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REGIONAL INTERCONNECTIONS AND GROWTH DYNAMICS: THE SPANISH CASE

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ABSTRACT: In this paper, an empirical dynamic model is presented in the context of regional economic interconnections. The model builds upon and extends the one proposed by Dendrinos and Sonis (1990) and can be used in order to make explicit the nature of macroeconomic interactions in the growth of regional economies within a multi-regional system. As an application, the new empirical model is estimated using data for Spanish regions for the period 1973-1999, and the results reveal that economic concentration is affecting regional competition. Further, this analysis is extended with an examination of the regional growth dynamics. In particular, the long-term impacts in each Spanish region due to exogenous shocks produced in that region or in the rest of the regions of the system are investigated by means of the use of generalized impulse response functions (Pesaran and Shin, 1998). The quantitative analysis reveals the underlying regional interconnections in the dynamic trajectory of the regions. The discussion illustrates how the impact on regional economies, as a result of one unit of exogenous shocks in the regional system, can shed light on the (in)effectiveness of exogenous economic initiatives intended to bring into equilibrium the spatial distribution of multi-regional income.

1. INTRODUCTION

Although regional interconnections should be considered an important factor in any investigation of the relevant influences on the multi-regional growth of a system, this area of study is not well developed[1]. External linkages are an important aspect in applied models and "Without a consideration of interregional and national-regional links, there is no consistency guarantee for a model of a spatial system as a whole" (Nijkamp *et al.*, 1986, p. 257). Thus, the literature

[1] Recent research suggests that disaggregated analyses by countries and/or regional systems can shed some light on the trends of regional economic processes (for example, Cuadrado–Roura (2001)).

suggests that the existence of interacting regional economies has to be considered, but in practice, not too many empirical options have been presented to evaluate the nature of these processes (Isard *et al*., 1998). The major shortcomings would appear to be the absence of dynamic approaches and the difficulties of working with models that become very complex when attempting to handle regional interaction. In this context, a major need is an investigation of the impact of competition on growth and the role played by agglomeration in regional competition.

This paper belongs to the ongoing evolution of models describing dynamic spatial interaction between different regions, and its main contributions are: a) it provides a new empirical model that facilitates the exploration of the outcomes of macroeconomic interconnections in multi-regional growth dynamics, revealing also the competitive behavior of regions within a system; and b) it examines the dynamic effects and propagation of exogenous shocks across regions in a regional system.

The rest of the paper is organized as follows. The next Section introduces the issue of regional interconnections, pertinent empirical studies and some topics related to them. Section 3 presents the empirical model, starting from the theoretical base of the Dendrinos-Sonis model and provides a new model. Next, this model is estimated by using data for regions of Spain during the period 1973-1999 (Section 4). In addition, this analysis is extended with an examination of the regional growth dynamics. In particular, the long-term impacts in each Spanish region due to the shocks produced in that region or the shocks produced in the rest of the regions of the system are investigated by means of the use of generalized impulse response functions (Pesaran and Shin, 1998). The results are then evaluated. The fifth section closes with a summary and concluding comments.

2. REGIONAL INTERCONNECTIONS IN CONTEXT

The issue of regional growth and interaction[2] fits into the current interest in spatial spillovers and regional growth from the spatial econometrics literature (see Quah 1996a,b; Rey and Montouri 1999 and Rey 2001). In all these studies, the unit of analysis has been different regions as part of an interregional system, and they consider the measurement and modeling of the economic interactions between the regions taking into account their geographical locations. Nonetheless, this approach is limited in that it only considers geographical relationships. In this sense, the nature of the economic interconnections among the regions as economic units could make reference to interregional spillover effects (external influences from one region to other region), interregional feedback effects (feedback from a region to itself through all or part of the rest of the system of regions) and some kinds of spatial-temporal feedbacks between the regions and the nation.

[2] As Nijkamp and Poot (1998, p. 9) emphasise: *"At the regional level, there is spatial interaction in terms of trade, capital flows, migration, diffusion of technological innovation and information exchanges"*.

When considering interregional spillover effects, interregional feedback effects and nationwide effects, some relevant questions may be raised: are there significant regional interconnections working over time within a system of regions, and what are the results of these dynamic interconnections? In Hewings *et al.* (1996), these questions were addressed by using a discrete nonlinear model proposed by Dendrinos and Sonis (1990)[3]. The central idea was to consider interactions between US regions within a context where regions achieved growth in the *relative* distribution of regional output through competition with other regions for shares of some macroeconomic variable (in this case, shares of gross national product). Within the same scheme, the regional complementarity can also be detected in this zero-sum game. The present paper will propose an improvement to this model.

Analyses of the regional interconnections are related to a number of frequently discussed topics such as concentration, competition and the effects of exogenous shocks to individual regions. Next, some comments are presented in order to show the connections of these topics with our issue. Although geographic space has re-acquired a preeminent role in regional economics, the analysis of the evolution of regional concentration has been neglected. The importance of analyzing regional concentration was demonstrated by Krugman (1991a,b,c)[4] in a formal model. Concentration is motivated by the presence of external economies like externalities and economies of scale that induce some sort of advantage. In our model, where we work with regions as economic units, the forces that condition the evolution of the spatial economic configuration are the externalities (since we deal with agglomeration effects between regional economies[5]). Regional concentration can generate different benefits; over time, these benefits reinforce the comparative advantages, and therefore the spatial distribution of the economic activity.

Taking a system of regions, a question of interest is: do regional economies that are less concentrated tend to grow more rapidly than those that are more concentrated? A negative response to this question would suggest that a lack of concentration could be a problem in the regional growth process. A positive response would show that there are forces working at subnational scales to equilibrate regional concentrations. Our approach is related to a few existing contributions that try to capture the spatial dimension of economic development by showing, for a particular case, the empirical relationships between concentration and multi-regional growth.

A second active discussion concerns whether interconnections affect the competitive situation of regions within a system. Regional competition is a

[3] It is important to distinguish between the Dendrinos-Sonis approach and the typical *modus operandi* of spatial econometrics, where a scheme of interaction directly related with the geographical location of the regions, usually a spatial weights matrix, is specified.

[4] In Krugman's models, spatial divergence in income levels is generated by agglomeration.

[5] In contrast to agglomeration effects within a regional economy, where the focus would be on the role of scale economies (see Parr (2002) for a review).

complex issue that involves different factors and up to now, there has been an overall, integrated theory of regional competition (Batey and Friedrich, 2000). When competition makes reference to regions as interacting economic entities, the concept of competition is directly related to the previous discussion, namely, regional interconnections and geographical concentration. A detection of the economic interconnections could provide a signaling device that informs about the way the processes of competition function between regions. This paper presents a framework to characterize the regional competition by suggesting a pattern of macroeconomic interdependence between regions. The main purpose is to provide a heuristic device to reveal the channels of regional competition based on regional interconnections. In addition, some hypothesis about the effect of geographical concentration on regional competition could be made (does economic concentration affect regional competition?).

