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Forecasting in a Small and Unstable Regional Economy Using Regime Shifting Models: The Case of Extremadura

We consider forecasting in a small and unstable regional economy subject to structural breaks. In this context, we work with two types of regime-shifting databased models using cointegration theory. The objective of the present work is to analyze the out-of-sample forecasting performance of the two approaches used to construct a short-term regional econometric model: stochastic and deterministic time varying parameters models. The forecasting experiments will be illustrated by specifying and estimating an econometric model for Extremadura, a small and unstable region in southwestern Spain.

1. INTRODUCTION

In an extensive review of approaches to the analysis of regional income inequality, Rey (2001) demonstrated the impact of the neglect of explicit attention to the spatial dimensions of data underlying the empirical analysis. A similar criticism could be applied to the design and execution of regional economic models. Although the estimation of macromodels at national level was already quite extensive by the 1950s and 1960s, regional econometric models were not implemented, in general terms, until the 1970s (see Bolton 1985; Courbis 1994). The first regional econometric models were simple extensions from experiences at the national level (see Klein 1969; Glickman 1977; Bodkin Klein, and Marwah 1991; Darnell 1994; or Hendry and Morgan 1995, for a historical overview). Subsequently, the construction of those models entered into a period of relative decline. However, in the case of Spain, regional econo-

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metric models have not been abandoned; the particular political circumstances (and their economic implications) surrounding the evolution of Spain over the last few decades have contributed to sustained interest in regional econometric models. Models developed by Suriñach (1987), Escolano (1993) and Aguayo, Guisan, and Rodríguez (1997) illustrate some recent regional Spanish models[1] that typify the types of problems and regional context that underlies the present contribution. Essentially, regional disparities in levels of welfare persist within Spain, challenging analysts to explore the functioning of regional economies in ways that will help examine the utility and effectiveness of regional policies promulgated by the national government and more recently the European Union. The task is made even more difficult by problems in transforming published data into a consistent database, difficulties that include discontinuities, base changes, changes in definitions, and the lack of both deflators and demand series for the regional data.

The regional econometric model built for the present analysis was intended to be more of a predictive rather than a decision-making model: in the level II of the NUTS, regional account updates are often very late, thus generating a need to obtain predictions about the evolution of sectoral activity in a more timely manner. However, the predictive component also feeds into the policy arena by providing on-going monitoring capabilities that may help shape policy adjustments.

Therefore, according to Weber's (1986) classification, this paper reports on the development of the block production in Extremadura of a satellite single region econometric model that will be used mainly for predictive purposes. This model is so characterized because the endogenous variables are dependent on endogenous and exogenous regional variables, and exogenous national ones. Hence, this model is for a single region (as the interrelations with other regions[2] are not taken into account), it is top-down (in the sense that the economic causality moves from the nation to the region), and possible feedback of the Extremadura region economy to the national one is not taken into consideration. For the inferences to be valid, the models that are constructed have to be "stable" in the sense that it is assumed that the future will be responsive to similar signals as in the past, with the implication that the parameters of the econometric model will be constant. If the hypothesis of constant parameters is not satisfied in practice, whatever inference obtained from them and whatever economic policy implication derived from the model will be biased.[3] In particular, the out-of-sample simulations and forecasts will be greatly affected, so that the usefulness of the model as a valid instrument on which to base economic policy decisions will be questionable. In the case of regional economies, the problem of instability becomes even more acute than in the case of a national economy, since the impact of external or internal shocks is much greater than for the country as a whole. Thus, the agricultural sector (for climatological reasons) or the industrial sector (for reasons of location policies or of the production policies of large industrial companies) are examples of economic activities for which it is difficult to assume that the structure of the system characterizing them will be stable in the future. A vast amount of literature concerns tests of the hypothesis of parametric stability (see, for example, Stock and Watson 1996), but far fewer contributions question how to model structural change once it has been detected. Often, a significant stability test result indicates some type of poor

1. Regions in level II nomenclature of territorial units for statistics (referred to by the French acronym NUTS) which subdivide the territory of the European Union in 211 regions at this level.

2. We are aware of the criticism a single-regional model can receive (see, for example, Nijkamp, Rietveld, and Snickars 1986, 259), but mainly due to statistical reasons, it is not possible, nowadays, to develop successfully a multi-regional model that covers two or more regional interactions. In the case of the Spanish regions, the only serious attempt of spatial economic model aims has been from the input-output perspective.

3. The issue of temporal stationarity is a critical one;see the recent review by Elhorst (2001).

specification, so that the next step is to try alternative specifications. However, at the regional scale, the parametric instability of the estimated models is quite usual, since "changes in regime" are frequent, and it is difficult to try alternative specifications due to the lack of data, and also because the source of misspecification is usually unknown.

Hence, this paper explores forecasting in a small and unstable regional economy subject to structural breaks. The broader geographical dimensions (i.e., interactions with other regions) of the structural changes are not taken into account because of the lack of statistical information. The statistical framework used is cointegration theory (Engle and Granger, 1987), which combines in its basic econometric specification the relationships of long-term equilibrium suggested by economic theory with the process of (short-term) adjustment to equilibrium of the said relationships by way of error correction mechanisms. In the long term, and given the interpretation of the cointegration relationships, the working hypothesis is that the changes can be modeled through the introduction of dummy variables.[4] In the short term, two types of regime shifting databased models are employed. The objective of the present work is to analyze the out-of-sample forecasting performance of the two approaches used to construct a short-term regional econometric model: stochastic and deterministic time-varying parameters models.

Therefore, the main contribution of this paper is in the field of the analysis of an unstable regional economy, combining information coming from different hierarchical levels (national and regional levels). In the next section, some brief introduction to the region in relation to Spain will be provided. Section 3 presents the basic modeling framework, highlighting the limitations imposed by statistical information that is available at a regional level in Spain. Section 4 presents the issues surrounding the construction of the econometric model that is estimated in Section 5. Section 6 provides some concluding remarks.

2. THE REGION

The spatial dimension of our analysis is placed in the level II of the NUTS. As regional objectives are mostly designated at NUTS II, this is a very relevant European geographical unit. At the level II of NUTS, there are seventeen regions in Spain (the so-called Autonomous Communities). The Autonomous Communities are regional governments that share governance with the Spanish central administration within their respective territories. The forecasting experiments will be illustrated using data for the Extremadura region in southwestern Spain, an Autonomous Community within the Spanish economic periphery. Extremadura is a very rich region in natural resources, but it has a low level of industrialization. Its average income per worker and its average expenditures per person are about 80% of the Spanish national average. During the analysis period, Extremadura had a population of approximately one million (about 2.7% of the Spanish population, whereas this region occupies 8.2% of Spanish territory). It contributes 1.8% of the gross added value (GAV) of the Spanish economy. Hence, by all measures, Extremadura is definitely a small regional economy in comparison with the rest of Spanish regional economies. Figure 1 shows the growth rate of value added in constant pesetas for both Spain (TGAVES) and Extremadura (TGAVEX). This rate in the Extremadura economy during this analysis period presented much greater instability for Extremadura than for Spain itself (see Márquez, Ramajo, and Fajardo 1998).

