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The Employment-Population Nexus and Implications for Sustainable Economic Development: Insights from Irish Regions using a Partial Adjustment Model

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Keywords: Partial Adjustment Model, Ireland, Population, Employment, Smart Specialisation, Place Based Policy.

JEL Codes: R11, R58, C21

Abstract

In this paper we use a partial adjustment model to analyse the relationship between employment and population growth in Irish district electoral divisions (DEDs). We employ a spatial estimator to augment our partial adjustment model with a spatial lag and spatial error process. Our results indicate a dual relationship between employment and population growth, suggesting that not only do people follow jobs but also jobs follow people. This finding has implications for economic development policies, which typically focus solely on attracting jobs to a location. The results suggest that a dual pronged approach to policy may be necessary including developing a region's amenities to ensure that it is attractive to people and to stimulate population growth. We highlight how our analysis can be used to inform policy through the lenses of place based and smart specialisation strategies.

Keywords: Partial Adjustment Model, Ireland, Population, Employment, Smart Specialisation, Place Based Policy.

JEL Codes: R11, R58, C21

1. Introduction

This paper employs a partial adjustment model of population and employment for Irish district electoral divisions (DEDs). As noted by Carruthers and Vias (2005) and De Graaff et al. (2012) partial adjustment models have become increasingly popular in regional analysis as they enable testing of the possible endogenous relationship between population and employment within a region. The basic premise of the partial adjustment system is that population (employment) is modelled dependent upon contemporaneous employment (population) as well as lagged population (employment) while including a set of exogenous covariates. This enables testing of endogenous relationships between population and employment through testing of reduced form coefficients derived from the model (Hoogstra et al., 2011). The ability to identify these endogenous relationships is incredibly important as it provides insight into the employment-population nexus including whether (i) jobs follow people; (ii) people follow jobs or (iii) a simultaneous system exists where both are co-determined.

From the perspective of placed based and smart specialisation policies this has important implications. It is held in the literature with substantial supporting evidence that people follow jobs. Therefore, regional policies typically focus on job creation in an effort to stimulate population growth and sustainable economic development. However, if it is the case that jobs also follow people [as suggested by Carruthers and Mulligan (2007)] then standard policies which only promote job creation are not addressing a vital component of sustainable economic development. Should jobs follow people the preservation and development of natural and constructed amenities provides another route to sustainable economic development, which could be a complementary factor in place based or smart specialisation policies targeted at regional economies, in order to further stimulate employment growth.

There is some overlap between place based policies and smart specialisation. Place based policies, broadly speaking, are government efforts to enhance the economic performance of an area, typically in the form of more job opportunities and higher wages (Neumark and Simpson, 2014). Such policies represent a movement away from 'space-neutral' or 'spatially-blind' development policies; these policies adopted a 'one-size-fits-all' approach while ignoring the underlying regional context in areas where the policies were implemented. McCann and Rodríguez-Pose (2011) argue that spatially blind policies are rarely space neutral; they usually promote capital cities which, the authors say, will grow without the need for intervention as highlighted by existing evidence. The central features of these policies focus on the provision of subsidies to firms or sectoral interventions with an exclusive focus on the creation of jobs or physical connections between places (Barca, 2009). The idea of smart specialisation as a policy concept is relatively new, with its origins in the work of Ortega-Argilés (2012).[i] However, as noted by McCann and Ortega-Argilés (2013), while the concept has emerged from a more sectoral focus, this has now changed. It is increasingly being utilised to address regional growth issues. It is the potential role of smart specialisation in regional development which is of particular interest to us specifically in the context of employment and population growth.

In the context of the global economic crisis the topic of regional development has become increasingly important. In the Irish context the National Spatial Strategy, which was designed to promote more equal spatial development, was abolished following the 2008 economic crisis. This provides an interesting backdrop to our analysis which focuses on the employment-population nexus and the importance of this nexus for regional development, which is now largely unfocused in the Irish context. The analysis and findings of this paper have general applications which are not limited to Ireland. For instance, in the UK, there has been much discussion as to the importance and role of regional development with the relatively recent abolition of the regional development agencies in favour of local enterprise partnerships. At a European level there is now much discussion on the role of place based policies and smart specialisation as determinants of regional development (Doran et al., 2016; McCann and Ortega-Argilés, 2015; Barca et al., 2012; Barca, 2009).

In order to estimate our partial adjustment model we use data from the Irish population census 2002 and 2006. The level of geographical disaggregation in the census most suited to our analysis is that of District Electoral Division (DED) of which there are approximately 3,440 in Ireland. By utilising the census we can relate population and employment levels to a variety of regional characteristics such as educational attainment, age profile and sectoral composition among other factors. In estimating our partial adjustment model we extend the model to contain explicit spatial processes. This is accomplished through the use of the Kelejian and Prucha (1998) general methods of moments (GMM) spatial autoregressive spatial error model. The advantage of utilising this estimator is that it allows for the inclusion of a spatial lag and spatial error process to be incorporated into our partial adjustment model to control for possible substantive and nuisance spatial processes which may be observed.

The main contribution of the paper to existing literature is to utilise a spatially augmented partial adjustment model to inform a discussion of the long run implications for economic development of a dual relationship between employment and population from the perspective of place based and smart specialisation policy. While the analysis utilises data on Ireland the findings have broader policy implications which are applicable to other developed economies that possess a strong urban/rural divide. It is the first paper to apply a partial adjustment model in the Irish context.

The remainder of this paper is structured as follows. Section 2 provides a brief overview of place based and smart specialisation policies as these are the underlying policy motivations for this paper. Section 3 presents an overview of existing literature on partial adjustment models. Section 4 describes the estimation procedure utilised by this paper. Section 5 presents the data used. Our results are presented in Section 6. Conclusions and policy implications are provided in Section 7.

2. Place Based Policy and Smart Specialisation

2.1 Place Based Policy

Following on from our discussion of smart specialisation we now consider place based policy which is similar in that it focuses on the importance of place/regions. Place based policies represent a new paradigm of regional policy (Barca, 2009). The objectives of these policies include "enhancing well-being and living standards in specific regions and at generating and sustaining regional competitive advantages with a fuller and better use of regions' assets" (Barca, 2009: 4). This approach is not defined by administrative boundaries but rather it is place-based and geared towards different types of regions (Barca, 2009). It aims at institutional building and/or strengthening and improving accessibility to goods, services and information, and the promotion of innovation and entrepreneurship. The OECD (2011) believes that a policy approach that accounts for the specific assets located in a particular place, and seeks to coordinate the various sectoral policies that impact that place, is more likely to be successful relative to spatially blind policies. The importance of understanding the individual characteristics of regions and their place specificity is to the fore in place based policies (OECD, 2009b). This approach advocates tailoring development policies to suit the needs of a specific region; in this way the policy can be more successful in achieving its goal whether it is job creation, entrepreneurship or innovation.