Finally, the introduction of exogenous shocks to individual regions to simulate its dynamic propagation throughout the system could give new stylized facts about the nature of multi-regional growth. This exploration would enable an appraisal of some empirical hypotheses and initiatives directed to issues of regional welfare. To our knowledge, there have been no empirical studies at all analysing the competitive evolution of a real regional system over time that consider the existence of interactions between the regional economies and exogenous shocks[6]. This perspective relates closely in its spirit to Maier (2000), whose two-region model forecasts which of the two regions will gain the most share in the long run. The winning region's concentration serves to attract innovations in the economic system. Maier shows some simulation results and analyzes the effect of the reassignment of exogenous innovations in different periods; however, these policies do not move the system towards a balanced path in the long term, maintaining the winner-loser structure. From another perspective, our work is also related to the analysis presented by Rey and Montouri (1999), where the degree of spatial spill-over is simulated in the presence of spatial error autocorrelation by means the introduction of a shock to the error for an individual state. These authors highlight one of the motivations of our simulation: "Examination of the interaction between the temporal and spatial dimensions of shocks to individual states remains an important area for future study" (p. 153).

3. THE EMPIRICAL MODEL

This research is a step towards the detection of regional interconnections, presenting a new empirical dynamic model. The model builds upon and extends the one proposed by Dendrinos and Sonis (1988, 1990), and can be used in order to make explicit the nature of the interaction (competition or complementarity) in the growth of regional economies nested within a national system. The refined model also provides: a) the detection and significance of the interregional spillover effects, interregional feedback effects, and the nationwide effects; b)

[6] Most of the available empirical evidence is employed in a static approach to illustrate dynamic issues.

the chance to contrast symmetric interactions and the existence of significant non contiguous ("extra-bordering") interaction effects; c) empirical indications about whether concentration is related to some sort of regional interconnections; and, d) a useful way to incorporate exogenous changes within the system, analyzing the regional growth dynamics.

The specification of the model is determined by both data availability and the application for which the model is built, for example, to analyze the role of regional interconnections in regional growth. Interregional and national-regional linkages among regions as economic units are specified to detect and describe their influences on the patterns of regional growth over geographic space.[7] The regional reaction to nationwide dynamics is specified in a way that regional shares depend on the performance of the nation, while the interdependence between regions is treated at the same time.

At this time, the model has limited use in policy analysis; the main contributions would be centered on exogenous impact analysis, exploratory analysis as point of departure for a confirmatory analysis (in the field of the identification of regional interconnections: are the regional interconnections due to demand effects, capital mobility effects, labor mobility effects, knowledge spillovers, industrial concentrations and so forth), and forecasting (an attractive property of our model is that it can easily be linked with a national one, analyzing regional consequences of national evolution).

Next, as a brief introduction, the essential features of the model proposed by Dendrinos and Sonis (1988, 1990) and used in Hewings *et al*. (1996) are introduced, and following this, some modifications over the basic specification are provided. Consider a national economy consisting of S regions in which there are no external economies and all the regions can interact with one another. Also, assume within this system that the national income is determined exogenously. In this context, if $w_i(t)$ denotes the share of some macroeconomic variable corresponding to the relative distribution of the region i in the national economy at time period t, the Dendrinos-Sonis (D-S) model tries to provide evidence about the existence of patterns of interregional competition by means of a description of the time evolution of the system given by the S-dimensional vector $W(t) = \left(w_1(t), w_2(t), \dots, w_S(t)\right)'$, where t=1,2,..,T (T denotes a finite time period). Expressing the variables of the vector $W(t)$ with respect to a reference region (a numeraire region designated as *1*), $F_i(t) = w_i(t) / w_1(t)$, the model describes the relative dynamics of the system[8]. A Cobb-Douglas type function is

[7] A top-down approach with interregional macroeconomic linkages is used.
[8] As Fry *et al*. (1996, p. 381) assert: "*all statistical procedures are invariant to the choice of component used as the denominator for the log ratios (…) This invariance property is similar to that in the traditional approach where the statistical procedures are invariant to the choice of equation deleted.*"

used as a basis for the specification, $F_i(t) = A_i \prod_{k=1}^{S} w_k(t-1)^{a_{ik}}$, where i=2,3,...,S, the parameter A_i represents the locational advantages of the region i, and the parameters $a_{ik} = \partial \log F_i / \partial \log w_k$ are the interregional growth pseudo[9]-elasticities (Hewings *et al*., 1996).

Applying logarithms to the function defined by Dendrinos and Sonis, the model can be written as the following linear system:

$$\log F_i(t) = \log A_i + \sum_{k=1}^{S} a_{ik} \log w_k(t-1) \text{; where i=2,3,...,S t=1,2,…,T} \quad (1)$$

Starting from this basic specification of the D-S model, two modifications are proposed. In summary, the D-S model is enriched by two new assumptions that generate a new model. The first assumption is structural, relaxing the verification of the *compositional invariance* restriction (Aitchison, 1986) that is implicitly imposed in the original specification of the D-S model. Thus, model (1) assumes that the regional distribution of the production is independent of the total level of national production. In other words, the D-S model imposes as a restriction that the distribution of the variables $w_i(t) = GRP_i(t)/GNP(t)$ is statistically independent of its size, $GNP(t) = GRP_1(t) + \ldots + GRP_S(t)$. This property was referred to by Aitchison (1986) as 'compositional invariance' and its relevance is clear: "... in any practical investigation ... we require our modeling to allow the possibility of the basis not possessing this property" (p. 221). Hence, it was decided not to impose *a priori* the property of invariance; this hypothesis will be considered *a posteriori*, once the data are observed.

Let $GNP(t)$ denote the national gross added value at time period t. Subsequently, the new model obtained from the original D-S model is

$$\log F_i(t) = a_{i0} + \sum_{k=1}^{S} a_{ik} \log w_k(t-1) + a_{iN} \log GNP(t) \quad (2)$$

where the parameter a_{iN} represents the national growth pseudo-elasticity and the parameters $\log A_i$ have been denoted as a_{i0}. The national gross added value represents a measure of the general evolution of the national economy (*economy-wide*), and its introduction is justified from an economic viewpoint if a *top-down* approach is assumed in the generation process of regional income (Bolton, 1985).

[9] The term *pseudo* (not included in Hewings *et al.*, 1996) is added for the purpose of stressing that these parameters measure the percentage change produced in the relative share of the region *i* when there is a variation in the absolute share of the region *k*.

Expressing the model in this fashion, the invariance hypothesis (that is, the validity of the original D-S model) is modified by the significance of coefficients a_{iN} in the multivariate regression given by Equation (2)[10].

The second modification that is proposed over the original D-S model makes reference to the reformulation of function $F_i(t)$. Instead of considering $F_i(t) = A_i \prod_{k=1}^{S} w_k(t-1)^{a_{ik}}$, it is supposed $F_i(t) = A_i \prod_{k=2}^{S} F_k(t-1)^{a_{ik}}$; that is, $F_i(t)$ is a function of the lagged values of F_k. The dependant variables are relative shares, and thus it would seem to be more advisable (a priori) to use a model formulated as a function of lagged relative shares rather than as a function of lagged absolute shares. The specification that we propose would be a particular case of the original D-S specification; when the restriction $\sum_{k=1}^{s} a_{ik} = 0$ is verified in every region *i*, the implication is that absolute shares are not relevant, and it is necessary to work with relative shares.

