*Performance, Position and Competition between Places**

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Working Paper No. 0137 **December 2008**

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* A version of this paper was presented at the meeting of the North American Regional Science Association, Savannah Georgia, November 2007. The research assistance provided by Amy O' Mahoney is acknowledged.

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Abstract

This paper uses a finite mixture modelling approach to investigate the likely determinants of relative economic performance of Irish towns. The particular success factors that we focus on are measures of connectivity, position and the competitive capacity of places. Our main argument is that these determinants of success can act in different ways on different groups of towns. The mixture model is able to detect this fact. The insights provided by the model are important additions to our understanding of spatial dynamics and contribute to the policy debate on spatial planning and infrastructural investment.

1. Introduction

Terms associated with central place theory — higher (lower) order center, market town service settlement — have traditionally evoked clear images of urban form and function. Now this formal framework for the classification of places and the understanding of roles, described by Camangi and Salone (1993) as ' the most elegant, abstract but consistent representation of the hierarchy of urban centres and the model that better interprets the spatial behaviour of many economic sectors' is regarded as less useful as an analytical device. New economic and social complexities present a challenge to notions of inherently coherent, integrated 'territory-based' systems of relations and suggest different concepts to help understand and frame newer territorial dynamics (Healey, 2004).

In the new 'relational' geography there is an entirely new vocabulary with terms like compact cities, urban networks, gateways, hubs concentrated deconcentration, polycentric development and development corridors (Healey, 2007). The European Spatial Development Perspective (ESDP) (European Commission, 1999) has helped to spawn and mainstream some of this terminology. The National Spatial Strategy for Ireland (2002), for example, draws heavily on the spatial vocabulary of the ESPD; the document refers to towns as Primary Development Centres, Gateways, Hubs, Towns with Urban Strengthening Opportunites. These descriptors are typically built around generic notions of spatial connectivity, critical mass, complementarity and capacity.

Researchers seeking to understand these new territorial complexities and assess their impacts on places have used a number of methodological approaches; discursive frameworks (Porter, 2003), standard regression methods (Erickcek et al., 2004) and other quantitative models (Plummer and Taylor, 2001). One popular area of research interest has been the development of typologies and the refinement of typology-building processes (Mikelbank, 2004; Baum et al., 2007). Baum et al. (pp. 262-263) describe the usefulness of the typology approach: 'Emerging from a need to understand and simplify complex processes, the use of typologies quantitatively identifies similarities and differences between observations… classifies observations according to these outcomes and provides substantive analysis and understandings of the groups. The typologies are not meant to be explanations of processes per se, but are 'an attempt to systemize classification in aid of explanation' (Marcuse 1997) and they provide a 'richer understanding of complex phenomena' (Mikelbank, 2004). It is the ability to elucidate the overall structure of localities and regions that makes these typology-building exercises useful.' There are several methods available to cluster or partition data into meaningful sub-groups but they are not model based and therefore, are quite limited (Johnson and Wichern, 1998). Baum et al (2007) have recently produced a classification using mixture models. Their approach is, in a sense, to formalize cluster analysis using finite mixture model methods. This allows them to choose the best cluster breakdown by using formal model selection and not 'by sight' which is the usual way in cluster analysis. In this paper we use a finite mixture model to identify different performance regimes amongst the set of Irish towns. We are not looking for clusters. We are not, that is, looking for groups of towns that are similar to each other in terms of their characteristics. Instead we are looking for towns that differ in terms of the nature of the relationship between their relative success and a group of determinants of that success.

All these classification studies have to contend with, and decide on, the trade-off between geographical and sectoral scale. Very few studies end up including small places per se, see Table 1. Plummer and Taylor (2001, p. 387) discuss some of the different and difficult issues that researchers, on choosing an econometric methodology, much face when they are trying to match sets of (vague) theoretical propositions with local level empirical evidence that is limited in terms of both quality and quantity. They draw attention to the general issue that 'empirical modeling is not a simple process of confronting theory with empirical evidence. Rather empirical modeling design involves a complex and iterative process involving the confrontation, and subsequent revision, of an empirical model specification to meet a set of predetermined model design criteria.' They

Table 1. Geographical Units used in Performance/Classification Studies

Study	Description	# Observations
Porter (2003)	Economic Areas (EAs) These areas are generally smaller than states but larger than most metropolitan statistical areas or MSAs	172
Baum et al. (2007)	Statistical Local Areas Population > 10,000	119
Erickcek et al.	Small metropolitan areas Population <1ml.	267
Plummer & Taylor (2001)	Regions	94
Mikelbank (2004)	non central-city incorporated metropolitan places	3567
Vias et al. (2002)	micropolitan areas, county level units with a central city/urbanised area >15,000	219
Garvey et al. (2007)	urban centres Populations 1,000 +	112

also allude to the pragmatic issue of appropriate proxy variable selection given the limited choice of variables that are typically available for this type of regional economic analysis. The focus in this paper is on the use of a finite mixture model to help identify different performance regimes amongst Irish towns. The data we use is from the 1988 Census of Services (CSO, 1991). This data, albeit somewhat dated, supplemented with some GIS type measurements, provides us with a neat and robust interpretative framework which allows us to include quite a number of small towns in our analysis.

A summary of our modeling framework is outlined in (1)

$$\text{Performance} = f(\text{Connectivity, Capacity, Competition, Complementarity}) \qquad (1)$$

Generic labels are used for now to identify the types of variables used. A complete list of variables used can be found in Table 2. This model is quite ordinary but, following Davis et al. (2007), we do this to focus attention on our main objective, the identification of different performance regimes. It may be the case that a model like (1) – by assuming a single regime - obfuscates as much as it clarifies about the determinants of performance. If variables (such as eigen-centrality or functional score) have contrasting effects on the relative retail performance for different kinds of towns, for example, then these contrasting effects may cancel each other out when all towns are put together, equally weighted, with the net result that they could become insignificant in a single regime specification. In contrast to the standard approach, we therefore estimate a finite mixture model in which towns are sorted into groups based on the similarity of the conditional distribution of their performance rates.

The first step is to run an OLS regression on (1) Then what happens is that a synthetic variable called 'guesprob' (the 'guessed probabilty') is regressed (iteratively from given starting values – again and again until a likelihood is maximized) on, in our case, two variables, unemployment rates and population size. This is the 'switching' regression. If we assume that there are two types of towns subsumed within the 112 towns of regression 1, then the switching regression divides our towns into these two groups (by giving the probabilities of being in group 1 or group 2), with the determinants of the division being the two chosen variables unemployment and population size. Both of these variables are significant in our regression. A high value of the predicted value means a high 'guesprob' which means a high probability of being in group 1. The characteristics of group 1 can only be investigated after the fact, as in any cluster analysis. The next step is the 'first component' regression which is a repeat of regression 1, but all data points are weighted by fitted 'guesprob' i.e. all data points are weighted by the probability of being in group 1: so this regression gives high weight to high unemployment, large size towns of regression 2. The 2nd component regression uses '1-guesprob' as the data point weights. So these are all the opposite end of the scale in terms of unemployment and size from regression 2. The formal econometric model is outlined in Section 3.