The place based approach has two fundamental features (Barca et al., 2012). First, it assumes that geographical context matters. Geographical context includes social, cultural and institutional characteristics. Barca (2009) says that regions can be trapped in a vicious circle of inefficiency or social exclusion because of the path dependent nature of ineffective institutions; the less likely a place is to have effective institutions at present the less likely it will have them in the future. Institutions need to be tailored to the context (Barca, 2009). Furthermore the effectiveness of these institutions depends strongly on them being adapted to places (Barca, 2009). Adaptation requires the involvement of local actors who have the knowledge necessary to design such institutions (Barca, 2009). Exogenous public authorities have little knowledge of local context but rather design a more general institutional blueprint which is not reflective of the context in which they are implemented. This links to the second aspect; place based policies focus on the role of knowledge in policy intervention; "who knows what to do and when?" (Barca et al., 2012: 139). The failure of local elites to act contributes to the underdevelopment of regions. It may be, for instance, that the appropriate institutions either intentionally fail or are not chosen by the local elites because of their own vested interests (Barca, 2009). New knowledge and ideas, stemming from local groups and external elites, to promote the development and growth of these regions is a necessary component of place based policies. These policies are interventions that include the coordination of infrastructure provision, schooling, business development and the promotion of innovation, as a way of achieving greater local development and thus greater aggregate growth, through spillovers (OECD, 2009a). This is where place based policies represent a departure from traditional, one-size-fits-all development policy. It does not assume that the exogenous State knows better (Barca, 2009).

Barca (2009) notes that while place based policies are advantageous in that they are transparent, verifiable and subject to the scrutiny of citizens they are also complex and risky for a number of reasons. The assumption that local elites know more than the exogenous State does not mean that place based policies will not suffer from the same problems. For example, investment may be directed towards activities which are not built on a region's competitive advantage. This may stem from the belief that individuals in charge of designing and implementing development policy are more knowledgeable and can thus 'pick winners' essentially. Furthermore, such policies may also lead to the creation of a dependency culture rather than a culture of innovation and entrepreneurship, which in many cases is the one of the aims of place based policies.

2.2 Smart Specialisation

The concept of smart specialisation has been described as an "*industrial and innovation framework for regional economies that aims to illustrate how public policies, framework conditions, but especially R&D and innovation investment policies can influence economic, scientific and technological specialisation of a region and consequently its productivity, competitiveness and economic growth path*" (OECD, 2013: 17).

Key characteristics or elements of smart specialisation are set out by Foray et al. (2009) and the OECD (2013).[ii] These characteristics include a suggestion that a large area for research and innovation is created, which facilitates unrestricted competition. The second characteristic emphasises the role of entrepreneurial activity in the process. As Foray et al. (2009: 2) note this represents a move away from government led attempts to impose specialisation through the implementation of a plan but instead emphasises the role of an "entrepreneurial process of discovery." Another characteristic they refer to is the role of government policies (Foray et al., 2009). These should focus on issues such as ensuring entrepreneurs are incentivised to engage in research and development (R&D) which may result in unanticipated results or discoveries. There is also a role for government to evaluate and monitor results. The OECD (2013: 19) point out that this must involve measurable outcomes and targets "whether it involves an increase in business R&D, R&D commercialisation or research excellence."

While the idea of smart specialisation was not originally applied to the area of regional growth, it is increasingly being used in this manner, particularly in a European context (McCann and Ortega-Argilés, 2013). McCann and Ortega-Argilés (2013) explore the issues in applying the smart specialisation concept in this manner and suggest that it can be usefully applied as a policy tool in a regional setting. Therefore they assert its use as part of Europe's cohesion policy is appropriate. They note the difficulty in ensuring there is a skills match within regions in the medium to long term. As well as this, they point to previous work suggesting that as workers within a region acquire more human capital and skills, there is a greater chance that such workers may move to more prosperous regions, as they are more mobile. Such investments in education and training in less well-off regions may have an unintended consequence of increasing out-migration from such regions. This is not a given and will clearly depend on the opportunity to secure employment within the region. It would seem that while equipping workers with the appropriate skills to attract and retain potential employers in a region is important, the availability of employment opportunities is also necessary to incentivise individuals to remain within a given region. A related point regarding the demand side issues is made by Morgan (2013). While acknowledging the importance of ensuring the availability of appropriately trained and skilled workers, he notes the need to facilitate measures on the demand side to "socialize risk and foster innovation" (Morgan, 2013: 122). Through addressing both demand and supply side issues an environment which would help support and encourage innovation can be developed.

2.3 Place Based and Smart Specialisation Policies in the Irish Context

It is this need to focus on the importance of place which is important from the perspective of our paper. As the standard policies, such as promoting educational attainment in rural areas, may lead to migration from peripheral, rural areas to metropolitan areas, there is an need for empirical analysis to consider how best to stimulate more equal spatial development. The two aforementioned policy instruments are useful to us as possible mechanisms through which balanced economic development can be stimulated. In the Irish context the analysis of spatial development is particularly relevant at the current time following the abandonment of the National Spatial Strategy in the wake of the 2008 economic crisis. The notion of balanced spatial development is once more on the policy agenda with increased attention being paid by policy makers to spatial inequalities in jobs and population growth/decline.

3. Partial Adjustment Framework

The concept of balanced spatial development is highly relevant in the context of Ireland where there has been significant spatial disparities in development. When considering these disparities one of the key policies implemented by the Irish Government has been an attempt to distribute employment spatially outside of the central urban areas of the country. This focus on employment, however, may be only once facet of a balanced regional development policy. The other is to create locations where individuals want to live outside of major urban areas. The central tenant of place based policy revolve around not just employment but also social, cultural and institutional characteristics. The advantage of the approach used by this paper is that it considers both the employment and population element of place based and smart specialisation policies. By applying a partial adjustment framework this paper analyses the impact of a variety of factors on population and employment dynamics across Irish regions. We then interpret the results of our analysis through the lenses of place based and smart specialisation strategies to provide possible insights into how best to stimulate, if needed, spatially balanced growth.