4. In Canarella, Pollard, and Lai (1990), the presence of long-term structural instability is modelled in a time-varying parameter approach.

Table 1 provides detailed data about the industrial structure for both Spain and Extremadura. These structures are very different, and it is in these differences that there are sources of instability. Extremadura is an economy dependent on agriculture, while the manufacturing industry is very limited, dominated by the consumer goods industry (about 80%) with a close link between this industry and the region's agricultural production.

There are many different factors that may cause instability in Extremadura. This region has experienced profound changes in the instrumental economic policy variables such as the political transition in Spain, the creation of regional governments, and, finally, the entry into the European Union. Secondly, the small size of this economy makes it more prone to shocks generated by fluctuations in the performance of supraregional or national economies. Finally, it is an economy whose agriculture sector is very dependent on the weather (dry-land farming accounts for about 50% of total production) providing a non-economic source of instability. Hence, any model developed for this region needs to include these diverse sources of instability in an explicit fashion.

3. THE BASIC STRUCTURAL MODEL

The econometric model for Extremadura was built in the spirit described so well by Weber (1986, 16): "[D]esigners of regional models do not have the luxury of working with a complete economic theory in developing their model. The concept of

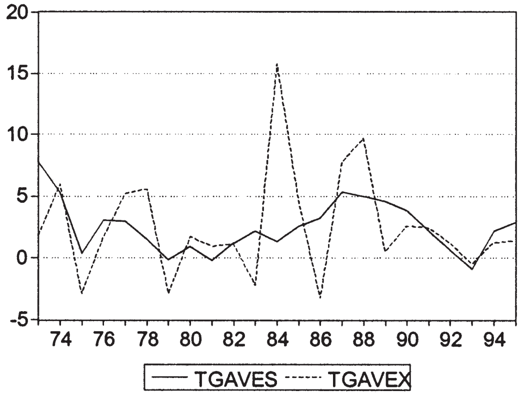

Fig. 1. Growth Rate of Value Added in Constant Pesetas for Spain (TGAVES) and Extremadura (TGAVEX)

TABLE 1
Mean Internal Percentage Structure in Spain and Extremadura: Results by Branches.

Branches	Spain	Extremadura
Agriculture	5,9%	14,0%
Energy	6,0%	10,3%
Construction	7,5%	10,9%
Manufacturing Industry	24,2%	8,5%
Sales-oriented Services	37,2%	32,4%
Transport and Communications	5,8%	3,8%
Non-sales–oriented Services	13,1%	19,9%

structural modeling is that endogenous variables are related to one another and to a set of exogenous variables. . . . The designers of the regional model are forced to rely on economic theory for the basic design, but must modify that design as dictated by the realities of the open system and data limitations."

The econometric model that has been constructed (described in Section 5) is based on the fundamental ideas of the "economic base" models (see, for example, Treyz 1993). For statistical reasons (in Spain there are no sufficiently long regional time series disaggregated from the perspective of demand), the proposed economic model performs a supply-side sectoral disaggregation. Specifically, the regional production is divided into seven economic sectors: agriculture, energy, manufacturing industries, construction, sales-oriented services (except transport and communications), transport and communications, and non-sales–oriented services. The endogenous variables to be explained (and forecasted) are given by the production of each of these sectors, measured by the gross value added at market prices in 1986 constant pesetas (which we shall represent as *GAV*).

Following the line of argument of the economic base models, one can distinguish between basic and non-basic or local sectors, the former being those whose production supplies the national or supranational market, and the latter whose production is sold in the regional market. For the former, the level of activity is fundamentally determined by external factors, so that the standard specification is of the form:

$$E[GAV^b \mid IE^b, IR_1^b, IR_2^b, \ldots] = \alpha_b + \beta_{b_0} IE^b + \sum_{i=1}^{n_b} \beta_{b_i} IR_i^b \tag{1}$$

where $E[.|.]$ represents the conditional expectation value; the superscript refers to the basic sector b; IE is an external indicator that measures the evolution of the cycle of the national market of sector b, and IRs are regional indicators that complement the basic specification (including variables that measure the advantages of setting the sector b in the region, as well as others that explain the intersectoral relationships). For the local sectors, the standard equation is:

$$E[GAV^l \mid IR, IR_1^l, IR_2^l, \ldots] = \alpha_1 + \beta_{l_0} IR + \sum_{i=1}^{n_l} \beta_{l_i} IR_i^l \tag{2}$$

where now IR is an indicator of the level of total internal demand in the region, and IR^ls are regional indicators that complement the basic relationships (including variables that reflect the relationships of the local sector with basic activities of the region).

In practice, however, there are no purely national or regional markets; the productive sectors are usually mixed in the sense that part of their activity is determined by factors that are exogenous to the region and part by endogenous circumstances. This fact implies that the relationships that will be specified for the different sectors could be a mixture between equations (1) and (2).

4. METHODOLOGY

4.1. The Econometric Specification

The functional structure of the equations making up the regional econometric model is based on the theory of cointegration (Engle and Granger 1987). Specifically, "standard" equations are proposed in the form of error correction mechanisms (ECM),[5] in which a long-term equilibrium relationship is set up between the explanatory and the explained (endogenous) variables, at the same time as allowing the existence of short-term deviations with respect to this equilibrium situation through the introduction of dynamic terms.

The basic structure that we propose for the model equations is a variant of the traditional ECM (since it introduces a vector of variables that accounts for the short-term deviations) and is given by the expression:

$$\Delta GAV_t^s = \gamma_0 + \sum_{i=1}^{p} \gamma_{1i} \Delta GAV_{t-i}^s + \sum_{i=0}^{q} \gamma_{2i} \Delta Z_{t-i}^s - \alpha(GAV_{t-1}^s - \beta' X_{t-1}^s) + u_t^s \quad (3)$$

where GAV^s represents the log gross value added of sector s, $\boldsymbol{X}^s$ is a vector of explanatory variables (generally also in logarithms) that cointegrates with the dependent variable GAV^s, and $\boldsymbol{Z}^s$ is a vector of variables that explain (together with the lagged values of the dependent variable) the short-term deviations of the situation from equilibrium (amongst the components of $\boldsymbol{Z}^s$ may be found some of the variables of the vector $\boldsymbol{X}^s$).