Therefore, the modified D-S model given by (2) can be written in terms of the relative variables, $F_i(t)$, as follows

$$\log F_i(t) = a_{i0} + \sum_{k=2}^{S} a_{ik} \log F_k(t-1) + a_{iN} \log GNP(t) \tag{3}$$

Stated this way, the D-S model can be presented as a first order vector autorregressive specification for the vector

$$\log F(t) = \left(\log F_2(t), \log F_3(t), ..., \log F_S(t)\right)' ; \tag{4}$$

in this model, variable $\log GNP(t)$ is used as the conditioning factor. Expression (3) facilitates the use of the tools of VAR analysis, particularly, the impulse response functions associated with the model that will provide the basis of the empirical analysis presented in next section.

4. EMPIRICAL ANALYSIS AND DISCUSSION

The model has been estimated by using an aggregate set of regions for the Spanish economy. The estimated model provides the opportunity to complete two tasks: (1) the multi-regional interconnection pattern that emerges from the estimated parameters can uncover the results of the macroeconomic competition and complementarity between regions (horizontal competition); and (2) the

[10] Taking into account the definition of variables $F_i(t)$, it is verified that $a_{iN} = e_i - e_1$ ($i = 2, \ldots, S$), where $e_i = \partial \log w_i / \partial \log GNP$ are the national growth elasticities. Hence, the property of compositional invariance ($a_{iN} = 0 \ \ \forall i$) implies a strong restriction: all the elasticities (e_i) must be equal.

model estimated reveals the dynamic behavior of the corresponding impulse response functions, as well as the long-term impacts in each Spanish region due to exogenous shocks in one or more regions. The rest of this section is organized in three parts. First, there will be a brief discussion of the data sources that will serve as the basis for our analysis. Secondly, the process of estimation is carried out employing different tests, and finally, the impulse response functions will be explored to examine the dynamic trajectory of the regions.

4.1 Regions and Data

Initially, it was hoped that it would be applied this model to the 15 peninsular regions in Spain[11]. However, problems with degrees of freedom (we have evident limitations since the time series extends for only 28 years) and the possibility of a high correlation among the regressors included in the model, suggested that the regional information should be aggregated in order to obtain an operational model. Obviously, the level of aggregation may affect the results; in using more aggregated data, some parts of the influences are missed, since geographical proximity is usually one of the relevant factors in explaining the evolution of the economic processes where different economic units are involved. Aggregation implies longer distances between economic units, and this would imply that some potentially important interrelations at a more disaggregated level may be excluded.

The original Spanish regions were grouped into 6 geographical zones, some of them multi-regional[12]. The criteria by which the aggregations were formed were both geographical and economic. Subsequently, the geographically contiguous regions were aggregated with the purpose of obtaining a well-balanced mixture from an economic point of view, avoiding problems associated with economies that were too large with respect to the other regional economies. In consequence, the system that results has well-balanced regional economic shares, but they have different spatial shares. Under this criterion, the economic concentration of regional areas (measured by *Gross Regional Added Value/Km*^{2} of the region) are different.

Figure 1 shows the original regions and the final aggregation used in our work. The shares of land area and gross value added are shown in Table 1. It is clear that there are some sharp disparities in terms of the way economic activity and land area are related. These spatial disparities form the underlying dynamics that significantly influence regional interaction.

Even though the *GRP* data were disaggregated into 9 sectors, we decided to work with the total gross added value in every region; future work will investigate the influences of the sectoral dynamics in the regional competition patterns.

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[11] Two Spanish regions (Canarias and Baleares) and two Spanish North African cities (Ceuta and Melilla) are not included due to their insular nature: this work does not take into account the regions without geographical connection.

[12] In Márquez and Hewings (2002), and using an alternative approach, 15 Spanish peninsular regions were analyzed and a structure of regional interrelations based on the regional geographical vicinity was a priori assumed.

Figure 1. Regional and Multiregional Zones in Spain.

Table 1. The Regions and their Share of National Totals.

Macro Region	Constituent Regions	% of National Gross Value Added	% of Total Land Area
North-West (NW)	Asturias, Cantabria, Castilla-Léon, Galicia	17.2	28.3
South-West (SW)	Andalucía, Extremadura	16.1	26.2
South-East (SE)	Castilla-La Mancha, Murcia, Valencia	16.5	23.1
North-East (NE)	Aragón, La Rioja, Navarra, País Vasco	13.2	14.3
Cataluña (CAT)		19.6	6.5
Madrid (MAD)		17.4	1.6

Finally, the database of the HISPALINK[13] project (HISPADAT) was employed. The homogeneity and quality of the observed data are guaranteed, as it is shown in Cabrer (2001), where a broad usage of this database is made. Thus, all variables referring to gross added value at market prices in 1995 constant pesetas at the regional levels were obtained from this database that covers the period from 1972 to 1999. However, since there is a one-period lag in the model, the history being analyzed is really that of the 1973-99 period.

As we are concerned about regional interconnection, the geographical distribution of the gross added value (*GAV*) across the Spanish regional system is

[13] For a more detailed information concerning the HISPALINK project, see Pulido and Cabrer (1994) and Cabrer (2001).

the basis of study, and we work with the regional shares of *GAV* within this system. In regional economies, it is usual to work in terms of regional *GAV* divided by labor, or *GAV* divided by population in order to capture the "per capita" dimension (per capita income and/or labor productivity).

Nonetheless, when the emphasis is on the spatial-economic conditions, the use of shares over the whole economy has some advantages, since this approach focuses attention on the connection between every region within a system based on this macro variable. Thus, the way in which the shares are distributed over the regional system provides an indicator that enables us both to operationalize the concept of regional competition and to evaluate the global behavior in a regional economic system. In this sense, the global behavior cannot be analyzed from knowledge of the underlying micro-behavior because, as Batten (2001) argues, a spatial economy is a complex adaptive system.

Figures 2 and 3 indicate respectively the macroeconomic behavior of the 6 regions and the relative shares of every region of the total *GNP* (the sum of the regional gross added values). From Figure 3, note that MAD and CAT, the regions with a clear concentration of economic activity, are increasing their share over time. This might be an indicator of the existence of agglomeration forces that are operating in the system; nevertheless, there is the possibility that other factors also played a role, augmenting or partially offsetting these forces. On the other hand, the less concentrated region (NW) is losing share. Nevertheless, this graphical information does not provide indications of the nature and strength of the inter-regional links; this issue will be addressed in the next section, drawing on the theoretical considerations articulated in Section 2.

4.2 Econometric Estimation

Using the data for the 6 Spanish regions, equations (3)[14] were simultaneously estimated by means of the SUR[15] method, with the South-West region (SW) as numeraire. Even though the North-East region (NE) has the smallest share, we decided to use the South-West region (SW) as the numeraire due to the high volatility of the series w_{SW}. This high volatility can be traced to the strong dependence of the two original regions (Andalucía and Extremadura) on an agricultural sector whose production levels are very dependent upon climate variability.

First, the hypothesis of invariance was tested, that is, the joint significance of the national growth pseudo-elasticities,

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[14] The economic model in (3) was transformed to an econometric model by adding to the system a vector of random errors, $e(t) = \left(e_2(t), e_3(t), \ldots, e_S(t)\right)'$. This vector assumes that $E[e(t)] = 0, E[e(t)e(t)'] = \Sigma \;\; \forall \; t$, where $\Sigma = \{s_{ij}, i, j = 2,3,\ldots,S\}$ is a (S-1)×(S-1) positive definite matrix, $E[e(t)e(t')'] = 0 \;\forall\; t \neq t'$ and $E[e(t) \mid \log GNP(t)] = 0$.

