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Is spatial dependence an instantaneous effect? Some evidence in economic series of Spanish provinces(*)

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ABSTRACT

The purpose of this article is to analyze if spatial dependence is a synchronic effect, as it has usually been defined. It is known that in many socio-economic phenomena spatial dependence can be not only contemporary but also time-lagged. In this paper, we use two Moran-based space-time autocorrelation statistics in order to evaluate the simultaneity of this spatial effect, allowing for mixed specifications with instantaneous and space-time dependence terms. Some applications with economic data for Spanish provinces shed some light upon these issues.

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Key words: Space-time dependence, Spatial autoregressive models, Moran's *I*, Spanish provinces.

JEL Classification: C15, C21, C51.

1. INTRODUCTION

The purpose of this article is to analyze the time-trend of spatial dependence, making a differentiation between two types of spatial dependence: contemporary or instantaneous and non-contemporary or serially lagged. The first type is the consequence of a very quick interaction of the process over the neighboring locations, while the second implies that a shock in a certain location needs some time to extend over its neighborhood. It is not easy to separate these types of spatial dependence but both are present very frequently and should be considered when specifying a spatial autoregressive model.

Spatial dependence has usually been defined as a spatial effect, which is related to the spatial interaction existing between geographic locations that *takes place in a particular moment of time*. When spatial interaction, spatial spillovers or spatial hierarchies produce spatial dependence in the endogenous variable of a regression model, the spatial autoregressive model has been frequently mentioned as the solution in the literature (e.g. Florax *et al.* 2003). Analogous to the Box-Jenkins approach in the time-series analysis, spatial model specifications consider autoregressive processes. Particularly, in the first-order spatial autoregressive model, SAR(1), a variable is a function of its spatial lag (a weighted average of the value of this variable in the neighboring locations) for *a same moment of time*.

However, in most socio-economic phenomena, this coincidence in value-locations is not only a synchronic coincidence but also a final effect of some cause that happened in the past, one that has spread through geographic space during a certain period. In this sense, there are some authors that have considered this pure simultaneity of spatial dependence as problematic (Upton and Fingleton 1985, pp 369), suggesting the introduction of a time-lagged spatial dependence term. Moreover, Cressie (1993, pp 450) proposes a generalization of the STARIMA models presented in Martin and Oeppen (1975) and Pfeifer and Deutsch (1980), among others, such that they also include not only time-lagged but also "instantaneous spatial dependence".

Recently, there are several contributions to this subject. For example, Elhorst (2001, 2003) presented several single equation models that include a wide range of substantive non-contemporary spatial dependence lags, not only in the endogenous but also in the exogenous variables. Anselin *et al.* (2006) present a brief taxonomy for panel data models with different kind of spatial dependence structure for the endogenous variable (space, time and space-time), referring to them as pure space-recursive, time-space recursive, time-space simultaneous and time-space dynamic models.

Space-time dependence has also been specified in spatial autoregressive models in either theoretical frameworks (Baltagi *et al.* 2003; Pace *et al.* 1998, 2000) or panel data applications (Case 1991; Yilmaz *et al.* 2002; Baltagi and Li 2003; Mobley 2003; Chasco and López 2004).

Similarly as in Pace *et al.* (1998, 2000), it is our aim to identify different components in the spatial lag term splitting it into instantaneous and time-lagged spatial dependence. That is to say, when spatial dependence is identified (e.g. with typical statistics as Moran's *I*), is it the consequence of a very quick diffusion that completely occur during the same moment of time? Otherwise, is there any part of this spatial effect that needs more than one period to take place?

Therefore, we propose the identification and use –if necessary- of the space-time lagged endogenous variable in a SAR(1) framework, since it reflects the effects due to spatial interaction as a spatial diffusion phenomena, which is not only “horizontal” but also time-wise. For this purpose, we present two space-time Moran-based statistics in order to identify the existence of not only instantaneous but also serially lagged spatial dependence. In addition, we illustrate the performance of these statistics with some examples for Spanish regional statistics.

The remainder of paper is organized as follows. In the next section, we derive two Moran-based autocorrelation statistics to evaluate the simultaneity of the spatial lag in the spatial autoregressive model. These tests allow identifying a potential time-lagged spatial component in the spatial lag term. In section 3, we illustrate the performance of the tests with some examples for economic series of Spanish provinces in the period 2000-2005. Some summary conclusions and references complete the paper.