4.2. The Statistical Model

In the specification (3), it has been assumed that the parameters are fixed, i.e., that the structural relationships are stable in the short and long term. To relax this hypothesis, two cases will be distinguished according to whether the structural instability is present in the long or the short term. Equation (3) assumes that the linear combination $GAV_t^s - \beta = X_t^s$ of the integrated variables has a stationary distribution. There exists, however, the possibility of a more general type of cointegration allowing the cointegration vector to change at some point during the sample period.[6] The standard cointegration null hypothesis implies the model:

$$GAV_t^s = \beta_0 + \beta_1' \boldsymbol{X}_t^s + e_t^s \quad (4)$$

where GAV_t^s and $\boldsymbol{X}_t^s$ are I(1) and e_t^s is I(0). If relationship (4) is stable, the parameters ? β_0 and β_1 must be constant (time invariant). If there exists structural instability, these parameters will remain constant over some period of time but will change subsequently (β_0 or some component of the vector β_1) to a new level, yielding another equilibrium relationship with different values for the slope or the intercept. This change may be definitive, but it may also happen that after a certain period of time one returns to the original situation or passes to another equilibrium state characterized by a new set of coefficients. If we assume that the change in the parameters is discrete, the structural change can be modeled by introducing a dummy variable of the type

$$\varphi_{[t_0,t_1]}(t) = \begin{cases} 0 \text{ if } t < t_0 \\ 1 \text{ if } t_0 \le t \le t_1 \\ 0 \text{ if } t > t_1 \end{cases} \quad (5)$$

5. LeSage (1990) used an export base error-correction model in order to forecast metropolitan employment, while our forecasting study focuses on the analysis of an unstable regional economy, combining information coming from different hierarchical levels (national and regional levels).

6. For simplicity of exposition, we assume that there exists only one breaking point.

where t_0 denotes the breaking point of the cointegration relationships and t_1 the point of return to the initial situation, with $1 < t_0$? t_1 ? T. In the most general case, where the structural change implies a modification of both the intercept and the slopes, the cointegration relationships with structural change is given by:

$$GAV_t^s = \beta_{01} + \beta_{02}\varphi_{[t_0,t_1]}(t) + \beta_{11}'\boldsymbol{X}_t^s + \beta_{12}'\boldsymbol{X}_t^s\varphi_{[t_0,t_1]}(t) + e_t^s \tag{6}$$

where β_{01} and β_{02} represent, respectively, the intercept before and after the structural change, and β_{11} and β_{12} the slope coefficients in the co-integration relationships before and after the change of regime. The above model can be generalized to allow more than one breaking point by simply introducing additional dummy variables; in any case, the change of regime that is being considered is entirely discrete.[7]

With respect to the parameters of the error correction mechanism, and expecting that in the short term there may exist major instabilities, two approaches were used, stochastic and deterministic (introducing dummy variables) time varying parameters models. The deterministic model of dummy variables is a priori too rigid, and thus it would seem to be more advisable to use a stochastic model that allows greater flexibility in the temporal evolution of parameters. In this sense, a model was formulated that is adaptable to any type of change (sharp or smooth) that may occur. Hence, our other alternative hypothesis to constancy is that the parameters are stochastic and vary according to a (multivariate) random walk model. The scope of the resulting model will then include all types of structural changes (sharp or smooth) that may have taken place during the sample period.

Respecifying the model (3) such that all the parameters $(\gamma_0,\gamma_{11},\ldots,\gamma_{1p},\gamma_0,\ldots,\gamma_{2p},-\alpha)$ appear in the vector α and all the explanatory variables appear in the vector $\boldsymbol{H}^s$, the structure of the equations of the model that we propose is the following:

$$\begin{aligned} \Delta GAV_t^s &= \alpha_t' H_t^s + u_t^s \\ \alpha_t &= \alpha_{t-1} + \eta_t \end{aligned} \tag{7}$$

where we assume that the errors u_t^s are normally distributed with zero mean and constant variance σ^2 and are mutually independent, and that η_t is a vector of normal random variables with zero mean and covariance matrix $\sigma^2\mathbf{P}=\mathbf{Q}$ whose distribution is independent of that of the errors u_t^s and of the vector α_0. The first equation of the system (7) is known as the measurement equation and the second as the transition equation, which describes the temporal evolution of the parameter vector of interest, α_t, now known as a state vector (and its components state variables). In the present application, it will be assumed that the matrix $\boldsymbol{Q}$ (known as the dispersion matrix) is diagonal, i.e., the state variables are not allowed to interact amongst themselves since this would involve non-zero off-diagonal elements. The case $\mathbf{Q}=\mathbf{0}$, of course, reduces to the constant parameter model (3).

The specification (7) assumes that the parameter vector α_t follows a random walk type of multivariate distribution that, as it is not stationary, evolves with time such that all the structural changes that have taken place during the sample period can be included. Obviously, other stochastic models for α_t can be put forward, depending on the a priori level of information that one possesses in the form, timing, and speed of the structural change (Hall 1994). In this case, given that we lack this information and

7. From the long-term perspective, if the parameters change continuously, in the sense that they presuppose a continuous structural change (from one period to the next, all the coefficients change), it would not have an easy economic interpretation.

the small number of observations, a random walk model was preferred as an alternative hypothesis, and this is quite customary in other applications.

5. THE EMPIRICAL RESULTS

5.1. Statistical Sources, Specification of the Model and Stochastic Properties of the Data

Most of the variables used in this work were obtained from the HISPALINK (Otero et al. 1996) and Cordero and Gayoso (1997) databases. The former is a historical collection of data for the period 1970–85 (see HISPALINK 1993) while the latter covers the period 1980–95 and consists of official data from the National Statistics Institute (INE), and the use of their own deflators. In particular, all variables referring to gross added value are at market prices in 1986 constant pesetas (GAV) by sector and at the regional and national levels were obtained from these bases. The homogeneity and quality of the observed data have been carefully evaluated (see Cabrer 2001). In addition, these data were analyzed in Márquez (2001) for the case of Extremadura, where the results affirmed confidence in the quality of these data. The rest was constructed from different sources of regional or national statistical information (see Ramajo and Márquez 1996). In general, the data that are to be used cover 1970 to 1995 (as the last year in which Cordero and Gayoso 1997 database is available), although the length of the series is reduced in some sectors due to the lack of disaggregated series for several years at the beginning of the period under consideration.

The goal of the present work is to analyze the out-of-sample forecasting performance of the yearly model, and for this reason data from 1991 to 1995 are excluded to make ex-post predictions. Therefore, the sample period used in the following estimates is generally between 1970 and 1990.

Concerning the specification of the model, as earlier mentioned, the dynamic economic approach provides the theoretical perspective that underlies the econometric model, since the specification starts by considering the existence of basic and non-basic sectors in the economy in Extremadura. This approach is based on its simplicity according to the specification, so the demand for both unavailable and hard-to-access regional variables are minimized. We used some exploratory data analysis for detecting data structure and for formulating hypotheses about the possible specification of the model (see Márquez 2001). For example, the input-output tables of Extremadura for 1978 and 1990 were examined in order to determine the basic and non-basic sectors. The ratios of external dependence divided by production and the ratios of external dependence divided by the overall exports suggest that agriculture, energy and the manufacturing industry branches can be considered as the exogenous economic base for Extremadura. The initial hypothesis is that these sectors are basic, and the remaining sectors (construction, transport and communication, sales-oriented services, and non-sales–oriented services) will be considered as non-basic sectors. The input-output data also provided empirical evidence about the interdependence of sectors in the regional economy, providing insights into the nature of short-term relationships.

