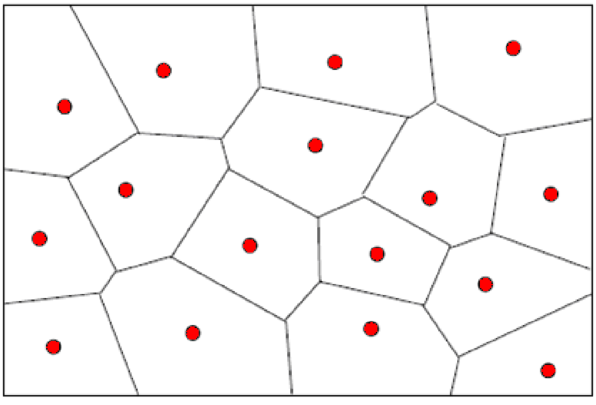
3. MARKET STRUCTURE AND COUNTERFACTUAL SIMULATION

Within the Voronoi area, a number of different measures of market structure may be investigated. These include demand and supply based measures such as geographic market share. Voronoi vertices are also useful, allowing both the construction of direct measures of market structure as well as generating counterfactual simulations of site acquisition and development.

A Voronoi vertex may either be mixed – surrounded by supermarkets owned by 2 or 3 different chains; or pure – surrounded by supermarkets owned by a single chain.

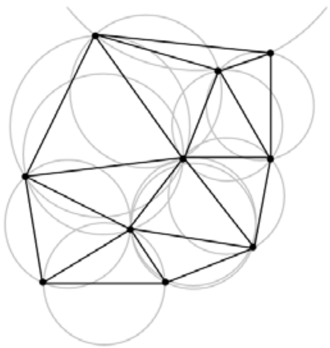
A pure vertex has the characteristic that there are a group of consumers in the vicinity of that vertex for which the nearest store in any direction is owned by the same chain. The size of that exclusive area is equal to the size of the Voronoi region created by including that vertex as a new reference point. Further, if a competing chain located at a pure vertex, the market share gained would purely be at the expense of the incumbent chain.

Figure 1A stylised Voronoi diagram



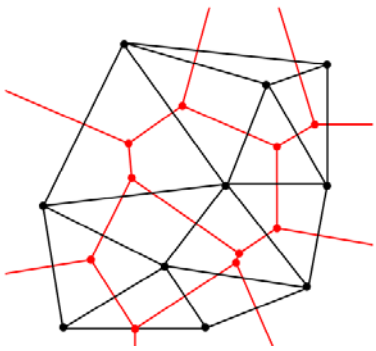
The vertex of the associated Voronoi polygon is equidistant from supermarkets that surround it. Voronoi polygons can be constructed from a Delaney tessellation, that is, a network of non-overlapping triangles connecting nearest neighbours. The centre of a circle inscribing the three points of a Delaunay triangle is the vertex of a Voronoi polygon. This is illustrated in Figures 2a and 2b. For a more detailed discussion of Voronoi diagrams and Delaunay triangulation visit www.qhull.org.

Figure 2a Delaunay triangles and circumcircles



Note: Black dots are the vertices of the Delaunay triangles and the Voronoi centres from Figure 1. The circumcircles bound the vertices of the Delaunay triangles such that there are no Voronoi centres inside any circumcircle.

Figure 2b Voronoi areas, and Delaunay triangles



Note: Black dots are the Voronoi centres, red dots are the vertices of the Voronoi areas, bounded by the red lines, Delaunay triangles are bounded by the black lines

Data source: Wikipedia

In contrast, a new entrant at a mixed site would potentially be in competition with itself. That is, part of the new entrant's catchment would come at the cost of another store owned by the same chain.

Determining the gains and losses to incumbents of new entrants at vertices of the Voronoi polygons, as a function of changes in population shares, forms the basis for developing counterfactual simulations of competition for new sites, as will be illustrated in the remainder of this paper.

4. STUDY AREA

The study area selected was the continental area of South East Queensland. In this area there are five major supermarket chains, located independently or collocated with another supermarket:

- Aldi (21 locations, 7 collocated);
- Bi-Lo (18 locations, 7 collocated);
- Coles (78 locations, 22 collocated);
- Supa-IGA (28 locations, 6 collocated);
- Woolworths (93 locations, 29 collocated)

In addition there are 135 independent grocery stores, although these are supplied, for the most part, by a single wholesale distributor. Independent grocery stores were not included in the determination of Voronoi areas.