Our results are shaped by the interpretative framework that we have adopted. Thus, we don't produce complete socio-economic classifications of places. We are not, that is, looking for groups of towns that are similar to each other in terms of their characteristics. Instead we are looking for towns that are different in terms of the nature of the relationship between their relative success and a group of determinants, summarized in (1), of that success. The nature of this relationship, we find, does in fact differ: for some towns, for example, position is good, for others it is not. In fact, there is nothing really in the nature of our approach that says that the summary tables of characteristics/features should differ amongst groups – we find that they do, but this is only a byproduct of the analysis.

The specific insights we offer are about the importance of connectivity or position or capacity for groups of towns. Our main point is that the determinants of success (e.g. centrality/road quality, capacity/functional score, supporting/competing hinterlands) can act in different ways on different groups of towns and the mixture model is able to detect this fact. These insights are important additions to our understanding of spatial dynamics and contribute to the policy debate on spatial planning and infrastructural investment. These insights are discussed in the final section of the paper. The following section discusses the variables and covariates that we use. Section 3 provides some details on the econometric methods. Section 4 presents our results and, again, the final section looks at our results and their policy implications.

2. Data

Our sample consists of 112 Irish towns with a population of over 1,000 persons, selected on the basis of data availability and a reasonable geographic spread – see Map 1. Our main dependent variable is the indicator of a town's relative retail success: retail turnover per head of population. The latest data available on turnover form retail services for Ireland comes from the 1988 Census of Services (Central Statistics Office, 1991), a survey of all permanent business premises operating in that year that were engaged exclusively or principally in distribution (i.e. retail or wholesale trade) or the provision of personal or business services (excluding financial services and the public sector). The

Census of Services includes tabulations for all towns in Ireland with a population over 1,000 persons on variables such as the number of retail outlets, turnover, gross margins, persons engaged and employee numbers for a number of retail services sectors.

The independent variables that we consider are the number and quality of roads running through the town (national, regional and secondary roads), census-derived education variables, unemployment variables and occupation categories variables, a "functional score" variable (which combines information on both the number and variety of outlets), a network centrality variable (described below) and two hinterland variables - population indicators for numbers living outside the town but within 5 mile (8km) radius of the town and similar (but less accurately measured) indicators for numbers living within a band of from 5 to roughly 12 miles (8km to 20km) from the town. The independent variables are summarized in Table 2.

Table 2: Summary Statistics

Variable	Mean	Std. Dev.	Min	Max
112 towns				
Turnover per capita	3.90	1.61	0.50	9.51
Eigen centrality	6.58	9.67	0.00	42.97
Centrality	19.01	3.50	9.25	25.94
National roads	1.10	1.10	0.00	3.00
Secondary roads	1.09	1.10	0.00	4.00
Regional roads	2.70	1.41	0.00	6.00
Functional score	0.078	0.051	0.005	0.290
Population	4298	4141	701	18018
Number of retail outlets	84	57	6	323
Occupational profile	0.54	0.09	0.34	0.78
Education	6.4	0.02	0.03	0.11
Unemployment	7.78	2.38	2.79	17.50
Near hinterland	2566	3569	547	36054
Far hinterland	12253	8104	1753	47950

The variables measuring the number of roads running through a town are estimated from a visual inspection of a road map of Ireland published in 1993. Specifically, the numbers of national, secondary and regional roads connected to each of the 112 towns were recorded. Secondary and national roads tend to connect larger towns with each other than do regional roads. They also tend to be far better roads. Given that we control for both the network centrality of a town and for its hinterland population, the quality aspect of these road connections is important in interpreting results from the models below. The variable used in the estimations reflects this: we use the number of national and secondary roads divided by the total number of roads running through the town as a 0-1 index of road quality.

Data relating to the education levels, unemployment and occupational profile of towns is taken from the 1986 Census of Population (CoP) for Ireland and act as indicators of income in our model. (The 1986 CoP was chosen as it represented the closest CoP to the 1988 Census of Services, the source of data for our dependent variables). Using the 1986 CoP, we calculated for each town its population, the proportion of adults with a third level education qualification, the percentage unemployed and the percentage of households in the top 3 socio-economic groups (ABC).

Towns differ in terms of the range of retail functions that they offer. The greater the range, the more opportunities the centre offers. A measure of these opportunities is calculated in the form of a *functional score* (Todd, 1982), defined as:

$$B_i = \sum_{j=1}^{H} f_{ij}$$

Where $f_{ij} = n_{ij} c_j$, n_{ix} = number of outlets of activity j in centre i and c_j = the centrality of activity j defined as the ratio $(j / \sum j)$ where the denominator is the total number of outlets of activity j in the system, and H = the number of central place functions. The *functional score* of each town is calculated using the 1988 Census of Services data. This functional index tends, in our case, to be highly correlated with the population of each town.

In order to capture the importance of network position on the economic performance of a town two centrality-related variables are also considered. The first, *centrality*, is a measure of closeness centrality. It is derived from a 0/1 adjacency matrix representing national and secondary road links in a graph and computed in the network software UCINET (Borgati, et al. 2002). The centrality of a node in a graph measures the relative importance/position of that node. Closeness centrality is measured by calculating the shortest-path (geodesic) length to all other nodes. More centrally positioned nodes have higher values.

A second network centrality measure, also computed in UCINET, *eigenvector centrality*, is also considered. It is a measure of the importance of a node in a network. It assigns relative scores to all nodes in the network based on the principle that connections to high-scoring nodes contribute more to the score of the node in question than equal connections to low scoring nodes.

Our main dependent variable, the indicator of a town's relative economic performance, is retail turnover per head of population. Given this measure we needed to consider the effects of competition, generated through potential geographic interdependence, in our model (Mushinski and Wailer, 2002). The way in which we capture this geographic interdependence is illustrated with the help of Figure 1, see Appendix 1. The near hinterland of a town is defined as an 8k radius and the population size of this area is specified as a positive driver of local town performance. Only towns for which it was possible to draw exclusive non-overlapping near-hinterlands/catchments are included in the analysis. A far hinterland area (defined as a 20k radius) is also used. This latter variable is expected to reflect competitive threats/competing sources of supply coming from other towns due to distance or the fact that there may actually be other towns within this 20k radius.