Specifically, in this paper we utilise a partial adjustment methodology to analyse the evolution of employment and population levels in Irish regions over the time period 2002 to 2006. Utilising this time period allows us to examine the dynamics of employment and population in the Irish economy prior to the onset of the 2008 economic crisis. We begin by using the Carlino and Mills (1987) partial adjustment specification which assumes that employment and population are co-determined. This suggests the following:

$$\Delta emp_i = emp_{i,t} - emp_{i,t-h} = \lambda_{emp}\left(emp^* - emp_{i,t-h}\right) \quad (1)$$

$$\Delta pop_i = pop_{i,t} - pop_{i,t-h} = \lambda_{pop}\left(pop^* - pop_{i,t-h}\right)$$

Where emp^* and pop^* are the equilibrium employment and population levels, λ_{emp} and λ_{pop} are the speed-of-adjustment parameters, *i* indicates the region, *t* indicates the time period and *h* denotes a time lag. Following the standard assumptions in the literature we can rearrange (1) to yield equation (2):

$$emp_{i,t} = \tilde{\alpha}_0 + \tilde{\alpha}_1 emp_{i,t-h} + \tilde{\alpha}_2 pop_{i,t-h} + \tilde{\alpha}_3 X_{i,t-h} \quad (2)$$

$$pop_{i,t} = \tilde{\beta}_0 + \tilde{\beta}_1 pop_{i,t-h} + \tilde{\beta}_2 emp_{i,t-h} + \tilde{\beta}_3 X_{i,t-h}$$

Where $\tilde{\alpha}$ and $\tilde{\beta}$ are our parameters to be estimated and *h* is the degree of lag existing between time period *t* and time period *t-h*.

In equation (2) we note that employment and population depend on one another as well as an autoregressive component. In addition to this they also depend on the exogenous set of variables *X*. These exogenous variables are factors which may impact upon employment and population but which are not determined within our system of equations. The exact variables we use are discussed in our data section but these include education, age and sectoral employment share among other factors.

4. Extending the Partial Adjustment Model to Control for Spatial Dependence

4.1 Spatial Model

As noted in Mulligan et al. (1999) equation (2) can be estimated using OLS. However, following a number of recent papers [see Brown et al. (2013) and Lambert et al. (2012) as examples] equation (2) can be extended to consider spatial dependence in the form of an endogenous spatial lag and a spatial auto-regressive error term. The need to capture spatial effects is emphasised by Gebremariam et al. (2011) and Boarnet (1994) among others. We specify equation (3) as:

$$y_{i,t} = \chi_0 + \chi_1 x_{i,t-h} + \varepsilon_{i,t} \tag{3}$$

Where $y_{i,t}$ is a vector of dependent variables $emp_{i,t}$ and $pop_{i,t}$, χ_0 is a vector of intercept coefficients $\tilde{\alpha}_0$ and $\tilde{\beta}_0$, $x_{i,t-h}$ is a matrix of independent variables incorporating $pop_{i,t-h}$, $emp_{i,t-h}$ and $X_{i,t-h}$, χ_1 are the associated coefficients and $\varepsilon_{i,t}$ is the error term.

We can incorporate spatial effects into this model and subsequently test the necessity of their inclusion. Following Brown et al. (2013) we allow for both substantive and nuisance spatial dependence in our model. Substantive spillovers are captured through the inclusion of our endogenous spatial lag given as $\rho_1 W y_{i,t}$ in equation (4) while nuisance spatial dependence is captured by the inclusion of a spatial autoregressive error term, also detailed in equation (4). These are included in our model as one would anticipate employment and population to exhibit strong spatial correlation:

$$\begin{aligned} y_{i,t} &= \chi_0 + \rho_1 W y_{i,t} + \chi_1 x_{i,t-h} + \varepsilon_{i,t} \\ \varepsilon_{i,t} &= \lambda M \varepsilon_{i,t} + u_{i,t} \end{aligned} \tag{4}$$

Where *W* and *M* are spatial weighting matrices of dimensions *N*N*. ρ_1 is a spatial lag coefficient and λ is the coefficient associated with the spatial autoregressive process. Both of these coefficients will vary across the population and employment equations.

This can take a number of forms and the exact specification employed in this paper is discussed in the data section. Among the alternative specifications for the W matrix is a binary contiguity matrix, where neighbours take a value of 1 and 0 otherwise, or a matrix of the inverse of the distance between the regions. This W matrix is row standardised so that the rows sum to 1. The value Wy can be thought of as a spatially weighted value of y based upon the type of weight matrix used. LeSage and Pace (2009) note that the omission of the spatially weighted dependent variable can cause biased estimates of β if excluded when it should have been included. Regarding the estimation of our spatial model specified in equation (4) we use the method developed by Kelejian and Prucha (1998).

The second form of spatial dependence is what Anselin et al. (2008) refers to as nuisance dependence. This occurs in the error term and is expressed as $\varepsilon_{i,t} = \lambda M\varepsilon_{i,t} + u_{i,t}$, where λ is a spatial autoregressive coefficient and $u_{i,t}$ is a standard spherical error term. In this instance shocks to a region are transmitted through the error term to other regions. Again M determines the way in which the shocks are transmitted across space. Ignoring the spatial dependence in the error term does not cause biased estimates of β but does cause biased estimates of their variance which has implications for statistical hypothesis testing.

4.2 Our Estimation Strategy

In this paper we apply the general method of moments estimator presented in Kelejian and Prucha (1998). This essentially proceeds in three stages. We present a condensed summary of the procedure here and refer the interested reader to the original exposition in Kelejian and Prucha (1998). We begin by writing equation (4) more compactly giving equation (5):

$$y_i = Z_i\delta + \varepsilon_i \qquad (5)$$
$$\varepsilon_i = \lambda M\varepsilon_i + u_i$$

Where $y_i = y_{i,t}$, $Z_i = (Wy_{i,t}, x_{i,t-h})$ and $\delta = (\rho_1, \chi_1)$. Applying a Cochrane-Orcutt type transformation to this model yields:

$$y_i^* = Z_i^*\delta + u_i \qquad (6)$$

Where $y_i^* = y_i - \lambda My_i$ and $Z_i^* = Z_i - \lambda MZ_i$.

There are three steps in the Kelejian and Prucha (1998) estimator. The first step of the procedure is to apply two stage least squares to equation (5) ignoring the spatial correlation of the error term. This results in a consistent estimation of δ. The second step in the estimator is to use this consistent estimation of δ to obtain our error term ε_i. We then apply general method of moments (GMM) to obtain consistent estimates of λ (also the variance of the error). The third step of the procedure is to use this estimate of λ to perform the Cochrane-Orcutt type transformation displayed in equation (6). We can then obtain more efficient estimates of δ which have taken into account spatial autocorrelation of the error term.

