The Spatial Pattern of Industrial Rents and the Role of Distance

Dunse N[1], Jones C[2], Brown, J[3] and Fraser W[4]

1 University of Aberdeen,
Dept. of Land Economy,
St Mary's, King's College,
Aberdeen, Scotland, UK,
AB24 3UF,
E-mail: n.a.dunse@abdn.ac.uk

2 Heriot-Watt University,
Dept of Building, Engineering and Surveying,
Riccarton Campus,
Edinburgh, Scotland, UK,
EH14 4AS.

3 University of St Andrews;
Department of Geography;
Irvine Building;
St Andrews;
Fife, KY16 9AL.

4 University of Paisley;
Paisley Business School;
High Street;
Paisley;
PA1 2BE.

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Abstract

The objective of this paper was to re-appraise intra-urban rent models in the context of a multi-nodal landscape. Primarily the study focuses on the early work of Alonso (1964) and more recently Di Pasquale and Wheaton (1996). Although the latter uses a more sophisticated approach, both models lead to similar outputs, notably a declining rent gradient from the CBD. However, throughout the twentieth century there has been a considerable process of urban industrial change. Di Pasquale and Wheaton (1996) recognise this and argue that this has led to an almost flat industrial rent gradient. To assess the current impact on industrial rents we apply a hedonic rent regression model which enables us to standardise for property characteristics. The results support the hypothesis that the rent gradient from the CBD for a large city is still downward sloping albeit very shallow. More interesting is the significance of proximity to motorway junctions. The analysis supports the hypothesis of a multi-nodal rent surface. Proximity to a motorway junction is the most important locational variable with a much steeper and negative gradient than that to the CBD albeit over a shorter distance. These results imply that the draw of the CBD in terms of agglomeration economies and its accessibility to labour for a city the size of Glasgow still remain but its attractions are much denuded with the development of a national motorway network.

1.0 Introduction

This paper reviews models of intra-urban rents (Alonso, 1964; Di Pasquale and Wheaton, 1996) and re-appraises them in the context of a uni-nodal urban landscape in which the assumptions underlying the bid rent curves for industrial property no longer hold. By re-examining the structure of spatial revenues and costs alternative forms of rent gradient will be postulated. This provides the framework for an examination of the intra-urban spatial pattern of rents of industrial properties. To test for the role of distance in the spatial variation of rents a hedonic regression model will be developed. This technique has been widely applied in the housing market and recently by Dunse and Jones (1998, 2002) for office markets.

The focus of the empirical analysis is the city of Glasgow. The paper begins with an appraisal of intra-urban industrial location theory. This is followed by an exposition of hedonic analysis applied to industrial property. A review of the current literature applying hedonic analysis to industrial markets is then undertaken. This leads to an exposition of the research goals of the paper, a brief a description of the data and the research method. In the penultimate section we discuss our empirical analysis and the final section highlights the key findings.

2.0 Intra-Urban Industrial Location Theory

Intra-urban location theory of relevance originates with Alonso's land use model (Alonso, 1964) derived from von Thunen's model of an agricultural economy. It is based on a city located on a featureless plain where land use is allocated to the highest bidder in a competitive land market. In this uni-nodal city the central business district (CBD) is the point of maximum accessibility where business revenue is at a maximum and costs (other than land costs) are minimised. Differences in the optimum locations of industrial and commercial land uses relate directly to the responsiveness of revenue and costs to distance from the centre. It is presumed that revenues fall and costs rise with distance from the CBD. The local industrial property market is defined by those locations where industrial users outbid other land users.

Di Pasquale and Wheaton (1996) develop a more sophisticated approach. In their stylised nineteenth century city the CBD is replaced with a central shipment/transportation terminal. All firms are initially assumed to produce identical products and using the same production process have equal outputs. There is no factor substitution so that the plot size and buildings are fixed for each firm, and output per acre is fixed.