3. Econometric Model

The equation estimated is:

$$r_i = \beta_0 + \sum_{j=1}^{p} \beta_j z_{ji} \tag{2}$$

In Equation (2), r is the dependent variable (relative retail success – turnover per head of population); the i subscript indicates the town, while the j subscript indicates the particular independent variable. The independent variables included are road quality index, the educational level, the functional score, a centrality measure, the two hinterland variables. A number of variables are excluded from the reported results, generally because of multicollinearity issues. The variables excluded from Equation (2) are occupational profile and unemployment (highly correlated positively and negatively respectively with education), population (highly correlated with functional score, which can be taken therefore as a very good indicator of town size as well as its absolute retail importance), centrality score (the eigen-centrality measure tends to provide a slightly better fit and is therefore preferred). Other variables considered in earlier versions but not included in the final version of the model are a) regional dummy variables (for the eight Irish NUTS 3 regions), b) interaction variables between the far hinterland and either the number of towns within the far hinterland or the number of other overlapping far hinterlands. These variables do tend to be significant but complicate the estimation process considerably when the number of regimes extends beyond two. The slight loss in fit that results from their omission is compensated for by an increase in clarity.

To estimate Equation 2 we use a finite mixture approach. As stated in the introduction, the observed conditional distribution for town retail performance is assumed to be a mixture of two or more distributions (henceforth, different performance "regimes"). We are particularly interested in identifying regimes (if they exist) where by being connected up (in the sense of either being more central placed within a network of towns or simply by having more/better roads running through it) a town may actually perform poorly(lose retail business).

Each putative regime will have a different conditional mean and variance. Parameters will also differ across regimes. Distributions and the parameters are jointly estimated for all regimes. As well as accounting for heterogeneity in the growth process, finite mixture models can explain the sources of systematic heterogeneity. We use indicators of town economic success (the unemployment rate) and town size (population) as explanatory variables for a town's potential assignment into a particular regime[1]. These two variables are excluded from the main equations but are, as we have seen, correlated with education and occupational profile, in the first case, and functional score, in the second. Model statistics and interpretability clearly improved when different variables were in the regime separating equation then in the substantive equations themselves.

Denoting the latter two covariates as z_i^c (where the vector of independent variables in Equation (3) is z_i^p) and letting x be the latent variable indicating class membership, we can write the probability structure for our model as:

$$f(r_i \mid \mathbf{z}_i) = \sum_{x=1}^{M} P(x \mid \mathbf{z}_i^c) f(r_i \mid x, \mathbf{z}_i^p). \tag{3}$$

We assume a normal distribution for the conditional distributions and that the latent variable follows a multinomial probability that yields the standard multinomial logit model:

$$P(x \mid \mathbf{z}_i^c) = \frac{\exp(\eta_{x|\mathbf{z}_i^c})}{\sum_{x'=1}^{M} \exp(\eta_{x'|\mathbf{z}_i^c})}, \tag{4}$$

where the linear predictor $\eta_{x|\mathbf{z}_i^c}$ is such that membership in class m is defined by:

$$\eta_{m|\mathbf{z}_i^c} = \log\left(\frac{P(x = m \mid \mathbf{z}_i^c)}{[\prod_{m'=1}^{M} P(x = m' \mid \mathbf{z}_i^c)]^{1/M}}\right) = \gamma_{m0} + \sum_{k=1}^{K} \gamma_{mk} z^c{}_{ik}. \tag{5}$$

The model is estimated via maximum likelihood. We maximize the log-likelihood function derived from the conditional probability density function in Equation 3:

[1] An alternative to the mixture approach is to interact unemployment and population, say, with the variables in the main model and estimate conventionally. But this would not account for any of the heterogeneity NOT explained by these two variables.

$$\log L = \sum_{i=1}^{I} \log f(r_i \mid \mathbf{z}_i^p, \mathbf{z}_i^c, \beta_0, \beta_p, \gamma_{mk}) = \sum_{i=1}^{I} \log[\sum_{x=1}^{M} P(x \mid \mathbf{z}_i^c) f(r_i \mid x, \mathbf{z}_i^p)] =$$

$$\sum_{i=1}^{I} \log[\sum_{x=1}^{M} \frac{\exp(\eta_{x|z_i^c})}{\sum_{x'=1}^{M} \exp(\eta_{x'|z_i^c})} f(r_i \mid x, \mathbf{z}_i^p)], \tag{6}$$

where the linear predictor $\eta_{x|\mathbf{z}_i^c}$ is defined by Equation 5 and $f(r_i \mid x, \mathbf{z}_i^p)$ is defined as follows: $f(r_i \mid x, \mathbf{z}_i^p) = \frac{1}{\sqrt{2\pi\sigma_m^2}} \exp\{-\frac{(r_i - \mu_m)^2}{\sigma_m^2}\}$. (7)

We use the empirical Bayes rule (Hartley, 1978) to calculate town-specific posterior membership probabilities $\hat{P}(x \mid z_i, g_i)$. Then each town is assigned to the class for which it has the largest posterior probability. In practice, the number of regimes is unknown to the researcher. We start with a one-regime model and then estimate subsequent models that increase the number of regimes by one each time (given our sample size, we only go up to a maximum of three regimes). We use the recommended adjusted Akaike Information Criterion (AIC3) statistic (Andrews and Currim, 2003) to select the preferred model and hence the number of regimes. We also provide the more commonly used BIC criterion as a benchmark. The BIC statistic tends to be more conservative than the AIC3 statistic (in the sense of favouring fewer regime splits), while the AIC3 statistic in turn is more conservative than the AIC statistic.

4. Model Results

The estimated model assuming a single regime (Table 3) shows that education has a positive association with relative retail performance. The near hinterland variable is also significant and positive, as is the road quality index. The far hinterland variable appears to have a small negative effect. The degree of eigen-centrality and the functional score variable are both insignificant. The Bayesian Information Criterion statistic is 394 for the model and the AIC3 is 382.

The most obvious conclusion from this estimation is that a town's own measured education level (correlated as this is with its occupational status profile and, ultimately, its per capita income), the quality of its road connections and the size of the town's immediate hinterland are the main determinants of a town's relative retail performance. The negative coefficient on the far hinterland variable suggests that relative retail

Table 3: Single Regime Regression

112 obs.	Coef.	s.e.	t-value
Education	0.470	.0777	6.12**
Functional Score	0.963	2.614	0.37
Eigen-centrality	0.008	0.013	0.62
Road Quality Index	1.657	0.455	3.64**
Near Hinterland	0.101	0.038	2.66**
Far Hinterland	- 0.031	0.017	-1.78
Constant	0.164	0.655	0.25
Log-Likelihood	**AIC3**	**BIC**	
-181.873	384.213	394.242	

performance may be reduced somewhat if there are other, competitor, shopping opportunities between about 5 and 12 miles away.

However, it may be that the model at hand – by assuming a single regime – obfuscates as much as it clarifies. If variables (such as eigen-centrality or functional score) have contrasting effects on the relative retail performance for different kinds of towns, then these contrasting effects may cancel each other out when all towns are put together, equally weighted, with the net result that they could become insignificant in a single regime specification.