4.3 The Final Model

The final set of models we arrive at are displayed in equation (7a) and (7b). We note at this point that *t* is taken as 2006 and *t-h* is taken as 2002. The reason for this is outlined in the data section below:

$$emp_{i,2006} = \tilde{\alpha}_0 + \rho_1 Wemp_{i,2006} + \tilde{\alpha}_1 emp_{i,2002} + \tilde{\alpha}_2 pop_{i,2002} + \tilde{\alpha}_3 X_{i,2002} + \varepsilon_{i,2006} \quad (7a)$$
$$\varepsilon_{i,2006} = \lambda M \varepsilon_{i,2006} + u_{i,2006}$$

$$pop_{i,2006} = \tilde{\beta}_0 + \rho_1 Wpop_{i,2006} + \tilde{\beta}_1 pop_{i,2002} + \tilde{\beta}_2 emp_{i,2002} + \tilde{\beta}_3 X_{i,2002} + \varepsilon_{i,2006} \quad (7b)$$
$$\varepsilon_{i,2006} = \lambda M \varepsilon_{i,2006} + u_{i,2006}$$

We estimate both of these equations using the procedure outlined in section 4.2.

4.4 Potential Endogeneity

At this point it is worth noting that we assume that $X_{i,2002}$ is exogenous in both equations (7a) and (7b). This assumption is consistent with existing literature on regional partial adjustment models. As noted by Brown et al. (2013: 209) "regional studies using partial adjustment models have typically assumed that the lagged adjustment variables are exogenous". However, while lagging the independent variables should mitigate for potential endogeneity it is possible that the error term could follow a first-order serially correlated time trend, which would result in current period errors being correlated with the lagged adjustment variable. This could be mitigated against by taking a second lag of the adjustment variables. However, in order to accommodate this a longer time series would be required than is available in our study. Therefore, we interpret our output with caution, noting association between the variables rather than causation.

5. Data

5.1 The Irish Census 2002 and 2006

The primary data sources used in this paper are the Census of the Irish Population 2002 and 2006. The Census provides information on the number of individuals employed and the population of Irish regions, along with a variety of factors which may help explain heterogeneity in employment and population levels such as educational attainment, gender, age profiles, nationality and employment share by industry. The variables derived from the census are displayed in Table 1 along with their definitions and descriptive statistics.

We can see that the average number of people in employment in 2006 per DED was 574, which is up from 488 in 2002 while the average population of a DED in 2006 was 1,251 in 2006 up from 1,165 in 2002. We note the substantial variation in employment and population size of DEDs as indicated by the standard deviations as well as minimum and maximum values.[1]

When considering population growth in the Irish context during this time period it is worth noting that Ireland experienced a large degree of inward migration. The estimated net migration figures for the period 2002-2006 for Ireland is approximately 230,900 people (CSO, 2016a). Therefore, when we consider population growth, we are not simply considering natural changes in the population or mobility within Ireland but also migration from other countries. As a result one must be cognisant of the impact these migration figures may have and it must be borne in mind when interpreting our results that population growth in this time period has been impacted significantly by migration.

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[1] Note that in the empirical estimation these variables are entered in natural logarithms which should reduce any potential heteroscedasticity problems in our estimation.

When we consider our independent variables the Census provides information on the number of people in a DED with a Bachelor's degree education or higher. This indicator proxies for the human capital of a region and again we can see that it varies substantially. The average proportion of people in a DED with a third level education or higher is a little above 21%. However, this varies from 1.85% to 74.14% across DEDs. This, like the employment and population statistics, is manifest of the strong urban-rural divide in Ireland. This divide is further highlighted by the composition of industry share of employment across DEDs. We can see that there is a large degree of heterogeneity across DEDs, with agriculture being highly prevalent in rural areas of society, while commerce and trade and manufacturing are located around the larger urban concentrations.

In terms of age share we have information on those less than 15 years old, greater than 65 years old and five year age intervals for those between 15 and 65 years of age. These enter as the share of age categories in a region in our empirical analysis. We also consider the nationality of individuals. Here we are somewhat constrained in what we can include. We possess information only for three categories; Irish, UK and Other. We can see that in general DEDs are predominantly Irish but that there are some exceptions which possess relatively high numbers of UK and Other nationalities.

We finally note that 21% of our DEDs can be classified as urban areas and that an average unemployment rate of 7.32% was observed across DEDs.

[insert Table 1 around here]

5.2 District Electoral Divisions

The level of geographical measurement used in this analysis is the district electoral division (DED). There are a total of 3,440 DEDs in Ireland and they are the smallest legally defined administrative areas in the State. There are 32 DEDs with low population, which for reasons of confidentiality have been amalgamated into neighbouring DEDs by the Irish CSO, giving a total sample size of 3,408 DEDs for each year. Furthermore, there are a number of cases of missing data for various variables which results in a reduction in our sample size to 3,341 DEDs.

Figures 1 and 2 display plots of the natural logarithm of employment and population density numbers respectively for 2006. Darker shading indicates a higher concentration of employment and population respectively. We can observe that the highest levels of employment and population occur around the major urban centres in Ireland such as Dublin, Cork, Galway, Limerick and Waterford.

Indeed if we consider Moran's I statistics[iii] for both employment and population there is clear evidence of a significant spatial pattern in the data with Z-scores of 59.421 and 59.977 respectively, both of which have associated p-values of 0.0001. These spatial patterns in our data lend support to the notion of utilising spatial econometric estimation techniques in order to ensure efficient estimation.

[insert Figure 1 around here]

[insert Figure 2 around here]

Fotheringham and Wong (1991) emphasise the sensitive nature of using spatial data in multivariate analysis and the importance of consideration of the modifiable areal unit problem. The spatial units we have used are DEDs, which are the lowest levels of spatial aggregation available, using Irish data. However, as with all spatial analysis which aggregates individual level data, it is possible that the results are impacted by the modifiable areal unit problem. This issue can be defined as relating to "the areal units (zonal objects) used … [being] … arbitrary, modifiable, and subject to the whims and fancies of whoever is doing, or did, the aggregating" (Openshaw and Openshaw, 1984: pp. 3). The most common issues discussed in relation to the modified areal unit problem is in relation to the issue of scale. When data is aggregated to different spatial scales the same analysis, performed on these different spatial scales, can result in differing results. Gehlke and Biehl (1934) was amongst the first to point to the fact that increases in geographical scale of the spatial units in an analysis typically leds to higher levels of correlation between the units. In an attempt to counteract this scale issue in our case we use data from the census of population which is aggregated by the Irish Central Statistics Office (CSO) to DED level. There are a number of other spatial units which could be utilised, all at a higher levels of aggregation. We choose to use these DEDs as they are "the smallest legally defined administrative areas in the State for which Small Area Population Statistics (SAPS) are published from the Census" (CSO, 2016b). It is true that these data are administrative boundaries rather than true functional economic areas, however, they provide the most detail at the smallest geographical scale in Ireland.