In this model the rent for buildings is fixed but the land rent per acre varies with location. Revenue and production costs are spatially invariant and given a competitive land market land rents in equilibrium will exactly compensate for transport costs which rise with distance from the transportation terminals. In this way a rent gradient is formed. When the assumption of identical production processes is relaxed the model can be extended to groups of identical firms or land uses. This leads to a range of potential different rent gradients. The land market is presumed to be competition, allocating land use on the basis of the highest rent.

Both Alonso (1964) and Di Pasquale and Wheaton (1996) models above lead to similar outputs, notably a negative rent gradient from the CBD. A major distinction in their assumptions is that while Di Pasquale and Wheaton presume revenue is spatially constant Alonso has revenue decreasing with distance from the CBD. Logically the Alonso model would lead to a steeper distance decay gradient.

In the twentieth century there has been a considerable process of urban industrial change. Three different processes have contributed to this - de-industrialisation, decentralisation and decongestion.

De-industrialisation is a consequence of traditional industries declining in the face of international competition and the globalisation of markets. Cities that had a high concentration of this type of industry have suffered severe economic decline. However, this structural explanation for decline will vary widely between cities, depending on the nature of their traditional industries.

Decentralisation involves the movement of manufacturing industries to better locations outside city core areas, and has become a world-wide phenomenon (Ingram, 1998). The reasons for this include lower inter-urban transport costs with the introduction of new transport and delivery technologies and the increasing requirement for land due to changing production and storage requirements. This has encouraged industry to move to decentralised locations where there is plentiful supply of land and easy access to the national motorway networks. Other factors have also contributed to a decline in the requirement for industries to be close to core city areas. Technological change has weakened the agglomeration economies of many cities. Transport costs and the need for large pools of labour have also declined as a result of:

1. miniaturisation of products;
2. the introduction of new lightweight materials;
3. a reduced number of moveable parts in machinery;
4. the increased use of electronics, as opposed to mechanical, parts and processes

The globalisation of industry and markets has reinforced these trends further. The creation of large multi-national companies has helped to increase the average size of an industrial plant and therefore increase industrial land requirements (Coffrey and Polese, 1988).

Decongestion is the decentralisation of manufacturing industries to suburban locations or locations at the periphery of the city. Decongestion is distinct from decentralisation because it occurs strictly within the urban setting. It is a form of extended suburbanisation that involves an intra-urban move as opposed to an inter-urban move. It is however a consequence of the same forces that cause decentralisation.

How do these factors affect the models outlined above? Industry generally serves regional or national markets and hence revenue will not vary according to spatial location within a city. This is accordance with the Di Pasquale and Wheaton model rather than Alonso's. Industrial change means that the spatial structure of costs has changed over time. Distribution costs were originally minimised at central locations near rail and sea terminals. With the advent of the use of containers and trucks, together with the development of inter-urban road networks, distribution costs are now minimised at peripheral locations accessible to the national road network. Di Pasquale and Wheaton argue that this has led to an almost flat industrial rent gradient. However, with revenue constant throughout the city, and costs falling with distance from a central point, the rent gradient is logically upward sloping. However, this is perhaps intuitively an incomplete argument.

It is therefore necessary to return to the basic model. The general trends in transportation costs noted above can either be incorporated by changing the assumption about the transport cost distance function or by introducing additional nodal points of accessibility. These may or may not be subservient to the CBD node. This latter approach is more appropriate on a theoretical basis as it is unlikely that transport costs will decline uniformly with distance from the CBD.

The analysis so far has assumed production costs are constant across an industrial property market area. However, it is possible that labour costs could be lower at or near the CBD because this is an attractive location to potential workers who can benefit from the social agglomeration economies nearby and the use of an intra-urban transport network centring on the CBD. Hence labour turnover is lower and recruitment easier in central locations. Similarly there are potential manufacturing agglomerations from a central location via access to business services and clustering (Henderson *et al.*, 1995; Gordon and McCann, 2000).