In the two-regime model (reported in Table 4), we now find that in the first regime (regime 1) all variables have positive coefficients, except for far hinterland which is negative but insignificant. Functional score is the only insignificant positive variable. The other coefficients are all smaller than in the single regime model, except for road quality and the centrality variable. The towns in regime 1, it would appear, benefit strongly from being connected with other towns by high quality roads.

In regime 2, the centrality variable has a clear negative association with relative retail performance (suggesting that the positive and negative effects of network centrality may indeed have cancelled each other out in Table 3). Education is strongly positive in regime 2 (even stronger than in Table 3). The functional score variable is positive, significant and high – bigger towns with a greater number and variety of outlets perform better relatively (not just absolutely) in this regime. The near hinterland variable is strongly positive. The far hinterland is negative again, as in Table 3.

The Bayesian Information Criterion statistic for this version of the model is 395 and the AIC3 statistic is 363. The first is almost the same as in the single regime model. The second is appreciably lower.

The regime splitting estimation results suggest that towns in regime 1 are larger but poorer than other towns (they have greater unemployment); towns in regime 2, conversely, are smaller and wealthier.

The summary statistics for the towns assigned into regimes using Bayesian posterior probabilities (Table 5) show more clearly the inter-regime differences. There are 77 towns classified as being in regime 1 and 35 towns in regime 2. Towns in regime 1 (those towns that benefit from good quality connections to other towns) have a higher population, a higher number of outlets and a higher functional score than towns in regime 2. They are better connected by all kinds of roads, but especially by national roads. They are a good deal more central within the overall network of towns (according to both centrality measures). They have larger near hinterlands than the towns in regime 2. They also have far hinterlands that have about 30% more people than those of towns in regime 2. Towns in regime 1 would appear to be less well off, however, than regime 2 towns on a number of fronts – they have greater unemployment, less education and a lower socio-economic occupational profile. Towns in regime 1 also have a far lower turnover figure per capita (about 50% lower).

Of course, these comparisons are made using averages and there are wide spreads for some of the variables. Nevertheless, the differences are striking. One plausible explanation for what seems to be going on is that some people in smaller, better-off, towns (regime 2 towns) with good and plentiful road connections to the wider network of towns must be leaving their own towns to do their shopping. The better the connections are with other towns, the more they leave.

The AIC3 Statistic, reported in Table 6, for the three regime model is 351, while the Bayesian Information criterion statistic is 402. The former is considerably lower than the AIC3 value for the two regime model, while the latter is considerably higher. By the recommended AIC3 criterion the three-regime model is preferred to the two-regime model but the large increase in BIC casts some doubt on this, and we give roughly equal weight to both two- and three-regime models.

In the 3-regime model, we again find towns dividing into positive and negative groups (in terms of the effects of centrality on relative revenue). Regime 1 towns benefit from centrality, as do regime 3 towns. Towns in regime 2 lose. There is little difference between the signs and size of the coefficients of variables in regimes 1 and 2 of this model compared to those in the previous version. The main difference is that towns in regime 2 now lose from road quality improvements, as well as losing from increased centrality. When one looks at the summary tables (Table 7) one finds that there are eleven fewer towns in regime 2 in this version than before. One can assume that the omitted towns benefited from good quality road connections. The values for other variables of regime 2 towns in this model are similar to those for regime 2 in the two-regime model, except that the social and income related variables veer slightly more towards the wealthier end of the spectrum.

Table 4: Two-Regime Regression

Regime 1	Coef.	s.e.	t-value
Education	0.174	.086	2.01*
Functional Score	3.298	2.160	1.53
Eigen-centrality	0.023	0.009	2.59**
Road Quality Index	1.967	0.460	4.28**
Near Hinterland	0.098	0.025	3.84**
Far Hinterland	-0.008	0.013	-0.60
Constant	0.880	0.588	1.50
Regime 2			
Education	0.458	.096	4.75**
Functional Score	32.236	10.838	2.97**
Eigen-centrality	-0.093	0.035	-2.65**
Road Quality Index	0.897	0.544	1.65
Near Hinterland	0.825	-0.393	2.10*
Far Hinterland	-0.130	0.048	-2.76**
Constant	-0.088	0.910	-0.10
Regime Splitting Regression			
Unemployment	0.739	0.258	2.86**
Population	0.001	0.000	2.70**
Constant	-6.661	2.020	-3.30**
/lnsigma1	*-0.208*	*0.098*	-2.13*
/lnsigma2	*-0.296*	*0.140*	-2.12*
sigma1	*0.812*	*0.079*	10.23**
sigma2	*0.744*	*0.104*	7.15**
Log Likelihood	**AIC3**	**BIC**	
-152.865	362.730	395.381	

Table 5: Summary Statistics for two regimes

Variable	Mean	Std. Dev.	Min	Max
77 towns in Regime 1				
Turnover per capita	3.41	1.17	0.50	6.37
Eigen centrality	7.94	11.01	0.00	42.97
Centrality	19.18	3.61	9.25	25.94
National roads	1.16	1.10	0.00	3.00
Secondary roads	1.13	1.09	0.00	4.00
Regional roads	2.82	1.44	0.00	6.00
Functional score	0.089	0.057	0.005	0.290
Population	5448	4515	1024	18018
Number of retail outlets	96	64	6	323
Occupational profile	0.52	0.08	0.34	0.78
Education	6	0.01	0.03	0.09
Unemployment	8.56	2.34	4.47	17.50
Near hinterland	3065	4200	692	36054
Far hinterland	13077	9199	2193	47950
35 towns in Regime 2				
Turnover per capita	4.97	1.91	1.61	9.51
Eigen centrality	3.59	4.57	0.03	22.06
Centrality	18.64	3.25	12.41	24.76
National roads	0.97	1.10	0.00	3.00
Secondary roads	1.00	1.14	0.00	4.00
Regional roads	2.43	1.31	0.00	5.00
Functional score	0.056	0.021	0.020	0.110
Population	1766	911	701	5219
Number of retail outlets	58	23	11	121
Occupational profile	0.58	0.09	0.37	0.78
Education	7	0.02	0.04	0.11
Unemployment	6.07	1.41	2.79	9.10
Near hinterland	1466	586	547	3567
Far hinterland	10440	4511	1753	20167

The (very small) extra regime in the 3-regime model does not come from a simple split of one of the regimes of the 2-regime model (see Appendix 2 for lists of the towns in all regimes). Rather, the sample of towns is re-split anew, with three towns in the new third regime coming from the old regime 2 and the other five towns coming from the old regime 1. The eight towns in regime 3 are moderately sized towns, on average, with moderate values for their social indicators. They have very high eigen-centrality figures and tend to have large far hinterlands. Their regression coefficients are positive and similar to those of regime 1, except that they are negative for functional score and for both near and far hinterlands. These towns perform relatively worse, therefore, as they get larger and have larger hinterlands. One possible explanation is that these are towns with good shopping facilities in their immediate hinterlands.