[15] Although the D-S model could have been estimated by means of individual OLS, because the SUR and OLS estimators are equivalent in the present situation, the joint estimation has been realized in order to test subsequently some joint contrasts.

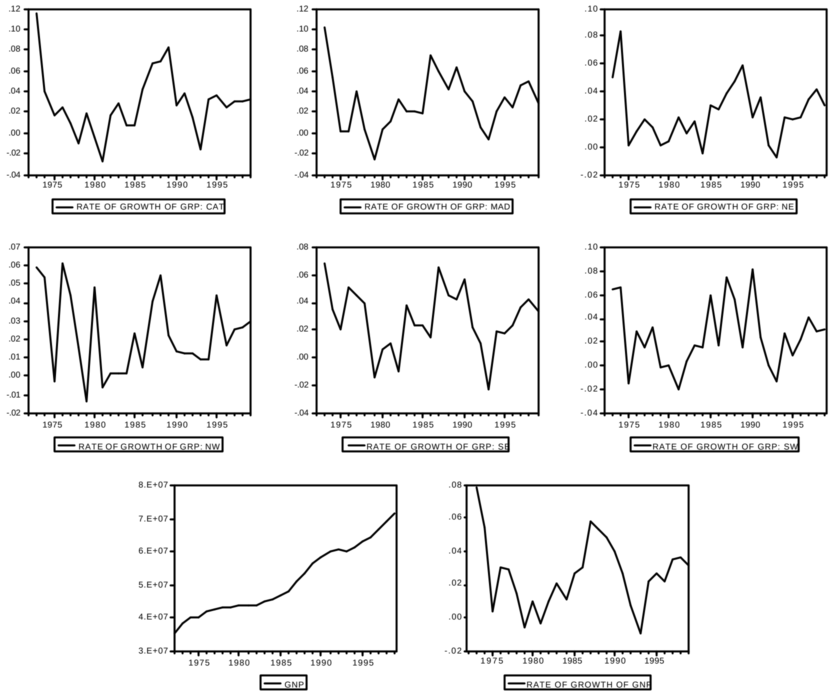

Figure 2. Regional and National Economic Behavior, 1973–1999.

$$H_0 \equiv \left\{ a_{CAT,N} = 0, a_{MAD,N} = 0, \ldots, a_{SE,N} = 0 \right\} \tag{5}$$

In this case, the Wald statistic was $W = 41.59$, with $P = 0.000$. Hence, in our study there is strong evidence in favor of the hypothesis of statistical dependence between $\log F_i(t)$ and $\log GNP(t)$.

Secondly, the joint hypothesis

$$H_0 \equiv \left\{ \sum_k a_{CAT,k} = 0, \sum_k a_{MAD,k} = 0, \ldots, \sum_k a_{SE,k} = 0 \right\} \tag{6}$$

was tested. The result of this test was a Wald statistic for our data of $W = 5.37$, and the associated p value was $P = 0.37$ (the null hypothesis is not rejected). Therefore, and as a consequence of the outcomes of these tests, the preferred model would be the one given by equation (3); that is, the expanded (invariance hypothesis) and restricted (written in terms of the relative variables) D-S model.

Table 2 presents a summary of the results after the estimation of the system given by equation (3) using the SUR method[16]. In Table 3 these results are

[16] Standard diagnostic tests were performed to assure validity of estimation results. Thus, multivariate tests suggested that the null hypothesis of correct specification, normality, absence of serial correlation, homoskedasticity and exogeneity of the variable $\log GNP(t)$

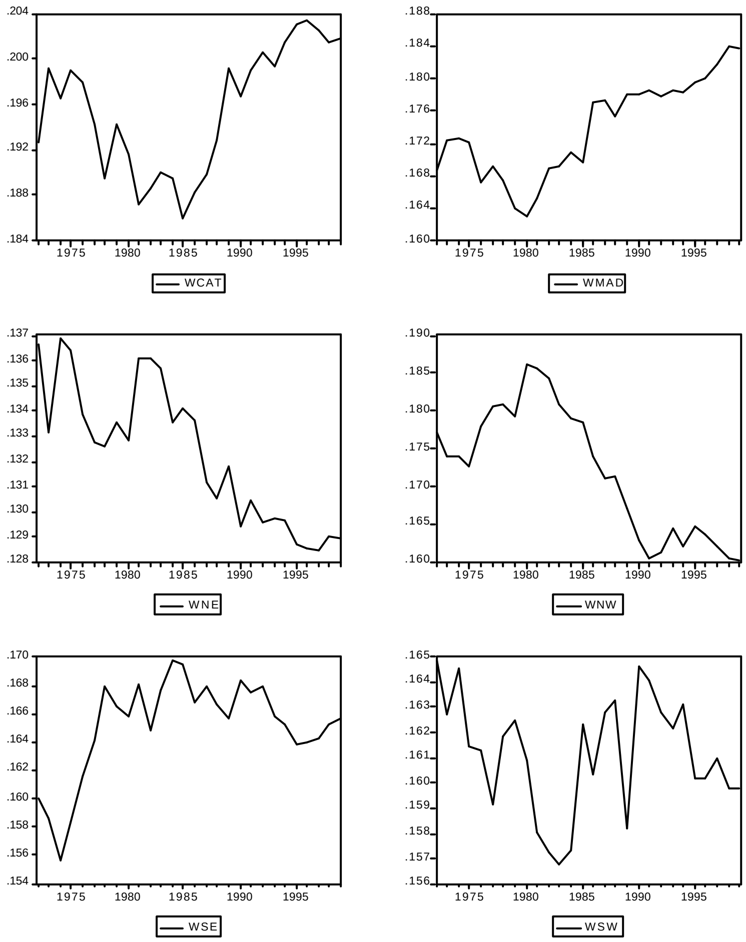

Figure 3. Series of (Macro) Regional Shares.

presented in a qualitative way, showing the sign of every parameter a_{ik} and its significance. The national growth pseudo-elasticities (a_{iN}) are all positive: when the total gross added value increases 1%, the relative shares (with respect to the

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are not rejected. In addition, all the roots of the characteristic equation for the model verify the stability condition (they are smaller than 1 in absolute value), and hence, the estimated model is well behaved. Finally, because structural changes -due to changes in the instrumental economic policy variables such as the political transition in Spain, the creation of regional governments, or the entry into the European Union- could be affecting the stability of the estimates, after the estimation of the system different stability tests were performed and these tests did not rejected the null hypothesis of stability of the parameters.

Table 2. Estimation of the Dendrinos-Sonis (Modified) Model.