2. MORAN SPACE-TIME STATISTICS FOR THE EVALUATION OF SPATIAL DEPENDENCE IN THE FIRST-ORDER SPATIAL AUTOREGRESSIVE MODEL

The first-order spatial autoregressive model, SAR(1) or simultaneous model, dates back to the work of Whittle (1954). In matrix notation, it takes the form:

$$\begin{aligned} & z = pWz + \varepsilon \\ & \varepsilon n N\left(0, \sigma^2 I_n\right) \end{aligned} \qquad [1]$$

where $z = \left[y - \overline{y}\right] / \sigma_y$ is a n by 1 vector of observations (variable vector *y* is expressed in deviations from the means form to eliminate the constant term in the model); W is the spatial weight matrix; ρ is the spatial autoregressive coefficient; and ε is a n by 1 vector of random error terms. W is the familiar spatial weight matrix that defines the neighborhood interactions existent in a spatial sample (Cliff and Ord 1981). In this context, the usual row-standardized form of the spatial weights matrix can be used, yielding an interpretation of the spatial lag (Wz) as an "average" of neighboring values.

The spatial term, Wz, is a way to assess the degree of spatial dependence of z (from now on, it is denoted as Wz_t). Nevertheless, in most socio-economic phenomena, the relationship between z_t and Wz_t is not only synchronic but also a final effect of some cause that happened in the past (Wz_{t-k}; k =1,2, …). Consequently, before estimating a SAR(1) model, we should identify correctly the form of the spatial effect, Wz_t, in this model.

In this section, we present two Moran-based statistics that are useful to detect the existence of time-lagged spatial dependence. First, we briefly present the space-time Moran's *I* statistic (STI), which evaluates spatial dependence in two instants of time. Secondly, we present a partial space-time Moran's function: the partial instantaneous Moran's *I* (PII). Our goal is to contribute towards obtaining appropriate indicators to evaluate the need of adding a temporal structure to the spatial lag term in the SAR(1) model(1).

2.1 A Moran space-time autocorrelation statistic

When considering both space-time dimensions, some Moran-based statistics can be defined to analyze and visualize the space-time structure of a distribution (Anselin *et al*. 2002). This is the case of the **space-time Moran's *I*** (STI). This instrument is similar to others already proposed in the literature (e.g. Cliff and Ord 1981, pp. 23)(2).

(1) In López and Chasco (2007), we evaluate empirically the Moran space-time autocorrelation statistics in a series of Monte Carlo simulation in order to obtain an initial assessment of their discriminating power of spatial dependence into instant and/or time-lagged. Specifically, we build three data generating processes based on different spatial dependence structures: only instant, only time-lagged and both instant and time-lagged. In the primary two cases, this experiment clearly revealed the good performance of the Moran's tests, mainly in processes with strong spatial autocorrelation (instant and/or time-lagged) and weaker temporal correlation. Nevertheless, in the extreme case of (nearly) null spatial autocorrelation and (nearly) perfect temporal correlation, it is very difficult to split both kind of spatial dependence, since there is a practical identification between the process in both –past and present- periods.

(2) The bivariate spatial correlation was previously proposed in a seminal paper by Wartenberg (1995), also cited in Anselin et al (2002). When a same variable is consider in two different moments, the bivariate Moran's *I* coincides with STI.

The STI is an extension of Moran's *I*. It computes the relationship between the spatial lag, Wz_t, at time t and the original variable, z, at time t – k (*k* is the order of the time lag). Therefore, this statistic quantifies the influence that a change in a spatial variable z, that operated in the past (t – k) in an individual location i (z_{t-k}) exerts over its neighborhood at present (Wz_t). Hence, it is possible to define it as follows:

$$STI = \frac{z_{t-k}' W z_t}{z_{t-k}' z_{t-k}} \qquad [2]$$

where the denominator can be substituted by *n* as this variable z is also standardized. The value adopted by this index corresponds with the slope in the regression line of Wz_t on z_{t-k}. Note that for k = 0, this statistic coincides with the familiar univariate Moran's *I*.

The significance of this statistic can be assessed in the usual fashion by means of a randomization (or permutation) approach. In this case, the observed values for a variable are randomly reallocated and the statistic is recomputed for each such random pattern.

Consequently, the space-time Moran's *I* function is the result of plotting all the values of the STI statistic, adopted by a variable *z* in time t, for different time lags k. The first value corresponds to the contemporary case, k = 0 which is the univariate Moran's *I*, whereas the other ones are proper space-time Moran's *I* coefficients (STI). This function is a particular case of the "full" space-time autocorrelation function (Pfeifer and Deutsch 1980, Bennett 1979), which is a 3-D plot that includes the correlation coefficients for all the space and time lags of a distribution.