6. Conclusions

This paper provides a first use of FMM econometric models to investigate the likely determinants of relative economic performance, with a particular focus on the effects on a town's relative retail performance of connectivity and links with other towns. Much of the work is necessarily descriptive and most of the discussion of the results revolves around comparing summary tables for towns classified probabilistically into different groups. However, the primary focus of the FM econometric technique itself is not descriptive but aims to identify different performance "regimes" and to estimate the parameters of their conditional probability distributions. The main implication of the econometric results generated by the application of the technique is that there seems to be a group of small Irish towns that would not do well were they more embedded in the network of towns nationally and if they had larger "outer" hinterlands. Furthermore, and largely from within that group, there appears to be a subgroup that also would suffer if the quality of their road connections were improved.

These are interesting results that become more interesting when comparisons are made, using the summary tables, between these towns (the likely "losers" from increased connectivity) and the clear majority of towns, that tend to gain from more and better connections with other towns. The losing towns tend to be smaller, wealthier, doing relatively well in terms of retail turnover per head and located, with a few exceptions, in the south-west and west of the country and close to the border with Northern Ireland. These towns, it would appear from the results, are exceptionally vulnerable, to competing sources of retail supply. This is the most important substantive (and, it should be said, somewhat counter-intuitive) result from this paper. This group of comparatively well-off towns gains from having fewer connections, worse roads and smaller "far hinterlands" to compete against. It could be they would gain absolutely (in terms of attracting more new inhabitants) with greater connectivity but the paper suggests that there are circumstances in which there can be relative gains from relative isolation. The FMM model, and the results, suggest that we should question the assumption, prominent, for example, in the ESPD, that somehow all towns can be key development nodes in a territory, capable of dispersing development to other areas. The model allows us to see that there are differences in roles and in the sets of factors that influence these roles and the challenge for both analytical and policy work is to try and better understand these issues in specific local contexts.

Table 6: Three-Regime Regression

Regime 1	Coef.	s.e.	t-value
Education	0.212	0.073	2.89**
Functional Score	1.906	2.023	0.94
Eigen-centrality	0.017	0.010	1.81
Road Quality Index	2.066	0.377	5.48**
Near Hinterland	0.103	0.000	4.02**
Far Hinterland	-0.015	0.013	-1.17
Constant	0.863	0.530	1.63
Regime 2	Coef.	Std.	t-value
Education	0.522	0.953	5.47**
Functional Score	22.496	8.598	2.62**
Eigen-centrality	-0.070	0.033	-2.13*
Road Quality Index	-0.998	0.456	-2.19
Near Hinterland	1.055	0.307	3.43*
Far Hinterland	-0.257	0.043	-5.97**
Constant	1.597	1.159	1.38
Regime 3	Coef.	Std.	t-value
Education	0.641	0.0012	518.61**
Functional Score	-2.446	0.055	-44.65**
Eigen-centrality	0.011	0.000	86.73**
Road Quality Index	2.196	0.007	293.22**
Near Hinterland	0.307	-0.012	-12.31**
Far Hinterland	0.043	-0.017	-111.54**
Constant	0.345	0.009	39.43**
Regime Splitting Regression			
Regime 1			
Unemployment	0.032	0.168	0.19
Population	0.000	0.000	0.74
Constant	1.688	1.553	1.09
Regime 2			
Unemployment	-0.676	0.298	-2.27*
Population	0.000	0.000	-1.38
Constant	6.717	2.233	3.01**
/lnsigma1	*-0.209*	*0.085*	-2.44*
/lnsigma2	*-0.733*	*0.179*	-4.09**
/lnsigma3	*-5.606*	*0.254*	-22.03**
sigma1	*0.811*	*0.069*	11.70**
sigma2	*0.481*	*0.086*	5.58**
sigma3	*0.004*	*0.001*	3.93**
Log Likelihood	**AIC3**	**BIC**	
-130.691	351.382	402.937	

Table 7: Summary Statistics for three regimes

Variable	Mean	Std. Dev.	Min	Max
80 towns in Regime 1				
Turnover per capita	3.42	1.17	0.50	6.37
Eigen centrality	7.01	10.13	0.00	42.97
Centrality	19.03	3.52	9.25	25.94
National roads	1.11	1.10	0.00	3.00
Secondary roads	1.13	1.10	0.00	4.00
Regional roads	2.70	1.44	0.00	6.00
Functional score	0.085	0.056	0.005	0.290
Population	5048	4493	1021	18018
Number of retail outlets	91	63	6	323
Occupational profile	0.53	0.08	0.34	0.78
Education	6	0.01	0.03	0.11
Unemployment	8.34	2.31	4.47	17.50
Near hinterland	2862	4075	692	36054
Far hinterland	12620	8511	1753	47950
24 towns in Regime 2				
Turnover per capita	5.16	2.02	1.61	9.51
Eigen centrality	4.11	4.93	0.03	22.06
Centrality	18.97	3.47	12.41	24.76
National roads	0.91	1.02	0.00	2.00
Secondary roads	1.17	1.17	0.00	4.00
Regional roads	2.50	1.22	0.00	5.00
Functional score	0.057	0.023	0.020	0.110
Population	1939	1028	701	5219
Number of retail outlets	59	26	11	121
Occupational profile	0.58	0.09	0.39	0.78
Education	8	0.02	0.05	0.11
Unemployment	5.76	1.32	2.79	8.53
Near hinterland	1505	675	547	3567
Far hinterland	9876	3983	1897	20167
8 towns in Regime 3				
Turnover per capita	4.85	1.73	2.26	7.92
Eigen centrality	9.76	14.51	0.08	40.60
Centrality	18.94	3.83	14.06	25.01
National roads	1.50	1.31	0.00	3.00
Secondary roads	0.50	0.93	0.00	2.00
Regional roads	3.25	1.67	1.00	6.00
Functional score	0.078	0.049	0.018	0.169
Population	3872	3860	1095	11929
Number of retail outlets	89	56	29	194
Occupational profile	0.54	0.09	0.36	0.66
Education	0.06	0.02	0.03	0.10
Unemployment	8.26	2.49	4.26	12.51
Near hinterland	2785	2860	1130	9452
Far hinterland	15704	11725	8328	43520

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Appendix 1. An Illustration of Geographical Interdependence