3.0 Hedonic Price Theory

Empirical testing of the significance of location as a determinant of property values has been undertaken using hedonic theory. This represent an extension to urban location theory in the sense that, rather than conceptualising the stock in terms of location and different sized units of homogenous property, hedonic functions allow for stock heterogeneity and explicitly recognise the effect of physical characteristics and tenure rights on rental values (Evans, 1995). By controlling for typical building characteristics and lease terms, evidence from these hedonic studies has been used to determine the slope of the bid-rent gradient in metropolitan office markets and yield further information regarding the importance of physical attributes and legal rights of tenure on the level of rent.

Rosen (1974) formalised the structural interpretations of the hedonic method. He hypothesised that heterogeneous "goods are valued for their utility-bearing attributes or characteristics" (Rosen 1974, p1) where the hedonic price is the implicit price of each attribute associated with that good.

Industrial property is a heterogeneous good. In addition to the location factors described above, the value of an industrial unit is also dependent upon the physical accommodation, quality, structure and tenure rights offered.

Physical Accommodation

At the most basic this is the floor area of the industrial unit, although it will also be influenced by any constraints the building's structure places on design and layout. Modern industrial units normally provide the greatest flexibility in this regard by the provision of open plan floor plates and high eaves height to allow the unobstructed operation of vehicles within the unit.

Quality

The quality of industrial space is not easy to define. There is a considerable range of potential internal services that add value although to different degrees. These include the electrical wiring, lighting, heating and security systems.

Physical Structure

The cladding and standard of the exterior and structure are important both to the image the occupier is trying to project, and to subsequent repair and maintenance expenditure. A major influence is the age of the building, for example pre-1960's buildings are mainly of solid construction with a large number of load bearing walls.

Tenure Rights

Typically, in the UK, commercial property has been let on a standard institutional 15 year lease in the UK with the tenant responsible for repairs and maintenance. However industrial property is generally let on more flexible lease terms with the tenant responsible for internal repairs and insurance only. Clearly the lease length and structure of the lease terms will have an impact on the agreed rent.

Each characteristic contributes to the value of the accommodation, but cannot be separated and traded individually. Rosen's interpretation purports that the price paid for a particular property is the sum of the implicit prices that the market gives to the different characteristics associated with that property. Hence with information on property prices and attributes it is possible, using regression analysis, to derive the implicit price of each attribute, the hedonic price, and the relative importance each attribute has in determining the overall price of the property.

Each industrial user is assumed to derive profit directly from the property characteristics and chooses the industrial unit (bundle of characteristics) which maximises profits. In this framework each industrial unit is completely defined by a vector of characteristics described above which encompass location and physical characteristics. Thus suppose the industrial unit, z, is composed of n attributes:

$$(z_1, \ldots\ldots\ldots\ldots\ldots, z_n) \qquad \textbf{(1)}$$

Equation (1) is the vector of n attributes for which price or rent (in our case) depends. The rent of the industrial unit, z, will depend upon the quantities of the various attributes for which z is composed. The rent can be expressed as some function R(z). Thus:

$$R(z) = f(z_, , z_2 \ldots\ldots z_n) \qquad \textbf{(2)}$$

R(z) is the rent of the industrial unit and the z_i's are the individual characteristics. By differentiating R(z) with respect to its i^{th} characteristic, z_i, the market equilibrium price function for z_i, that is implicit in R(z) can be derived.

$$R_i = \frac{dR(z)}{dz_i} \qquad \textbf{(3)}$$

Empirical testing of this involves obtaining a price measure, R(z_k), the corresponding z_i's for the k^{th} property, and estimating the hedonic equation using regression analysis.

$$R(z_k) = \boldsymbol{b}_0 + \sum_{i=1}^{n} \boldsymbol{b}_i z_{ik} + \boldsymbol{e}_i \qquad \textbf{(4)}$$

Equation (4) is a general hedonic price function for both linear and non-linear representations of equation (2). The implicit price functions may be increasing, decreasing or constant depending on the functional form of R(z).