For long-term relations, simple specifications have been explored. It would be expected that the basic sectors (agriculture, energy, and manufacturing industry) have a similar evolution as the national sectors; so, it is supposed that a long-term relation exists between the basic sectors and their respective national sectors. For the non-basic sectors (construction, transports and communications, sales-oriented services and non-sales–oriented services) it is hypothesized that a long-term relation exists with either one or several indicators of the level of total internal demand in the region. Subsequently, the proposed long-term relations have been established by means of the cointegration theory.

Now that the statistical sources have been described, and the process followed in the specification, attention is now directed to the analysis of the order of integrability (d) of all the exogenous and endogenous variables that appear in the model (see footnote 15). For this purpose, the augmented Dickey-Fuller (ADF) test (Dickey and Fuller 1981) was used based on the following regression equations (the null hypothesis being H_0:$\{x_t \sim I(d)\}$ and the alternative hypothesis H_1:$\{x_t \sim I(d-1)\}$):

$$\Delta^d x_t = \alpha_0 + \alpha_1 \Delta^{d-1} x_{t-1} + \sum_{j=1}^{p} \gamma_j \Delta^d x_{t-j} + \varepsilon_t$$

$$\Delta^d x_t = \alpha_0^* + \alpha_1^* \Delta^{d-1} x_{t-1} + \alpha_2^* \Delta^{d-1} t + \sum_{j=1}^{p} \gamma_j^* \Delta^d x_{t-j} + \varepsilon_t^* \tag{8}$$

where the errors are assumed to be Gaussian "white noise"–type perturbations. The t statistics of α_1 or α_1^* are the values used to test the hypothesis that this coefficient is zero or significantly different from zero.

Taking into account, however, previous experiences with the study of the stochastic properties of Spanish macroeconomic series (Andrés et al. 1990; Molinas, Sebastián, and Zabalza 1991), as well as the nature of the regional series themselves (with frequent break points[8]), the more general version of the ADF test was considered to include the possibility of the existence of segmented deterministic trends in the mean (Rappoport and Reichlin 1989). In this case, the mean can be written as:

$$\mu_t = \begin{cases} c_1 + b_1 t \text{ if } t \leq t_1^* \\ c_2 + b_2 t \text{ if } t_1^* \leq t \leq t_2^* \\ \dots \\ c_n + b_n t \text{ if } t \geq t_{n-1}^* \end{cases} \tag{9}$$

where t_i^* are the points when there is a break in the trend. The ADF test then takes the form

$$\Delta^d x_t = \alpha_1 \Delta^{d-1} x_{t-1} - \alpha_1 \Delta^{d-1} \mu_{t-1} + a^{**}(L) \Delta^d x_{t-1} + a^*(L) \Delta^d \mu_t + \varepsilon_t \tag{10}$$

where the lag polynomials a^*(L) and a^{**}(L) are related (imposing the normalization constraint $a^*(0)=1$) through the equation $a^*(L) = 1 + a^{**}(L)L$. The regression equation (10) is made operational by replacing μ_t by the expression

$$\mu_t = c_1 + b_1 t + \sum_{i=2}^{n} (c_i - c_{i-1}) D_{i-1,t} + \sum_{i=2}^{n} (b_i - b_{i-1}) D_{i-1,t} t \tag{11}$$

where the dummy variable $D_{i,t}$ takes the value unity from the instant t_i^*.

8. Due not only to structural changes such as those analyzed in the present work, but also to problems "in origin," such as changes of basis, redefinition of variables, measurement errors caused by the application of distribution methods, use of approximate deflactors, etc.

The results of applying the tests described above to the variables under study are listed in Table 2.[9] The conclusion to be drawn is that all of the series, except one, which can be considered as I(0), can be regarded as I(1) variables, some of them with a single deterministic trend, and the rest of the variables with various segmented trends in their means.

5.2. The Estimation of the Model

Following the procedure of the two-stage method proposed by Engle and Granger (1987), the long-term relationships of the type (4) were estimated using the theoretical arguments outlined in Section 2.[10] In all cases, the cointegration test of Engle and Granger (which uses the unit root test of Dickey and Fuller 1979) was applied to determine whether the variables involved in the regression were cointegrated. The result was that the null hypothesis of the existence of a unit root in the residuals (i.e., the absence of cointegration) was not rejected in most of the tests.

In the light of this evidence, and taking into account the results of Campos, Ericsson, and Hendry (1996), that show not only that the presence of structural change in stationary series may lead to spurious unit roots (see Perron 1989; Hendry and Neale 1991), but also that such breaks affect considerably the power of co-integration tests

TABLE 2
Results of the Unit Root Tests.

	$H_0:\{I(2)\}$ vs $H_1:\{I(1)\}$ ADF			$H_0:\{I(1)\}$ vs $H_1:\{I(0)\}$ ADF			
Variable	PGD	*t*	*VC*	PGD	*t*	*VC*	Result
LVAES	*CT*,0	−5,49	−3,61	*C*,0	−2,46	−2,98	I(1)
LVAEX	*N*,1	−5,58	−1,95	*C*,0	−3,08	−3,73*	I(1)
LVOLAG	*N*,0	−5,95	−1.95	*CT*,0	−2,52	−3,60	I(1)
LVEES	*CT*,0	−5,21	−3,61	*C*,0	−2,69	−2,98	I(1)
LVEEX	*N*,0	−6,17	−1,95	*CT*,0	−2,44	−3,60	I(1)
LPRECIP	*N*,2	−4,58	−1,95	*C*,0	−4,20	−2,98	I(0)
LENERG	*RR*,2	−6,58	−4,08	*RR*,2	−2,48	−4,08	I(1)
LVBEX	*C*,0	−5,59	−2,99	*CT*,0	−2,72	−3,60	I(1)
LGAVES	*C*,1	−3,09	−2,99	*CT*,1	−3,93	−4,39*	I(1)
LGAVEX	*C*,0	−5,17	−3,00	*CT*,0	−2,40	−3,62	I(1)
LVIEX	*N*,0	−5,21	−1,95	*C*,0	−2,42	−2,98	I(1)
LVIES	*N*,0	−3,20	−1,95	*CT*,1	−2,77	−3,62	I(1)
LVNOAE	*C*,0	−5,07	−3,00	*CT*,0	−1,95	−3,62	I(1)
LVLEX	*N*,1	−2,35	−1,95	*RR*,3	−4,26	−4,76	I(1)
LVLES	*RR*,2	−4,14	−4,08	*CT*,1	−2,85	−3,62	I(1)
LVZEX	*N*,0	−3,11	−1,95	*CT*,1	−2,28	−3,62	I(1)
LVZES	*RR*,2	−4,39	−4,08	*CT*,1	−3,33	−3,62	I(1)
LVGEX	*RR*,2	−7,55	−4,08	*RR*,2	−3,72	−4,08	I(1)
LVGES	*RR*,2	−4,16	−4,08	*CT*,1	−2,86	−3,61	I(1)