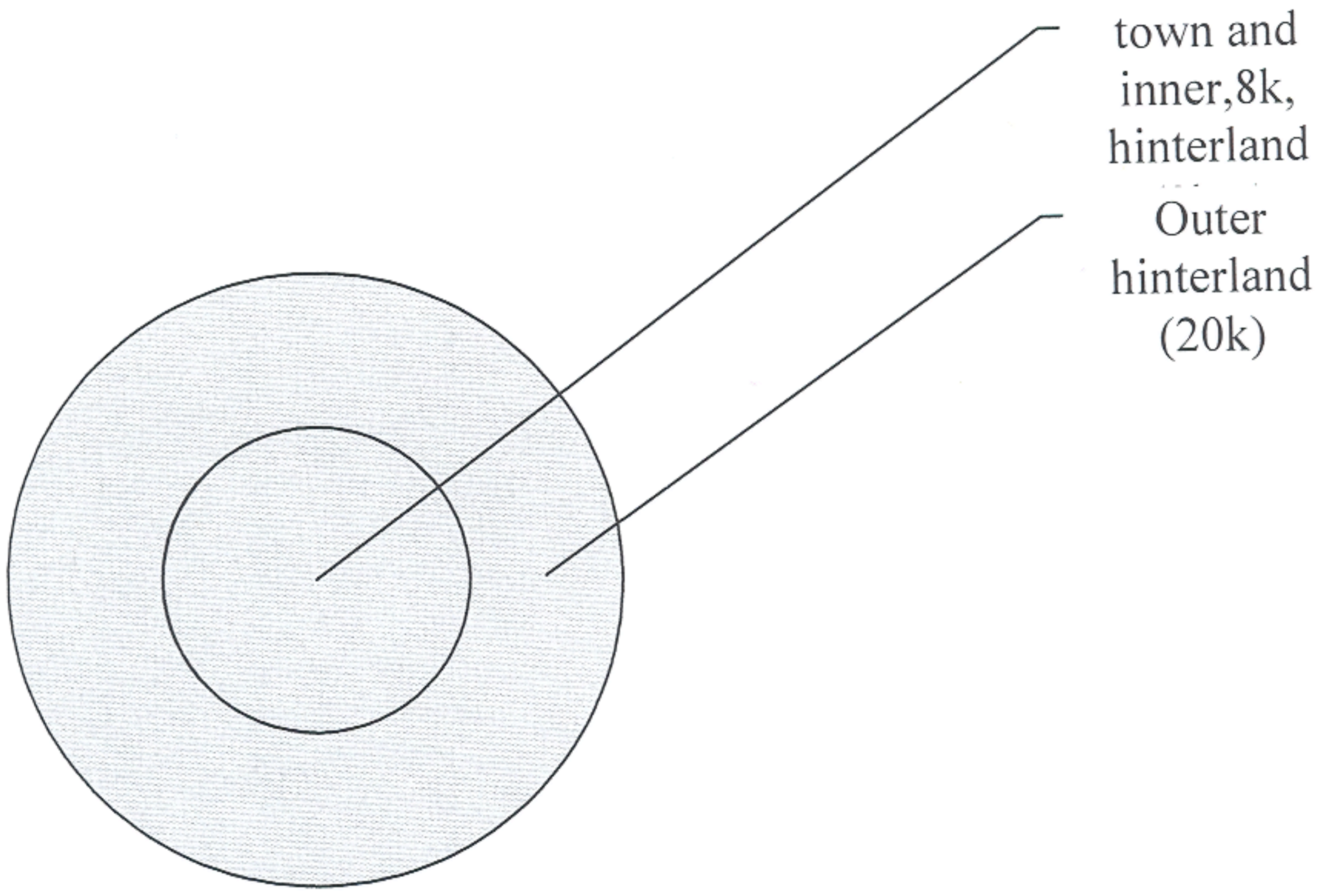
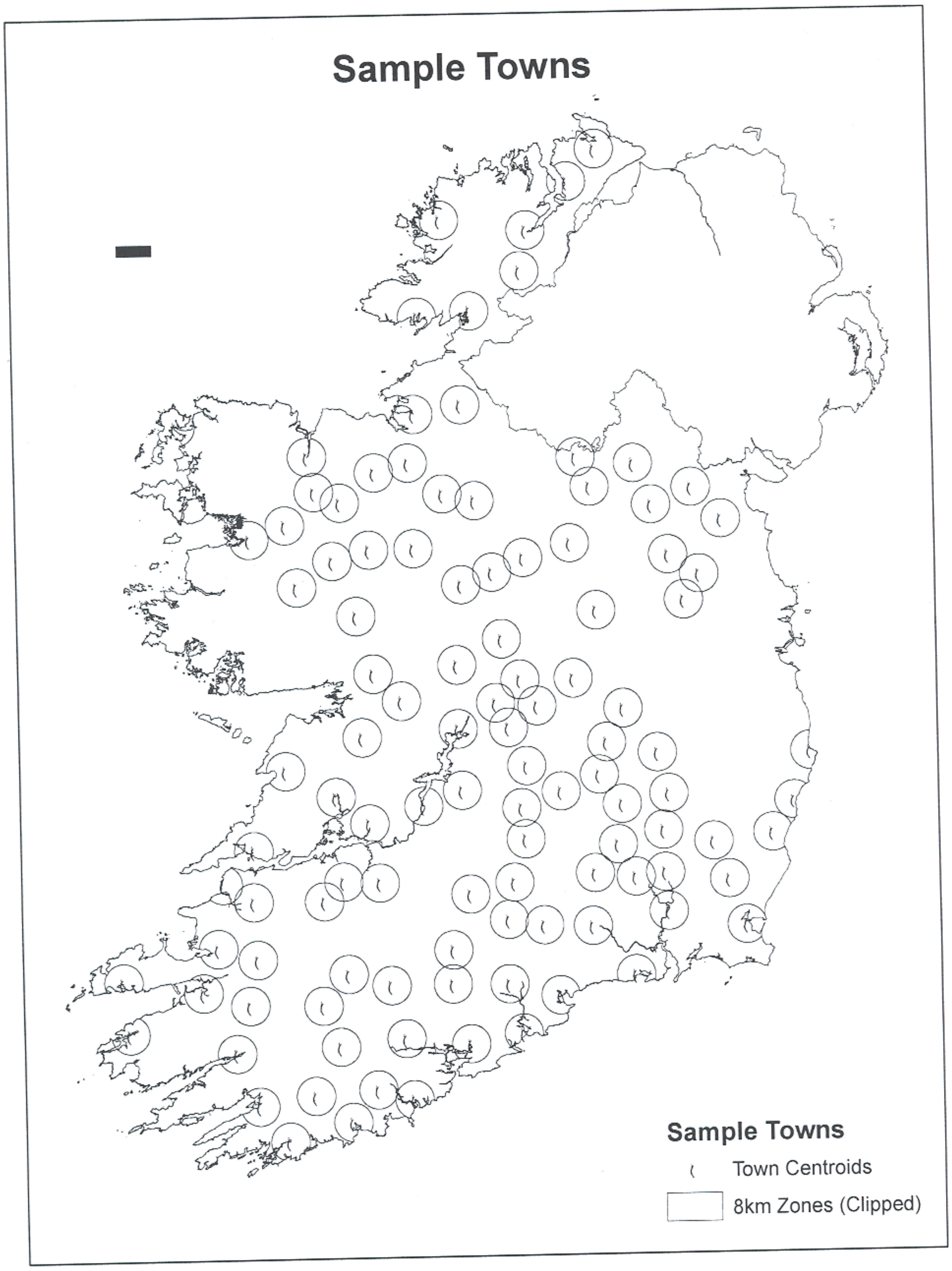