The measurement of the implicit prices of the different attributes of the hedonic model raises questions about the correct model specification. Unfortunately, hedonic theory gives no indication of the best functional form to use. Whether the hedonic model specifies a log-linear or a linear estimate will influence the interpretation of the results generated. For example a log-linear format will estimate demand elasticities, whereas a linear format estimates the price values attached to the different attributes. It would appear from the housing literature that the method used to identify model specification is often assessed purely by *"empirical experimentation"* (Forrest (1991, p233)). In practice the appropriate format for model specification can be determined by two approaches. A pragmatic approach simply identifies which set of results generated produces the best fit (as revealed by the R squared or the adjusted R squared) and provides the most consistent and plausible models (as revealed by the sign and significance of the independent variables). At a more complex level Box-Cox transformations may be used. In the housing literature this technique has improved the methodology for selecting the appropriate functional form, however a review of the outcomes of the Box-Cox transformation is by no means conclusive. A number of studies support the semi-log form, others the linear form and other studies produce a variety of outcomes such as a square root form. Dhrymes (1971) provides an interesting insight on the subject when he states that:

"the clustering of data (characteristics of housing) can restrict the range of the sample such that it covers only a relatively small proportion of the hypothetical price surface. If such is the case, it would not be unreasonable for many functional forms to be an equally good approximation to the true (and more complicated) surface over that range."

In general, hedonic modelling is open to criticism on the grounds that the theory involves a substantial simplification of a complex system. The model assumes equilibrium throughout the property market and no inter-relationship between the availability of attributes. The effect of this is that the implicit price for an additional attribute is equal across all locations and property types (although explicit dummies may be used for example to account for explicit neighbourhood effects). Arguably, in the light of market imperfections, dis-equilibrium could be a more realistic assumption but the data required for this form of modelling places this outside the scope of most research. Despite these failings, the technique has been widely applied to housing market analysis and has become well established (see for example Cheshire and Sheppard,1995),. In defence of hedonic analysis, Freeman (1979, p155) argues that hedonic technique "*seems to pass the appropriate tests about as well, or as poorly, as any empirical technique (in economics)*".

4.0 Industrial Hedonic Price Studies

There are only a limited number of hedonic price modelling of industrial property, and these have been confined to a few studies undertaken in the United States. Hoag (1980) uses industrial property in an attempt to develop an index of real estate value and return. He uses a sample of 463 transacted prices spanning a five-year period between 1973 and 1978. The study tests the significance of property characteristics, national and regional economic indicators and location variables. Location variables were found to be significant, although the paper fails to define what these variables actually measure. Unusually he discards these variables in the final model, despite their statistical significance, and retains the economic indicators instead.

Ambrose (1990) purely concentrates on property specific factors and ignores location variables. The data is located in a highly concentrated area of metropolitan of Atlanta and hence it is argued that there will be no location bias. The study tests a series of property characteristics which include; size, office space, ceiling height, number of drive-in doors, number of high docking doors, presence of a railway siding, presence of sprinklers and building age. Using a linear form all of these variables produced the expected sign and were significant at the 10% level.

Fehribach et al (1993) recognises the shortcomings of the work of Ambrose and Hoag. This study extends the work by taking account of location specific variables. The study area consists of two counties in the Dallas/Fort Worth area. The dependent variable in this study is the sales price for the industrial building; this is regressed against eleven independent variables which include physical attributes, economic and financial indicators and location variables. The two key location variables were the county the property was located in and the distance from the main airport. The results of the study highlight the statistical significance of these and other physical and economic variables.

Lockwood et al (1996), in line with earlier studies, test the effects on property value of physical characteristics, national market conditions, local market conditions, interest rates and location variables are undertaken. Again the study is based on Fort Worth/Dallas. However, this study extends the development of location measurements compared to the others. Four measures are tested; distance to the CBD, distance to the airport, distance to the nearest major road and access to the rail network. Despite the use of a different technique the results confirm the findings of the earlier studies. The major findings of this study indicate that local market conditions, physical characteristics and location of the property are the primary sources of value for industrial property. However the location variable, distance to the CBD, was not significant.