If STI function is significant for the first k-values (e.g. $k = 0,1,2,3$), it is a proof of the existence of spatial dependence: contemporary and non-contemporary. We wonder if there any time lag for which both spatial dependence components are jointly significant, e.g. this spatial effect can be decomposed into two moments of time. We will ask this question with the help of a partial statistic.

2.2 A Moran space-time partial autocorrelation statistic

There is no doubt that the spatial dependence measures that have been presented include different sources of dependence that are difficult to separate.

$$Cov(z_{it}, z_{js}) \neq 0 \qquad [3]$$

where sub-indexes i, j are different spatial locations and t, s are different instants of time.

Therefore, we consider the following types of dependencies:

(a) There is a dependence in expression [3] that is the result of time evolution:

$$Cov(z_{it}, z_{js}) \neq 0 \quad ; \quad \forall i = j \qquad [4]$$

This expression affirms that (for s = t – k) the value of the z variable in period *t* is more or less related to t – k. This assertion is more correct for lower values of k.

(b) There is a dependence in expression [3] that is the result of spatial interactions:

$$Cov(z_{it}, z_{js}) \neq 0 \quad ; \quad \forall t = s \qquad [5]$$

This second type of dependence –spatial dependence– can be produced by two sources:

(b1) Instantaneous spatial dependence constitutes the usual definition of spatial dependence in the literature and it is the consequence of very rapid, spatial diffusion of a phenomenon in geographic space. It can also be connected to a lack of concordance between a spatial observation and the region in which the phenomenon is analyzed.

(b2) Time-lagged spatial dependence is the result of a slower diffusion of a phenomenon towards the surrounding space. This kind of dependence is due to the usual interchange flows existing between neighboring areas, which requires of a certain time to be tested.

Although it is very difficult to divide spatial dependence into its two dimensions, it is worth trying to compute them separately in order to correctly specify a spatial process that exhibits spatial dependence. One of the aims of this article is to show two Moran-based statistics that allow justifying the inclusion of both kind of spatial lags, contemporary (Wz_t) and time-lagged (Wz_{t-k}), to explain z_t in a SAR(1).

Since the space-time Moran's *I* (STI) –equation [2]– equals to the slope of the regression of Wz_{t-k} on z_t, it is possible to connect this statistic with the standard Pearson correlation coefficient between these two variables, as also derived by Lee (2001). Therefore, we can express the STI statistic as:

$$STI = r_{z_{t-k}, wz_t} \sqrt{Var(Wz_t)} \qquad [6]$$

where r_{z_{t-k}, wz_t} is the Pearson linear correlation coefficient between z_{t-k} and Wz_t.

The basic underlying idea consists of eliminating the influence of one of the dimensions in order to compute separately contemporary and non-contemporary spatial dependence. For this purpose, if we substitute in [6] the space-time correlation coefficient by a partial correlation one, we can define a space-time partial autocorrelation statistic: the **partial instantaneous Moran's *I* (PII)**. It consists of computing synchronic spatial dependence after removing the influence of time-lagged spatial dependence by means of an index:

$$PII = Corr(z_t, Wz_t \mid z_{t-k}) \sqrt{Var(Wz_t)}\ ;\ k = 1, 2, ..., t-1 \qquad [7]$$

where $Corr(z_t, Wz_t / z_{t-k})$ is the partial correlation coefficient of variables z_t and Wz_t after eliminating the correlation from z_{t-k}.

When dealing with normal distributions, the inference of the common partial correlation coefficient can be applied to the PII, as it is the result of multiplying the former by a constant. In case of non-normality, a permutation approach can be the solution to calculate the moments.

This indicator computes the influence of synchronic spatial dependence (relation between variables z_t and Wz_t), once controlling for time-lagged dependence (z_{t-k}). If no spatial dependence is present in a phenomenon, the PII values will be all close to zero, whereas significantly non-zero PII's point out the strength of instantaneous spatial dependence in spite of the influence of serially lagged one.

