Estimating Agglomeration and Dispersion Forces in a Multi-Region

Geography Model as Applied to Spain

By

Henk Brand and Razzaque Bhatti*

Tentative version presented at the European Trade Study Group, Vienna, Austria

September 2006

Abstract

This paper examines the effects of agglomeration and dispersion forces of trade liberalisation amongst the administrative regions of Spain using the national three-region–core, adjacent, and periphery (CAP)–model using contiguity analysis. The results indicate the existence of an income and wage gradient due to agglomeration forces and a strong convergence of cost and production structures among core-adjacent, core-periphery, and adjacent-periphery regions due to the competition force. Conclusions that emerge from these results are threefold. First, the presence of agglomeration forces between core periphery regions lends support to Krugman's (1991b) assertion that trade liberalization will stimulate migration of firms and labour to densely populated regions. Second, the inclusion of an adjacent region between core and periphery sets a spatial geographic continuum along which production activities may be located. Third, the existence of dispersion forces between core-adjacent regions results in relocation of firms requiring intra- and inter industry linkages to achieve economies of scale in production, a possibility that is neglected in the conventional core periphery model. Fourth, there appears to be some evidence of industry structure and average wage convergence between domestic and foreign border regions.

Keywords: regional agglomeration and dispersion forces, competition effect, home market, convergence and diverge of regional demographic and economic variables

JEL classification F12, F15

*The authors are affiliated with the Gulf University for Science and Technology, in Hawally, Kuwait.

1. Introduction

This paper presents an empirical analysis of the demographic and economic effects of agglomeration and dispersion forces as embodied in the 'new' international trade and economic geography theories (Krugman, 1980, 1991b). The analysis is conducted at the national regional level where the economic impact of trade liberalisation is initially felt. The method of contiguity analysis is used to obtain empirical measurements of the inter-regional mobility of firms and labour, and the subsequent degrees of convergence and/or divergence of average labour wages, gross investments, average production costs, and regional per capita incomes.[1] The paper also examines the Krugman and Venables (1996) theory that trade liberalisation leads to a convergence of industry structures and economic variables between connex border regions.[2] To date, no empirical work has examined these issues in a national regional framework.

The empirical analysis in this paper departs from the conventional two-region Krugman (1991b) national geographic core periphery framework commonly used in the study of industry concentration and/or dispersion (Brülhart and Torstensson, 1996; Brülhart, 1998; Haaland *et al.,* 1999; Forslid *et al.,* 1999, Midelfart *et al.,* 2000; and Brülhart, 2003). Instead, we use a national three-region – core, adjacent, periphery – model that readily extends into a multi-regional model. The theoretical foundation for the three-region model is found in Von Thünen's (1842) concentric circle theory framework. In this setting, the core, adjacent, and periphery regions are defined sequentially along a radius extending outward from a core region. An urban population density criterion is used to define regions according to type. The density criterion is a proxy for the level of demand and potential expenditure. Adjacent regions border on core regions and are found in the first-concentric circle around the core region. Periphery regions border on adjacent regions and are located in the second-concentric circle around the core. Contiguity analysis measures the direction of economic development between the core region and regions in the first- and second concentric circles.

The analysis will focus on the seventeen-administrative NUTS 2 regions of Spain. An empirical analysis of the manufacturing industry in Spain (Brand, 2004)[3] has shown it to have a multi-agglomerate production structure with three distinct core regions. In 1997, fifteen of the twenty-three manufacturing industries in Spain were absolutely concentrated in core regions, while the remaining eight were relatively concentrated in both core and adjacent regions.

Trade liberalisation in Spainhas acted as a catalyst for strong convergent industry developments between the core and adjacent regions. An examination of industry characteristics show that fifteen industries, located in core and adjacent regions, required medium to high *intra*-industry linkages, and thirteen industries, located in similar region types, required medium to high *inter*-industry linkages (Brand, 2004). These outcomes support the concentric circle theory and the assumption that inter-

[1] Contiguity analysis allows us to use two discrete observations on a variable at different points in time. This study uses the data points for 1989 and 1997.
[2] The outcome reveals some border region convergence of industry structure, and Stolper-Samuelson factor-price equalisation effects.
[3] Brand (2004). See Section 6.2 *Industry Index Within the CAP Cluster.*

regional input-output structures – forward and backward linkages – exist between core agglomerates and their adjacent regions (Paelinck and Nijkamp, 1975; Krugman and Venables, 1996; Midelfart *et.al.,*2000). This result strongly suggests the development of economics districts in administrative core and adjacent regions.

The paper consists of six sections. Section 2 discusses the relationship between the Core, Adjacent, and Periphery framework, Eurostat's urbanisation criteria, Von Thünen's (1842) concentric circle theory of production location, and the statistical method of contiguity analysis. Section 3 describes data sources and methodology and provides an analytical discussion of the empirical outcomes. In section 4, the conclusions of the contiguity analysis can be found. In section 5, the analysis is opened to include Portuguese and French border periphery regions. The conclusions of the border periphery analysis are found in section 6.

2. Theoretical and Empirical Foundations

2.1 Common Regional Nomenclature

Spain's administrative regions are classified into three-region types – *Core, Adjacent*, and *Periphery* (CAP). This nomenclature of national regions is found in the seminal theoretical literature of classical regional economists (Perroux, 1955; Pottier, 1963; Boudeville, 1963; Klaassen, 1967; and Paelinck and Nijkamp, 1975). A *core* region is a densely populated region "… that consists of economic interdependencies between economic and spatial elements."[4] An *adjacent* region is defined as a region contiguous to and bordering on a core region. Its economic structure is dependent on that of the core region, as evident through its intersectoral and interregional input-output linkages with the core. A *periphery* region is an outlying region geographically distanced in space from a core region with little or no developed intersectoral and interregional economic linkages between them. Krugman (1980, 1991a, 1991c, 1991d) has described a periphery region as "a geographic area with a low population density, consisting mainly of farmers, and a small share of manufacturing labour vis-à-vis the polarised region."

2.2 Eurostat Constructs

Regional classification is determined by a population density criterion. In their publication, *Labour Force Survey,* Eurostat[5] (1998) introduced the concept of urbanisation and urban areas for each of the European administrative regions. Their regional classification scheme resembles that of the regional economists. Three types of regions are defined according to their degree of urbanisation. A *densely* populated (core) region is one where one or more urban areas have a population density of more than 500 people per square kilometre. The region may also contain other urban areas with a lower population density. An *intermediate* (adjacent) region is one that is composed of one or more urban areas with a population density of more than 100 people per square kilometre, [but less than 500 per square

[4] Boudeville, (1963)
[5] Eurostat, Labour Force Survey in *Statistics in Focus: Regions, 1998 (4)*

kilometre, and borders on a densely populated region].[6] Any region that does not border on a densely populated core region, but only on an intermediate (adjacent) region, is classified as a periphery region. This classification of national regions differs from the conventional two-region Krugman (1980, 1991b) core periphery model by inserting a region between them, thereby creating a continuum of geographic production locations extending outward along a radius from the core region.

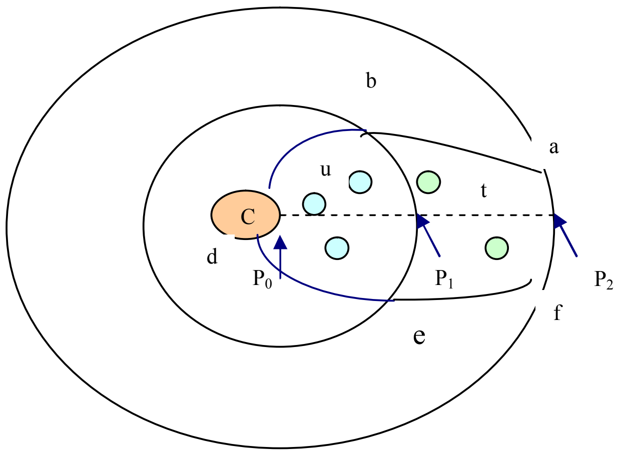
2.3 Concentric Circle Theory of Production Location

Von Thünen's (1842) concentric circle theory of cultivation locates production activity across three geographic areas consisting of a populated urban area that serves as the manufacturing and consumption (expenditure) core, and a first and second ring of regions where agricultural production is located. Von Thünen's model proves that the transportion costs of market access will reduce the level of rental income in direct relation to the distance between the location of production activity and the core region. The further production activity is located away from the core region, the lower will be the level of wages and incomes received. Transportation costs creates an income differential along an imaginary radius extending outward from the core (Krugman, 1991b, Venables and Limao, 2000).

2.4 Concentric Circles

A diagrammatic representation of the CAP model is offered in Diagram 1, where the concept of core, adjacent, and periphery (administrative) regions is superimposed upon Von Thünen's (1842) concentric circle model.

DIAGRAM 1.
RELATIONSHIP BETWEEN CONCENTRIC CIRCLES AND REGIONS



The inner circle C represents the central urban area. Similarly, P_0P_1 and P_1P_2 respectively respresent the distance, θ, of the first and second rings from the centre. This defines the concentric circles. The urban area C represents an administrative *core* region. Contiguous to the core region is an

[6] Author's insertion and modification.

area whose administrative boundaries are indicated by *bcde*. This area is an *adjacent* region which encompases, for example, three urban centres, *u.* This adjacent region falls within the first concentric circle. Juxtaposed to the adjacent region is a region, *abef,* which falls in the second concentric circle. This region is a *periphery* region consisting of two small towns, *t.* Jointly these three regions define the CAP model. Distance from the core to the periphery is represented by the radius $P_0P_1P_2$, or the distance measure θ,

In reality, the first concentric circle is defined by the number of administrative regions that border on a core region. The number of these adjacent regions can vary. It is possible that the entire geographic area surrounding a core region is one adjacent region. An example of this would be the city region of Berlin and its surrounding adjacent region of Brandenburg. The importance of the adjacent region is its distance to the core. Since it is geographically closer to the core than the periphery region, its proximity enhances its locational attractiveness. In this respect the CAP model distinguishes itself from the conventional country level core periphery model, such as in the empirical work of Forslid *et al.,* (1999) and Midelfart *et. al.,*(2000), where firms relocate either from the outer core to the inner core or vice-versa and from the core to the periphery or vice-versa. The adjacent region eliminates this gap. Any wage differential, between the core and the adjacent region, increases the attractiveness of this region for industry location, while retaining profitable access to the core region.

This study uses the Eurostat urbanisation criteria for regional classification purposes. A *core region* is defined as a region with one or more urban areas with a population density greater than 500 people per square kilometre. Such an urban area is called urban *agglomerate.*[7] A core region can consist of one or more urban agglomerates. The term, *adjacent region,* refers to those regions, which border on core regions, and that have one or more urban areas with a population density greater than 100 people, but less than 500 / km^2. Finally, a *periphery region* is a region bordering only on an adjacent region or another periphery region. Furthermore, a periphery region can have one or more urban areas with a population density less or between 100 and 500 people per square kilometre.