Parameter Estimates	Region 1	Region 2	Region 3	Region 4	Region 5
	LWCAT-LWSW	LWMAD-LWSW	LWNE-LWSW	LWNW-LWSW	LWSE-LWSW
LWCAT(-1)-LWSW(-1)	0.151173	-0.469956	-0.123882	0.226293	-0.096444
	(0.15619)	(0.16935)	(0.14881)	(0.18344)	(0.13910)
	[0.96788]	[-2.77502]	[-0.83249]	[1.23361]	[-0.69334]
LWMAD(-1)-LWSW(-1)	-0.618320	-0.020972	-0.489093	-1.070556	-0.625619
	(0.23409)	(0.25382)	(0.22303)	(0.27493)	(0.20848)
	[-2.64134]	[-0.08262]	[-2.19296]	[-3.89389]	[-3.00089]
LWNE(-1)-LWSW(-1)	0.724150	0.791272	0.594749	0.506767	0.628260
	(0.32465)	(0.35201)	(0.30930)	(0.38129)	(0.28912)
	[2.23056]	[2.24790]	[1.92286]	[1.32910]	[2.17297]
LWNW(-1)-LWSW(-1)	0.090237	0.256578	0.473102	0.778179	0.244944
	(0.18298)	(0.19840)	(0.17433)	(0.21490)	(0.16296)
	[0.49315]	[1.29325]	[2.71382]	[3.62110]	[1.50312]
LWSE(-1)-LWSW(-1)	-0.905306	-0.852822	-0.568603	-0.231538	0.216306
	(0.21239)	(0.23029)	(0.20235)	(0.24944)	(0.18915)
	[-4.26247]	[-3.70330]	[-2.80998]	[-0.92822]	[1.14358]
C	-4.874632	-6.140161	-3.052484	-2.312926	-4.050908
	(1.12503)	(1.21982)	(1.07185)	(1.32129)	(1.00192)
	[-4.33291]	[-5.03365]	[-2.84787]	[-1.75050]	[-4.04315]
LGNP	0.295423	0.364426	0.169764	0.138895	0.239094
	(0.06652)	(0.07213)	(0.06338)	(0.07813)	(0.05925)
	[4.44081]	[5.05233]	[2.67849]	[1.77773]	[4.03567]
R-squared	0.782523	0.835234	0.792667	0.926862	0.815337
Sum sq. resids	0.004507	0.005298	0.004091	0.006216	0.003574
S.E. of equation	0.015011	0.016276	0.014302	0.017630	0.013369

Residual Covariance Matrix

	LWCAT-LWSW	LWMAD-LWSW	LWNE-LWSW	LWNW-LWSW	LWSE-LWSW
LWCAT-LWSW	0.000225	9.13E-05	9.37E-05	8.12E-05	4.50E-05
LWMAD-LWSW	9.13E-05	0.000265	0.000117	2.67E-05	1.06E-05
LWNE-LWSW	9.37E-05	0.000117	0.000205	0.000112	5.11E-05
LWNW-LWSW	8.12E-05	2.67E-05	0.000112	0.000311	0.000107
LWSE-LWSW	4.50E-05	1.06E-05	5.11E-05	0.000107	0.000179

Note: Sample (adjusted): 1973-1999 [Included observations: 27 after adjusting endpoints]; Standard errors in ( ) & *t*-statistics in [ ].

region SW) increase. Also, the pseudo-elasticities are statistically different from zero at the 1% level of significance (except in the case of region NW, where the null hypothesis is rejected at the 10% level of significance)[17]. This conclusion indicates that $\log GNP(t)$ is a very important variable when the goal is to explain the ratios $F_i(t)$. When the total gross added value increases 1%, the region that has the higher percentage change in its relative share is MAD, followed by CAT and SE. These regions show the higher sensitivities in relation to the general macroeconomic circumstances; in addition, they are the regions that are sending negative agglomeration effects elsewhere (see table 3) as they capture share from the others regions over time. It is clear that nationwide innovations are favoring the regions with larger economic concentrations.

With respect to the regional growth pseudo-elasticities, a_{ik}, in the first place, a question of interest is to contrast the existence of symmetric interconnections (symmetric interregional spillover effects), that is, the expectation that $a_{ik} = a_{ki}$. If this hypothesis is not rejected, a variation in the relative share of region i (with respect to regional SW) produces over the relative share of region k the same effect that a variation in the relative share of region k over the relative share of region i. As regional economic activity is not equally distributed and symmetry depends on the geographic similarity of economic activity, it was expected asymmetric interregional spillover effects. The Wald statistic for the contrast of this hypothesis [which implies 10 restrictions on model (3) in our application] was $W = 74.33$, with a *P*-value of $P = 0.000$. Thus, the hypothesis about the existence of symmetric interregional spillover effects was rejected (when all regions were considered), although between the regions with higher economic concentration (CAT and MAD) it was not rejected (The Wald statistic was $W = 0.26$, with a *P*-value of $P = 0.61$). Hence, it would appear that symmetry is linked in our system to economic concentration.

Another particularly interesting hypothesis is the significance of the "extra-bordering" interconnection effects, that is, the significance of the higher order (non-contiguous) spatial effects.[18] When contrasting this hypothesis, the full matrix of elasticities [$A_1 = (a_{ik})$] is broken down as the sum of first, second or higher order of spatial interaction matrices plus the autocorrelation diagonal matrix for each region ($A_1 = A_1^1 + A_1^{2+} + A_1^d$); also, the null hypothesis of the parameters included in matrix A_1^{2+} are tested. In our application, this decomposition becomes (see also Figure 1):

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[17] The joint significance hypothesis, $H_0 \equiv \{a_{CAT,N} = 0, a_{MAD,N} = 0, \ldots, a_{SE,N} = 0\}$, was realized, and the Wald statistic was $W = 71.87$, with an associated P-value $P = 0.000$.

[18] This issue would be more important to consider in the case where the number of regions, and thus the number of non-contiguous relations, was much larger.

Table 3. Qualitative Analysis of the Competitive/Complementary Relationships.

(a) Qualitative Relationships

	CAT	MAD	NE	NW	SE	SW	+	-
Region CAT	+	- (**)	+ (**)	+	- (**)	+ (**)	4	2
Region MAD	- (**)	-	+ (**)	+	- (**)	+	3	3
(Macro) Region NE	-	- (**)	+ (**)	+ (*)	- (**)	+	3	3
(Macro) Region NW	+	- (**)	+	+ (**)	-	-	3	3
(Macro) Region SE	-	- (**)	+ (**)	+	+	- (*)	3	3
+	2	0	5	5	1	3		
-	3	5	0	0	4	2		

Note: The parameters for the (macro) region SW has been obtained from the restriction $a_{i1} = -\sum_{k=2}^{S} a_{ik}$ i=2,3,…,S; * indicates significant at 10%, ** indicates significant at 5%.

(b) Qualitative Ordering.