Both space-time Moran's *I* values can be of help to identify a time-lagged spatial dependence component in the spatial lag term of a SAR(1). In effect, we can distinguish two main situations in a variable: no spatial dependence and –at least instantaneous– spatial dependence.

a) No spatial dependence: when for the first k-values (e.g. k = 0,1,2,3), both STI and PII's values are close to zero, e.g. non-significant.

b) Spatial dependence: when for the first *k*-values (e.g. k = 0,1,2,3), both STI and PII's values are significantly different from zero. At this point, we want to know if spatial dependence is only synchronic –as it is usually expressed in spatial econometrics– or also serially lagged.

b.1) When STI and PII statistics are significant in a certain time-lag k (using the regular inference process), we can expect –for this variable– the existence of not only instantaneous spatial dependence but also a k^{th} order time-lagged one (particularly if $PII \geq STI$). In this case, not only present but also past values of variable *z* can completely explain its present spatial lag. Therefore, we could capture spatial dependence in an endogenous variable z_t specifying both a contemporary and a non-contemporary spatial lag of $z\left(Wz_t, Wz_{t-k}\right)$ as explanatory variables in the model.

$$z_t = \rho_1 Wz_t + \rho_2 Wz_{t-k} + \varepsilon_t \qquad [8]$$

where ρ_1, ρ_2 are spatial parameters to estimate. This model is the mixed regressive-spatial autoregressive model or a spatial lag model that includes as explanatory not only the spatial-lagged endogenous variable (Wz_t) –as in (1) - but also a true exogenous variable (Wz_{t-k}).

b.2) If there is no time lag for which PII is significant jointly with STI, it will be a proof of the existence of only contemporary spatial dependence. That is to say, it is not possible to separate from instantaneous spatial dependence a serially lagged component. In this case, spatial dependence takes place in a quicker process, mainly during a same period. Therefore, we could capture spatial dependence in the common fashion, introducing an instantaneous spatial lag of *z* (Wz_t) as an explanatory variable in the model.

$$z_t = \rho Wz_t + \varepsilon_t \qquad [9]$$

where ρ is the spatial parameter. This model is the spatial autoregressive model or spatial lag model.

3. SOME EMPIRICAL EVIDENCE

Now, we test the simultaneity of spatial dependence in some socio-economic variables. For each one, we have collected a panel space-time data of 50 Spanish provinces by 4 periods. They have been defined in growth rates as follows:

- *Housing price* is the appraisal housing average price per square meter of province capitals and municipalities above 100,000 inhabitants. In the case of provinces with more than one city, the aggregate price has been computed as the average price in euros weighted by each involved municipality population. The data is computed in growth rates for the period 2000-2004. This variable was published by the *Ministerio de Fomento*(3).

- *Broadband lines* is the number of RDSI and ADSL telephone lines provided by Telefonica S.A. The data are computed in growth rates of lines per capita for the period 2000-2005.

(3) The *Ministerio de Fomento* published these data in *Precio medio del metro cuadrado de las viviendas*. Since 2005, new series are available from the *Ministerio de la Vivienda* website (http://www.mviv.es).

• *Foreign residents* is the number of residents born abroad as a proportion of total population. This variable is available in the *Padrón de Habitantes* of the Spanish Office for Statistics (INE). The data are computed in growth rates for 2001-2005.

• *GDP* is the Gross Domestic Product per capita provided by INE in the *Contabilidad Regional de España*. The data are computed in growth rates for the period 2000-2004.

Information on the distributions of these variables across the Spanish provinces during the 4 periods is given in Table 1, which displays a typical five-number summary for each variable showing the minimum and maximum values across the 50 provinces during the 5 periods, the median and the lower and upper quartiles. *Foreign residents* is the variable that exhibits larger differences across provinces, particularly in the first period: this is due to the regularization process tackled during 2000 for a better accounting of foreign population. The variable broadband lines also shows a spread distribution in the second period (2002-03) coinciding with a rapid implementation of this new technology in Spanish homes. On the other hand, per capita GDP is the less-ranged variable, with average growth rates about 5-6% during the four periods.

Table 1

DESCRIPTIVE STATISTICS OF THE PROVINCIAL SERIES IN GROWTH RATES

Periods	*Stats*	*Housing price per square meter*	*Broadband telephone lines*	*Foreign residents*	*GDP per capita*
	Min	4.0	20.1	-84.3	2.5
	Q1	9.8	26.5	-26.5	4.7
1	Median	11.9	30.7	27.7	6.3
	Q3	14.2	35.1	167.0	7.4
	Max	20.1	43.3	691.7	10.1
	Min	5.3	75.7	5.9	2.0
	Q1	8.7	96.9	18.9	4.5
2	Median	12.3	112.4	23.3	5.9
	Q3	15.1	128.8	31.9	7.3
	Max	21.3	146.6	56.0	11.3
	Min	3.5	26.2	2.1	1.8
	Q1	9.0	35.4	8.6	4.2
3	Median	11.4	39.1	13.7	5.4
	Q3	14.3	43.1	17.6	6.5
	Max	25.1	54.9	28.9	12.6
	Min	4.2	20.3	5.7	2.7
	Q1	10.8	28.8	15.4	5.5
4	Median	14.2	35.1	19.2	6.4
	Q3	17.6	38.7	22.3	7.2
	Max	28.9	51.3	35.1	8,0

Note: For broadband lines, period 1 is 2001-02, 2 is 2002-03, 3 is 2003-04 and 4 is 2004-05. For the rest of the variables, period 1 is 2000-01, 2 is 2001-02, 3 is 2002-03 and 4 is 2003-04. Refer to text for full definitions of variables.