2.5 Contiguity Analysis

Contiguity analysis is a statistical method used to quantify the relationship between a common variable in two or more administrative regions. It is also known as a ‘spatial correlation coefficient.’ This coefficient is a statistic that indicates the extent to which agglomeration and dispersion forces have influenced the development of economic variables between the regions. The contiguity coefficient is defined by the following statistic:

[7] Eurostat definition.

$$c_k = \frac{\sum_{r=1}^{R} \sum_{i_{kr}}^{I_{kr}} (x_r - x_{i_{kr}})^2}{2I_k} \bullet \frac{R-1}{\sum_{r=1}^{R} (x_r - \bar{x})^2} \qquad (1)$$

where x is the value of a demographic or economic variable in region r ($r = 1,\ldots, R$) and the statistic c_k is called a *contiguity coefficient*. Contiguity analysis is based on the concentric circle theory of the CAP model. The contiguity coefficient captures the strength of the spatial correlation of an economic variable between the core and an adjacent region in the first concentric circle (k = 1), and the core and the periphery region in the second concentric circle (k = 2). The subscript i_{kr} ($i_{kr} = 1_{kr}, 2_{kr} \ldots I_{kr}$) refers to each region i_{kr}, which possesses a k^{th} order contiguity with respect to region r. Thus, the total number of k^{th} connections for region r is equal to I_{kr}, where I_k is defined as the total number of connections of order k within the whole system, that is;

$$I_k = \sum_{r=1}^{R} I_{kr} \qquad (2)$$

Finally, $\bar{x}$ is defined as the national average of the demographic or economic variable under consideration, such that;

$$\bar{x} = \sum_{r=1}^{R} \frac{x_r}{R} \qquad (3)$$

The first element on the right hand side of equation (1) is the statistical contiguity variance. The numerator of this element is a measure of the aggregated squared differences of a variable between a central region and its surrounding regions, calculated over all the regions. The value of the denominator measures the total number of k - order connections i.e. I_k. In the denominator, the factor 2 is used to assure that the value of the spatial correlation coefficient of being equal to unity in case there is no spatial correlation of order k.

The second element on the right hand side of equation (1) is the inverse of the variance of the particular variable under consideration. It measures the aggregated squared differences between each observation in the variable and its national average.

Contiguity analysis measures the correlation between the observations on one single variable dispersed over two or more different regions. A *positive* correlation exists when the contiguity coefficient exhibits a value $0 < c_k < 1$. Consequently, the closer the value lies to zero, the stronger the relationship between the values in a variable in two different regions, and hence, the more they have converged. A *negative* correlation exists when the value of $c_k > 1$. A negative value of the contiguity coefficient indicates that the values of the variable in the two different regions are moving in the opposite direction i.e. divergence. When the correlation coefficient shows a value $c_k = 1$, there is no correlation between the values of a variable in the two different regions.

The compliment of the contiguity coefficient is given by the coefficient of spatial influence δ_k, which is defined as:

$$\delta_k = 1 - c_k \tag{4}$$

If, $\delta_k = 0$, there is no spatial correlation; if $\delta_k > 0$ a positive spatial correlation is present, and if $\delta_k < 0$, the spatial correlation effect is negative. The statistical value of the spatial correlation coefficient varies with the value of k. For a first-order contiguity, $k = 1$, the spatial correlation coefficient c_k or the coefficient of spatial influence, δ_k, calculates the direct spatial correlation of the first ring of adjacent (contiguous) regions. For a second-order contiguity, $k = 2$, the indirect influence of the first on the third (periphery) region is measured.

2.6 Stylised Spanish Geographic Facts

The mathematical basis for the core, adjacent and periphery model can be found in Appendix A. The CAP model postulates that a core region can be surrounded by a first-ring of adjacent regions, and a second-ring of periphery regions. The number of adjacent and periphery regions in a cluster can vary depending on the dispersion and density of urban agglomerates. A *CAP* cluster j is defined in equation (A.10) as follows:

$$CAP_j = C_j \cap \sum_{j=1}^{A} A_j \cap \sum_{j=1}^{P} P_j(\theta_{CP} > \theta_{CA} \geq \theta_{AP}) = \varnothing \tag{A.10}$$

To obtain a three-region CAP model, assume that $j = 1$, and rewrite equation (A.10) to include the regional criteria as follows:

$$CAP_1 = \varphi(upd_i) \in C_1 \cap \gamma(upd_i) \in A_1 \cap \gamma(upd_i) \in P_1(\theta_{CP} > \theta_{CA} \geq \theta_{AP}) = \varnothing \tag{A.10a}$$

Expression (10a) defines a three-region *CAP* model consisting of one core, one adjacent, and one periphery region. The hierarchical link between the regions is determined by the population density and distance criteria. The subscripts i refer to the number of urban areas in the respective regions.

The classification procedure uses the urban population density criteria for the cities in the Spanish administrative regions. The regions are classified into core, adjacent, and periphery based on the urban population and the distance criteria. The region types are identified by the symbols $R(\zeta, \delta)$, where R refers to region type: C, A, and P, ζ indicates the regions population criterion, and δ represents the number of urban areas in the region that meet the required criterion.

The geographic locations of the Spanish regions are portrayed on Map 1. The empirical outcomes of Spanish regional classification are listed in Table 1. The CAP clusters, as listed in Table 1, are determined by the population density $(upd)_i$, and the distance criteria, θ, using equation (A.10a). The regional classification outcome identifies three core regions, eight adjacent regions, and two periphery regions (Brand, 2003).

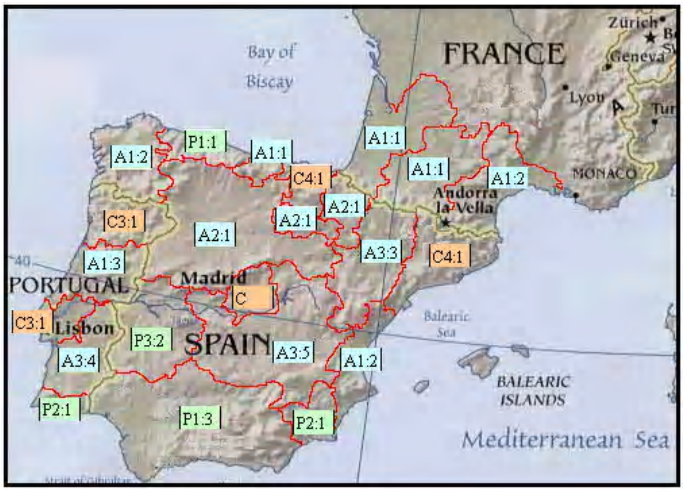
TABLE 1
REGIONAL CLASSIFICATION OF THE SPANISH REGIONS

CAP Cluster Pias Vasco		CAP Cluster Madrid		CAP Cluster Cataluna	
(1)	(2)	(3)	(4)	(5)	(6)
Regions	*Type*	*Regions*	*Type*	*Regions*	*Type*
Galicia	A1:2	Castilla Leon	A2:1	Aragon	A3:3
Asturias	P1:1	Madrid	C	Cataluna	C4:1
Cantabria	A1:1	Castilla La Mancha	A3:5	Communidad Valencia	A1:2
Pias Vasco	C4:1	Extremadura	P3:2	Murcia	P2:1
Navarra	A2:1	Andalucia	P1:3		
La Rioja	A2:1				

Source: Brand (2003). *C* = core, *A* = adjacent, and *P* = periphery

Spain has three core agglomerates, each of which is surrounded by adjacent regions in the first-concentric circle, and one or more periphery regions in the second-concentric circle. The CAP cluster of Pias Vasco is a multi-region model consisting of six regions. This outcome means that Spain is characterised by a multi-agglomerate production structure (Krugman, 1990).

MAP 1
SPANISH FOREIGN BORDER REGIONS: FRANCE AND PORTUGAL



Pias Vasco is a multi-region CAP cluster with four adjacent and one periphery region. The core is characterised by the symbols C4;1. This means that Pias Vasco is a core region with one urban centre having a population density greater than 500 people per square kilometre. The adjacent regions of

Galicia[8] and Cantabria have respectively two and one urban centre(s) with a population density between 100 – 500 people /km^2. The adjacent regions of Navarra and La Rioja respectively have one urban area with a population density between 50 – 99 people/km^2. Andalucia is a periphery region with three urban areas with a population density between 100 – 500 people/km^2. (See Appendix B for the EU regional classification scheme).

3. Empirical Estimation

3.1 Data

The sources of the geographic and demographic data for the analysis of the Spanish regions at the NUTS 2 level[9] are the Eurostat publications *Portrait of the Regions* (1993), *Regions: Statistical Yearbook* (1999, 2000), *Statistics in Focus: Regions, Theme 1, General Statistics* (1991, 1993, 1995, 1998, 1999 and 2000), and *Statistics in Focus, Regions, Labour Force Survey* (1998), vol.4.

The industry data sources for the regional economic geography model are as follows; Eurostat (1993), *The Structure and Activity of Industry; Data by Regions 1988/89, Theme 4, Energy and Industry*; Eurostat (1999), *Industry, Trade, and Services, Theme 4, SBS – Structural Business Statistics (Industry, Construction, Trade, and Services)*, and Eurostat (1999, 2000, and 2001), *Regions: Statistical Yearbook*. Regional data is provided for the following variables per industry: number of units (firms), number employed, wages and salaries, and gross investment.

3.2 Methodology

The method of contiguity analysis uses the available economic variables of the regions in the respective CAP clusters to provide three separate samples and unique contiguity coefficient calculations for the Spanish regions. For example, a first order contiguity uses three core regions and eight adjacent regions. A second order contiguity coefficient uses three core regions and four periphery regions. As a result of the varying number of regions within a multi-region CAP cluster, the sample sizes can differ. The *k*-order-connections between the regions are presented in Appendix B, Table B.1.

Contiguity analysis is used to examine the relationship between the economic variables of the CAP clusters of regions. The analysis examines the spatial relationship between the following regional variables: per capita income (*Y/P*) in PPP, total population (*P*), total number of firms (*n*), total number of manufacturing employees (*L*), the ratio of manufacturing employment to population (*L/P*), total wages and salaries (*w*), total gross investment (*K*), the average number of employees per firm (*L/n*), the average gross investment per firm (*K/n*), the average gross investment per employee (*K/L*), the average wage per employee (*w/L*), and the average wage costs per firm (*w/n*). By focusing on the direction of development

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8 In the pre-integrated geographic clustering, Galicia was classified as a border periphery region in the Pias Vasco cluster of regions. Since Galicia borders on the Portuguese core region of Norte, post EU 1992 trade liberalisation policies would make Galicia an adjacent region. For a more extensive discussion of this classification logic see Brand (2003).

9 NUTS is Eurostat's acronym for 'Nomenclature of Territorial Units for Statistics'.

between economic variables, this analysis illuminates the extent to which agglomeration and dispersion forces have influenced the development of these variables between regions.

3.3 Empirical Outcomes

Cross-sectional data is used for 1989 and 1997. The economic and demographic variables (*Y/P*) and (*P*) respectively are disaggregated data per region *j*. The economic variables pertaining to manufacturing are aggregated across all industries *i,* per region *j*. Table 2.a reports the empirical results of the calculated contiguity coefficients for three sets of relationships; one, the *first-order* contiguity relationships between the core and adjacent regions; and two the adjacent and periphery regions, and three, the *second-order* contiguity relationship pertains to the core and periphery regions.