NOTES: The notation used to represent the variables is *L* indicates logarithms; *V* denotes gross added value in constant 1986 pesetas for sectors - *VA*: agriculture; *VE*: energy; *VB*: construction; *VI*: manufacturing industry; *VL*: sales-oriented services (except transport and communications); *VZ*: transport and communications; *VG*: non-sales–oriented services). In addition, *GAV*: total gross added value; *VNOAE*: total non-agricultural and non-energy gross added value). Variable is also specified as either national (ES) or for Extremadura. *VOLAG* is the volume of reservoir water at the end of each year in Extremadura. *PRECIP* is the mean volume of precipitation recorded in Extremadura. *ENERG* is the gross electrical energy production in Extremadura. The column PGD specifies the data generation process that was considered for the variable in question. Thus the letter *N* indicates that the estimated auxiliary regression included no deterministic component; *C* indicates the admission of a constant term; and *CT* denotes the presence of a constant and a deterministic linear trend. The number immediately following these letters (separated by a comma) indicates the number of lags introduced into the *ADF* test. The letters *RR* mark the consideration of segmented deterministic trends in the mean for the *ADF* test (the number of segments being indicated by the corresponding digit). *VC* is the tabulated critical value at a 5% (1% shown with an asterisk) significance level for each of the tests obtained from McKinnon (1991) or Rappoport and Reichlin (1989).

9. We know that this conclusion is debatable because the time-series are short. For reasons of space, details will not be given of each of the regressions carried out.

10. It is necessary to point out that the use of Johansen method (1988; 1995) was discarded in the estimation for two reasons: firstly the lack of data, which forced to use a simple method (Engle and Granger 1987), secondly, the existent difficulty when identifying (and separating) the dummy variables that are introduced in order to yield structural changes in the short and the long terms.

in general, and in particular of the two-stage procedure of Engle and Granger), a series of parametric stability tests was applied to detect the presence of breaking points in each of the equations of long-term behavior.[11]

Specifically, various tests were applied based on the calculation of Wald sequential statistics, $F_T(\delta)$, which test the null stability hypothesis against the alternative of the existence of some breaking point in the observation t_0 (more precisely, in the fraction $\delta_0 = t_0/T$ of the sample). The exact localization of the possible points of intersection is not known a priori, so that the statistics $F_T(t/T)$ are calculated for all the points of the sample,[12] and then some function of these statistics is constructed. The three functions considered[13] in this work are:

the Quandt (1960) likelihood ratio statistic:

$$SupF = \underset{\delta \in [\delta_1, \delta_2]}{\text{supr}} F_T(\delta) \tag{12}$$

the mean statistic proposed by Andrews and Ploberger (1994) and Hansen (1992):

$$MeanF = \int_{\delta_2}^{\delta_1} F_t(\delta) d\delta \tag{13}$$

and the average exponential statistic proposed by Andrews and Ploberger (1994):

$$ExpF = \ln\left\{\int_{\delta_2}^{\delta_1} \exp\left(\frac{1}{2} F_t(\delta)\right) d\delta\right\} \tag{14}$$

In all cases of applying these three tests to the model's long-term equations except one, the values of the tests surpassed the critical values corresponding to a 1% significance level. (In the sole exception, the null hypothesis was rejected at the 5% level).

The following step introduced the fictitious variables needed to approximate the structural changes detected through the sequential application of Wald statistics,[14] i.e., co-integration relationships of type (6) were estimated with the same number of functions $\varphi_{[t_0,t_1]}$ as breaking points detected. The results for each of the sectors considered are listed in Table 3.

The main findings of the results can be summarized as follows. First, for each of the estimated equations, the stability tests *SupF*, *MeanF*, and *ExpF* were again ap-

11. Indeed, on applying the co-integration tests proposed by Gregory and Hansen (1996), which allow the possibility of changes of regime, the result was that in all cases the null hypothesis of no co-integration was rejected (in this case, as against the alternative of cointegration in the presence of a possible breaking point). Since, however, the tests of Gregory and Hansen only permit one breaking point (the procedure they use also allows the point to be identified), and given the possibility that a greater number exist in our case, the process of structural change modelling has been continued.

12. As noted by Andrews (1993), one can not use all the points $t/T[0,1]$, since in this case the tests will diverge to infinity, so that he proposes using the region $T=[^*_1, ^*_2]=[0.15, 0.85]$.

13. The asymptotic distributions of these statisitcs are discussed in Andrews (1993) and in Andrews and Ploberger (1994), being in all cases non-standard (functionals of multi-dimensional Brownian motions).

14. We are aware of some of the problems to which this approach might lead. First, MCO estimation is not efficient, and the significance tests do not have the standard asymptotic distributions under the hypothesis of co-integration with changes of regime. Second, under the null hypothesis of parameter stability, and given that the breaking points are unknown a priori, the Wald statistics constructed also have non-standard distributions. The results of Hansen (1992) and Quintos and Phillips (1993) might be useful in resolving these problems.

TABLE 3

Estimation of the Co-integration Relationships (OLS with dummy variables).

AGRICULTURE

ESTIMATED EQUATION (t = 1971,...,1990)

$LVAEX_t = -5{,}635 + 1{,}177\ LVAES_t + 0{,}175\ \mathrm{D7175}_t + 0{,}169\ \mathrm{F72}_t - 0{,}387\ F83_t$

(−2,147) (6,477) (4,692) (2,928) (−7,249)

R^2 = 0,889; Durbin-Watson = 2,196; ADF = 2,196; *SupF* = 2,453; *MeanF* = 1,931; *ExpF* = 1,567.

ENERGY

ESTIMATED EQUATION (t = 1970,...,1990)

$LVEEX_t = -10{,}000 + 1{,}392\ LVEES_t + 0{,}733\ \mathrm{D7073}_t + 1{,}111\mathrm{D8493}_t + 0{,}623\ \mathrm{F77}_t$

(−1,531) (3,035) (3,665) (6,884) (0,623)

R^2 = 0,922; Durbin-Watson = 1,863; ADF = −4,215; *SupF* = 6,294; *MeanF* = 2,523; *ExpF* = 1,798.

CONSTRUCTION

ESTIMATED EQUATION (t = 1972,...,1990)

$LVBEX_t = -0{,}168 + 0{,}843\ LVABEX_t - 21{,}275\ \mathrm{D7079}_t + 1{,}613\ \mathrm{D7079}{*}LVABEX_t$

(−0,062) (4,147) (−2,680) (2,646)

R^2 = 0,925; Durbin-Watson = 1,953; ADF = −4,080; *SupF* = 4,845; *MeanF* = 1,523; *ExpF* = 1,482.