Overall these studies leave some confusion on the role of location, brought about partly because of the variation in the definition of locational variables and partly because of study area definitions are not clearly set within a mono-centric traditional core city. In addition to these studies Colwell and Munneke (1997) examine the spatial pattern of vacant industrial land prices in Chicago. They find that prices have a negative concave relationship with distance from the CBD, that the airport has a significant positive effect but only within three miles, and that price varies also with spatial sector of the city.

5.0 Research Objectives, Study Area and Data

This study attempts to use the framework of comparative static models of the urban land use market to examine the spatial pattern of industrial property rents. Although these theoretical models are much criticised for their simplistic assumptions they can provide coherent insights into urban spatial structure (see for example Egan and Nield (2000)). By extending the intra-urban rent models with revenue spatially invariant it is possible to see industrial rent surfaces with a series of minor rental peaks at accessibility nodes. There is no logical reason to presume any specific node should be dominant. Specifically in this paper we assess the significance of the negative rent gradient from the CBD and the proximity to the motorway network on rents. The former recognises the traditional role of the CDB and the latter the influence of decentralisation and reduced transportation costs on the periphery of a city. The test for the significant determinants of industrial rents using hedonic analysis. In common with most hedonic property studies the dependent variable is the asking rent which avoids standardising for variations in lease terms (Dunse and Jones,1998).

The chosen study area is Glasgow, which is Scotland's largest city situated on the west coast of central Scotland. It serves as a major provincial industrial, office and retail centre. Glasgow has experience considerable de-industrialisation and decentralisation of industry over the last three decades. The city has suffered from a severe decline in shipbuilding and many of the dock areas have been redeveloped for housing and offices. Industry is now predominantly light engineering, electronics and other service industries. The local authority area of Glasgow City has approximately 2.3 million square metres of industrial floor space. There are approximately 2700 industrial units giving an average size of 875 square metres[4].

The data used in this study is a subset of a database maintained by Scottish Property Network, at the University of Paisley. This database comprises a comprehensive core of all individual industrial properties in Scotland, together with information on asking rents and property characteristics which includes size, age, type, structure and condition. To this basic data set a range of distances linked to key points of accessibility have been augmented. A total of 429 asking rent observations for new lettings, located within recognised industrial estates were collected spanning the period 1994-1998. Table 1 shows the distribution of transactions per year. Each record has information on the transaction, physical and location characteristics that are described in Table 2.

Table 1: Number of Transactions per Year

Year	No. of Transactions
1994	78
1995	25
1996	77
1997	80
1998	169

Table 2: Variable Description

Variable Name	Description
LREN	Natural Logarithm of asking rent per square metre
Y94-98	Year of transaction (1994 = 0)
Physical	
SIZEBAND	The data is classified into 8 size bands; 0-99, 100-199, 200-499, 500-999, 1000-1999, 2000-4999, 5000-9999 and 10,000 +.
AGE (1 to 4)	Categorised into four age band dummy variables; (Before 1960 = 0), 1960- 69, 1970-79,1980-89 and 1990 onwards
CONST (1 to 2)	Categorised into two types of dummy variables; (traditional construction=0), steel portal frame and refurbished buildings
USE (1 to 2)	Categorised into two use dummy variables; (manufacturing=0), workshop and warehousing
COND (1 to 2)	Categorised into two measures of condition; (good=0), poor and new
Location	
GLASCEN	Straight-line distance in kilometres to Glasgow city centre
DIST2400	A measure of distance in kilometres to the nearest motorway junction within 2.4 km from the junction (see text)
NC	A dummy variable; North (1) and South of the River Clyde

The most modern and flexible construction forms are steel portal frames that are constructed of steel frames, which enable large unobstructed floor space. Traditional construction relates to buildings generally constructed in brick. This material does not allow large unobstructed floor plates to be constructed. As the floor area gets larger additional supports have to be added internally, effectively restricting the movement of

[4] Source: Scottish Property Network, University of Paisley

plant and machinery within the unit. The final construction form is refurbished which refers to buildings of traditional construction modified in recent times to improve the internal layout and hence improve the internal accessibility of the unit. Warehousing is simply space primarily used for the storage and distribution of goods. Both manufacturing space and workshops are primarily used for the construction and manufacture of goods. The difference in the definition of these is primarily related to the size of the unit. Workshops tend to be small units supporting small businesses whereas manufacturing space is primarily occupied by medium sized to large businesses. In addition workshops tend only to have manufacturing space whereas manufacturing units tend to have other areas such as office suites and staff areas.