In order to test if spatial dependence is contemporary or also serially lagged, first we check the significance of spatial dependence by means of the classical Moran's *I* test, which coincides with the STI value for k = 0 as stated in equation [2]. These values and their corresponding significance levels (p-values) are shown in Figure 1.

For the computation of the spatial lag we have consider W as a row-standardized contiguity matrix; e.g. two provinces are neighbors if they share a common border. We have calculated these statistics in GeoDa software (Anselin, 2005). Inference has been computed with permutation approach (999 permutations)(4). All the Moran's *I* values are very significant, over 99% for rejecting the null of no spatial autocorrelation. Therefore, we can conclude that the variables exhibit strong instantaneous (k = 0) spatial autocorrelation.

The question is analyzing if besides contemporaneous spatial dependence we can also find a significant serially lagged component. Therefore, we wonder if spatial dependence is the effect of a very quick interaction of each variable over the neighboring locations or if it is also caused by something that happened in the past. For this purpose, the space-time Moran's *I* coefficients can shed light: if both are significant (particularly if $PII \geq STI$) for a certain time-lag k, then there will be not only instantaneous but also a k^{th} order time-lagged spatial dependence. We have computed and represented the test values in Figure 1 for four –annual- time-lags.

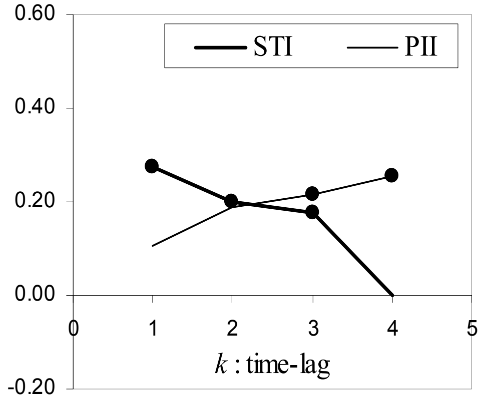
Figura 1

SPACE-TIME MORAN'S *I* STATISTICS OF SOME PROVINCIAL INDICATORS

(Continues)

Housing price growth rate (2000-2004):

k	STI	p-val	PII	p-val
0	0.390	0.00	-	-
1	0.275	0.00	0.107	0.60
2	0.201	0.01	0.187	0.14
3	0.176	0.04	0.215	0.03
4	0.001	1.00	0.256	0.00



Note: Significant values are highlighted with black circles in the graphs

(4) The significance level of the statistics have been computed with the Moran's *I* permutation approach. In this, the observed values for one of the variables are randomly reallocated and the statistic is recomputed for each such random pattern. The resulting empirical reference distribution provides a way to quantify how "extreme" the observed statistic is relative to what its distribution would be under spatial randomness. This should not be interpreted as a probability in the traditional sense, but is a so-called pseudo-significance level (Anselin et al, 2002).

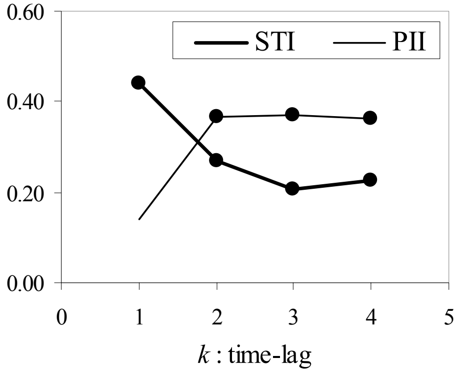
Figura 1

SPACE-TIME MORAN'S *I* STATISTICS OF SOME PROVINCIAL INDICATORS

(Conclusion)

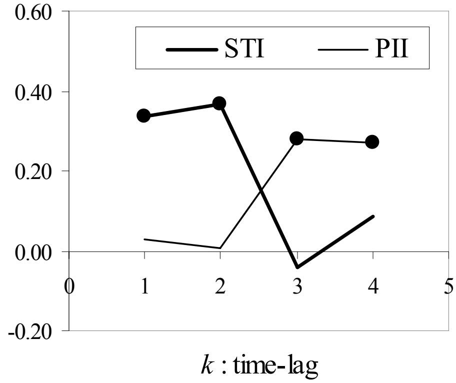
Broadband lines growth rate (2000-04):

k	STI	p-val	PII	p-val
0	0.406	0.00	-	-
1	0.442	0.00	0.140	0.11
2	0.267	0.00	0.366	0.00
3	0.207	0.01	0.372	0.00
4	0.224	0.01	0.364	0.00