5.3 Specifying our W Matrix

In order to operationalise our spatial estimator we must first define our W and M matrices. These matrices measure the connectivity between our spatial units (Corrado and Fingleton, 2012). We utilise what is probably the most common format for the W and M matrix and base this upon the contiguity of our DEDs (LeSage and Pace, 2009). In essence a contiguity matrix is a $N*N$ matrix (where N is the number of regions in our analysis) which contains a series of 0s or 1s. 0 indicates that two regions are not contiguous (neighbours which do not share a border) while a value of 1 indicates that two regions are contiguous (i.e. they do share a border). This gives a matrix such as the one displayed in equation (8), where k takes a value of 1 if region i and j are neighbours and 0 otherwise.

$$W = M = \begin{bmatrix} k_{1,1} & & & k_{1,N} \\ \vdots & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ k_{N,1} & \cdots & \cdots & k_{N,N} \end{bmatrix} \tag{8}$$

We also normalise our W and M matrix so that the rows sum to one. In our estimations both W and M are identical queen contiguity matrices. However, to ensure that our results are robust to alternative specifications of W and M we also employ two alternative specifications of these matrices. In these alternative specifications, rather than assuming that the spatial process is based upon contiguity, we instead measure the distance from the centroid of each DED to the centroid of every other DED in kilometres. In this instance k in equation (8) takes the value 1/(distance in km) between region i and region j. It is common to use the inverse distance, as we have done, for ease of interpretation of the subsequent coefficient estimations. In the first of our alternative W specifications we use the distance from each DED to every other DED. In the second specification we assume that the spatial effects are bounded and assume that the effects of spillovers from one region to another do not exist past the median distance. Therefore, in the second specification distances greater than the median are entered as 0. Again we row normalise both matrices. The results of the estimation of our models using these alternative *W* and *M* specifications are presented in Appendix 1.

6. Empirical Results

Table 2 displays the results of our empirical estimation of equations (7a) and (7b) using the Kelejian and Prucha (1998) estimator outlined in Section 4. In the case of lagged employment and population both variables have a significantly positive impact on employment and population in 2006. It is necessary when considering a partial adjustment model to assess the stability of the endogenous coefficients in the system. Carruthers and Mulligan (2007) note that for the adjustment coefficients to have any meaning the system must be stable. To assess stability the coefficients from the partial adjustment mechanism are placed in a 2*2 matrix and the characteristic unit roots were obtained by solving the detrementional equation (Carruthers and Mulligan, 2007; Carlino and Mills, 1987). When we test for the stability of the system we observe that the absolute value of the characteristic roots is less than 1 indicating that the system is stable. This suggests a dual causality between employment and population. Having established that the coefficients are significant (using t-tests), and that the characteristic roots are within normal bounds, we can interpret these coefficients as having real effect. The results suggest that, as one would expect, higher employment in a region will result in a higher population level. However, we also observe that higher population levels can stimulate employment. This suggests that there is scope for development policies to not only focus on promoting employment growth but also to promote population growth. The implications of this finding for policy are discussed in the conclusion.

We also observe that there is negative spatial correlation among population and employment centres suggesting that highly populous and employment rich areas border less populous and lower employment areas. This is consistent with our data visualisation presented earlier which highlights the strong urban-rural divide in Irish DEDs. Urban concentrations with large population and employment levels are proximate to more rural locations which have low concentrations of employment and population. A possible explanation for this is the sharp urban-rural divide in Ireland. As noted by Guinnane (2015) while Ireland was historically a very rural country over the course of the past 100 years it has experienced a significant increase in urbanisation, with large degrees of migration from rural areas to urban concentrations. These urban concentrations are typically bordered by more rural DEDs which may be driving this negative spatial correlation. Urban areas with higher levels of population (employment) may, over time, draw population (employment) away from neighbouring rural areas in a type of Krugman shadow effect (McCann and Ortega-Argilés, 2015).

Industry concentration of employment also has a significant impact on the employment and population levels across DEDs. The reference category is Agriculture, Forestry and Fishing. In terms of positive population and employment effects we also observe that regions with a strong specialisation in building and construction have higher population and employment levels relative to the other sectors considered. We note that this result is probably related to the time period. During the 2002-2006 period construction was a leading employer in both urban and rural Ireland. However, after 2008, this sector shed hundreds of thousands of jobs. Therefore, an analysis based on post-recession data may find alternative sectoral effects to those presented in Table 2. Concentration of employment in Public Administration and Commerce and Trade respectively has the next largest effects on employment and population followed by manufacturing and industries.

We also observe that a region's age profile has an effect on employment and population levels. DEDs with an age profile between 30 and 34 and 35 and 39 have higher levels of population and employment. Regions with an older and younger population have lower levels of population and employment. This suggests that regions with high concentrations of young and old individuals can expect to observe lower levels of population and employment. A possible explanation for this age effect relates to the structure of urban and rural areas in Ireland, which are typically populated by working age individuals, densely populated, with significant employment opportunities. This is in contrast to rural areas where there is typically an aging population (due to young individuals migrating to urban areas), less population density, and fewer employment opportunities. This is supported by the results indicating that urban areas have higher levels of employment and population relative to rural areas.

[insert Table 2 around here]

7. Conclusions and Implications

This paper analyses the employment population nexus for Irish DEDs in order to shed light on the importance of regional development policy in promoting more even regional development. We estimate a partial adjustment model controlling for spatial autoregressive and spatial error processes using data from the Irish Censuses 2002 and 2006. The results indicate that there is dual causality between employment and population in Irish DEDs, suggesting that policies aimed at fostering regional development need to consider more than simply job creation. We have shown in our analysis that the employment-population nexus flows both ways. While people do follow jobs it is also the case that jobs follow people. Therefore, when striving for sustainable regional development, policies which promote population growth in more rural areas should aid in the subsequent attraction of jobs (this could be through outside private investment into the region to access the pool of workers or organic entrepreneurial processes which lead to the formation and creation of new businesses).

From the perspective of smart specialisation our findings have a number of implications. McCann and Ortega-Argilés (2013) note that the size of the region, in terms of population, may have an impact on the usefulness of smart specialisation strategies. They suggest that regions require a certain critical mass to "generate agglomeration or network effects" (McCann and Ortega-Argilés, 2013: 8). Furthermore it is noted that isolated regions are likely to lack scale needed to facilitate smart specialisation while large urban areas are likely to already benefit from a diversity of sectors and technological capability. Da Rosa Pires et al. (2014) refer to the work of Corrado and Dematteis (2013) and Dematteis (2011) who argues that a novel policy vision is required to attract young and skilled workers to more rural areas as happened in the Alpine region in Italy. In that instance, efforts were made to promote the benefits of a rural lifestyle, as well as enhancing the accessibility of the region and improving information technology infrastructure. While they concede that the numbers of people involved are small this shows how placed based policies can be successful. The arrival of new, skilled workers may ultimately add to the innovative and entrepreneurial capacity of the region, resulting in an increased rate of job creation and employment growth. Policies such as this could help in stemming the tide of young individuals leaving rural locations in Ireland for metropolitan areas.