Location of each industrial unit is defined in three dimensions. First, by distance from a central point within the city of Glasgow and; second, the distance to the nearest major trunk road/motorway junction. The former is simply measured as the straight-line distance in kilometres from the city centre. The latter is more complex adopting an approach used by Colwell and Munneke (1997). This approach assumes that only occupiers who want to be located close to a motorway junction will be willing to pay a premium for that benefit. It is assumed that distance from the nearest motorway junction only matters to industrial occupiers up to a maximum point. Beyond this point industrial occupiers are not actually interested in locating close to the motorway.

The distance within the boundary is defined as the maximum distance (D_{max}) less the straight-line distance (SD) (D_{max} - SD). If the industrial unit is located within the boundary it is given a dummy variable (D) of 1, if the unit is beyond the boundary it is designated a dummy variable of 0. Hence, the final distance variable is defined as $D*(D_{max} - SD)$. However, theory does not dictate what this maximum distance should be. An algorithm is used that tests a series of maximum distance intervals of 800 metre (0.5 miles) around the nearest motorway junction. The criteria used to choose D_{max} is to estimate the variable ($D(D_{max} - SD)$) that minimises the standard error in the regression equation. Applying this algorithm gives a maximum distance of 2.4km as the best measure.

Finally, a dummy variable (NC) is used to identify the location of each industrial unit relative to the River Clyde. The River Clyde is a natural barrier to movement around the city. To travel from one side of the city to the other a bridge has to be crossed and historically, it has been easier to access the city from the south, due to better transport infrastructure.

Overall the independent variables comprise a comprehensive set of industrial attributes. While there are a few potential characteristics that are absent from our original discussion on the nature of industrial accommodation it is possible to argue that they are subsumed within the age, use and construction variables.

6.0 Analysis

The initial base model for the analysis, in linear form and without any transformations to the independent or dependent variables are specified as follows:

$$RENT_i = \hat{a}_0 + \hat{a}_1\, SIZEBAND_i + \hat{a}_2\, Y94_i + \hat{a}_3\, Y96_i + \hat{a}_4\, Y97_i + \hat{a}_5\, Y98_i + \hat{a}_6\, AGE\_1_i + \hat{a}_7\, AGE\_2_i + \hat{a}_8\, AGE\_3_i + \hat{a}_9\, AGE\_4_i + \hat{a}_{10}\, USE\_1_i + \hat{a}_{11}\, USE\_2_i + + \hat{a}_{12}\, COND\_1_i + \hat{a}_{13}\, COND\_2_i + \hat{a}_{14}\, CONST\_1_i + \hat{a}_{15} CONST\_2_i + \hat{a}_{16}\, GLASCEN_i + \hat{a}_{17}\, DIST2400_i + \hat{a}_{18}\, NC_i + + \mathring{a}_i \quad \textbf{(5)}$$

Functional Form

As noted earlier there is no theoretical *a priori* functional form of equation within hedonic regression analysis. The choice of functional form cannot be based solely on the adjusted R^2 since the transformed dependent variable is not the same for all models. In order to choose between alternative models a series of Box-Cox transformation and likelihood ratio tests are used (Box and Cox, 1964). The likelihood ratio tests are based on the theory that under the null hypothesis twice the difference in the logarithmic likelihood (*ln L*) between a null and alternative hypothesis is distributed as chi-squared ($\div^2$) with the number of degrees of freedom equal to the difference in the number of unrestricted parameters (Halvorsen and Pollakwoski, 1981). The significance tests are based on the 95% level of confidence.