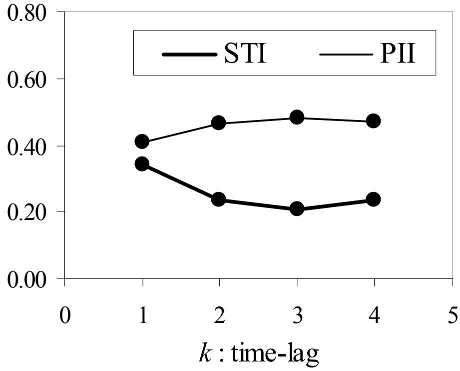
Foreign residents growth rate (2001-05):

k	STI	p-val	PII	p-val
0	0.282	0.01	-	-
1	0.337	0.00	0.030	0.74
2	0.367	0.00	0.007	0.94
3	-0.042	0.59	0.277	0.00
4	0.086	0.30	0.269	0.00



GDP per capita growth rate (2000-2004):

k	STI	p-val	PII	p-val
0	0.494	0.00	-	-
1	0.340	0.00	0.408	0.00
2	0.237	0.00	0.462	0.00
3	0.209	0.01	0.481	0.00
4	0.235	0.00	0.468	0.00



Note: Significant values are highlighted with black circles in the graphs a). Housing price growth rate (2000-2004): the PII coefficient shows significant values for time lags 3 and 4, but only for the third one (k = 3), STI is also significant though not very strongly ($PII \geq STI$). At this moment, instantaneous spatial dependence remains significant in spite of the influence of serial dependence. Hence, housing price growth rate in a province during 2004 clearly depended on some effects taken place in neighboring provinces not only during this same period (instantaneous spatial dependence), but also 3 years ago (in 2001).

b). Broadband lines growth rate (2000-2004): both STI and PII tests are clearly significant from the second time lag (k = 2) and ($PII \geq STI$). Therefore, broadband lines growth rate in the Spanish provinces during 2004 is caused by shocks happened in their neighboring provinces during this not only same period but also –at least- two years ago(5).

c). Foreign residents growth rate (2001-2005): in this case, the PII statistic is only significant in time lags first and second, whereas STI coefficient is not. This means that it is not possible of splitting a time-lagged component from instantaneous spatial dependence in this variable. Consequently, foreign residents growth rate in a province during 2005 is a quick result of some effects that took place in neighboring provinces only during the same period.

d). GDP per capita growth rate (2000-2004): STI and PII are significant for all the time lags, being $PII \geq STI$. As a result, it is possible to split spatial dependence into instantaneous and time–lagged from k = 1 to the end of the period. Then, GDP per capita growth rate of a province in 2004 depended of growth rates of neighboring provinces during this year and –at least- one period before.

Consequently, these tests shed light upon the speed of diffusion of a phenomenon. For instance, we can order these four variables from faster diffusion speed (or only instantaneous spatial dependence), as in the case of foreign residents growth rate, to slower speed (contemporaneous and non-contemporaneous spatial dependence), in the rest of the variables.

Finally, we can test these conclusions estimating the mixed regressive-spatial autoregressive model for all the variables and time lags. In Table 2, we have presented the results for the complete set of specifications. It is easy to check that the only possibilities of splitting spatial dependence into instantaneous and serially lagged takes place in the same cases pointed out by the space-time Moran's coefficients: housing price,

(5) When there are more than one time lags with significant STI and PII tests, the first one is expected to be the best, since time-lagged spatial dependence term works here as an AR(1) – which is the commonest specification for autocorrelation in time series -with respect to the endogenous variable.

broadband lines and GDP per capita. In the case of foreign residents, instantaneous spatial dependence (variable Wz_t) has not significant coefficients in any regression jointly with either of the time-lagged ones (Wz_{t-1}, Wz_{t-2}, Wz_{t-3}, Wz_{t-4}); i.e., there is no time lag for which spatial dependence can be divided.