Barca (2009) points to Ireland's National Spatial Strategy as a successful example of a spatially oriented regional policy. The strategy focuses on regional gateways and related hubs to promote regional development. It is recognised within the strategy that the spatial structure of Ireland is strongly influenced by the location of investment which subsequently influences where people work and live. Furthermore, the complementary nature of population growth and regional development is recognised where the authors of the report state that a growing population is a key asset that can be harnessed towards balanced regional development. As previously mentioned while people do follow jobs it is also the case that jobs follow people. However, based on the projected population increases contained in the National Spatial Strategy, this suggests that Ireland's regional development will continue in the same fashion because the largest population growth is set to occur in the existing large cities. Smaller towns and rural areas, it appears, will not witness much, if any, population growth over the coming years, with our results suggesting that this will hamper the rate of job growth in these regions. This implies that the less developed regions in Ireland will continue on this path. It may be that more attention needs to be given to measures that can boost population growth in less developed regions in Ireland, which based on our findings, would lead to an increase in the number of jobs flowing to those regions ultimately contributing both to regional and national development and growth. However, in this context it is worth noting that the National Spatial Strategy has essentially been wound down and there is, as yet, little specific focus on regional policies for growth in Ireland.

Our paper also points to the need for further research in this area. For instance, our analysis is based on cross sectional data and, as more census data in Ireland becomes available, this issue would be worth re-visiting in a panel context. This would have the advantage of being better able to account for potential endogeneity in our model providing more robust causal inferences. Secondly, we have not considered the role of migration in impacting population change. Over the time period considered Ireland has experienced significant levels of inward migration which will have driven population growth to be higher than it otherwise would have been. Likewise during the 2006-2011 period Ireland suffered significant levels of outward migration due to worsening economic conditions and post 2011 positive net inward migration occurred (although at a slower rate than previously). Barry (2002: 39) notes that during times of economic crisis Ireland's well educated workforce was more likely to be found "showing up in London or Boston rather than in Dublin". Our paper began with an analysis of population and employment growth using partial adjustment models, however, it would be appropriate in the Irish context if this could be extended to include migration. This has not been possible in the data used in this paper because, while information is provided on the nationality of individuals, no information is provided on whether they migrated to Ireland since the last census or have been there for years. Therefore, other data may need to be explored to fully address this issue.

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Appendix 1: Estimation Results using Alternative Specification of W and M

Table A1.1

Variables	Population (coefficient)	Employment (coefficient)	Population (coefficient)	Employment (coefficient)
Constant	0.299***	-0.122	0.327**	-0.284
Spatial Lag	(0.107)	(0.139)	(0.135)	(0.270)
W*Employment	Na	-0.0209	Na	-0.0188*
		(0.0194)		(0.0113)
W*Population	-0.0207*	Na	-0.0172**	Na
	(0.0110)		(0.00855)	
Employment 2002	0.0507*	0.662***	0.0490*	0.661***
	(0.0299)	(0.0375)	(0.0290)	(0.0374)
Population 2002	0.945***	0.331***	0.947***	0.332***
	(0.0301)	(0.0378)	(0.0301)	(0.0377)
Degree Education or Higher	0.0266***	0.0524***	0.0269***	0.0526***
	(0.00784)	(0.00986)	(0.00784)	(0.00982)
Industry Share				
Building and construction	0.252***	0.189***	0.253***	0.189***
	(0.0577)	(0.0724)	(0.0577)	(0.0722)
Manufacturing industries	0.0585	-0.00113	0.0610	0.000228
	(0.0430)	(0.0541)	(0.0430)	(0.0538)
Commerce and trade	0.161***	0.0824	0.159***	0.0818
	(0.0462)	(0.0582)	(0.0463)	(0.0580)
Transport and communications	0.167*	0.331***	0.171*	0.337***
	(0.0915)	(0.115)	(0.0916)	(0.115)
Public administration	0.120	0.182*	0.119	0.181*
	(0.0830)	(0.105)	(0.0834)	(0.104)
Professional services	0.00651	-0.128*	0.00861	-0.127*
	(0.0578)	(0.0726)	(0.0579)	(0.0725)
Other	-0.0271	-0.178***	-0.0261	-0.178***
	(0.0453)	(0.0569)	(0.0454)	(0.0567)
Age Share				
15 - 19 years	-0.396***	0.158	-0.394***	0.162
	(0.141)	(0.176)	(0.141)	(0.176)
20 - 24 years	-0.640***	-0.500***	-0.636***	-0.496***
	(0.116)	(0.146)	(0.116)	(0.145)
25 - 29 years	0.213	0.703***	0.210	0.699***
	(0.154)	(0.193)	(0.154)	(0.192)
30 - 34 years	0.596***	0.993***	0.598***	0.993***
	(0.166)	(0.208)	(0.166)	(0.208)
35 - 39 years	0.387**	0.782***	0.386**	0.778***
	(0.186)	(0.233)	(0.186)	(0.233)

40 - 44 years	-0.488***	0.0814	-0.487***	0.0820
	(0.176)	(0.220)	(0.176)	(0.219)
45 - 49 years	-0.183	0.450**	-0.179	0.454**
	(0.168)	(0.210)	(0.168)	(0.210)
50 - 54 years	-0.181	0.274	-0.176	0.279
	(0.157)	(0.197)	(0.157)	(0.197)
55 - 59 years	-0.401**	-0.299	-0.397**	-0.297
	(0.159)	(0.199)	(0.159)	(0.199)
60 - 64 years	-0.489***	-0.931***	-0.489***	-0.932***
	(0.169)	(0.211)	(0.169)	(0.211)
65 - 69 years	-0.414**	-0.518**	-0.410**	-0.514**
	(0.179)	(0.224)	(0.179)	(0.224)
70 - 74 years	-0.574***	-0.371	-0.573***	-0.368
	(0.187)	(0.234)	(0.187)	(0.234)
75 - 79 years	-0.626***	-0.694***	-0.625***	-0.693***
	(0.202)	(0.253)	(0.202)	(0.253)
80 - 84 years	-0.294	0.233	-0.297	0.231
	(0.258)	(0.322)	(0.258)	(0.322)
85 years and over	-0.204	-0.0687	-0.194	-0.0549
	(0.263)	(0.329)	(0.263)	(0.329)
Nationality				
UK	-0.0167	-0.0719	-0.00732	-0.0606
	(0.105)	(0.133)	(0.106)	(0.132)
Other	0.326***	0.595***	0.320***	0.592***
	(0.0888)	(0.111)	(0.0887)	(0.111)
Urban Area	0.00163	0.00891	0.00143	0.00870
	(0.00945)	(0.0118)	(0.00946)	(0.0118)
Unemployment 2002	-0.00386	-0.000305	-0.00405	-0.000539
	(0.00494)	(0.00619)	(0.00495)	(0.00619)
Rho	0.1280***	0.1475***	0.0979***	0.1014***
	(0.015)	(0.014)	(0.026)	(0.0059)
No of Obs.	3341	3341	3341	3341

Note 1: ***, **, and * indicate significance at the 99%, 95% and 90% confidence level.