TABLE .2 a

SPATIAL CORRELATION COEFFICIENTS FOR THE CAP REGIONS IN SPAIN

		CONTIGUITY ORDER: k = 1,2					
		1 CORE-ADJACENT		2 CORE-PERIPHERY		1 ADJACENT-PERIPHERY	
	VARIABLES	*1989*	*1997*	*1989*	*1997*	*1989*	*1997*
1	Per Capita Income (*Y / C*)	1.370	1.350	1.708	1.747	0.607	0.826
2	Population (*P*)	0.851	0.838	1.208	0.768	0.637	0.626
3	Number of Firms (*n*)	0.582	0.667	0.933	0.770	0.786	0.593
4	Number of Manufacturing Employees (*L*)	0.986	0.922	1.081	0.963	0.790	0.698
5	Manufacturing Employees / Population (*L / P*)	0.389	0.500	0.473	0.821	0.630	0.643
6	Wages and Salaries (*w*)	1.296	1.159	1.173	1.058	0.916	0.827
7	Gross Investment (*K*)	1.047	1.132	0.387	0.951	0.792	0.825
8	Average Number of Employees per Firm (*L / n*)	2.035	0.284	0.966	0.346	0.605	0.161
9	Average Gross Investment per Firm (*K / n*)	1.954	0.347	0.983	0.211	1.064	0.257
10	Average Gross Investment per Employee (*K / L*)	1.458	0.626	0.557	0.599	1.089	1.443
11	Average Wage per Employee (*w / L*)	1.544	0.606	1.295	0.925	0.499	0.393
12	Average Wage Costs per Firm (*w / n*)	2.089	0.309	1.049	0.359	0.560	0.335

Source: Authors own calculations / Contiguity Analysis / Excluding the Island Regions

The complement of the contiguity coefficient is given by the coefficient of spatial influence δ_k, of which the outcomes are presented in Table 2.b. below.

TABLE1 2.b

COEFFICIENT OF SPATIAL INFLUENCE FOR THE CAP REGIONS IN SPAIN

		CONTIGUITY ORDER: k = 1,2											
		1 CORE - ADJACENT				2 CORE - PERIPHERY				1 ADJACENT - PERIPHERY			
	VARIABLES	*1989*	*t*	*1997*	*t*	*1989*	*t*	*1997*	*t*	*1989*	*t*	*1997*	*t*
1	Per Capita Income *(Y / P)*	-0.370		-0.350		-0.708	2	-0.747	1	0.393		0.174	
2	Population *(P)*	0.149		0.164		-0.601		0.675		0.363		0.374	
3	Number of Firms *(n)*	0.418		0.333		0.067		0.230		0.214		0.407	
4	Nr. of Manufacturing Employees *(L)*	0.014		0.078		-0.081		0.037		0.210		0.302	
5	Manufacturing Employees/Population *(L / P)*	0.611	3	0.500	3	0.527	3	0.179		0.370		0.357	
6	Wages and Salaries *(w)*	-0.296		-0.159		-0.173		-0.058		0.084		0.173	
7	Gross Investment *(K)*	-0.047		-0.132		0.613	3	0.049		0.208		0.175	
8	Avg. Nr. of Employees per Firm *(L / n)*	-1.035		0.716	1	0.034		0.654	2	0.395		0.839	1
9	Avg. Gross Investment per Firm *(K / n)*	-0.954	1	0.653	2	0.017		0.789	1	-0.064		0.743	1
10	Avg. Gross Invest. per Employee *(K / L)*	-0.458	3	0.374		0.443	3	0.401		-0.089		-0.443	3
11	Avg. Wage per Employee *(w / L)*	-0.544	3	0.394		-0.295		0.075		0.501	3	0.607	3
12	Avg. Wage Costs per Firm *(w / n)*	-1.089		0.691	2	-0.049	3	0.641	2	0.440	3	0.665	2

Legend: Level of significance. 1 is $\alpha = 0.01$; 2 is $\alpha = 0.05$; 3 is $\alpha = 0.10$.

The *t*-test significance level, α, of a correlation is given in the column next to the correlation, and is represented with a number ranging from 1 to 3.

3.3.1 Empirical Outcome Core-Adjacent Regions Contiguity Coefficients

The estimated contiguity coefficients for the core-adjacent regions represent a *first-order connection* of regions $k = 1$, and therefore a first-order contiguity coefficient. The sample of regions for this estimation consists of the three core regions and their immediate adjacent regions. The estimated coefficients enable us to make a number of observations on the empirical results in Table 2.a.

First, the first-order contiguity coefficients between the core and adjacent regions for the year 1989 reveal a tendency towards a negative spatial correlation for eight of the twelve variables. A negative correlation indicates a dissimilar value of the variable between the regions. For example, the variable per capita income with a high value in Madrid is correlated with a low value of the corresponding variable in its adjacent regions Castilla Leon and Castilla La Mancha. A positive spatial correlation is found for the 2^{nd}, 3^{rd}, 4^{th}, and 5^{th} correlations, indicating that these variables in the adjacent regions have similar values as those in the core regions. The negative spatial correlations in 1989, for variables six through twelve are signals of microeconomic variable divergences in manufacturing production and cost-structures between the core and adjacent regions.

In 1997, the pattern is reversed with nine of the twelve contiguity coefficients indicating a positive value. The microeconomic variable ratios show a strong convergence of variable values between the core and adjacent regions. However, the 1^{st}, 6^{th}, and 7^{th} correlations continue to show a marginally improved negative value. The contiguity coefficient values for the variables per capita income, total wages and salaries paid in the manufacturing sector, and gross investment remained negative in 1997. This points to an uneven development of these three variables in the core and adjacent regions. This result is informative, since the data reveals a stronger growth in the core than the adjacent regions, ensuring the continuity of the negative values of the contiguity coefficients.

Second, a further inter-temporal comparison of the first-order contiguity coefficients for the core and adjacent regions reveals a marginal deterioration in the positive contiguity coefficients for two variables; the number of firms (n), and the ratio of manufacturing labour to total population (L/P). This development can be combined with the three negative spatial correlations to explain the attraction function of the core regions and the cumulative causation process of agglomeration. Relatively more firms (n) located in the core, which attracted relatively more manufacturing employees (L) and their families than the adjacent regions. The relative increase in firms resulted in relatively higher total wage and salary (w) disbursements to labour. The forces of imperfect competition, in tandem with a relatively higher growth of the number of firms, led to a relatively higher level of gross investment (K) in the core regions (Krugman, 1991b). The diminishment of the coefficient is due to the abnormally high gross investment in the core region of Cataluna versus the other core and adjacent regions. In fact, gross investment in Cataluna was three times that of the levels observed in the remaining two core regions, and, on average, four times that seen in the adjacent regions. This development clarifies the divergent industry structure between Cataluna and its adjacent regions. Cataluna experienced strong agglomeration effects with a divergent outcome in its adjacent regions.

Third, the strong convergence of the 8th through 12th first-order contiguity coefficients in 1997 cast light on the strength of the competition effect in eliminating the wide disparities in manufacturing cost and production structures between the core and adjacent regions, as was evident in 1989. There was a strong convergence between the core and adjacent regions with respect to the average number of employees per firm (*L/n*), and average wages per employee (*w/L*). This outcome captures the increased similarity in average production cost and production structures within the core and adjacent regions. The average number of employees per firm in 1997 in the core and adjacent regions was 17.9 and 18.1 respectively, in contrast to 21.2 and 12.2 in 1989. This outcome points to the rationalisation in manufacturing's use of labour. The average wages per employee in the adjacent regions changed relatively more than in the core regions, but remained at a lower level. In the core regions, average manufacturing wages increased by €3,500 from €14,908 in 1989 to €18,420 in 1997, while in the adjacent regions average wages increased by €5,300 from €10,951 in 1989 to €16,280 in 1997. The combined effects of increased similarity in labour inputs per firm and the strong relative growth of average manufacturing wages in the adjacent regions resulted in the strong convergence of average wage costs per industry (Venables, 1994).

In 1989, average gross investment per firm (*K/n*) in the core regions exceeded that of the adjacent regions by an average factor of two, resulting in a strong negative spatial correlation value. In 1997, the contiguity coefficient shows a very strong convergence in the values of this variable between the core and adjacent regions. Although the average levels of gross investment per firm, between the two region types, are almost identical, the rate of change is substantially higher in the adjacent regions. This outcome provides insight, since it reveals a 'catching-up' effect to achieve economies of scale in production. This further suggests that the cumulative process of agglomeration has increasingly been fortified in the adjacent regions, with the rate of return on capital being relatively higher, offsetting market access costs (Venables, 1994 and 2000). Finally, the 'catching-up' effects in average wages (*w/L*) and average gross investment per firm (*K/n*), in the adjacent regions, leads to the conclusion that the competition effect is dispersing economic activity, from the core to the relatively lower cost adjacent regions, leading to a convergence in the values of these variables between these regions. Average wages remained relatively lower in the adjacent regions in 1997. The outcome of the Spanish industry index analysis (Brand, 2003) showed a greater similarity in industry structures between core and adjacent regions. The spatial correlation analysis confirms this convergence on the microeconomic level.

3.3.2 Empirical Outcome Core-Periphery Regions Contiguity Coefficients

This analysis identifies the periphery regions associated with each of the core regions in Spain. Since a periphery region is connected to an adjacent region and theoretically represents a region in the second-ring of regions around the centre, it is considered to be a *second-order connection,* such that k = 2. The estimated spatial correlation between the core and periphery regions is therefore a second-order contiguity coefficient. The sample of regions for this estimation is composed of the three Spanish core regions and the respective periphery regions associated with each core. The core region with which they are associated is determined by the distance criteria. For example, Extremadura and Andalucia are identified as periphery regions associated with the core region of Madrid; Murcia is allied with the core region of Cataluna, and Galicia and Asturias are associated with the core region of Pias Vasco.

First, the second-order contiguity coefficients for 1989 indicate assorted values. Six of the twelve estimates display a negative correlation. However, a positive correlation is found for the 3rd, 5th, 7th, 8th, 9th, and 10th correlations. In 1997, ten of the twelve correlation estimates exhibit a positive value. This outcome proves a degree of convergence between these regions. However, the 1st and 6th correlations continue to show a negative value. The contiguity coefficient values for the variables per capita income (*Y/P*), and total wages/salaries (*w*) remained negative in 1997, indicating a continued divergence in the value of these variables between the core and periphery regions. Between 1989 and 1997, the growth of manufacturing income (wages and salaries), in the core regions, exceeded that of the periphery regions. This outcome indicates agglomeration forces in favour of the core regions, and a relative wage-cost advantage for periphery regions (Venables, 1994).

Second, an inter-temporal comparison of the second-order contiguity coefficients for the core and periphery regions indicates a substantial (more than fifty-percent) deterioration in the positive values of the spatial correlation coefficients for the variables gross investment (*K*), and the ratio of manufacturing labour to total population (*L/P*). In the case of the former, the increased disparity is caused by the relatively larger growth in gross investment in the periphery regions although their absolute levels remain lower than in the core regions. This suggests high rates of return on capital formation in the periphery regions (Venables, 2000). For the latter variable, (*L/P*), the deterioration is caused by the decline in manufacturing employment in the periphery regions versus an increase in the core regions. This increase is evidence of the home market effect, i.e. labour migration in response to higher wages in the core regions (Krugman, 1991b). Industry concentration analysis (Brand, 2004) has shown the strong economic geography effects resulting in absolute and relative concentration of industry in core regions that underlie this signalled discrepancy.