Following Brennan *et al* (1984) five functional forms are considered: log-linear, logarithmic, reciprocal, semi-log, and linear. It should be noted that log transformations could not be used for dummy variables and other independent variables that have possible magnitudes of zero. The procedure consists of an iterative search of a grid constructed for $\ddot{e}_L$ and $\ddot{e}_R$. Following Brennan et al (1984) a range of magnitudes from –1.5 to +1.5 based on increments of 0.01 was applied. The objective of this grid search is to find the combination of $\ddot{e}_L$ and $\ddot{e}_R$ that generate the maximum logarithmic likelihood (MLE).

Table 3: Results of Box-Cox Transformations

	ln L	$\div^{2}_{\text{calc}}$
Box-Cox	-1590.87	0.00
Log-Log	-1673.54	165.33*
Log	-1671.13	160.51*
Reciprocal	-1601.34	20.93*
Semi-Log	-1592.73	3.71
Linear	-1588.39	-4.96*

* Rejected at the 5% significance level. Critical Value = 3.84

Based on the likelihood ratio test only the semi-log model ($\ddot{e}_L = 0$, $\ddot{e}_R = 1$) has a logarithmic likelihood that is not significantly different from the maximum logarithmic likelihood. Therefore it is concluded that the semi-log model is the most appropriate of the five models initially considered, on the basis of empirical evidence.

Hedonic Results

A number of models are tested using stepwise regression procedures. This procedure is argued to be the most robust method of testing for the 'best' equation. In the model being tested, the criteria used is that a variable is entered into the equation if it is significant at the 5% critical value and is removed if the variables significance level falls below the 10% critical value.

In total 18 independent variables are regressed on the rent on the basis of a semi-log specification. Table 4 gives the results for the final model that was tested on the basis of this specification. An examination of the output produced by the stepwise procedure indicated that the regression coefficients remained stable throughout with no significant changes in sign or magnitude. The explanatory power of the model is reasonable, explaining 44.9% of variation in rental value. In the 'best' model all the variables are significant at the 95% level and they all have plausible signs and magnitudes.

The constant represents the starting point of any examination of results produced by hedonic modelling. This term includes the influence of all attributes not included in the regression equation and is the base from which other variables are added. The coefficients generated in the hedonic model represent an implicit value of buying that attribute which is not included in the constant term. In this study the constant term represents a pre-1960's manufacturing unit of traditional construction, let in 1995, in good condition, and located at the city centre on the south side of the River Clyde.

Table 4: Results of the "best" Regression Equation

Coefficient	B	t	VIF
(Constant)	4.101**	70.312	
SIZEBAND	-0.153**	-13.192	1.197
DIST2400	0.124**	6.285	1.323
AGE_1	-0.218**	-4.181	1.169
AGE_4	0.124**	3.563	1.113
COND_1	-0.190*	-2.328	1.069
GLASCEN	-0.01246*	-2.101	1.120
NC	-0.06573*	-1.972	1.281
No. of observations	429		
R^2	0.458		
Adjusted R^2	0.449		
Standard Error	0.2804		
F-Stat	50.734 (0.000)		

** significant at the 99% critical value

* significant at the 95% critical value

An examination of the regression coefficients in the 'best' model emphasises the importance that location, size, condition and age have in explaining the variation in rent across industrial units. The results are now considered in more detail below.

Physical attributes appear to be less important in this model. Size band is the most significant variable indicating that rental values per square metre fall with increasing size of property. The results suggest that rent per square metre declines by 15.3% per each incremental increase in the size band. This is a logical result given that there will probably be a quantum effect with increasing size.