In constructing all of the market structure measures, collocated sites were treated as unique identities based on the ownership of the stores present. For example, there were 14 collocated 'Coles – Woolworths' locations and 4 collocated 'Aldi – Coles – Woolworths' locations. Collocation was defined as being within 100 metres.

The Voronoi polygons were calculated from the latitudes and longitudes of the supermarket locations using Matlab. Some of the bordering polygons were open. These polygons were closed to the convex hull of the supermarket locations and then intersected with the geographic region of interest. For this study the geographic area was bounded by the southern Queensland border, the mainland coast and latitudes south of -26.8 degree and longitudes east of 152.8. Other geographic features, such as rivers and bridges, could be used to separate and join polygons; however, a simple coverage is sufficient to illustrate the issues at hand. The Voronoi diagram is show in Figure 3.

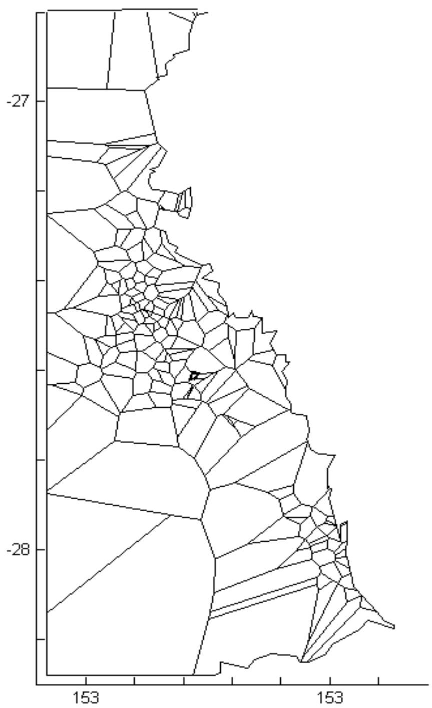
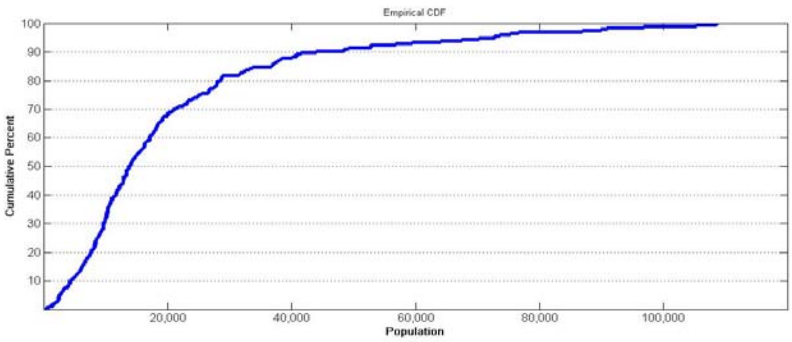


Figure 3The Voronoi diagram for supermarkets in South East Queensland

The area of each Voronoi area was then calculated. A simple nearest neighbour krig was then used to estimate population density at each store location and Voronoi polygon vertex using Statistical Local Area data from the 2006 census. The centroid of the Statistical Local Area was used as a reference point.

The cumulative distribution of the estimated Voronoi area population is shown in Figure 4. Not surprisingly, the distribution is compact as supermarkets require a substantial population base from which to draw customers. Approximately 70 per cent of the Voronoi areas have a population of fewer than 20,000 and 90 per cent under 40,000. Some of the Voronoi areas on the western boundary of the study area are large and the use of simple krig is likely to have overstated the population density in these regions.