In 1997, the 2nd, 3rd, and 4th second-order contiguity coefficient values capture an unexpected improvement over those of 1989. All three correlations are positive, indicating a convergence of values of these variables in the core and periphery regions.[10]

The positive change in the population correlation, (*P*), is due to the marginal convergence of variable values between Pias Pasco, Galicia and Asturias. Population decline in Galicia and Asturias is more than twice that of Pias Vasco, thereby reducing the disparity between the values of this variable. In the periphery region of Murcia, population increased, while that of the core region Cataluna declined. This factor caused the variable values to converge. Between the core region Madrid and its periphery

[10] It is important to note that the relationship between the core regions and their respective periphery regions is the only variable being measured, and not all second-ring regions around the core. The adopted procedure allows for a more accurate detection of nuances in the development of the regional variables. In light of this procedure, the reasons for the strengthening of these three correlations can be explored.

regions Extremadura and Andalucia, there were offsetting values in the change of population variable values. This resulted in an almost constant difference versus 1989.

The strengthening of the correlation for the variable number of firms (*n*) from 0.933 to 0.770 is due to developments in two periphery regions. First, the periphery region of Galicia has experienced a substantial reduction in the number of its firms[11]. This factor caused a strong convergence in variable values with the core region Pias Vasco. Second, the periphery region of Andalucia has also seen a significant reduction in the number of its firms. Of particular interest is the fact that the variable value became almost identical to that of the core region, Madrid, which saw an increase in the number of its firms in 1997. This development is of interest since it reflects symmetry in the number of firms between a core and a periphery region. This study has posited that periphery regions have a lower concentration of manufacturing activity than a core region. The outcome contradicts our assumption and warrants further investigation into the economic developments in Andalucia[12]. In Andalucia, firms are spread out over a larger geographic area because of its many population centres. Finally, the decline in the number of firms in the periphery regions of Asturias and Extremadura contributed to narrowing the discrepancies between contiguity values.

The contiguity coefficient for the variable number of manufacturing employees (*L*) turned positive in 1997 from its negative value in 1989. This marginal improvement is due to two developments in the periphery regions around the core region of Pias Vasco. First, in comparison to the decline in the periphery region of Asturias, Pias Vasco also experienced a substantial out-migration of its manufacturing employees (Brand, 2004). Second, this substantial decline was offset by an increase in the number of manufacturing employees in the *ex ante* border periphery region of Galicia, resulting in a marginal improvement in the contiguity value.

The contiguity coefficients for the microeconomic variables 8 to 12 indicate significant improvements over their 1989 values. The rationalisation of production, as indicated by the average number of employees per firm (*L/n*), also extended to manufacturing production in the periphery regions. There was a noticeable convergence in the value of this variable between the core and periphery regions. The ratio measuring the average number of employees per firm (*L/n*) changed to 0.346 in 1997 from a high of 0.966 in 1989. This result exemplifies the competition effect on cost minimisation within firms (Baldwin *et al.,* 2002) and the need to increase efficiency in production to compensate for the distance from core regions (Venables and Limao, 2002).

The variable average gross investment per firm (*K/n*) shows the strongest improvement. The high levels of gross investment per firm, in the respective periphery regions, are the source of this

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[11] This reduction could be due to mergers. This would be the case if the number of manufacturing employees in the region remained constant or even increased.

[12] The geographic area of the region of Andalucia is 87.3 thousand square kilometres with a total population of 7,1 million, and population density of 81.3 / km^2. It consists of 57 urban areas of which nine have a population of greater than 100,000, but less than 500,000. It has an urban population concentration of 36.6%, with 57% of its land use for agricultural production. The geographic area of the region of Madrid is 8 thousand km^2 with a total population 5,028 million, and a population density of 629 /km^2. The region of Madrid has fifteen urban areas of which six have a population greater than 100,000, with an urban population density of 89.3%. The land use in the region of Madrid is 51% agriculture.

development. The most noteworthy development is found in Pias Vasco and its periphery regions. Of the three core regions, Pias Vasco experienced the highest level of gross investment per firm. Its periphery region of Galicia experienced an increase by a factor of 1.2 the level of Pias Vasco, while in Asturias the variable increased by a factor of 2.4 that of Pias Vasco. These outcomes in the CAP cluster of Pias Vasco are due to location of medium and high growth export industries requiring medium internal returns to scale and medium levels of capital intensity (Brand, 2004). In the periphery region of Murcia, average gross investment per firm exceeded that of the core region Cataluna by a factor of 5.3. Murcia experienced an increase in new firms in the Extraction and Processing and Engineering sector. The decline in average gross investment per firm in the core region of Madrid and its periphery region of Extremadura was offset by substantial increases in the Engineering sector in the periphery region of Andalucia. These outcomes are informative, since they lead to the conclusion that the coastal-periphery regions are expanding physical plant capacity to acquire economies of scale in production.

By doing so, they are attaining the objective of the new regional policy. Regional policy encouraged investment into profitable and self-sufficient production activities in order to increase the periphery region's levels of economies of scale (Venables, 2000). This would help to eliminate economic disparities between periphery and central regions (Doyle, 1989). We may further conclude that the cluster of regions around the core region of Pias Vasco is clearly a developing economic region. The high levels of average gross investment per firm in the adjacent regions of Pias Vasco support this conclusion. The home market effect is very strong in this cluster of regions for industries with a low demand bias (Midelfart *et. al.* 2000; Brand, 2004).

The variable average gross investment per employee (*K/L*), although positive, shows marginal deterioration versus its 1989 value. This weakening is caused by the fact that, in general, the average levels of gross investment per employee in the periphery regions continued to exceed that of the core regions in 1997. The level of average gross investment per employee in Galicia and Asturias exceeded that of Pias Vasco respectively by a factor of 1.3 and 3.2. A similar pattern is found in the periphery region of Andalucia, in which average gross investment per employee exceeds that in the core region of Madrid by a factor of 2.5. Finally, average gross investment per employee in Murcia was five times that of the core region Cataluna. These outcomes are consistent with the goals of regional policy to encourage new and existing firms – intermediate and final goods producers – in the periphery regions to become more capital intensive to enhance their economies of scale in production (Delores Report, 1989)

The contiguity coefficient on the 11th variable, average wage per employee (*w/L*) reveals a particularly interesting development for a second-order contiguity coefficient. The negative value of this correlation in 1989, signals a divergence in the value of average wage per employee between the core and periphery regions at that time. In 1997, however, this contiguity coefficient turned positive, indicating a convergence, however slight, between average wages per labour in the core and periphery regions.

The data reveals that of the three core regions, the core region of Pias Vasco experienced the largest increase in average wage per employee. This increase was paralleled by an equal increase in the periphery region of Asturias, and a higher increase in the periphery region of Galicia. This finding represents a strong convergence of average wage per labour between a core and periphery regions. The same phenomenon is also evident between the core regions of Madrid and its two periphery regions of Extremadura and Andalucia. Although the absolute levels in the periphery regions remained lower than that of the core region, their rates of change were larger than that of the core region. The data reveals that the reason for the positive direction of this second-order contiguity coefficient is primarily due to the convergence of average labour wages in the core and periphery regions of the Pias Vasco cluster. The higher average wages in the CAP cluster Pias Vasco is explained by the characteristics of growing export industry's need for skilled employees (Midelfart *et. al.,* 2000). The outcome is an example of the workings of the competition effect (Venables, 1994; Krugman and Venables, 1996; Baldwin *et al.,* 2002)

Finally, average wage costs per firm (*w/n*) in the periphery regions converged significantly with those in the core regions. This convergence turned the spatial correlation from a negative value, in 1989, to a very strong positive value in 1997. In general, the absolute levels of average wage costs per firm remained lower in the periphery regions than their respective core regions. However, the rates of change in the periphery regions exceeded those of the respective core regions. Once again, the increase in average wage costs per firm in the periphery regions of Asturias and Galicia were more than twice those of Pias Vasco. The diminishing value of this variable in Madrid was offset by respective comparable individual increases in its periphery regions. The rate of change in the periphery region of Murcia also exceeded that of Cataluna, although its absolute level remained almost half of that of the core region.

3.3.3 Empirical Outcome Adjacent-Periphery Regions: Contiguity Coefficients

The study has thus far examined the economic relationship between the core and adjacent regions, and the core and their respective periphery regions. The existence of economic influences between the adjacent and periphery regions is assumed by virtue of proximity. Periphery regions are connected to adjacent regions and thus have a *first-order connection.* The strength of this spatial influence can be captured in a first-order contiguity coefficient. The results of this estimation are listed in the most right hand column of Table2.a.

First, the first-order contiguity coefficients in 1989 show a tendency towards a positive relation, except for the 9^{th} and 10^{th} coefficients, which are negative. In 1997, eight of the twelve variables showed a convergent relationship, while the 1^{st}, 5^{th}, 7^{th}, and 10^{th} variables diverged. Per capita income (*Y/P*) in the adjacent regions grew relatively faster than in the periphery regions. The labour force population ratio (*L/P*) indicates a marginal decline. The divergence in gross investment (*K*) reflects the relatively higher levels of this variable in the periphery regions versus the adjacent regions. Also, the strong significant divergence – at the $\alpha = 0.10$ level – of average gross investment per employee (*K/L*) signifies the relatively larger changes in the periphery regions. These developments signal a level of capital formation that exceeds that of the adjacent regions. It suggests a 'catching-up' effect in the creation of scale economies in the periphery regions, a fact that is substantiated by the significant increase – at the 1% level – in average gross investment per firm (*K/n*).

The convergence in the number of firms (*n*) between the adjacent and periphery regions is explained by the relatively larger decline of establishments in the adjacent than that in the periphery regions. The respective changes in the number of firms are 14,764 and 11,878. This resulted in a relatively larger out migration of labour from the periphery regions[13]. Average wage per employee (*w/L*) and average wage costs per firm (*w/n*) indicate significant convergence with the adjacent regions. With the exception of Asturias, the absolute level of average wages per employee remained relatively lower creating a wage cost differential in favour of the periphery regions (Venables, 1994).