Table 2

REGRESSION RESULTS OF THE SAR (1) MODELS

Variables		House price		Broad-band lines		Foreign residents		GDP per capita	
Equation		Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
1	Wz_t	0.075	0.68	0.087	0.62	0.443	0.69	0.443	0.00
	Wz_{t-1}	0.650	0.00	0.993	0.00	0.493	0.00	0.493	0.01
2	Wz_t	0.214	0.23	0.561	0.00	0.526	0.86	0.526	0.00
	Wz_{t-2}	0.457	0.05	0.408	0.03	0.410	0.00	0.410	0.07
3	Wz_t	0.301	0.08	0.582	0.00	0.509	0.00	0.509	0.00
	Wz_{t-3}	0.343	0.09	0.264	0.21	0.667	0.88	0.667	0.01
4	Wz_t	0.407	0.01	0.407	0.00	0.522	0.00	0.522	0.00
	Wz_{t-4}	0.179	0.50	0.179	0.20	0.399	0.94	0.399	0.05

Note: z_t is the endogenous variable. t = 2004, except in foreign residents, in which t = 2005. Wz_t is the instantaneous spatial dependence term. Wz_{t-1}, Wz_{t-2}, Wz_{t-3}, Wz_{t-4} are the time-lagged spatial dependence terms. coeff are the maximum-likelihood estimates. p-*value* is the lower significance level of rejecting the null hypothesis. In grey, the selected models.

Therefore, in the case of housing price, broadband lines and GDP per capita, it is possible to identify a time-lagged effect in spatial dependence and compare it with instantaneous spatial dependence. In effect, the regression results are the following:

a) Housing price growth rate, i = 1,….,50 provinces ; t = 2004:

$$\hat{z}_{i,t} = 0.301 Wz_{i,t} + 0.343 Wz_{i,t-3} \qquad [10]$$

b) Broadband lines growth rate i = 1,….,50 provinces ; t = 2005:

$$\hat{z}_{i,t} = 0.561 Wz_{i,t} + 0.408 Wz_{i,t-2} \qquad [11]$$

c) Broadband lines growth rate, i = 1,….,50 provinces ; t = 2005:

$$\hat{z}_{i,t} = 0.443\,Wz_{i,t} + 0.493Wz_{i,t-3} \qquad [12]$$

In the selected regressions, both components have similar coefficients; i.e. both spatial effects, contemporaneous and non-contemporaneous, have more or less the same influence on each spatial unit. Only in the case of broadband lines, instantaneous spatial dependence is significantly higher than time-lagged (more or less a 58% of "total" spatial dependence, whereas in the other two regressions, it reaches a 47%). That is to say, the dynamism of this variable in a province is affected by its dynamism in neighboring provinces during either the same period or two years ago, although present effects are a bit higher than past ones.

CONCLUSIONS

The main aim of this paper was the analysis of the dynamics of spatial dependence making a differentiation between two types of spatial dependence: contemporaneous and non-contemporaneous. The first one is the consequence of a very quick diffusion of the process over the neighboring locations, while the second one implies that, a shock in a certain location needs of several periods to take place and be tested over its neighborhood. Hence, we propose the identification and use of time-lagged spatial dependence terms in regression models. These variables –when applicable– allow explaining the effects due to spatial interaction, which is not only "horizontal" or simultaneous but also time-wise.

For the fulfillment of this aim, we propose a two space-time Moran's *I* tests for the specification of spatial regression models. Firstly, the PII evaluates the simultaneity of spatial dependence even in presence of time-lagged spatial effects, which are detected by the STI coefficient. Hence, if both PII and STI are significant for a certain time lag *k* then it will be possible to split spatial dependence into instantaneous and k^{th} order time-lagged.

In the second part of this paper, we illustrated the process for the identification of different types of spatial dependence in some variables, with the help of these two space-time Moran's tests. We have shown that spatial dependence, when present in a variable, can be decomposed in two components –contemporaneous and non-contemporaneous– or in case of quicker synchronic spatial dependence only a spatial lag should be specified.

These instruments also can be of help to know the time the diffusion process takes to end up, which has revealed slower in the case of housing price –for the Spanish provinces in 2004– and much higher in foreign residents. They are also useful to know the proportion of spatial dependence that is due to present and past effects. For instance, in the analyzed variables, we have identified an approximate equal proportion in contemporaneous and non-contemporaneous spatial dependence, with the exception of broadband lines variable, in which instantaneous spatial dependence is significantly higher than time-lag one.

REFERENCES

ANSELIN L (2005) «Exploring spatial data with GeoDa: a workbook». *Center for Spatially Integrated Social Science*. Available in http://sal.agecon.uiuc.edu.

ANSELIN L, LE GALLO J, JAYET H (2006) «Spatial panel econometrics». In: MATYAS L, SEVESTRE P. (eds) «The econometrics of panel data». *Kluwer Academic Publishers*, Boston.