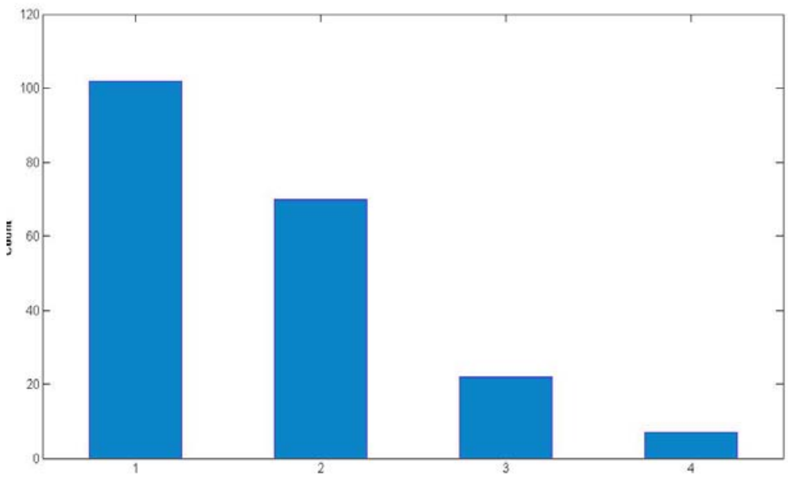
Figure 4Cumulative distribution of the estimated Voronoi populations in South East Queensland



5. MEASURES OF MARKET STRUCTURE

The distribution of independent grocery stores in the Voronoi areas is shown in Figure 5. Roughly half of the areas have one or more independent grocery stores, with most regions having none or one.

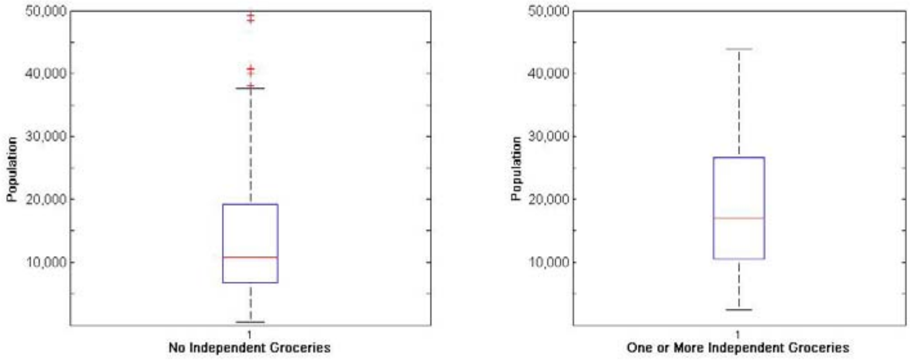
Figure 5Distribution of independent grocery stores in the Voronoi regions of South East Queensland



The population distribution in regions with none versus one or more independent grocery stores is shown in Figure 6. It clear from the box and whisker plots that independent grocery stores are located in larger catchments. The median population for regions with no independent is about 11,000 while around 17,000 for catchments with one or more independents. Approximately 75 per cent of catchments with an independent grocery store have a population above 11,000.

It is of interest to note that roughly 50 per cent of the Voronoi areas have a population of less than 11,000 (see Figure 4) this is the same proportion of Voronoi areas that have no independent grocery stores located within.

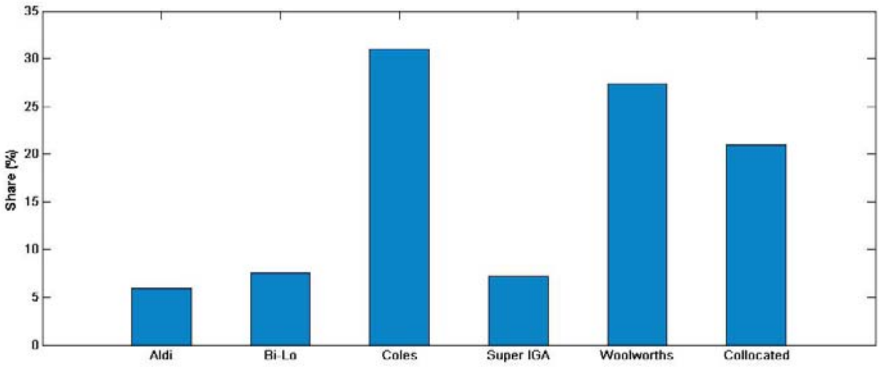
Figure 6 Population distribution in regions with none versus one or more independent grocery stores



6. GEOGRAPHIC MARKET SHARES

- Geographic market shares were computed by simply multiplying Voronoi areas by their estimated population density and summing according to ownership structure. The results are summarised in Figure 7. No attempt was made to apportion population in areas with collocated supermarkets, though it is of interest to note that collocated markets have geographic market share in excess of 20 per cent.