Second, the contiguity coefficient on the population variable (*P*) reveals a marginal convergence with the adjacent regions in 1997. It must be noted that the periphery regions collectively have a relatively higher total population level than all of the adjacent regions combined, and their size is comparable to that of the core regions. This fact contradicts the theory of relatively low population levels in the periphery regions vis-à-vis the core regions (Krugman, 1991b). To explain this phenomenon, we must shift our gaze to the regional classification scheme. It reflects the large number of urban areas in periphery regions with population densities between 100 but less than 500 people per square kilometre. An example would be Andalucia with nine urban areas of such size.[14]

Third, although the data values capture the idea that periphery regions showed a relatively higher population level, the adjacent regions have a relatively higher total number of manufacturing employees. This fact is reflected in the respective labour to population ratios (*L/P*) of 7.8 and 4.4. The ratio indicates a marginal divergence in value from 1989, due to the relatively large labour outflow from the periphery regions. Population migration from the periphery exceeded that of the adjacent regions, but was less than the out-migration from the core regions. However, labour migration out of manufacturing from the periphery was significantly larger than its population migration. This development suggests labour preference for current living conditions and their willingness to trade-off between commuting to work in the adjacent regions in lieu of abandoning local life style in the periphery regions (Ludema and Wooton, 1997).[15]

4. Conclusions of the Contiguity Analysis of the CAP Clusters

The objective of section 3.3 was to examine the 'black-box' of economic geography and assess the convergence or divergence of the economic, demographic, and manufacturing variables, within the CAP clusters, as a consequence of trade liberalisation. To this end, the method of contiguity analysis was employed to estimate the contiguity coefficients and to evaluate change in a variable value between the

[13] The adjacent and periphery regions respectively experienced a manufacturing labour outflow of 9,531 and 21,897.
[14] See Eurostat (1993), *Portrait of the Regions,* Vol. 1 – 4, Luxembourg
[15] The authors assume perfect international mobility of labour. They argue labour is internationally imperfectly mobile because of their utility preference for living conditions. In this case, the negative commuting utility is outweighed by the positive utility received from local living conditions.

region types. The analysis is informative, since it provides insights into the effects of trade liberalisation on the regional economic development of a small economy. Specifically, it illuminates the manner in which firms and manufacturing employment responded to greater competition, and how wages, salaries, the cost of production, and gross investment were affected within the regions. A number of conclusions can be drawn.

First, as proponents of the new economic geography theory of trade predict, the core regions in Spain exert a strong attraction force. The core regions, by definition, have the highest population density and attracted the largest number of firms. The increased manufacturing base in the core brought with it relatively more manufacturing labour, which resulted in relatively higher wage and salary disbursements, as well as an absolute higher level of gross investment in manufacturing to achieve economies of scale. These outcomes are salient, since they substantiate the existence of agglomeration forces in the new economic geography trade theory (Krugman, 1991b; Krugman and Venables, 1996).

Second, the forces of economic integration had their most significant effect on the structural adjustment in the adjacent regions – the first-concentric circle of regions. Specifically, the adjacent regions experienced a relatively larger readjustment in the number of firms versus the core region than did the periphery regions. The data reveals a reversal in the total number of firms between the core and adjacent regions. The adjacent regions experienced a net loss of firms through relocation to the core. Forslid *et al.,* (1999) found that the firms that did relocate to the core were those in need of input-output structures, facing high demand elasticities, and that were in need of high levels of economies of scale. These initial findings have subsequently been verified by the empirical work of Davis and Weinstein (1999), Midelfart *et. al.,* (2000), and Brand (2004). The latter found the creation of economic districts between core and adjacent regions by firms requiring strong *inter* and *intra* industry relationships. Venables and Limao (2002) have argued that industries with high transport intensive commodities will also locate in or close to the core because of their production specialisation.

Third, although the core regions in the CAP model act as attraction regions, stimulating the cumulative process of agglomeration, this process spilled over into the adjacent regions, through the competition effect, as confirmed by the strong convergence of the microeconomic variables. Industries in the adjacent regions experienced a relatively higher rate of change in the average number of employees per firm, average wage per employee, and average gross investment per firm. The relatively larger change in average wages and salaries per employee in the adjacent regions suggests a relatively higher demand for labour in these regions. The higher relative average gross investment per firm suggests an expansion of plant capacity to achieve economies of scale in production and/or expand forward and backward linkages (Krugman and Venables, 1996; Brand, 2004). The absolute level of average wage per employee remained below those in the core region.

Fourth, these outcomes have captured a strong competition effect. This competition effect resulted in the convergence of economic variables between the core and periphery regions. Manufacturing in the periphery regions experienced a significant relatively higher rate of growth in the following variables: average gross investment per firm (*K/n*), average number of employees per firm (*L/n*), and average wage costs per firm (*w/n*). The relatively higher rate of growth in average gross investment per firm indicates an expansion of plant and capacity to attain economies of scale in production (Krugman, 1979). The strong convergence with the core, in average number of employees per firm points to a greater similarity in the production technology across the regions. The relatively higher growth rate of average wage costs per firm indicates a relocation of industries to the periphery relying on skilled labour inputs (Forslid *et al.,* 1999; Venables, 2000; Midelfart *et.al.* 2002). These developments are most pronounced in the periphery regions – Galicia and Asturias – belonging to the CAP cluster Pias Vasco where an export industry developed (Brand, 2004). It can be noted that the competition effect has stimulated the development of an economic district in Pias Vasco by growing and existing industry base, starting from low initial levels, in the regions surrounding the core (Krugman and Venables, 1996).

Fifth, the industry index analysis (Brand, 2004) of the CAP clusters illuminated the manner in which both agglomeration and dispersion forces modify the industry structure between contiguous regions. In the CAP cluster of Cataluna, the agglomeration effect was most robust. This is manifested by the creation of a divergent production structure in relation to Cataluna's adjacent regions. For example, spatial correlation analysis captured an increase in the contiguity coefficient between the core and adjacent regions with respect to the variable gross investment (*K*). The source of this change is found in the size of the change in gross investment in Cataluna, which exceeded that of its adjacent regions, as well as the other core regions. This development substantiates Krugman and Venables' (1996) earlier conclusion pertaining to modifications in industry structures, through industry specialisation, in the core region of Cataluna. The data reveal a significant entry of new firms in the Extraction and Processing, Engineering, and Other manufacturing sectors in this agglomerate.

In contrast, the CAP clusters of Pias Vasco indicated a strong convergence of industry structure with its adjacent regions. In Pias Vasco trade liberalisation resulted in a reduction in the number of firms, and an out-migration of population and manufacturing labour. A similar trend, but of greater magnitude, was evident in its adjacent regions. The initial reduction in the supply of manufacturing employees and the need for skilled labour in export oriented firms (Forslid *et.al.,* 1999; Midelfart *et.al.,* 2000; Brand, 2004)), raised the average wage per employee to such an extent that, by 1997, not only had the average wage per employee converged between all the regions in the cluster, but they had also become the highest in Spain! Developments in this CAP cluster strongly support the home market economic geography effects found by Davis and Weinstein (1999). The strong convergence of interregional industry structures and high average wages, in this cluster, suggests production specialisation in transport intensive products (Venables and Limao, 2002).

In the CAP cluster Pias Vasco, the foreign border periphery region of Galicia saw its labour force increase with total and average wages per employee rising more than in the core region. Furthermore, the average number of employees per firm, and gross investment per employee were also relatively higher than in the core region. These developments in Galicia illustrate the forces of cumulative causation generated by the competition effect in a domestic border periphery region adjacent to a foreign core region. The outcome captures the impact that trade liberalisation has had on Galicia, which has, as a result of trade liberalisation, evolved into an attractive adjacent region for industry relocation. This is particularly relevant for those industries wishing to retain their national identity and now find themselves in the position to establish demand and supply linkages with a foreign core region (Krugman and Venables, 1996).

In the CAP cluster of Madrid, industry structures converged completely between the core region of Madrid and its two adjacent regions. Agglomeration forces in the core region of Madrid led to an inflow of firms and manufacturing labour in response to higher nominal wages and salaries (Krugman, 1991b). In contrast to this, the adjacent region of Castilla Leon saw an outflow of labour, while Castilla La-Mancha experienced an increase. In both Castilla Leon and Castilla La Mancha, the total number of firms was reduced. However, there was a convergence in the microeconomic variables, caused by the relatively larger increases in the adjacent regions off; average number of employees per firm (L/n), average wage per employee (w/L), gross investment per firm (K/n), gross investment per employee (K/L), and average wage costs per firm (w/n). Once again, these developments reflect manufacturing's goal of achieving economies of scale in production. In absolute terms, the rates of change and the levels of these variables exceeded those in the core region.

5. A Spanish CAP Analysis Including Contiguous Foreign Border Regions

This section examines the effects of trade liberalisation on the economic interaction between the Spanish, French, and Portuguese contiguous border regions. Krugman and Venables (1996) have noted that:,

> *'Barriers to trade between national economies – both formal barriers such as tariffs and the de facto barriers created by differences in language and culture, lack of factor mobility, and the sheer nuisance presented by the existence of a border – are often enough to block the expansion of a successful industrial district beyond its national market.'*

The objective is to study the extent to which industry structures and economic variables, in these border regions, have converged or diverged.[16] To examine these issues, an industry index and contiguity analysis are conducted to include Portuguese and French border regions. The Portuguese regions are the core region of Norte, the adjacent regions of Centro and Alentejo, and the periphery region of Algarve. The French regions consist of *ex ante* periphery regions: Aquitaine, Languedoc Roussillon, and Midi-Pyrenees. These border regions are shown in Map 1.

In the Spanish west, the Portuguese core region of Norte borders on the Spanish regions of Galicia, and Castilla Leon; the adjacent region of Centro in Portugal borders on the Spanish regions of

[16] The analysis of the CAP-model in a closed Spanish economic system has two major drawbacks. First, it cannot be assumed that there has been an absence of trade or economic activity between Spain, its border-regions, and their foreign neighbouring

Castilla Leon and Extremadura; while, the adjacent Portuguese region of Alentejo borders on Extremadura and Andalucia; and, finally, the periphery region of Andalucia borders on the Portuguese periphery region of Algarve.

In the Spanish north, the French region of Aquitaine borders on the Spanish core region of Pias Vasco, and the adjacent regions of Navarra and Aragon; The French region of Midi-Pyrenees borders on the adjacent region of Aragon, and the core region of Cataluna; while, finally, the French region of Languedoc Roussillon borders entirely on the core region of Cataluna.

5.1 Industry Index Bordering Regions

The Krugman's (1991a) industry index is used to measure trade liberalisation effects on the degree of industry structure similarity or diversity in the border regions. The industry index is calculated with the following statistic;

$$I = \sum_{j}^{i} \left| s_{ij} - s_{ij}^{*} \right|$$

where, s_{ij} is the share of industry i in total manufacturing employment in region j ($i \neq j$), and s_{ij}^{*} is the regional share of manufacturing employment in the region with which the comparison is made. The industry index can take on a value from zero to two such that $0 \leq I_j \leq 2$. In those instances in which the industry structure in two regions is the same, (i.e. the share of employment in the respective industries is identical), the index value will be zero. Similarly, if the industry structures in the two regions are completely dissimilar, if the index value will be 2. Based on this method, the index quantifies the difference or similarity in regional industry structure, and hence regional specialisation.

The outcome of the industry index analysis is presented in Table 3. The contiguous border regions are grouped into region types in column (2) of Table 3. Their industry index values for 1989 and 1997 are respectively listed in columns (3) and (4). The mutations in industry structures between the contiguous regions are listed in column (5).

In general, it is evident that the industry structures between Spain and Portugal converged, while those between Spain and France diverged. More specifically, the strongest convergence occurred between the core region of Norte in Portugal and Galicia in Spain. This change exceeded all of the convergence values between Galicia and its accompanying regions in the CAP cluster of Pias Vasco. This development can be explained by Galicia's relative proximity to Norte versus Pias Vasco (Krugman and Venables, 1996).