MANUFACTURING INDUSTRY

ESTIMATED EQUATION (t = 1970,...,1990)

$LVIEX_t = -7{,}994 + 1{,}182\ LVIES_t + 0{,}206\ \mathrm{F78}_t + 0{,}223\ \mathrm{F80}_t + 0{,}104\ \mathrm{D8285}_t$

(−5,158) (12,039) (2,551) (2,767) (2,400)

R^2 = 0,894; Durbin-Watson = 1,995; ADF = −4,476; *SupF* = 5,213; *MeanF* = 3,428; *ExpF* = 1,956.

SALES-ORIENTED SERVICES

ESTIMATED EQUATION (t = 1972,...,1990)

$LVLEX_t = -8{,}430 + 1{,}274\ LVLES_t + 47{,}001\ \mathrm{D8185}_t - 2{,}914\ \mathrm{D8185}{*}LVLES_t - 0{,}231\ \mathrm{D8690}_t$

(−3,535) (8,601) (5,468) (−5,485) (−5,903)

R^2 = 0,903; Durbin-Watson = 1,874; ADF = -3,874; *SupF* = 8,265*; *MeanF* = 2,365; *ExpF* = 2,144.

TRANSPORT AND COMMUNICATIONS

ESTIMATED EQUATION (t = 1972,...,1990)

$LVZEX_t = -5{,}269 + 0{,}722\ LVZES_t + 0{,}399\ LVLEX_t + 0{,}257\ \mathrm{F72}_t + 17{,}686\ \mathrm{D8084}_t$

(−6,491) (16,269) (4,422) (7,038) (2,505)

$- 1{,}232\ \mathrm{D8084}{*}LVZES_t - 0{,}131\ \mathrm{D8889}_t$

(−2,493) (−5,414)

R^2 = 0,980; Durbin-Watson = 1,988; ADF = −4,335; *SupF* = 7,559; *MeanF* = 3,168; *ExpF* = 2,224.

NON-SALES–ORIENTED SERVICES

ESTIMATED EQUATION (t = 1971,...,1990)

$LVGEX_t = -4{,}140 + 1{,}037\ LVGES_t + 4{,}150\ \mathrm{D7078}_t - 0{,}290\ \mathrm{D7078}{*}LVGES_t - 9{,}948\ \mathrm{D7985}_t$

(−3,429) (13,148) (3,085) (−3,275) (−5,896)

$+ 0{,}656\ \mathrm{D7985}{*}LVGES_t$

(5,907)

R^2 = 0,998; Durbin-Watson = 2,731; ADF = −3,878; *SupF* = 2,598; *MeanF* = 0,634; *ExpF* = 0,415.

NOTES: t statistics shown below the estimated coefficients and is provided only as descriptive measures. *denotes rejection of the null hypothesis at 10%, ** at 5%, and *** at 1%. Refer to table 2 for variable definitions. Concerning the dummy variables, D followed by 4 numbers (for example D8690) indicates a dummy variable that takes value 1 in the years 1986,1987,...,1990 and 0 in the rest. F followed by 2 numbers, for example F78, indicates a dummy variable that takes 1 in 1978 and 0 otherwise.

plied, with the result that the null hypothesis of stability of the estimated parameters was not rejected in any case. Second, as can be seen in the table, the *DF* statistic rejects in all cases the presence of a unit root in each equation's estimated errors, i.e., the linear combinations of the variables of each model are stationary and, therefore, the relationships can be interpreted as long-term co-integration or equilibrium equations with changes of regime.

Third, one observes that there are few breaking points,[15] with at most three structural changes per equation (in the cases of the industrial, the transport and communications, and the non-sales–oriented services sectors). Also, in several cases, there are simultaneous changes in the level and in the slopes of the model, with two sectors (those of sales-oriented and non-sales–oriented services) in which different regimes were detected, with two breaking points with change both in the slope and in the intercept.

Finally, there was evidence to be extracted about the long-term relations between the agriculture, energy, and manufacturing industry sectors (which we pointed out as basic) and their respective national sectors. Nevertheless, in the case of the sectors that were proposed as non-basic (construction, sales-oriented services, non-sales–oriented services sector), the following results were derived. The construction sector is the paradigm of local sectors since a long-term relation with the overall GAV for Extremadura (excluding the GAV for the construction) was found. For the sales-oriented services and non-sales–oriented services, it was impossible to find evidence of a long-term relationship with one or several indicators of the level of total internal demand in the region. However, its co-integration relation showed that these sectors are determined in the long term by the evolution of the respective national sector. In the case of the transport and communication sector, a mixed relationship resulted in the long term, because its level of activity is determined by an external factor (GAV of the national transports and communications sector) and an indicator of the level of internal activity in the region: GAV of sales-oriented services in Extremadura. After the estimation of the long-term relationships, the second step of the procedure of Engle and Granger (1987) consists in estimating the short-term equations given by (3), with the expression in parentheses, which would now be of the type (6) with various functions $\varphi_{[t_0,t_1]}$ replaced by the estimated errors that are derived from Table 3.

As in the case of the long-term model, the individual equations without dummy variables were estimated first, and then the three stability tests were performed. Except for the case of the transport and communications sector, in the rest of the sectors the three statistics rejected simultaneously the null hypothesis of stability of the parameters of the error correction mechanisms.

Two options were considered to take into account the presence of structural change. One was to use, as in the long-term case, dummy variables to pick up the effect of the structural changes. The other consisted in modeling the structural break by proposing as an alternative the adaptive model represented by equation (7). These two options are developed in the following presentation.

The information provided by the Wald statistics used in the stability tests (complemented with a graphical analysis of each dependent variable and of the residuals estimated from the initial model) aided in identifying the dummy variables to be introduced into each of the equations of short-term behavior. The final result is the set of regressions presented in Table 4.

With reference to the number of fictitious variables introduced, two remarks should be made. First, the number of fictitious variables of each equation is determined by the values of the stability tests: with the variables that are introduced (and

15. This in a certain sense justifies the dummy variable approach, because of its ready implementation as against other more elaborate alternatives.