	NE	NW	SW	CAT	SE	MAD
Region CAT	+	+	+	+	-	-
Region MAD	+	+	+	-	-	-
(Macro) Region NE	+	+	+	-	-	-
(Macro) Region NW	+	+	-	+	-	-
(Macro) Region SE	+	+	-	-	+	-

$$\begin{pmatrix} a_{CAT,CAT} & a_{CAT,MAD} & a_{CAT,NE} & a_{CAT,NW} & a_{CAT,SE} \\ a_{MAD,CAT} & a_{MAD,MAD} & a_{MAD,NE} & a_{MAD,NW} & a_{MAD,SE} \\ a_{NE,CAT} & a_{NE,MAD} & a_{NE,NE} & a_{NE,NW} & a_{NE,SE} \\ a_{NW,CAT} & a_{NW,MAD} & a_{NW,NE} & a_{NW,NW} & a_{NW,SE} \\ a_{SE,CAT} & a_{SE,MAD} & a_{SE,NE} & a_{SE,NW} & a_{SE,SE} \end{pmatrix} = \begin{pmatrix} 0 & 0 & a_{CAT,NE} & 0 & a_{CAT,SE} \\ 0 & 0 & 0 & a_{MAD,NW} & a_{MAD,SE} \\ a_{NE,CAT} & 0 & 0 & a_{NE,NW} & a_{NE,SE} \\ 0 & a_{NW,MAD} & a_{NW,NE} & 0 & a_{NW,SE} \\ a_{SE,CAT} & a_{SE,MAD} & a_{SE,NE} & a_{SE,NW} & 0 \end{pmatrix} +$$

$$+ \begin{pmatrix} 0 & a_{CAT,MAD} & 0 & a_{CAT,NW} & 0 \\ a_{MAD,CAT} & 0 & a_{MAD,NE} & 0 & 0 \\ 0 & a_{NE,MAD} & 0 & 0 & 0 \\ a_{NW,CAT} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{pmatrix} + \begin{pmatrix} a_{CAT,CAT} & 0 & 0 & 0 & 0 \\ 0 & a_{MAD,MAD} & 0 & 0 & 0 \\ 0 & 0 & a_{NE,NE} & 0 & 0 \\ 0 & 0 & 0 & a_{NW,NW} & 0 \\ 0 & 0 & 0 & 0 & a_{SE,SE} \end{pmatrix} \quad (7)$$

Contrasting the hypothesis that the parameters of the matrix A_1^{2+} are equal to zero, we obtained a value of $W = 26.26$, with an associated *P*-value of $P = 0.000$. Therefore, the effects of non bordering regions are significant when explaining the behavior of the variable $\log F_i(t)$ in each region[19].

On the other hand, some relevant conclusions can be extracted from the qualitative information shown in Table 3 that reveals the competitive-complementarity pattern in the Spanish regional system. First, the parameters estimated for the autocorrelation diagonal matrix (interregional feedback effects) are all positive (except in the case of MAD, but this parameter is not significant). Secondly, the interregional spillovers effects would suggest that the more competitive regions are MAD, SE and CAT. Therefore, some regions are gaining share in the system by means capturing relative activity from other regions, and what our results show is that the regions that are more concentrated (MAD and CAT) are generating centripetal forces to the rest. This situation is clear in Table 3 (b), where the regions on the right have a negative influence on the others. On the contrary, regions to the left have a positive influence on the others, that is, when they improve their relative shares, other regions obtain also benefit.

4.3 Impulse Responses

Once model (3) parameters are obtained, the impulse response functions associated with unitary shocks are estimated (measured with the standard error of the disturbances $e_i(t)$, *i*=2,...,*S*) in each of the equations of the system. These functions analyze the possible deviations with respect to the expected evolution as a result of an unpredictable shock. The analysis represents a complementary way of dynamic interconnection analysis among the variables $\log F_i(t)$, by examining the individual innovation effects over the whole dynamic system.

If the variance-covariance matrix of the system, $E[e(t)e(t)'] = \Sigma$, is diagonal, there are no problems characterizing the transmission of a shock across the dynamic model (3). Nevertheless, when the errors $e_i(t)$ are contemporaneously correlated, a common component exists among the variables, and this creates an identification problem. The traditional approach in order to solve this problem was suggested by Sims (1980), who proposed a Cholesky decomposition of the matrix Σ, $PP' = \Sigma$, where vector $x(t) = P^{-1}e(t)$ has orthogonal components ($E[x(t)x(t)'] = I_{S-1}$). The problem of this approach is that the orthogonalized shocks ($x(t) = P^{-1}e(t)$) assign all of the common component to only one variable, the first in a natural ordering, and so, a causal ordering for the variables in the VAR is demanded. Accordingly, the results vary

[19] Concerning the significance of the parameters in the matrices A_1^1 and A_1^d, the *W* statistic had values $W = 82.79$ and $W = 19.06$, respectively, with *P*-values given by $P = 0.000$ and $P = 0.002$, so, in both cases the matrices happen to be jointly significant.

with reference to the ordering of the variable in the vector $\log F(t)$ (Lütkepohl, 1991). This is a consequence of the non-uniqueness of the Cholesky factor *P*. This makes it difficult to justify the use of the Sims approach in our application, because there is no theoretical justification that suggests a possible *a priori* ordering (for example, by exogeneity degree) in the variables $\log F_i(t)$.

Recently, Pesaran and Shin (1998) proposed a generalisation of the Sims approach that does not require the orthogonalization of the shocks and it is invariant to the ordering of the variables in the system. Basically, the Pesaran-Shin approach consists of producing a shock in an element of the vector $e(t)$ (and not in all, as in the case of the Sims approach) and to *"integrate out"* the rest of shocks by using either a theoretical distribution or the distribution of the errors in the sample. The result is a unique impulse function that takes into account all the information concerning the historically observed correlation among the different shocks, and that does not depend on the order in which the variables are modeled.

Next, the transmission for the Spanish economy of exogenous shocks from one region to the regional system is reported. We incorporate unexpected impulses in the regions in the form of exogenous shocks in standard deviations of the estimated errors in each of the equations of the VAR model. Through such practice, it will be possible to find out the types of behaviors of the impulse response functions that will serve as basis for a discussion of the role of exogenous shocks to individual regions. Therefore, generalized impulse functions associated with unitary shocks in each of the equations from the model (3) are presented in Figure 4.

Figure 4a shows the individual functions (unbroken line), together with a confidence interval (broken lines) that represent the critical lines of the band of ± 2 standard errors estimated within the 15 years considered in the simulation. Due to the stability of our VAR model, these impulse responses disappear after some years. What our results emphasize is that an exogenous positive shock to a relative regional share in the same region (own shock) has a significant and positive effect in the first period before settling at zero (in the case of NW and SE, the effects in the second period are also significant and positive). Also, it is possible to assess the relative regional responses in shocks to the others relative regional shares.

Combined function graphs are displayed in Figure 4b for a better evaluation of the different innovation effects over each equation. These figures indicate that a positive shock to the relative share of a region always has an initial and positive effect on the other regions' relative shares,[20] although after the first period, different behaviors are shown to diminish to zero. It is worthwhile to highlight that the response of MAD to shocks disappears faster than in the rest of regions. This would suggest that this region has a better sectoral composition to weather the consequences of shocks than is the case for the other regions. In large part, this may be explained by the functions that are located there

[20] This would imply a negative effect in SW (the numeraire).

associated with the capital activities (i.e. relatively high and stable government employment) and, perhaps, a greater degree of self-sufficiency in supply-demand relationships.

Additionally, Figure 5 represents the accumulated response for the same time period (15 years). Now, the stationarity of the VAR model implies that these responses are asymptotically moving to a constant value, positive or negative, although in the short term all the regions are affected positively. Over the long run, the effects of the shocks are negative in 6 cases of the 25 total cases. First, the respective responses to one generalized impulse from the relative share of MAD to the relative shares of NE, NW and SE are all negative. Secondly, SE is the only region that produces negative effects on the relative shares of MAD and CAT (the more concentrated regions). Finally, just like SE, NW produces negative effects to MAD's share. These findings would suggest that an exogenous shock from the MAD region produced by a specific political decision may not produce redistributive outcomes in terms of more homogeneous economic shares over the system. On the contrary, policies applied to the SE and NW regions would do more to stimulate these geographical redistributive purposes. Figure 5 also indicates that the rise in the relative share of CAT or NE would cause positive accumulated responses in all regions. This would have, as a necessary consequence, a negative effect in SW (the numeraire).