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regions in 1989. Second, neither can it be assumed that the Spanish data for 1997 does not include the effects of trade barrier reductions with its immediate neighbouring regions.

TABLE 3
INDUSTRY INDEX VALUES FOR SPANISH AND FOREIGN BORDER REGIONS

(1)	(2)	(3)	(4)	(5)
COUNTRIES	BORDER REGIONS	Index value 1989	Index Value 1997	Index Value Changes[1]
	CORE – ADJACENT			
Spain / Portugal	Norte – Galicia	1.610	0.935	0.675
	Norte – Castilla Leon	1.154	1.053	0.101
Spain – France	Pias Vasco – Aquitaine	0.833	0.842	-0.009
	Cataluna – Midi-Pyrenees	0.516	0.610	-0.093
	Cataluna – Languedoc Roussillon	0.616	0.636	-0.020
	CORE – PERIPHERY			
Spain – Portugal	Norte – Asturias	1.470	1.204	0.196
	Norte – Extremadura	1.074	0.927	0.147
	ADJACENT – PERIPHERY			
Spain – France	Navarra – Aquitaine	0.698	0.682	0.016
	Aragon – Midi Pyrenees	0.619	0.687	-0.068
Spain – Portugal	Centro – Extremadura	1.004	0.640	0.364
	Centro – Castilla Leon	0.997	0.770	0.227
	Alentejo – Extremadura	0.800	0.498	0.302
	Alentejo – Andalucia	0.573	0.419	0.154
	Algarve – Andalucia	0.746	0.621	0.125

1. Positive value = Convergence. Negative value = Divergence
Source: Author's own calculations.

The other significant development of trade liberalisation is the increased convergence between the Portuguese adjacent regions of Centro and Alentejo and the Spanish periphery regions of Extremadura and Andalucia. Specifically, Extremadura has evolved to become more similar to the adjacent region of Centro, than to its core region of Madrid[17], which demonstrated a divergence in index values. Of greater significance is the fact that Extremadura has shown the strongest convergence in industry structure with the Portuguese adjacent region of Alentejo. The Spanish periphery region of Andalucia and the Portuguese adjacent region of Alentejo, where the same strong convergence has occurred in the industry structures, parallel this development. Both of these Spanish regions have diverged strongly, in industry structure, with regions in their own Spanish CAP clusters. These outcomes suggest the development of interregional economic manufacturing linkages (Krugman and Venables, 1996; Venables and Limao, 1999).

The border regions of France experienced a marginal divergence from their Spanish counterparts in industry structure. A salient point is that prior to 1989, the industry structures of the Spanish and French border regions paralleled each other to a greater degree. This similarity was more pronounced than between the Portuguese and Spanish border regions (with the exception Alentejo/Extremadura /Andalucia). Although the outcomes revealed that the core region of Cataluna diverged marginally from the two French regions of Midi-Pyrenees and Languedoc Roussillon, this Spanish core region maintained a stronger similarity to the French regions *ex post*, than it did to the regions in its own CAP cluster.

[17] Extremadura – Madrid I = 0.73. The following values for Extremadura are also significant: Extremadura – Castillia La Mancha I = 0.63; Extremadura – Andalucia I = 0.62.

This section can be concluded with the following observations. First, Spain joined the EU customs union in 1986, and by 1989, its industry structure more closely resembled that of the French border regions, than of the Portuguese border regions. This implies the existence of economic ties with France before Spain joined the EU. Second, by 1989, there also appears to have been some similarity between the Spanish southern periphery regions and the Portuguese adjacent regions. EU 1992 has amplified these similarities to a significant degree. In fact, the Spanish periphery regions converged more with the Portuguese adjacent regions, than with their own Spanish adjacent regions[18] . This explains the divergence of industry structures between these periphery regions and the regions in the Madrid CAP cluster. A possible explanation for this development in the Spanish and Portuguese border regions is the combination of comparable regional geographic location, commodity transport intensity, and factor intensity in comparison to existing economic activities in Portugal (Venables and Limao, 2002)

Third, in general, trade liberalisation had a greater relative convergence effect on the Spanish border regions than on the French border regions. This may be due to geographic proximity and Portuguese/Spanish cultural affinity, exemplified through labour's location preference in periphery regions (Ludema and Wooton, 1997).

5.2 Contiguity Analysis Including Spanish Foreign Border Regions

The objective of this section is to analyse the effects of agglomeration and dispersion forces on the economic development of the border regions. The spatial correlation analysis now includes the Portuguese and French border regions in the respective k – connections. The core adjacent connections now include Norte, Centro, Aquitaine, Midi Pyrenees, and Languedoc Roussillon. The adjacent periphery regions include: Centro, Alentejo, and Algarve.

In Table 2.a below, the original contiguity values for the closed economy (CE) are presented for comparison with the new calculations of the open economy (OE) listed in Table 4. We highlight the most salient developments.

TABLE 2.a
CONTIGUITY COEFFICIENTS FOR THE CAP REGIONS IN SPAIN

		Contiguity Order: k = 1,2					
		1 *Core-Adjacent*		2 *Core-Periphery*		1 *Adjacent-Periphery*	
	Variables	*1989*	*1997*	*1989*	*1997*	*1989*	*1997*
1	Per Capita Income (Y / C)	1.37	1.35	1.71	1.75	0.61	0.83
2	Population (P)	0.85	0.84	1.21	0.77	0.64	0.63
3	Number of Firms (n)	0.58	0.67	0.93	0.77	0.79	0.59
4	Number of Manufacturing Employees (L)	0.99	0.92	1.08	0.96	0.79	0.69
5	Manufacturing Employees / Population (L / P)	0.39	0.50	0.47	0.81	0.63	0.64
6	Wages and Salaries (w)	1.29	1.16	1.17	1.06	0.92	0.83
7	Gross Investment (K)	1.05	1.13	0.39	0.91	0.79	0.83
8	Average Number of Employees per Firm (L / n)	2.04	0.28	0.97	0.35	0.61	0.16
9	Average Gross Investment per Firm (K / n)	1.95	0.35	0.98	0.21	1.06	0.26
10	Average Gross Investment per Employee (K / L)	1.46	0.63	0.56	0.59	1.08	1.44
11	Average Wage per Employee (w / L)	1.54	0.62	1.29	0.93	0.49	0.39
12	Average Wage Costs per Firm (w / n)	2.09	0.31	1.05	0.36	0.56	0.34

Source: Authors own calculations / Contiguity Analysis / Excluding the Island Regions

[18] See footnote 21.

TABLE 4
CONTIGUITY COEFFICIENTS FOR THE SPANISH AND FOREIGN BORDERING CAP REGIONS

		CONTIGUITY ORDER: k = 1,2					
		1		2		1	
		CORE-ADJACENT		*CORE-PERIPHERY*		*ADJACENT-PERIPHERY*	
	VARIABLES	*1989*	*1997*	*1989*	*1997*	*1989*	*1997*
1	Per Capita Income (*Y / C*)	0.39	0.86	1.10	1.31	0.44	0.99
2	Population (*P*)	1.34	1.30	0.81	0.81	1.19	1.18
3	Number of Firms (*n*)	1.41	1.54	0.71	1.49	0.84	0.83
4	Number of Manufacturing Employees (*L*)	1.98	1.92	1.21	1.49	0.94	0.90
5	Manufacturing Employees / Population (*L / P*)	0.70	1.30	0.61	1.39	0.61	1.03
6	Wages and Salaries (*w*)	2.05	2.03	1.04	1.09	1.01	0.95
7	Gross Investment (*K*)	1.54	1.77	1.02	1.15	0.90	1.02
8	Average Number of Employees per Firm (*L / n*)	0.94	0.50	1.43	0.49	0.80	0.25
9	Average Gross Investment per Firm (*K / n*)	0.75	0.71	1.46	0.80	1.41	0.50
10	Average Gross Investment per Employee (*K / L*)	0.58	0.84	1.28	0.88	0.62	0.23
11	Average Wage per Employee (*w / L*)	0.61	0.48	1.08	1.03	0.41	0.32
12	Average Wage Costs per Firm (*w / n*)	0.74	0.45	1.40	0.70	0.18	0.05

Source: Authors own calculations / Contiguity Analysis / Excluding the Island Regions

First, the contiguity coefficients for the closed economy in 1989 indicate a different pattern than that for the open economy case. In the former, the first-order contiguity values of the 8th through the 12th variables, in 1989, are all negative. Conversely, in the latter, the same variables report positive values. In general, this outcome suggests a stronger convergence between the core and adjacent regions in the open economy model in 1989, than in closed economy model for the same year. The opposite is true for the second-order contiguity coefficients in 1989, where there appears to be a strong negative relationship between the core and periphery regions.

Second, in 1997, the first-order coefficients on the 8th through 12th variables show convergence, with the exception of the variable (10th) average gross investment per employee (*K/L*). The same second-order coefficients reveal a much larger magnitude of convergence with the exception of average wage per employee (11th), than do the first order coefficients. This indicates a strong convergence between the core and periphery border regions in the open economy case.

Third, the second-order contiguity coefficients, variables 1 through 7, exhibit a strong divergence in the open economy case. This divergent pattern between 1989 and 1997 is at variance with the closed economy case. The reason for this must be found in developments in the periphery regions.

Fourth, the first-order contiguity values for the adjacent periphery regions, variables 8 through 12, illustrate a very strong convergence in the open economy model in 1997. On average their values are more robust than in the closed economy case.

5.2.1 A General Analysis of the Variables in the Border Regions

In 1997, the variable per capita income (*Y/P*) captures a divergence in value between all regions. This divergence in 1997 is caused by the significant per capita income increases in the Portuguese border regions, and the declining per capita income levels in the French border regions. The average decline in the French regions was 11.2%, while the Portuguese regions showed 22.9 % increase. In comparison, the average per capita income increase in the Spanish border regions was about 5.1%

The population variable (*P*) indicates a constant positive relation for the core and periphery regions between 1989 and 1997. This reflects the population inflow into the Spanish periphery regions of

Murcia and Andalucia, as well as into the three French border periphery regions. Similarly, the Portuguese core region of Norte experienced a population increase.[19]

The variable, number of firms (*n*), shows a divergent trend between the core and adjacent, and the core and periphery regions. This divergence is caused by the significant increases in the number of firms in the Portuguese core (39,096) and adjacent regions (17,970), as well as the large increases in the French border periphery regions (36,674). The Portuguese periphery region of Algarve also experiences industry growth. In contrast, only the Spanish core regions of Cataluna and Madrid observed an increase in their industry base, while the Spanish foreign border regions all witnessed a decline! The reasons for this decline in the Spanish regions is twofold: one, a relocation of industry and manufacturing labour, which appears to be the case in Pias Vasco, Navarra, Aragon, Castilla Leon, Extremadura, and Andalucia; two, the merger of firms, which appears to be the case in Galicia, since it experienced an inflow of manufacturing labour.[20]

The negative contiguity coefficient on the 4th variable, number of manufacturing employees (*L*) is the result of the labour inflow with the newly established firms in the border periphery regions of Portugal and France. The increases were respectively: in Portugal, the core region of Norte (264,307); the adjacent regions of Centro and Alentejo (70,818); in France, the periphery regions of Aquitaine, Midi-Pyrenees, and Languedoc Roussillon (36,674). The labour inflows into the foreign border regions resulted in a sharp divergence of the ratio, manufacturing employees to population (*L/P*), between 1989 and 1997. The most significant increases occurred in the Portuguese and French regions, while declines were evident in most of Spanish adjacent and periphery regions.