Figure 7Estimated geographic market shares

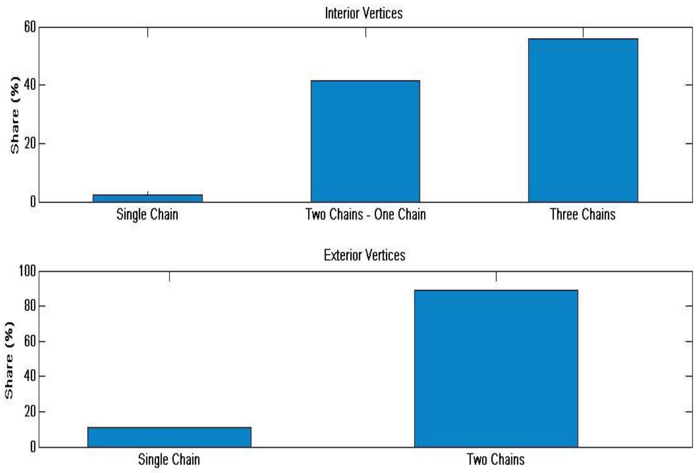


The 80 per cent market share of the major supermarket chains does not take into account the independent grocery stores (IGAs) so the overall geographic market share would be well below 80 per cent.

6.1. Vertex Composition

There are two types of vertices. Interior vertices, given the triangular tessellation, are surrounded by three Voronoi areas of supermarket locations. There are also exterior vertices on the boundaries of the overall study region. These are typically coastal and are associated with two supermarket locations. The distributions of pure and mixed vertices are shown in Figure 8.

Figure 8Distribution of pure and mixed vertices at interior and exterior locations



What is striking is that there are very few pure vertices; less than 5 per cent of interior locations and around 10 per cent of exterior locations. Consideration of the combinatorics clearly indicates that this is well less than what would be expected if supermarkets located randomly. Given the frequency of each chain across South East Queensland, a random placement of stores would result in 6.7 per cent of interior nodes being pure, and 23 per cent of exterior nodes being pure.

This may be explained, in part, by the fact that pure nodes are very attractive to competition as there is a potential gain in market share for any new chain without loss from competition with one of their own stores. Further, to block competitors and establish at their own, pure node, the incumbent must compete with two or more of its own stores. It would appear on first inspection that it would be difficult for a chain to acquire new sites in a way that would give them a large contiguous region in which they were the only supermarket present, allowing them a degree of market power. This can be examined in greater detail through counter factual simulation of site acquisition

6.2. Site Acquisition.

It is the vertices of the Voronoi areas that are of interest in determining the optimal positioning of a new store. These points identify the greatest distance from the given surrounding Voronoi centres, or adjacent supermarket locations. That is, selecting a vertex will maximise geographic market share relative to other locations, so long as the population densities in the surrounding Voronoi areas are uniform.

For this study, vertices of containing collocated supermarkets were excluded. The top 5 sites in terms of gains and losses in geographic market share are shown for a single acquisition by each competitor in Tables 1. and Table 2. As this exercise is theoretical, no care has been taken to ensure that the vertices chosen represent a viable location for a new store.

Table 1 Top estimated geographic share gains from locating a new store

Aldi		Bi-Lo		Coles		Super IGA		Woolworths	
Gain %	Vertex	Gain %	Vertex	Gain %	Vertex	Gain %	Vertex	Gain %	Vertex
3.12	19	3.11	19	3.05	19	3.10	19	2.02	181
1.79	31	1.79	31	1.40	29	1.74	27	1.90	179
1.78	168	1.75	29	1.35	168	1.73	169	1.74	27
1.77	29	1.34	172	1.13	20	1.73	31	1.65	31
1.74	27	1.24	27	1.00	169	1.71	29	1.64	169

Table 2 Top estimated geographic share losses from a competitor locating a new store