TABLE 4

Estimation of the Error Correction Models (OLS with dummy variables)

AGRICULTURE

ESTIMATED EQUATION (t = 1972,...,1990)

$$\mathrm{D}\mathit{LVAEX}_t = \underset{(-0{,}681)}{-0{,}007} - \underset{(-4{,}169)}{0{,}697}\,\hat{\mu}_{t-1} + \underset{(5{,}809)}{1{,}064}\,\mathrm{D}\mathit{LVAES}_t + \underset{(1{,}849)}{0{,}101}\,\mathrm{D}\mathit{LVOLAG}_{t-1} + \underset{(3{,}012)}{0{,}136}\,\mathrm{DD7175}_t - \underset{(-11{,}950)}{0{,}373}\,\mathrm{DF83}_t + \underset{(5{,}613)}{0{,}180}\,\mathrm{DF72}_t$$

R^2 = 0,943; Adjusted R^2 = 0,918; Durbin-Watson: DW = 2,379; Jarque-Bera: P-val. = 0,290;
Breusch-Godfrey: a) [AR(1)] P-val: 0,126; b) [AR(2)] P-val: 0,131;
Ljung-Box (p=6): P-val.= 0,644; ARCH: a) [ARCH(1)] P-val: 0,757; a) [ARCH(2)] P-val: 0,766;
White: P-val. = 0,847; *SupF* = 5,279; *MeanF* = 3,918; *ExpF* = 2,350.

ENERGY

ESTIMATED EQUATION (t = 1972,...,1990)

$$\mathrm{D}\mathit{LVEEX}_t = \underset{(-1{,}218)}{-0{,}069} - \underset{(-4{,}114)}{0{,}640}\,\hat{\mu}_{t-1} + \underset{(2{,}231)}{2{,}218}\,\mathrm{D}\mathit{LVEES}_t + \underset{(6{,}362)}{0{,}406}\,\mathrm{D}\mathit{LPRECIP}_t + \underset{(9{,}434)}{0{,}973}\,\mathrm{D}\mathit{LENERG}_t - \underset{(-4{,}275)}{0{,}307}\,\mathrm{D7476}_t + \underset{(8{,}653)}{0{,}671}\,\mathrm{DF77}_t + \underset{(3{,}209)}{0{,}434}\,\mathrm{F82}_t$$

R^2 = 0,965; Adjusted R^2 = 0,943; Durbin-Watson: DW = 2,432; Jarque-Bera: P-val. = 0,929;
Breusch-Godfrey: a) [AR(1)] P-val: 0,121; b) [AR(2)] P-val: 0,111;
Ljung-Box (p=6): P-val.= 0,127; ARCH: a) [ARCH(1)] P-val: 0,098; a) [ARCH(2)] P-val: 0,220;
White: P-val. = 0,250; *SupF* = 6,281; *MeanF* = 3,270; *ExpF* = 2,757.

CONSTRUCTION

ESTIMATED EQUATION (t = 1973,...,1990)

$$\mathrm{D}\mathit{LVBEX}_t = \underset{(0{,}758)}{0{,}008} - \underset{(-5{,}406)}{0{,}517}\,\hat{\mu}_{t-1} + \underset{(5{,}847)}{0{,}901}\,\mathrm{D}\mathit{LVABEX}_t + \underset{(2{,}676)}{0{,}728}\,\mathrm{D}\mathit{LVABES}_t + \underset{(2{,}991)}{0{,}207}\,\mathrm{D}\mathit{LVBEX}_{t-1} - \underset{(-6{,}234)}{0{,}084}\,\mathrm{D7475}_t + \underset{(4{,}635)}{0{,}063}\,\mathrm{D7677}_t + \underset{(3{,}046)}{0{,}062}\,\mathrm{F83}_t - \underset{(-9{,}132)}{0{,}176}\,\mathrm{F85}_t + \underset{(6{,}326)}{0{,}128}\,\mathrm{F86}_t - \underset{(-11{,}613)}{0{,}234}\,\mathrm{F88}_t$$

R^2 = 0,984; Adjusted R^2 = 0,962; Durbin-Watson: DW = 2,108; Jarque-Bera: P-val. = 0,932;
Breusch-Godfrey: a) [AR(1)] P-val: 0,623; b) [AR(2)] P-val: 0,357;
Ljung-Box (p=6): P-val.= 0,160; ARCH: a) [ARCH(1)] P-val: 0,515; a) [ARCH(2)] P-val: 0,277;
White: P-val. = 0,521; *SupF* = 8,635; *MeanF* = 4,191; *ExpF* = 3,376.

MANUFACTURING INDUSTRY

ESTIMATED EQUATION (t = 1973,...,1990)

$$\mathrm{D}\mathit{LVIEX}_t = \underset{(-3{,}000)}{-0{,}056} - \underset{(-2{,}674)}{0{,}575}\,\hat{\mu}_{t-1} + \underset{(5{,}419)}{2{,}190}\,\mathrm{D}\mathit{LVNOAEEX}_t + \underset{(2{,}042)}{0{,}225}\,\mathrm{D}\mathit{LVIEX}_{t-1} + \underset{(2{,}376)}{0{,}175}\,\mathrm{D}\mathit{LVAEX}_t + \underset{(2{,}569)}{0{,}114}\,\mathrm{DF80}_t + \underset{(2{,}991)}{0{,}126}\,\mathrm{DD8285}_t + \underset{(2{,}172)}{0{,}136}\,\mathrm{F77}_t + \underset{(2{,}543)}{0{,}146}\,\mathrm{F85}_t$$

R^2 = 0,869; Adjusted R^2 = 0,795; Durbin-Watson: DW = 2,020; Jarque-Bera: P-val. = 0,542;
Breusch-Godfrey: a) [AR(1)] P-val: 0,808; b) [AR(2)] P-val: 0,917;
Ljung-Box (p=6): P-val.= 0,923; ARCH: a) [ARCH(1)] P-val: 0,378; a) [ARCH(2)] P-val: 0,493;
White: P-val. = 0,639; *SupF* = 9,629; *MeanF* = 5,930*; *ExpF* = 5,234*.

SALES-ORIENTED SERVICES

ESTIMATED EQUATION (t = 1973,...,1990)

$$\mathrm{D}\mathit{LVLEX}_t = \underset{(-0{,}460)}{-0{,}003} - \underset{(-5{,}097)}{0{,}774}\,\hat{\mu}_{t-1} + \underset{(3{,}137)}{0{,}455}\,\mathrm{D}\mathit{LVNOAE}_t + \underset{(5{,}289)}{1{,}293}\,\mathrm{D}\mathit{LVLES}_t - \underset{(-4{,}342)}{0{,}064}\,\mathrm{F77}_t - \underset{(-5{,}865)}{0{,}051}\,\mathrm{D8085}_t - \underset{(4{,}139)}{0{,}062}\,\mathrm{F87}_t$$

R^2 = 0,962; Adjusted R^2 = 0,941; Durbin-Watson: DW = 2,445; Jarque-Bera: P-val. = 0,510;
Breusch-Godfrey: a) [AR(1)] P-val: 0,075; b) [AR(2)] P-val: 0,988;
Ljung-Box (p=6): P-val.= 0,301; ARCH: a) [ARCH(1)] P-val: 0,884; a) [ARCH(2)] P-val: 0,988;
White: P-val. = 0,248; *SupF* = 3,520; *MeanF* = 2,384; *ExpF* = 1,248.