The significant increase in the number of manufacturing employees in the Portuguese and French border regions resulted in relatively higher level of wage and salary disbursements (*w*) than in the Spanish regions. As a result, the contiguity coefficients between the region pairs remained negative. The marginal convergence of this variable between the adjacent and periphery regions is due to the relatively higher wage and salary levels in the French periphery regions.

The 7th contiguity variable, gross investment (*K*) also indicates a divergence in value between the *k* region pairs. The change in gross investment in the Portuguese core region of Norte exceeded that of its adjacent regions by a factor of 1.6. The three French periphery regions combined revealed a change in their levels of gross investment comparable to the change in the core region of Norte, and that of Cataluna in Spain. On average, the change in the level of gross investment in the respective three French regions was comparable to that of the Spanish periphery border region of Galicia. The three-periphery French regions border on two Spanish core regions, while the periphery region of Galicia borders on the core region of Norte. This is a significant outcome, since it reveals the need by industries, in the former periphery regions, to acquire economies of scale in production. It is again evidence of the strength of the competition effect to achieve profitability in production.

[19] This study does not examine the issue of international migration. We assume population increases in regions are the result of domestic internal interregional migration.

The 8th variable indicates a strong convergence in the average number of manufacturing employees per firm (*L/n*). This strength of this convergence is derived from the significant declines in this ratio in the Portuguese regions of Norte, Centro, Alentejo, and Algarve. The French regions also exhibit a significant reduction in this ratio. In the open economy case, the average value of this ratio has shown a strong convergence between all region types. It is interesting to note that the French regions reveal values for this ratio that lie below the average for all the periphery regions. The overall development of the contiguity values of the ratio reflects an increased similarity in production structures among the regions, especially between the core and adjacent regions.

There was also a significant convergence of average gross investment per firm (*K/n*) between the *k* - region pairs. For example, significant declines occurred in all of the French and Portuguese regions to bring them in line with their Spanish counterparts. In 1997, the average value of this ratio was highest in the adjacent regions (€ 108.500), followed by the periphery (€ 95.600) and the core (€ 94.500) regions. In general, industries in the Spanish adjacent regions experienced the largest increase in this ratio, indicating a 'catching-up' effect with the core regions.

The 10th variable, gross investment per employee (*K/L*) indicates a strong positive relationship between the core and adjacent regions in 1989, but a negative value between the core and periphery regions. The average value for this variable was the same for the core (€3,400) and for the adjacent (€3,400) regions in 1989, but diverged with the periphery (€5,300) regions. In 1997, the first-order contiguity coefficient reveals a positive diverging value that reflects the significantly high level of gross investment per employee in the Portuguese adjacent region of Alentejo. The significant convergence of variable value between the core and periphery is due to a relatively higher rate of change in the periphery regions. This is best exemplified by the Spanish region of Murcia. The relatively high levels of gross investment in the adjacent region of Alentejo, and the periphery region of Murcia, led to the strong convergence in this variable between adjacent and periphery regions. Gross investment per employee was, on average, higher in the periphery regions than in the adjacent regions. This, again, supports the earlier findings of high investment levels to attain economies of scale in production to offset a geographic location disadvantage.

The 11th variable, average wage per employee (*w/L*), exhibits a positive value between the core and adjacent regions, but a negative value between the core and periphery regions. In 1989, the average wage per employee was higher in the core than in the adjacent regions, but lower than in the periphery regions. This higher average value in the periphery regions signals the high average wage per employee in the French periphery regions where the average wage per employee exceeded that of the Spanish core regions. In contrast, the average wage per employee in the Portuguese regions was absolutely lower than in Span.

In 1997, the French regions continued to enjoy a higher average wage per employee (€22,178), than displayed in any of the Spanish or Portuguese regions. The average rate of change in the French

[20] A third possibility would be the wholesale death of firms with labour migrating to other regions.

regions (€5,008) was comparable to the rate of change in the Spanish core regions of Pias Vasco (€4,102) and Cataluna (€4,013), but remained below that of the adjacent region of Navarra (€9,016) on which they border. The adjacent region of Navarra has the highest level of average wage per employee (€21,957) in Spain. This convergence of average wage per employee in these adjoining border regions is evidence of Stolper-Samuelson factor-price equalisation.

In contrast, the Portuguese average wage per employee in the core region of Norte is about one-third that of the Spanish core regions (€6,363). In the Portuguese adjacent regions the average wage per employee is approximately one-half of that of its contiguous Spanish border regions (€7,262). There is no convergence of average wage per employee between the Spanish and Portuguese border regions. The Portuguese border regions, whether core or adjacent, have an absolute lower level of average wage per employee. The convergence of wages between the adjacent and periphery regions, as revealed by the contiguity coefficient, consists entirely of convergence between the French and Spanish border regions in the north.

Finally, average wage costs per firm (*w/n*) converged strongly between the core and adjacent regions. This result highlights the competition effect at work in the adjacent regions versus the core regions. In Portugal, average wage costs declined significantly in the core and adjacent regions and remained absolutely lower than in any of the Spanish or French regions. The formidable convergence in wage costs between the core and periphery regions is the direct result of significant wage cost declines in the French border regions, to equate with levels in the Spanish border regions. The reduction in average wage costs in both the French and Portuguese regions resulted in the strong convergence between the adjacent and periphery regions.

6. Conclusion on Border Regions

The objective of the analysis in section 4.2 was to examine the effects of agglomeration and dispersion forces on the economic geography of these regions. What have we learned from the border region analysis with respects to the effects of trade liberalisation? The analysis has revealed two sets of results; the first of these pertains to industry structures, and the second, concerns economic growth in the border regions.

First, the development of industry structures in the two sets of Spanish border regions contiguous to Portugal and France is unequal. However, a strong convergence in industry structures occurred between the Portuguese and Spanish border periphery regions. The most significant of which was found in the Spanish periphery region of Galicia. The changing composition of industry structure in the periphery regions of Extremadura and Andalucia resulted in a stronger convergence with the Portuguese border regions than with the regions in their own CAP cluster of Madrid.[21]

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[21] Andalucia experienced an employment increase in all branches of the Engineering sector with the exception of electrical machinery and other transportation sectors. See Brand (2004), Table A.3, *Employment Change and Regional Industrial Shares.*.

The reasons for this convergence could possibly be explained by; i) geographic proximity to the densely populated Portuguese core regions of Norte and Lisboan, ii) the freedom to develop interregional and inter(intra) sectoral linkages, and iii) the need to exploit comparative advantage (Ludema and Wooton, 1997; Forslid *et al.* 1999; Venables and Limao, 2002).

The similarity in industry structures between the French and Spanish border regions remained unaltered subsequent to economic integration. This invariability suggests that industry structures had converged before 1989. It also points to the existence of interregional and inter(intra) sectoral economic linkages between French periphery regions and Spanish core and adjacent regions.

Second, both agglomeration and dispersion forces endogenously changed the economic variables in the border regions. Agglomeration forces resulted in the pronounced increases in the number of firms (n), manufacturing labour (L), and wages (w) in the core regions. The competition effect manifested itself strongly in the *ex ante* border periphery regions contiguous to foreign core and adjacent regions. In the *ex post* period, these reclassified adjacent regions[22] experienced strong inflows of: population, labour, and firms. These factors combined to raise total wages and salaries. In these regions, average wages per employee converged strongly with their contiguous core and adjacent regions. Given the imperfect mobility of labour between these foreign bordering regions, average wage convergence implies factor-price equalisation through trade.

The competition effect in the border regions resulted in relatively high levels of gross investment that converged with levels in the Spanish and Portuguese core regions. The convergence of the average number of employees per firm ratio between the core and adjacent regions, combined with the convergence of average wage costs per firm, implies the attainment of cost minimising production structures in the Spanish, and the *ex post* adjacent regions. A relatively lower average number of employees per firm ratio, and a relatively higher level of average gross investment per employee, offset the relatively higher average wage in the French regions. This finding implies French industry is relatively more capital intensive.

Finally, although the competition effect is evident in the Spanish border periphery regions of Extremadura and Andalucia, causing industry structure to convergence with the Portuguese adjacent regions, there is no convergence of average wages between these border regions. In absolute terms, Portuguese border region wages remain significantly lower than Spanish border region wages. The existing wage differential between these region types, illustrates that Portugal, is geographically, relatively more peripheral than Spain.

[22] Before EU 1992 border regions were separated by legal structures and commercial laws preventing the development of economic ties between border regions whether they be core or periphery. In France, and elsewhere, some of the southern most periphery border regions bordered on foreign core regions which by definition reclassified them as adjacent regions with trade liberalisation.

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Appendix A

The Mathematics of the CAP Model

Let U represent any country with a set of urban population density elements upd_i where $i = 1\ldots I$. This set of population density elements is represented by:

$$U = \{upd_i \mid i = 1,\ldots,I\} \qquad (1)$$

where i is the urban population density of a given urban area, and I is the total of all urban areas in a country. It is possible to create three proper subsets of U, with the symbols C, A, and P, such that $C \subset U$, $A \subset U$, and $P \subset U$, given the condition that $C \neq A \neq P \neq U$. By using the *extension theorem* of set theory, specific values of the elements from U can be assigned to the three respective subsets: C, A, and P. Let the function $\varphi(upd_i)$ be the criterion for the subset C, such that $\varphi(upd_i) \in$ C. Subset C is then characterised by the following condition:

$$\varphi(upd_i) \in C \leftrightarrow upd_i \in U \cap \varphi(upd_i) \qquad \forall i \qquad (2)$$

Thus each element upd_i in U that satisfies the criterion $\varphi(upd_i)$ is assigned to the subset C. For subset A, $\gamma(upd_i) \in A$, and is characterised by the following equation:

$$\gamma(upd_i) \in A \leftrightarrow upd_i \in U \cap \varphi(upd_i) \cap \gamma(upd_i)\theta_{CA} \qquad \forall i \qquad (3)$$

Equation (3) states that every element upd_i, in U that satisfies the criteria $\gamma(upd_i)$ and not the criteria $\varphi(upd_i)$ will be assigned to the subset A. Finally, the criterion for subset P is the same as for subset A since a region that is two regions removed from the core can theoretically have the same $\gamma(upd_i)$ as an adjacent region. However, it is differentiated from an adjacent region by its geographic location and lies in the second ring of regions around the core. The distance criterion is incorporated in equation (4) indicating that the distance between the core and adjacent regions, θ_{CA} is less than the distance between the core and the periphery regions, θ_{CP}. This also implies that the distance between a periphery and an adjacent region θ_{AP} is less than the distance between the core and periphery regions, such that $\theta_{CP} > \theta_{AP}$.