Figure 1. Near and Far Hinterlands

Map 1. Map showing towns and inner hinterlands



Appendix 2 Regime Membership Probabilities

	2-regime model				3-regime model					
	PRIOR PROBABILITIES		POSTERIOR PROBABILITIES		PRIOR PROBABILITIES			POSTERIOR PROBABILITIES		
	regime 1	regime 2	regime 1	regime 2	regime 1	regime 2	regime 3	regime 1	regime 2	regime 3
Manorhamilton	0.042	0.958	0.061	0.939	0.118	0.864	0.018	0.185	0.815	0.000
Claremorris	0.044	0.956	0.005	0.995	0.092	0.895	0.013	0.012	0.988	0.000
Lanesborough	0.066	0.934	0.032	0.968	0.188	0.784	0.028	0.074	0.926	0.000
Lismore	0.074	0.926	0.993	0.007	0.186	0.787	0.027	1.000	0.000	0.000
Dunmanway	0.078	0.922	0.002	0.998	0.181	0.793	0.026	0.002	0.025	0.973
Kenmare	0.084	0.916	0.000	1.000	0.205	0.766	0.030	0.002	0.998	0.000
Dingle	0.112	0.888	0.000	1.000	0.250	0.715	0.035	0.000	1.000	0.000
Belturbet	0.126	0.874	0.077	0.923	0.274	0.687	0.039	0.124	0.876	0.000
Carrick-on-shannon	0.130	0.870	0.073	0.927	0.256	0.709	0.035	0.239	0.761	0.000
Ballinrobe	0.136	0.864	0.022	0.978	0.287	0.673	0.040	0.057	0.943	0.000
Abbeyleix	0.144	0.856	0.047	0.953	0.287	0.673	0.040	0.066	0.934	0.000
Ballyhaunis	0.149	0.851	0.019	0.981	0.303	0.655	0.042	0.039	0.961	0.000
Caherciveen	0.167	0.833	0.996	0.004	0.331	0.623	0.046	1.000	0.000	0.000
Swinford	0.180	0.820	0.000	1.000	0.357	0.593	0.050	0.000	0.001	0.999
Ballymote	0.195	0.805	0.153	0.847	0.387	0.559	0.054	1.000	0.000	0.000
Gort	0.214	0.786	0.143	0.857	0.415	0.527	0.058	0.586	0.414	0.000
Athenry	0.243	0.757	0.244	0.756	0.404	0.542	0.054	0.305	0.695	0.000
Thomastown	0.281	0.719	0.387	0.613	0.459	0.479	0.062	0.988	0.012	0.000
Skibbereen	0.310	0.690	0.000	1.000	0.449	0.493	0.058	0.000	1.000	0.000
Roscommon	0.313	0.687	0.096	0.904	0.344	0.614	0.041	0.105	0.895	0.000
Ferbane	0.330	0.670	0.063	0.937	0.515	0.417	0.069	0.041	0.959	0.000
Cootehill	0.342	0.658	0.073	0.927	0.495	0.441	0.064	0.068	0.932	0.000
Baileborough	0.343	0.657	0.329	0.671	0.507	0.426	0.067	0.541	0.459	0.000
Clonakilty	0.353	0.647	0.941	0.059	0.433	0.514	0.053	0.999	0.001	0.000
Castlerea	0.365	0.635	0.459	0.541	0.513	0.421	0.066	0.789	0.211	0.000
Millstreet	0.399	0.601	0.000	1.000	0.577	0.347	0.076	0.001	0.999	0.000
Blarney	0.399	0.601	1.000	0.000	0.535	0.397	0.068	1.000	0.000	0.000
Foxford	0.405	0.595	0.480	0.520	0.601	0.318	0.080	1.000	0.000	0.000
Kanturk	0.428	0.572	0.000	1.000	0.565	0.363	0.072	0.000	1.000	0.000
Rathdowney	0.432	0.568	1.000	0.000	0.617	0.301	0.082	0.009	0.000	0.991
Macroom	0.490	0.510	0.000	1.000	0.575	0.354	0.071	0.000	1.000	0.000
Templemore	0.520	0.480	0.544	0.456	0.602	0.324	0.074	0.884	0.116	0.000
Boyle	0.526	0.474	0.148	0.852	0.607	0.319	0.074	0.177	0.823	0.000
Belmullet	0.588	0.412	0.153	0.847	0.719	0.188	0.093	0.995	0.005	0.000
Mitchelstown	0.588	0.412	0.127	0.873	0.602	0.329	0.070	0.156	0.844	0.000
Killorglin	0.606	0.394	0.231	0.769	0.717	0.191	0.091	1.000	0.000	0.000
Killybegs	0.611	0.389	0.614	0.386	0.706	0.206	0.088	0.848	0.152	0.000
Portumna	0.611	0.389	0.040	0.960	0.731	0.175	0.094	0.100	0.900	0.000
Ballybofey	0.636	0.364	0.859	0.141	0.654	0.270	0.076	0.593	0.407	0.000
Tubbercurry	0.653	0.347	0.990	0.010	0.745	0.161	0.094	1.000	0.000	0.000
Cashel	0.654	0.346	0.989	0.011	0.674	0.247	0.079	0.984	0.016	0.000
Banagher	0.655	0.345	0.760	0.240	0.738	0.169	0.092	1.000	0.000	0.000
Kinsale	0.684	0.316	0.802	0.198	0.708	0.209	0.083	0.804	0.196	0.000
Bantry	0.695	0.305	0.904	0.096	0.704	0.215	0.082	0.728	0.272	0.000
Loughrea	0.696	0.304	1.000	0.000	0.677	0.247	0.076	1.000	0.000	0.000
Portarlington	0.709	0.291	1.000	0.000	0.740	0.172	0.088	1.000	0.000	0.000
Donegal	0.709	0.291	0.246	0.754	0.739	0.174	0.088	0.348	0.652	0.000
Kilcormac	0.712	0.288	0.921	0.079	0.779	0.123	0.098	1.000	0.000	0.000
Listowel	0.722	0.278	1.000	0.000	0.679	0.246	0.075	1.000	0.000	0.000