Of the four age bands included in the model Age1 and Age4 are significantly different from the constant term. Age1 represents a 1960 -1969 building; a period of building that is notorious, for all property types, to be least attractive in terms of aesthetic appeal and architectural quality. The analysis suggests that this age band suffers a reduction in rent per square metre of 24.3% when compared to the constant. Age4 represents a 1990's building and attracts a premium of 13.2%. Properties in poor condition (Cond_1) see a reduction of the rent per square metre by 20.92%. Construction and use variables do not prove to be significant. However, many of these characteristics may well be subsumed into age band.

Location appears to have a major influence upon the rent. All variables included are significant. The arguments for a negative rent gradient from the city centre are upheld. . As the distance increases from the city centre rent reduces by 1.2**%** per kilometre. However, the effect while significant suggests a very shallow rent gradient. The theoretical significance of distance to the nearest motorway junction is also upheld. This is the most significant location variable and second only to size band. The coefficient suggests that as the junction is approached from the boundary limit of 2.4km the rent increase is 12.4**%** per kilometre[5]. This is an entirely logical result since a location close to the junction will not only be more accessible but also more prestigious in terms of visibility from the road. Finally, the location relative to the River Clyde is also significant. Being located to the North of the River Clyde causes a reduction in rent by approximately 6.5%. This result is as anticipated given the poorer transport links to the north of the city.

Technical Robustness

In addition to the reasonable consistency with theoretical expectations of the signs and magnitudes of the estimated implicit values, the explanatory power of the model described above compares well with others reported in the literature. The r-squared of 0.458 and the adjusted r-squared of 0.449 are comparable with those studies reviewed earlier. Also the F-statistics are significant at the 1% level which implies that overall the equation is significant.

Multicollinearity is a common problem in hedonic models. Although it is impossible to completely eliminate it, the variable inflation factors (VIF) reported in Table 4 indicate the problem of multicollinearity is minimised in the final model. A VIF of greater than ten indicates the presence of multicollinearity (Myers, 1990).

Ambrose (1990) and Can (1990) argue that there is good reason to expect the assumption of unequal variances to be violated in hedonic price models of real estate. Consequently we use the Goldfeld-Quant test for heteroscedasticity. The test statistic was calculated to be 0.1308 which is less than the critical value of 1.29 at the 5% level of significance. Thus the null hypothesis that the residual variance is constant fails to be rejected.

[5] A simple measure of straight-line distance from the motorway junction was also tested in a separate model. This also proved to significant suggesting the rent per m^2 reduces by 6.5% per kilometre as the distance increases from the motorway junction. Although significant this model specification gave slightly poorer results. The adjusted R^2 was 0.431 and the standard error 0.2847

7.0 Conclusions

The objective of this paper was to re-appraise intra-urban rent models in the context of a multi-nodal landscape. Primarily the study focuses on the early work of Alonso (1964) and more recently Di Pasquale and Wheaton (1996). Although the latter uses a more sophisticated approach, both models lead to similar outputs, notably a declining rent gradient from the CBD. However, throughout the twentieth century there has been a considerable process of urban industrial change. Decentralisation has been partly brought about by the spatial structure of costs changing over time. For example, distribution costs were originally minimised at central locations near rail and sea terminals. However with changed transport infrastructure peripheral locations are now more accessible. Di Pasquale and Wheaton recognise this and argue that this has led to an almost flat industrial rent gradient.

To assess the current impact of industrial rent we apply a hedonic rent regression model which enables us to standardise for property characteristics. The general trends in transport costs can either be incorporated by changing the assumptions about the transport cost/distance function or by introducing additional nodal points of accessibility. This paper adopts the latter approach and hypothesises an industrial rent surface consisting of a series of peaks representing nodal points of accessibility.

The results support the hypothesis that the rent gradient from the CBD for a large city is still downward sloping albeit very shallow. More interesting is the significance of proximity to motorway junctions. The analysis supports the hypothesis of a multi-nodal rent surface. This is the most important locational variable with a much steeper and negative gradient than that to the CBD albeit over a shorter distance. These results imply that the draw of the CBD in terms of agglomeration economies and its accessibility to labour for a city the size of Glasgow still remain but its attractions are much denuded with the development of a national motorway network.

8.0 References

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