Aldi		Bi-Lo		Coles		Super IGA		Woolworths	
Loss %	Vertex	Loss %	Vertex	Loss %	Vertex	Loss %	Vertex	Loss	Vertex
-0.04	168	-1.00	169	-4.94	181	-0.88	20	-2.96	19
-0.03	29	-0.88	165	-4.64	179	-0.79	157	-1.22	4
-0.02	170	-0.69	171	-3.82	151	-0.74	10	-1.12	29
-0.01	32	-0.63	155	-3.02	144	-0.65	9	-0.93	140
-0.01	19	-0.62	168	-1.51	31	-0.64	2	-0.82	20

There are a number of overlapping sites. Overall, it appears that the smaller chains have a greater incentive to expand into new locations all other factors being equal. In contrast, Coles and Woolworths can achieve smaller gains and face larger potential losses. Coles in particular faces relatively large potential losses. This is simply a reflection of the fact that they will compete with their own stores more frequently.

Assuming that gains and potential losses are weighted equally we can construct the preferential sites for the two main chains in rank order, as shown in Table 3. These results weigh an avoidance of market loss, by blocking a competitor locating on a vertex, equally with gaining outright market share. For simplicity, ties were eliminated from consideration.

Table 3 Potential market share gains from preferential site selection by Woolworths and Coles

Coles					Woolworths				
Block or gain	Change in market share	Vertex	Indeps	Selected order	Block or gain	Change in market share	Vertex	Indeps	Selected order
Block	4.94	181	2	1	Block	2.96	19	1	1
Block	4.64	179	1	-	Gain	2.02	181	2	-
Block	3.82	151	1	2	Gain	1.90	179	1	-
Gain	3.05	19	1	-	Gain	1.74	27	1	2
Block	3.02	144	3	3	Gain	1.65	31	0	3

The selected sites were then introduced to the study area to generate a counterfactual simulation. The associated changes in market share are shown in Table 4. Overall, there are only small shifts in market shares as Coles and Woolworths predominantly compete with themselves.

Table 4 Changes in market share from Woolworths and Coles acquiring preferential sites

Supermarket	Existing Share (%)	Simulated Share (%)
Aldi	4.1	4.1
Bi-Lo	7.1	6.7
Coles	33.2	33.9
Super IGA	11.2	10.6
Woolworths	30.0	30.4
Collocated Supermarkets	14.4	14.3

We repeat the exercise for Aldi and Supa IGA, the results area shown in Table 5. The gains in Aldi and Super IGA shares are substantially higher than the gains to Coles and Woolworths in the previous simulation. The fact they have more opportunities to locate new stores that are purely in competition with other competitors is a clear advantage to the smaller chains.

Table 55Changes in market share from Aldi and Supa-IGA acquiring preferential sites

Supermarket	Existing Share (%)	Simulated Share (%)
Aldi	4.1	5.1
Bi-Lo	7.1	7.0
Coles	33.2	32.5
Super IGA	11.2	12.3
Woolworths	30.0	29.1
Collocated Supermarkets	14.4	14.0

7. DISCUSSION

This analysis has brought forward the discussion of the relevance of current locational and spatial information of supermarkets when considering market and can provide insight into competitive tensions and constraints within the market. The results also highlighted the lack of contiguous regions dominated by a single major supermarket chain. The spatial pattern of stores has evolved such that there is likely to be a limited ability for any one of them to establish a large geographically monopolised area.

The potential to consider blocking competitors through establishing a store location, as well as establishing a new store to gain market share, introduces a game theoretic dynamic into the assessment of geographic market structure. The major chains have a greater incentive to block the establishment of competitors to protect existing market share. Small chains have less market share to loose and so hold a comparative advantage in choosing sites to locate new stores. Smaller supermarket chains appear to have a comparative advantage in the location of new stores. When establishing new stores smaller chains tend to have a much larger level of market share to be gained, due to a larger selection of locations in which they will not have to compete with themselves.

Additional observations of interest include the perceived critical population mass within a Voronoi area required for a supermarket to locate or before an independent grocery store is likely to be positioned within the area as a nearby competitor.

Future work in this area would firstly be directed at game theoretic aspects of competition as well as more detailed and accurate and detailed measures of the Voronoi areas and populations. For example, there for natural barriers to competition, transport infrastructure and population could be considered.

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