Granard	0.726	0.274	0.709	0.291	0.779	0.125	0.097	0.799	0.201	0.000
Callan	0.765	0.235	0.749	0.251	0.799	0.102	0.099	0.965	0.035	0.000
Carrickmacross	0.785	0.215	0.444	0.556	0.740	0.179	0.081	0.347	0.653	0.000
Westport	0.785	0.215	0.998	0.002	0.740	0.179	0.081	0.997	0.003	0.000
Ennistymon	0.805	0.195	0.838	0.162	0.821	0.078	0.101	0.871	0.129	0.000
Muinebeag	0.831	0.169	0.932	0.068	0.796	0.115	0.089	0.967	0.033	0.000
Castlecomer	0.836	0.164	1.000	0.000	0.827	0.074	0.099	1.000	0.000	0.000
Fermoy	0.844	0.156	1.000	0.000	0.730	0.197	0.073	1.000	0.000	0.000
Castleisland	0.857	0.143	0.248	0.752	0.823	0.083	0.094	0.005	0.000	0.995
Carndonagh	0.859	0.141	1.000	0.000	0.835	0.066	0.099	1.000	0.000	0.000
Cavan	0.865	0.135	0.000	1.000	0.738	0.189	0.072	0.000	1.000	0.000
Trim	0.879	0.121	0.902	0.098	0.794	0.124	0.082	0.980	0.020	0.000
Sixmilebridge	0.888	0.112	1.000	0.000	0.853	0.045	0.102	1.000	0.000	0.000
Newcastle	0.894	0.106	0.960	0.040	0.819	0.095	0.086	0.985	0.015	0.000
Killaloe	0.909	0.091	0.865	0.135	0.863	0.035	0.103	0.979	0.021	0.000
Ardee	0.912	0.088	1.000	0.000	0.836	0.077	0.087	1.000	0.000	0.000
Bandon	0.923	0.077	1.000	0.000	0.817	0.104	0.079	1.000	0.000	0.000
Cahir	0.926	0.074	0.962	0.038	0.863	0.041	0.096	0.935	0.065	0.000
Birr	0.928	0.072	1.000	0.000	0.838	0.078	0.084	1.000	0.000	0.000
Kells	0.933	0.067	0.918	0.082	0.851	0.062	0.087	0.924	0.076	0.000
Wicklow	0.933	0.067	0.995	0.005	0.815	0.108	0.076	1.000	0.000	0.000
Kilrush	0.936	0.064	0.998	0.002	0.862	0.047	0.091	0.999	0.001	0.000
Croom	0.937	0.063	0.999	0.001	0.874	0.024	0.102	1.000	0.000	0.000
Ballinasloe	0.942	0.058	1.000	0.000	0.811	0.116	0.073	1.000	0.000	0.000
Castlebar	0.951	0.049	1.000	0.000	0.777	0.158	0.064	1.000	0.000	0.000
Bunclody	0.951	0.049	0.999	0.001	0.880	0.019	0.101	1.000	0.000	0.000
Tuam	0.963	0.037	1.000	0.000	0.850	0.075	0.075	1.000	0.000	0.000
Tramore	0.969	0.031	0.980	0.020	0.861	0.064	0.076	0.757	0.243	0.000
Roscrea	0.970	0.030	0.968	0.032	0.880	0.036	0.084	0.985	0.015	0.000
Graignamanagh	0.971	0.029	0.997	0.003	0.888	0.012	0.100	0.038	0.000	0.962
Thurles	0.977	0.023	1.000	0.000	0.856	0.075	0.069	1.000	0.000	0.000
Athy	0.979	0.021	0.982	0.018	0.884	0.037	0.079	0.987	0.013	0.000
Longford	0.981	0.019	0.999	0.001	0.876	0.052	0.072	0.999	0.001	0.000
Buncrana	0.984	0.016	1.000	0.000	0.897	0.019	0.084	1.000	0.000	0.000
Tipperary	0.984	0.016	0.995	0.005	0.894	0.026	0.080	0.978	0.022	0.000
Rathkeale	0.984	0.016	0.999	0.001	0.897	0.008	0.095	1.000	0.000	0.000
Nenagh	0.986	0.014	0.997	0.003	0.895	0.028	0.077	0.008	0.000	0.992
Portlaoise	0.988	0.012	0.995	0.005	0.879	0.056	0.066	0.965	0.035	0.000
Middleton	0.989	0.011	0.990	0.010	0.900	0.025	0.075	0.034	0.000	0.966
Mallow	0.990	0.010	1.000	0.000	0.892	0.040	0.069	1.000	0.000	0.000
Bunbeg	0.991	0.009	1.000	0.000	0.901	0.004	0.095	1.000	0.000	0.000
Dungarvan	0.993	0.007	1.000	0.000	0.908	0.020	0.072	1.000	0.000	0.000
Gorey	0.994	0.006	0.983	0.017	0.911	0.006	0.083	0.988	0.012	0.000
Killarney	0.996	0.004	1.000	0.000	0.900	0.042	0.059	1.000	0.000	0.000
Youghal	0.996	0.004	1.000	0.000	0.917	0.009	0.074	1.000	0.000	0.000
Letterkenny	0.996	0.004	1.000	0.000	0.910	0.030	0.060	1.000	0.000	0.000
Ballina	0.998	0.002	1.000	0.000	0.923	0.012	0.065	1.000	0.000	0.000
Enniscorthy	0.999	0.001	0.996	0.004	0.929	0.006	0.065	0.837	0.163	0.000
Mullingar	0.999	0.001	1.000	0.000	0.922	0.026	0.052	1.000	0.000	0.000
Tullamore	0.999	0.001	0.999	0.001	0.934	0.007	0.059	0.997	0.003	0.000
Ballybunion	0.999	0.001	1.000	0.000	0.914	0.000	0.085	1.000	0.000	0.000
Arklow	1.000	0.000	1.000	0.000	0.938	0.002	0.060	1.000	0.000	0.000
Athlone	1.000	0.000	1.000	0.000	0.950	0.008	0.042	1.000	0.000	0.000
Carrick-on-Suir	1.000	0.000	1.000	0.000	0.933	0.000	0.066	1.000	0.000	0.000
Carlow	1.000	0.000	1.000	0.000	0.951	0.003	0.045	1.000	0.000	0.000
Ennis	1.000	0.000	1.000	0.000	0.953	0.007	0.040	1.000	0.000	0.000
Navan	1.000	0.000	1.000	0.000	0.950	0.002	0.048	0.084	0.000	0.916
Clonmel	1.000	0.000	1.000	0.000	0.961	0.001	0.039	1.000	0.000	0.000
Kilkenny	1.000	0.000	1.000	0.000	0.966	0.001	0.033	1.000	0.000	0.000
Wexford	1.000	0.000	1.000	0.000	0.963	0.000	0.036	1.000	0.000	0.000

Sligo	1.000	0.000	1.000	0.000	0.969	0.001	0.031	1.000	0.000	0.000
Tralee	1.000	0.000	1.000	0.000	0.969	0.000	0.031	1.000	0.000	0.000
New Ross	1.000	0.000	1.000	0.000	0.921	0.007	0.070	0.990	0.010	0.000