5. SUMMARY AND CONCLUSIONS

In this paper, we formulate an empirical model in order to detect and describe the underlying regional economic interconnections in the process of multi-regional dynamic growth, contributing to fill a current vacuum in the literature referring to empirical models that operate in both the temporal and spatial dimensions. It should be emphasized that the model includes equations that are macro-functions, and that no explicit consideration is given to the micro-level foundations of the macro outcomes. Hence, this model does not provide an explanation for the economic mechanisms of regional growth; i.e., the origin of the interregional externalities is not determined, although new tools and insights appear with reference to the study of regional interconnections.

In considering the application to the Spanish regional system (where the regions have similar economic shares, but different geographical concentrations of economic activity), interregional spillover effects, interregional feedback effects and nationwide effects were determined. The estimated dynamic process is the indicator of the pattern of regional competition in the Spanish system. Nationwide innovations are favoring the regions with higher economic concentrations. However, two other findings revealed the existence of significant links between non-contiguous regions while the existence of symmetric interregional spillover effects was rejected.

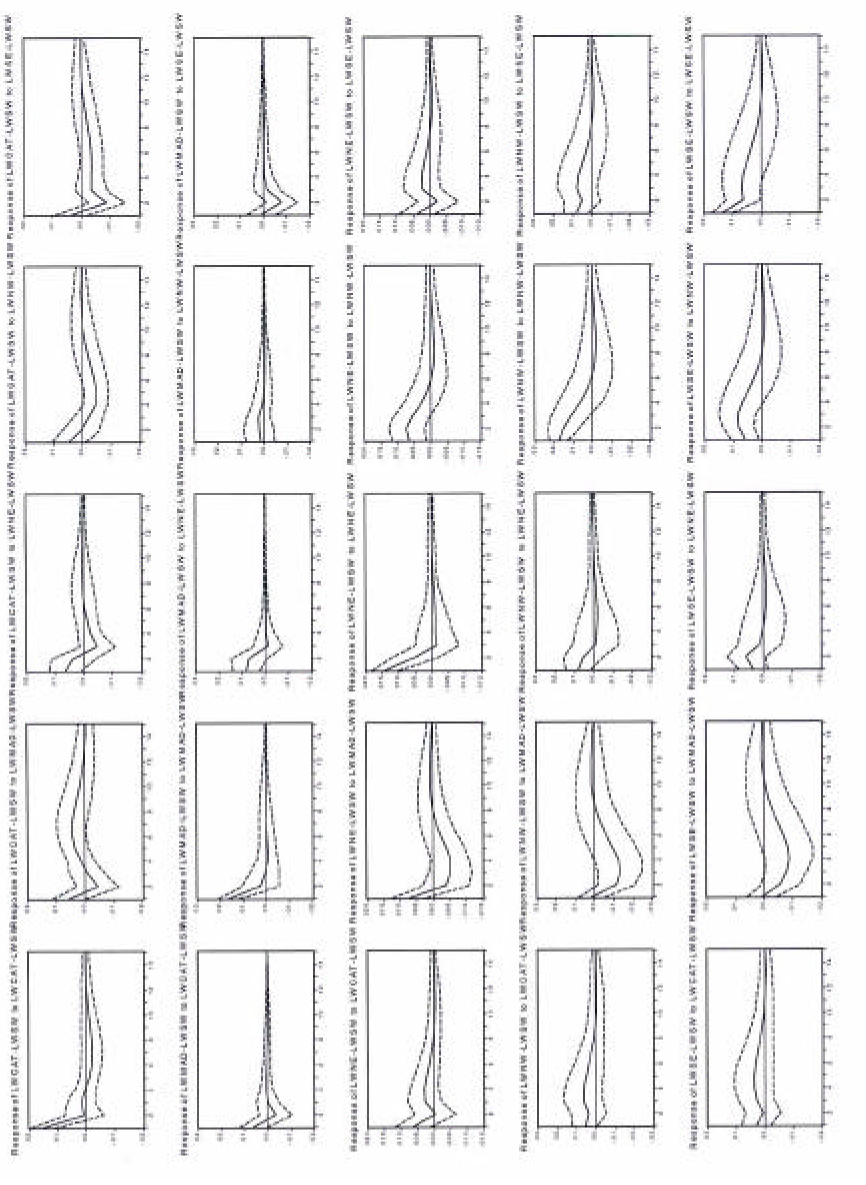

Figure 4. Impulse Response Functions. Individual Response to Generalized One Standard Error Shocks ±2 Standard Errors.

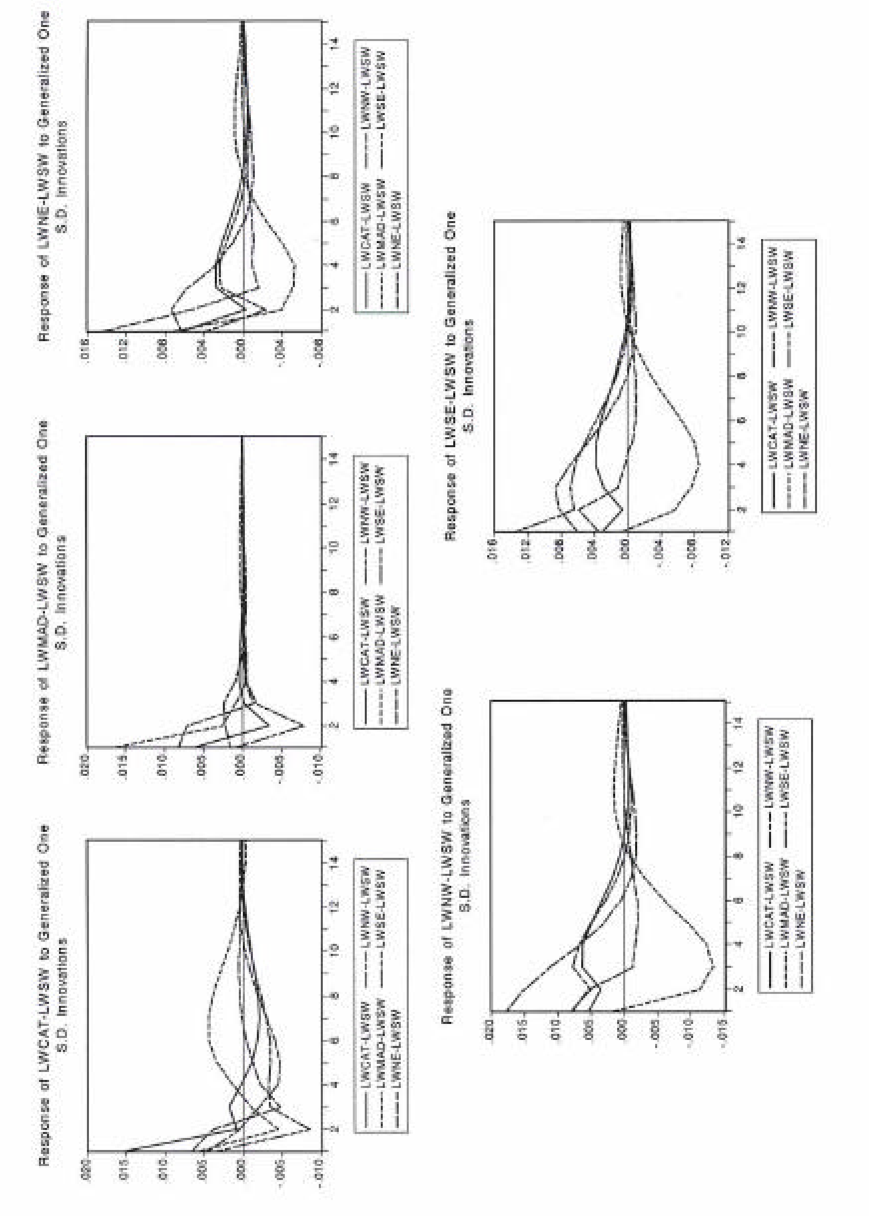

Figure 5. Impulse Response Functions. Response of Each Variable to Generalized One Standard Error Shocks in all Equations.