Table 1: Description of Variables

Variables	Mean	Stan. Dev.	Min	Max
Employment$_{2006}$	574	973	25	16837
Population$_{2006}$	1261	1997	76	32288
Employment$_{2002}$	488	806	23	12663
Population$_{2002}$	1165	1772	57	24404
Degree Education or Higher 2002	21.20%	10.13%	1.85%	74.14%
Industry Share 2002				
Agriculture, forestry and fishing				
Building and construction	11.14%	4.46%	0.00%	32.47%
Manufacturing industries	16.60%	6.07%	0.00%	43.24%
Commerce and trade	20.71%	7.41%	0.00%	52.05%
Transport and communications	4.68%	2.54%	0.00%	30.47%
Public administration	4.96%	2.69%	0.00%	35.64%
Professional services	14.53%	4.36%	1.92%	36.51%
Other	12.98%	6.36%	0.00%	59.52%
Age Share 2002				
<15				
15 - 19 years	8.11%	1.99%	0.00%	28.13%
20 - 24 years	6.86%	3.19%	0.00%	37.46%
25 - 29 years	6.54%	2.69%	0.00%	26.53%

30 - 34 years	6.89%	2.01%	0.85%	20.59%
35 - 39 years	7.22%	1.69%	1.51%	16.11%
40 - 44 years	7.13%	1.59%	1.75%	14.71%
45 - 49 years	6.74%	1.62%	0.88%	16.81%
50 - 54 years	6.29%	1.66%	1.42%	16.67%
55 - 59 years	5.39%	1.55%	0.63%	15.24%
60 - 64 years	4.25%	1.45%	0.00%	14.61%
65 - 69 years	3.85%	1.43%	0.27%	10.87%
70 - 74 years	3.38%	1.40%	0.00%	12.80%
75 - 79 years	2.80%	1.28%	0.00%	11.11%
80 - 84 years	1.84%	0.99%	0.00%	8.51%
85 years and over	1.25%	0.91%	0.00%	10.55%
Nationality 2002				
Irish				
UK	3.16%	2.21%	0.00%	22.99%
Other	3.00%	3.58%	0.00%	57.69%
Urban Area (1/0)	21.04%	40.76%	0	1
Unemployment 2002	7.32%	4.81%	0.41%	53.80%

Note 1: Data for the dependent variables from Census 2006. All other data is from Census 2002.