ANSELIN L, SYABRI I, SMIRNOV O (2002) «Visualizing multivariate spatial correlation with dynamically linked windows». In: Anselin L, Rey S (eds) New tools in spatial data analysis, proceedings of a workshop. *Center for Spatially Integrated Social Science*, University of California, Santa Barbara, CDROM.

BALTAGI BH, LI D (2003) «Prediction in the panel data model with spatial correlation». In: Anselin L, Florax R, Rey S (eds) *New Advances in Spatial Econometrics, Springer* Berlin Heidelberg New York, pp 283-296.

BALTAGI BH, SONG SH, KOH W (2003) «Testing panel data regression models with spatial error correlation». *Journal of Econometrics* 117-1: 123-150.

BENNETT RJ (1979) «Spatial time series analysis, forecasting and control». Pion, London.

CASE A (1991) «Spatial patterns in household demand». *Econometrica* 59: 953–965.

CHASCO C, LÓPEZ F (2004) «Modelos de regresión espacio-temporales en la estimación de la renta municipal: el caso de la Región de Murcia». *Estudios de Economía Aplicada* 22: 605-629.

CRESSIE N (1993) «Statistics for spatial data». New York, Wiley.

CLIFF A, ORD J (1981) «Spatial processes, models and applications». Pion Limited, London.

ELHORST JP (2001) «Dynamic models in space and time». *Geographical Analysis* 33: 119-140.

ELHORST, JP (2003). «Specification and estimation of spatial panel data models». *International Regional Science Review*, 26(3):244–268.

FLORAX, R, FOLMER H, REY S (2003) «Specification searches in spatial econometrics: the relevance of Hendry's methodology». *Regional Science and Urban Economics* 33: 557-579.

LEE S-I (2001) «Developing a bivariate spatial association measure: An integration of Pearson's *r* and Moran's *I*». *Journal of Geographical Systems* 3:369-385.

LÓPEZ F, CHASCO C (2007) «Time-trend in spatial dependence: Specification strategy in the first-order spatial autoregressive model».Estudios de Economía Aplicada 25-2, art. 25213.

MARTIN RL, OEPPEN JE (1975) «The identification of regional forecasting models using space: time correlation functions». *Transactions of the Institute of British Geographers* 66: 95-118.

MOBLEY LR (2003) «Estimating hospital market pricing: An equilibrium approach using spatial econometrics». *Regional Science and Urban Economics* 33: 489–516.

PACE RK, BARRY R, CLAPP JM, RODRÍGUEZ M (1998) «Spatiotemporal autoregressive models of neighborhood effects». *Journal of Real State Finance and Economics* 17(1): 15-33.

PACE RK, BARRY R, GILLEY OW, SIRMANS CF (2000) «A method for spatial-temporal forecasting with an application to real estate prices International». *Journal of Forecasting* 16: 229-246.

PFEIFER PE, DEUTSCH SJ (1980) «Identification and interpretation of first-order space-time ARMA models». *Technometrics*, 22(3), 397-403.

UPTON G, FINGLETON B (1985) «Spatial data analysis by example: volume 1 point pattern and quantitative data». Wiley, New York.

WARTENBERG D (1985). «Multivariate spatial correlation: A method for exploratory geographical analysis». *Geographical Analysis*, 17: 263–283.

WHITTLE P (1954) «On stationary processes in the plane». *Biometrika* 41, 434-449.

YILMAZ S, HAYNES KE, DINC M (2002) «Geographic and network neighbors: spillover effects of telecommunications infrastructure». *Journal of Regional Science* 42-2: 339-360.

¿ES LA DEPENDENCIA ESPACIAL UN EFECTO INSTANTÁNEO? ALGUNAS EVIDENCIAS EN SERIES ECONÓMICAS PROVINCIALES

RESUMEN

El objetivo de este artículo es analizar hasta qué punto la dependencia especial es un efecto sincrónico, tal y como suele ser definido. Es bien sabido que en muchos fenómenos económicos, la dependencia especial es no sólo un efecto contemporáneo sino también retardado en el tiempo. En este trabajo, aplicamos dos estadísticos de autocorrelación espacial basados en el test I de Moran para evaluar el grado de simultaneidad de este efecto. Para ello, especificamos modelos mixtos de dependencia espacial instantánea y retardada en el tiempo. La aplicación de estos modelos sobre algunas series económicas provinciales da lugar a resultados que avalan esta hipótesis.

Palabras clave: Dependencia espacio-temporal, Modelos espaciales autorregresivos, I de Moran, Provincias españolas.

Clasificación JEL: C15, C21, C51.