Some regions dominate the landscape of the distribution of the economic activity. In the Spanish case these are the more competitive regions, MAD, SE and CAT (see Table 3). The dynamic process is cumulative: over time, the regions with higher concentration of economic activity (MAD and CAT) increasing their participation (share) over the whole economy.[21] Hence, economic concentration affects regional competition that in turn will affect economic concentration. These processes could be the basis of the explanation for the persistence of unequal geographical distributions of economic activity. Even though not formally tested, the evidence presented would provide support for the role of agglomeration factors. These are issues that are now being addressed in an attempt to link agglomeration, growth and core-periphery dynamics; however, as Thisse and Fujita (2002), two authors at the forefront of this inquiry, have noted “Clearly, space and time are intrinsically mixed in the process of economic development. Because either agglomeration of growth is a complex phenomena by itself, one should expect any integrated analysis to face many conceptual and analytical hurdles.”

One conclusion we draw from our empirical study is that regional economies that have more economic concentration tend to grow more rapidly than those that have less economic concentration. As expected in this type of dynamic process (Maier, 2000), the agglomeration effects (in the form of dynamic externalities) drive the trajectory of the Spanish multi-regional growth, constituting the forces that fix the “game rules,” and limiting and obstructing the emergence of another hypothetical new pattern. Findings would suggest that there are not forces working to equilibrate regional concentrations. In consequence, the “winner-loser” structure is maintained.

Finally, we studied the effects of exogenous shocks to the evolution of the Spanish multi-regional system. Using generalized impulse response functions, empirical evidence was revealed about the effects from a shock to one regional economy on the evolution of the regional economies in the system. Even though this implementation is a-theoretical, since its basis is statistical, the model allows us to simulate the impacts of one (hypothetical) unit of exogenous innovation. Some suggestions may be drawn from the results of our empirical exercise. As exogenous initiatives would have short-term effects over a region, this type of recommendations would serve as a complement and support of long term (endogenous) initiatives with the main goal of developing a well-balanced geographical redistribution in the economic activity. Impulse response analysis confirms that exogenous innovations applied to the SE and NW regions are the best options for most of the economic initiatives with redistributive purposes directed to the multi-regional system. In summary, policymakers should consider these facts when they are intending to bring the spatial distribution of the national income into some equity-based equilibrium since it would appear that these spatial disparities are likely to persist.

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[21] The role of “cumulative causation” (Krugman, 1995) could be reinforcing the spatial distribution in this regional system.

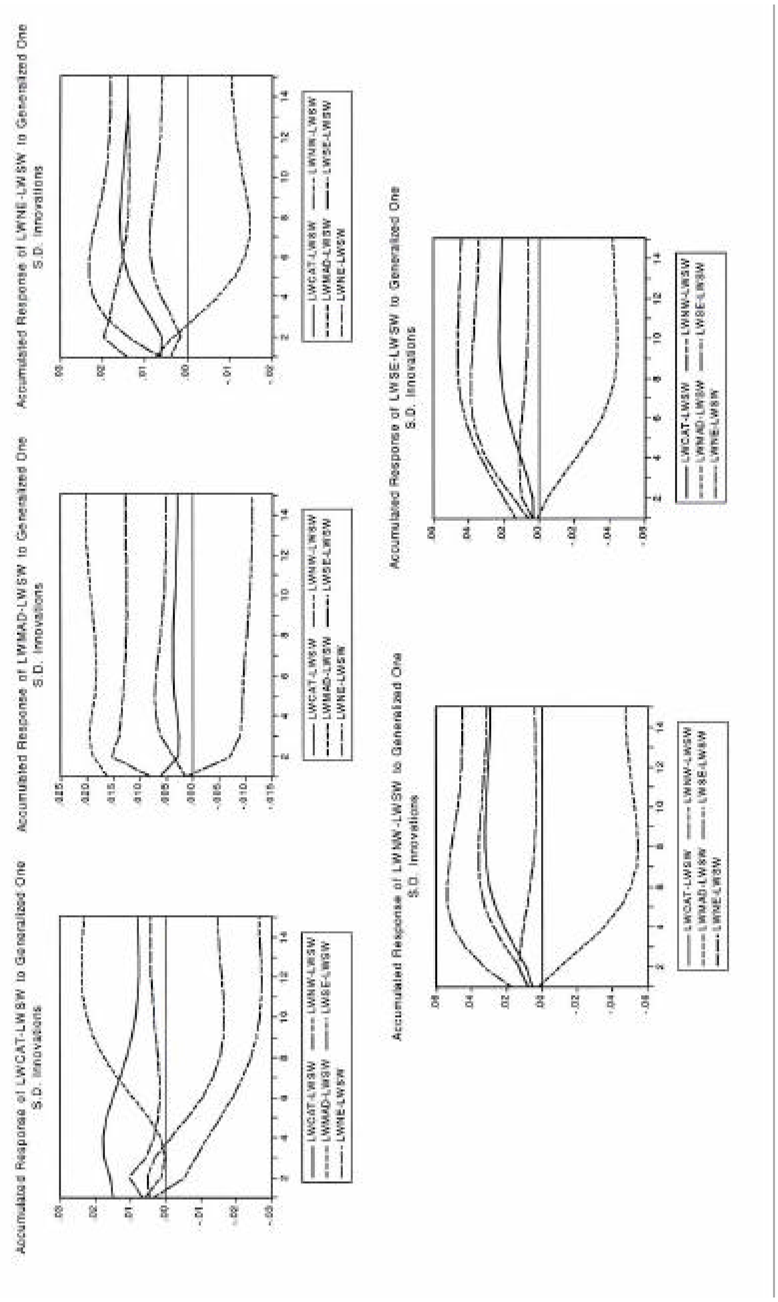

Figure 6. Accumulated Response of Each Variable to Generalized One Standard Error Shocks in all Equations.

The most important finding of this paper, although only shown for a multi-regional economic system, is that spatial structure and the concentration of economic activity have fundamental implications on the evolution of the multi-regional system. The task consists of carrying out a determination of the driving economic fundamentals in the dynamic interconnections. To do this, adequate data would be necessary to empirically verify the theoretical models that describe the underlying processes in economic growth (in the line of Barro and Sala i Martin, 1995, and Temple, 1995). Further insights may also be gleaned from a disaggregation of GAV into sectoral components so that both interregional and intersectoral effects can be considered simultaneously.

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