$$\gamma(upd_i) \in P \leftrightarrow upd_i \in U \cap \varphi(upd_i) \cap \gamma(upd_i)(\theta_{CP} > \theta_{CA} \geq \theta_{AP}) \qquad \forall i \qquad (4)$$

The extension theorem holds only if the following conditions are met. If $\varphi(upd_i) \rightarrow C \cup (A \cup P) = U$, $\gamma(upd_i) \rightarrow A \cup (C \cup P) = U$, and $\gamma(upd_i)(\theta_{CP} > \theta_{CA} \geq \theta_{AP}) \rightarrow P \cup (C \cup A) = U$, then:

$$\exists \quad C \cup A \cup P(\theta_{CP} > \theta_{CA} \geq \theta_{AP}) = U \qquad \forall i \qquad (5)$$

and

$$\exists \quad C \cap A \cap P(\theta_{CP} > \theta_{CA} \geq \theta_{AP}) = \varnothing \qquad \forall i \qquad (6)$$

The regions are disjoint because of the urban population density – and distance criteria assigned to each subset of regions. The regions are individual non-overlapping units bordering on each other in the order as given by equation (6). The universal set of regions can be rewritten as follows:

$$U = \bigcup_{j=1}^{J} R_j \qquad \forall i \qquad (7)$$

Then one may write,

$$U = \bigcup_{j=1}^{J} R_j = C \cap A \cap P(\theta_{CP} > \theta_{CA} \geq \theta_{AP}) = \varnothing \qquad \forall i \qquad (8)$$

For any country, *U,* the union of its regions is a disjoint universal set. The union of the regions is a collection of a number of core, adjacent, and periphery regions that are non-overlapping as defined by the extension and distance criteria of set theory. This is expressed in the following equation;

$$U = \bigcup_{j=1}^{J} R_j = \sum_{j=1}^{C} C_j \cap \sum_{j=1}^{A} A_j \cap \sum_{j=1}^{P} P_j (\theta_{CP} > \theta_{CA} \geq \theta_{AP}) = \varnothing \qquad (9)$$

This equation states, that for any country *U*, the union of its administrative regions is equal to the sum of its economics regions; core, adjacent, and periphery. These regions form a non-overlapping collective. This model serves as a framework to study the dispersion of economic activity within the geographic confines of a country.

The multi-region CAP model is defined as follows: [23]

$$CAP_j = C_j \cap \sum_{j=1}^{A} A_j \cap \sum_{j=1}^{P} P_j (\theta_{CP} > \theta_{CA} \geq \theta_{AP}) = \varnothing \qquad (10)$$

Where, CAP_j represents a core, and a cluster of *j* adjacent, and periphery regions. These region types are symbolised by: C_j core, A_j adjacent, P_j periphery. Distance from the core is represented by the symbol θ. The expression in brackets states that the distance from the core to the periphery θ_{CP} is greater than the

[23] Each CAP cluster is a union of administrative regions around a core region that form a non-overlapping collective.

distance from the core to the adjacent θ_{CA}, and the distance from the adjacent to the periphery θ_{AP} is greater than, or equal to the distance from the core to the adjacent. The symbol $\varnothing$ indicates that the regions are non-overlapping.

The multi-region CAP model is called a CAP cluster. The number of first and second ring regions around the core agglomerate determines the number of regions in the cluster. For example, if a core agglomerate is contiguous to one adjacent and one periphery region such that $j = 1$ for both A_j and P_j, this results in a basic three-region CAP cluster. On the other hand, if a core region is surrounded by three adjacent regions and two periphery regions, then $A_j = 3$, and $P_j = 2$, this would provide us with a six-region model, with economic interaction occurring between the regions due to their geographic proximity.

A multi-region country U_i can consist of a number of CAP_j clusters, each with a varying number of regions. An individual country is the sum of its CAP_j clusters, expressed as follows:

$$U_i = \sum_{j=1}^{CAP} CAP_j = \sum_{j=1}^{C} C_j \cap \sum_{j=1}^{A} A_j \cap \sum_{j=1}^{P} P_j (\theta_{CP} > \theta_{CA} \geq \theta_{AP}) = \varnothing \qquad (11)$$

Where, country U_i is the sum of it CAP_j clusters. For example, Spain has the three CAP clusters of Pias Vasco, Madrid, and Cataluna, with each cluster consisting of a different number of regions. This would typify a national multi-agglomerate production structure.

The multi-region CAP model ceases to exist in two cases. First, when the regions in a country do not meet the adjacent and/or periphery region criteria; it is entirely possible that a country consists of a collection of regions where each adjoining region meets the core region criteria. This results in a geographic area of contiguous densely populated regions or agglomerates. An example of this would be the collection of core regions in the German provinces of Baden-Württemberg and Bayern. Second, the model is not applicable when a country has no periphery regions. In this instance, the adjacent region would become the growth region, as would be the case in Belgium.[24]

The core regions within a country represent a central geographic location of concentrated production activity. These regions attract or disperse economic activity. If the core is an attraction region, the agglomeration forces pull economic activity from the adjacent and the periphery regions, to the core as a result of higher wages. Conversely, if the core is a dispersion region, the competition effect will push economic activity in the opposite direction. That is, if the cost of production in the adjacent and periphery regions is relatively lower than in the core region i.e. a wage differential, the core becomes a dispersion region.

The CAP model postulates that the pre-integration regions in the CAP clusters are asymmetrical. Manufacturing is not equally distributed over the regions, but instead the CAP model indicates a

[24] See Brand, (2003)

sequentially declining manufacturing concentration from the core to the periphery. The model also assumes, by definition of the regions, that the regional concentration of agricultural production is the inverse of manufacturing concentration. This means that agricultural imports to the core are subject to transportation costs, resulting in an upward sloping factor input supply curve that will eventually mitigate the forces of agglomeration in the core regions (Krugman and Venables, 1990).

Theory (Krugman, 1991b) postulates that the economic dynamics (gradually declining trade costs) released by the forces of trade liberalisation will initially impact the core agglomerates, and subsequently or simultaneously affect the lower cost adjacent and periphery regions (Forslid, *et.al.,* 1999). Reduced market access costs affect a firm's (industry's) geographic location decision. Together with an improved domestic infrastructure, reduced transportation costs, would encourage the relocation of firms away from the core that are: i) not dependent on strong input-output structures, ii) and/or have low demand elasticities, iii) and/or wish to relocate to lower cost regions, to enhance their comparative advantage position. This implies a movement of production activity along a radius extending outward from the core as the CAP model postulates.

APPENDIX B

TABLE B.1
CLASSIFICATION OF NUTS 2 REGIONS INTO CORE, ADJACENT, PERIPHERY, AND ISLAND PERIPHERY[25]

DESCRIPTION OF AREA TYPES		
CORE		
1	C	= a single city region
2	C_1	= multiple city region with no employment in agriculture
3	C_2	= contains one or more urban area's (UA) with a population density ≥ 2 thousand / km^2
4	C_3	= contains one or more urban area's with a population density ≥ 1 thousand / km^2
5	C_4	= contains one or more urban area's with a population density ≥ 500 / km^2
6	C_5	= a single national urban area with a population density (PD) < 500 / km^2
ADJACENT		
7	A	= any adjacent region which completely surrounds a core region
8	A_1	= any region adjacent to a core with one or more UA's with a PD between 100 – 500 / km^2
9	A_2	= any region adjacent to a core with one or more UA's with a PD between 50 – 99 / km^2
10	A_3	= any region adjacent to a core with one or more UA's with a PD less than 50 / km^2
PERIPHERY		
11	P_1	= a region bordering on an adjacent or other periphery with one or more UA's with PD ≥100 / km^2
12	P_2	= a region bordering on an adjacent or other periphery with one or more UA's with PD ≥ 50 / km^2
13	P_3	= a region bordering on an adjacent or other periphery with one or more UA's with PD ≥ 20 / km^2
14	P_4	= a region bordering on an adjacent or other periphery with one or more UA's with PD < 20 / km^2
ISLAND PERIPHERY		
15	IP_1	= a peripheral island region with one or more UA's with a PD ≥100 / km^2
16	IP_2	= a peripheral island region with one or more UA's with a PD ≥ 50, / km^2
17	IP_3	= a peripheral island region with one or more UA's with a PD between 20 – 49 / km^2
18	IP_4	= a peripheral island region with one or more UA's with a PD < 20 / km^2

Source: Author's own classification scheme.

Table B.1 ranks the regions according to the size and number of urban areas. For example, Madrid is a C, which indicates it is an official region with an urban area whose size is equal to that of the county. The periphery region of Andalucia, represented by (P1:3), is a region with three urban areas with respective population densities between 100 – 500 people/km^2. Greater Manchester is a C1, which indicates that it is a multiple urban region with no agricultural production. Düsseldorf is a C2:5 indicating that it is a core region containing five urban areas each with a population density greater than 2 thousand / km^2 .

[25] This table is taken from Brand (2003), *A Regional Core, Adjacent, Periphery Model for National Economic Geography Analysis*, December, University of Glasgow Discussion Paper 2004-1

APPENDIX C

TABLE 1C

DEFINING THE REGIONAL CONNECTIONS

1.1 Regions	*1st – Order-Connections for Core Adjacent Regions*				I_k
1. Galicia					
2. Asturias					
3. Cantabria	Pias Vasco				1
4. Pias Vasco	Cantabria	Navarra	La Rioja	Castilla Leon	4
5. Navarra	Pias Vasco				1
6. La Rioja	Pias Vasco				1
7. Aragon	Cataluna				1
8. Madrid	Castilla Leon	Castilla La Mancha			2
9. Castilla Leon	Madrid	Pias Vasco			2
10. Castilla La Mancha	Madrid				1
11. Extremadura					
12. Cataluna	Aragon	Communidad Valencia			2
13. Communidad Valencia	Cataluna				1
14. Andalucia					
15. Murcia					
				$I_k =$	16

1.2 Regions	*2nd – Order-Connections for Core periphery Regions*			I_k
1. Galicia	Madrid			1
2. Asturias	Pias Vasco			1
3. Cantabria				
4. Pias Vasco	Asturias			1
5. Navarra				
6. La Rioja				
7. Aragon				
8. Madrid	Galicia	Extremadura	Andalucia	3
9. Castilla Leon				
10. Castilla La Mancha				
11. Extremadura	Madrid			1
12. Cataluna	Murcia			1
13. Communidad Valencia				
14. Andalucia	Madrid			1
15. Murcia	Cataluna			1
			$I_k =$	10

1.3 Regions	*1st – Order-Connections for Adjacent -Periphery Regions*			I_k
1. Galicia	Castilla Leon			1
2. Asturias	Castilla Leon	Cantabria		2
3. Cantabria	Asturias			1
4. Pias Vasco				
5. Navarra				
6. La Rioja				
7. Aragon				
8. Madrid				
9. Castilla Leon	Galicia	Asturias	Extremadura	3
10. Castilla La Mancha	Andalucia	Murcia	Extremadura	3
11. Extremadura	Castilla Leon	Castilla La Mancha		2
12. Cataluna				
13. Communidad Valencia	Murcia			1
14. Andalucia	C.L. Mancha			1
15. Murcia	C.L. Mancha	Communidad Valencia		2
			$I_k =$	16