Figure 1: Log of Employment Density 2006

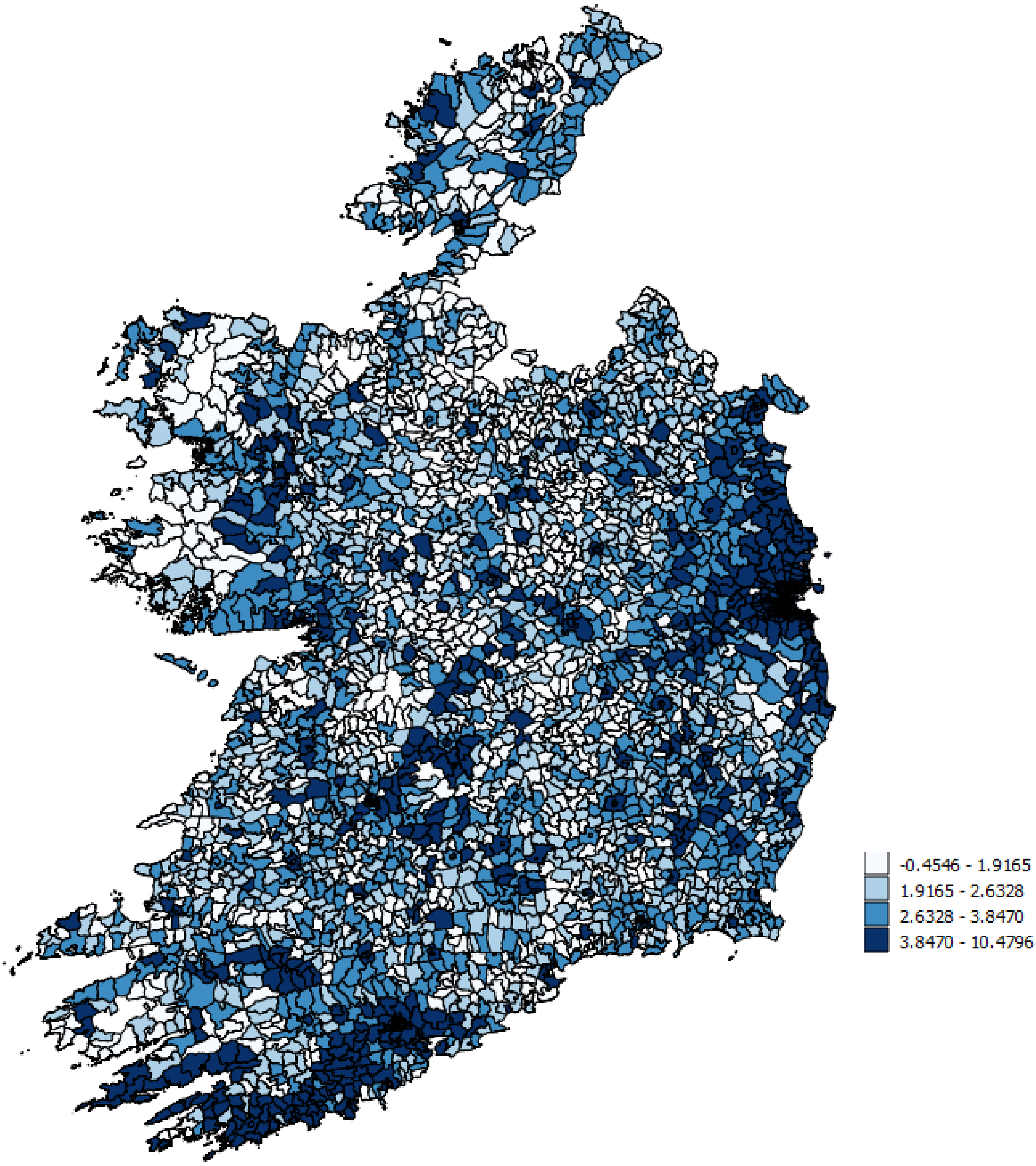

Figure 2: Log of Population Density 2006

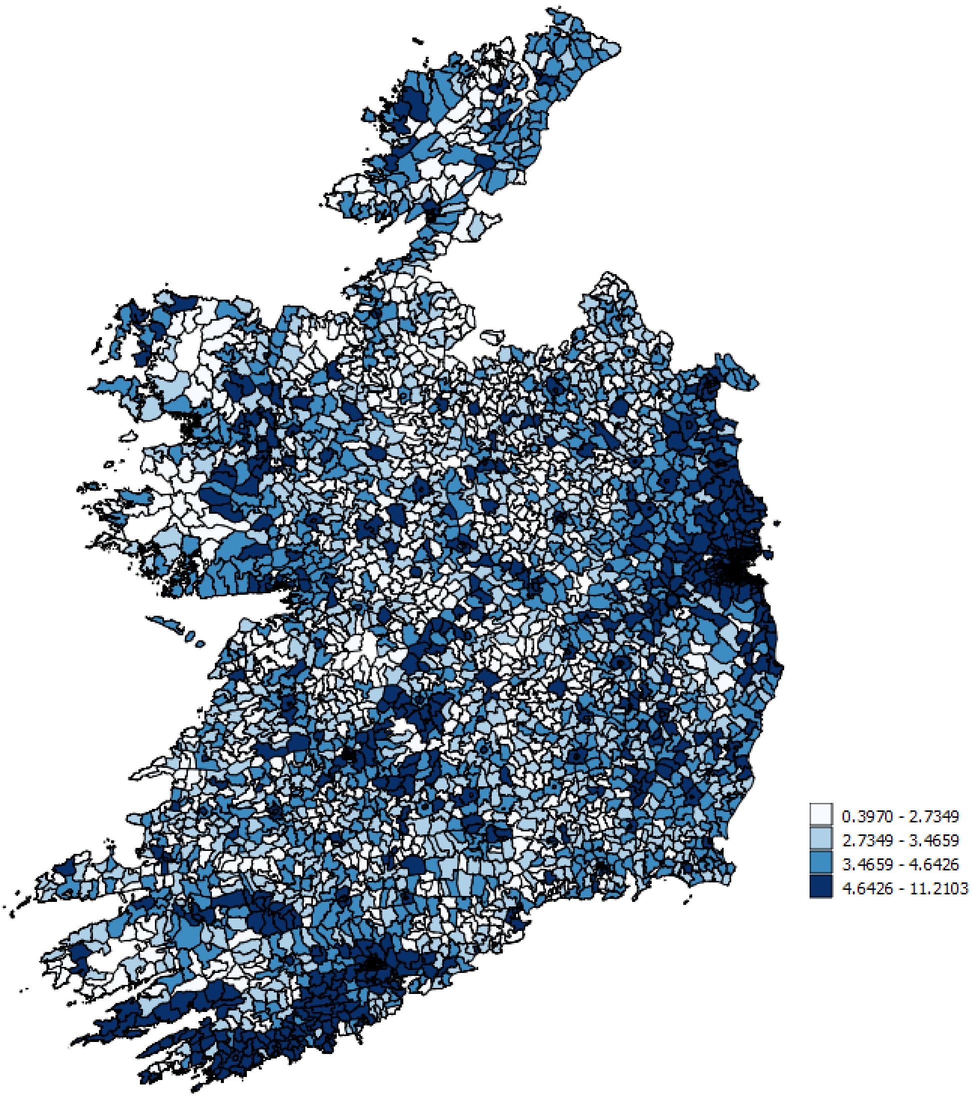

Table 2: Results

Variables	Population (coefficient)	Population (standard Error)	Employment (coefficient)	Employment (standard Error)
Constant	0.3370***	(0.0972)	-0.0158	(0.1218)
Spatial Lag				
W*Employment	Na	na	-0.0092***	(0.0028)
W*Population	-0.0086***	(0.0023)	Na	na
Employment 2002	0.0687***	(0.0298)	0.6859***	(0.0373)
Population 2002	0.9269***	(0.0300)	0.3078***	(0.0376)
Degree Education or Higher	0.0277***	(0.0079)	0.0557*	(0.0099)
Industry Share				
Agriculture, forestry and fishing				
Building and construction	0.2463***	(0.0587)	0.19159***	(0.0735)
Manufacturing industries	0.0814*	(0.0435)	0.01409	(0.0544)
Commerce and trade	0.1142**	(0.0450)	0.01565	(0.0562)
Transport and communications	0.0699	(0.0911)	0.19388*	(0.1142)
Public administration	0.1325*	(0.0819)	0.20102**	(0.1026)
Professional services	-0.0087	(0.0584)	-0.1677**	(0.0731)
Other	-0.0300	(0.0460)	-0.1884***	(0.0576)
Age Share				
<15				
15 - 19 years	-0.4194***	(0.1402)	0.0960	(0.1758)
20 - 24 years	-0.7554***	(0.1125)	-0.7023***	(0.1408)
25 - 29 years	0.1597	(0.1530)	0.5789***	(0.1917)
30 - 34 years	0.5447***	(0.1662)	0.9106***	(0.2083)
35 - 39 years	0.2896	(0.1850)	0.6271***	(0.2318)
40 - 44 years	-0.5849***	(0.1747)	-0.0714	(0.2189)
45 - 49 years	-0.2459	(0.1676)	0.3375*	(0.2101)
50 - 54 years	-0.1998	(0.1570)	0.2326	(0.1968)
55 - 59 years	-0.4002***	(0.1589)	-0.3300*	(0.1993)
60 - 64 years	-0.5145***	(0.1671)	-1.0176***	(0.2095)
65 - 69 years	-0.4484***	(0.1770)	-0.6237***	(0.2219)
70 - 74 years	-0.6451***	(0.1856)	-0.4586**	(0.2327)
75 - 79 years	-0.6635***	(0.2017)	-0.7846***	(0.2529)
80 - 84 years	-0.3233	(0.2558)	0.1966	(0.3208)
85 years and over	-0.2400	(0.2614)	-0.1694	(0.3278)
Nationality				
Irish				
UK	0.0486	(0.1049)	-0.0077	(0.1314)
Other	0.2731***	(0.0880)	0.5360***	(0.1103)
Urban Area	0.0021	(0.0095)	0.0097	(0.0119)
Unemployment 2002	-0.0020	(0.0049)	0.0019	(0.0062)

Rho	0.2072***	(0.0225)	0.2026***	(0.0228)
No of Obs.	3341		3341	

Note 1: ***, **, and * indicate significance at the 99%, 95% and 90% confidence level.

[i] It was initially developed in an attempt to explain the productivity gap between the US and Europe.

[ii] According to Morgan (2013: 104), Foray, David, Hall and others can be regarded as "conceptual architects" of the smart specialisation concept.

[iii] Based on a contiguity matrix of our DEDs which is discussed in detail in section 5.3