TRANSPORT AND COMMUNICATIONS

ESTIMATED EQUATION (t = 1974,...,1990)

$$\mathrm{D}\mathit{LVZEX}_t = \underset{(0{,}869)}{0{,}006} - \underset{(-4{,}831)}{0{,}756}\,\hat{\mu}_{t-1} + \underset{(2{,}951)}{0{,}215}\,\mathrm{D}\mathit{LVLEX}_t + \underset{(2{,}343)}{0{,}401}\,\mathrm{D}\mathit{LVZES}_t + \underset{(2{,}960)}{0{,}226}\,\mathrm{D}\mathit{LVZEX}_{t-1} + \underset{(7{,}687)}{20{,}679}\,\mathrm{DD8084}_t - \underset{(-7{,}552)}{0{,}081}\,\mathrm{DD8889}_t - \underset{(-7{,}669)}{1{,}443}\,\mathrm{D}(\mathrm{D8084}\mathit{LVZES})_t$$

R^2 = 0,942; Adjusted R^2 = 0,912; Durbin-Watson: DW = 2,019; Jarque-Bera: P-val. = 0,776;
Breusch-Godfrey: a) [AR(1)] P-val: 0,706; b) [AR(2)] P-val: 0,091;
Ljung-Box (p=6): P-val.= 0,630; ARCH: a) [ARCH(1)] P-val: 0,176; a) [ARCH(2)] P-val: 0,292;
White: P-val. = 0,645; *SupF* = 5,166; *MeanF* = 2,447; *ExpF* = 1,699.

Table 4 continued next page

TABLE 4 (*continued*)

NON-SALES–ORIENTED SERVICES
ESTIMATED EQUATION (t = 1972,...,1990)

$DLVGEX_t$ = −0,004 − 0,710 $\hat{\mu}_{t-1}$ + 1,032 $DLVGES_t$ + 2,707 $DD7078_t$ − 0,199 $D(D7078LVGES)_t$
(−0,645)(−6,476) (8,972) (3,492) (−3,912)
− 17,798 $DD7985_t$ + 1,175 $D(D7985LVGES)_t$ + 0,014 $F80_t$ − 0,040 $F82_t$ − 0,040 $F84_t$
(−10,715) (10,737) (2,737) (−6,669) (−7,486)
+ 0,022 $F88_t$
(4,432)

R^2 = 0,990; Adjusted R^2 = 0,979; Durbin-Watson: DW = 2,418; Jarque-Bera: P-val. = 0,668;
Breusch-Godfrey: a) [AR(1)] P-val: 0,210; b) [AR(2)] P-val: 0,078;
Ljung-Box (p=6): P-val.= 0,273; ARCH: a) [ARCH(1)] P-val: 0,146; a) [ARCH(2)] P-val: 0,250;
White: P-val. = 0,416; *SupF* = 4,661; *MeanF* = 2,810; *ExpF* = 1,955.

NOTES: t statistics shown in parentheses below estimated coefficients. *denotes rejection of the null hypothesis at 10%, ** at 5%, and *** at 1%. Additional notation to that used in Tables 2 and 3: $\hat{\mu}_{t-1}$ are the residuals (lagged a period) of the long-term relation estimated in each of the equations in Table 3; D followed by a variable denotes the first difference of a variable, whether it is a dummy variable (DD7175), or the product of two variables (D(D7078*LVGES*)).

only with these) one attains stability for the error correction mechanisms in the sense that none of the three proposed statistics surpasses the corresponding threshold. Second, and as was to be expected, the number of break points that appears is far greater than in the long-term relationships, pointing to the presence of greater instability in the short-term relationships than in the equilibrium equations.

With respect to the estimation of equation (7) for each of the seven sectors considered,[16] the technique used was based on the recursive application of the Kalman filter[17] (Kalman 1960). At each instant t, and given the observations $\Delta W_1^s,\ldots,?\Delta W_t^s$, the interest is centered on estimating the vector α_t using the model equation (7). Under the normality hypotheses established for the errors of the model (and for the initial state vector ?$_0$), and assuming that σ^2, **P** (or **Q**), and the mean and covariance matrix of σ_0 are known,[18] the optimal estimator of α_t using the information I_s available up to instant s, is given by the conditional expectation of α_t taking I_s as known, which we will denote by $E[\alpha_t|I_s] = a_{t|s}$; and the optimal estimator for the covariance matrix of α_t using the available information I_s will be given by $Cov[\alpha_t|I_s] = \Sigma_{t|s}$.

The Kalman filter recursions for t = 0, 1, 2, … are given by the following equations (see, for example, Lütkepohl 1993):

$$a_{t+1|t} = a_{t|t}$$

$$\Sigma_{t+1|t} = \Sigma_{t|t} + \mathbf{Q}$$

$$a_{t+1|t+1} = a_{t+1|t} + k_{t+1}[\Delta W^s_{t+1} - \alpha'_{t+1|t}H^s_{t+1}]$$

$$\Sigma_{t+1|t+1} = \Sigma_{t+1|t} - k_{t+1}H^s_{t+1}\Sigma_{t+1|t} \tag{15}$$

where

16. Although it was not in principle necessary to re-estimate the model corresponding to the transport and communications sector, which is stable in the short term, it was also included in this phase in order to compare the results of the fixed parameter and the varying parameter models.
17. Duncan, Gorr, and Szczypula (1995) provide a cross-sectional multi-estate Kalman filter in the case of "*time-varying-parameter univariate models with pooling.*" They show that this approach is useful when the time series are short and unstable. Although this work does not have a direct relationship with our study, the attempts to incorporate spatial information from the neighbors of Extremadura showed that, at this level, it was not possible to find evidence of significant influences from the neighbors.
18. We shall denote this by $\mathbf{a}_{0|0}$ and $E_{0|0}$, respectively.

$$k_{t+1} = [\mathbf{H}^s_{t+1}\Sigma_{t+1|t}\mathbf{H'}_{t+1} = \sigma^2]\Sigma_{t+1|t}\mathbf{H'}_{t+1} \qquad (16)$$

Then the n-period forward forecast of ?W^s_{t+n} will be given by

$$\Delta W^s_{t+n|t} = \alpha'_{t'|t}H^s_{t+n} \qquad (17)$$

In the application of the above formulae, there are a number of problems that it is necessary to address, referring to the set of parameters that are assumed as known a priori. Specifically, since a "random walk" parametric variation model was specified for α_t, there do not exist any automatic values (such as the unconditional mean or the unconditional covariance matrix) for the values $\mathbf{a}_{0|0}$ and $\Sigma_{0|0}$. Neither are the elements of the matrix $\mathbf{Q}$ nor the parameter σ^2 known. The latter is the least problematic since it may be estimated by maximum likelihood, isolating it from the rest of the parameters (Chow 1984, 1222).

With respect to the initialization values of the Kalman filter, one may use the first K observations, with K being the dimension of the state vector (Harvey 1981; 1989), or an a priori "diffuse" value (Ansley and Kohn 1983), or they can be estimated by maximum likelihood together with the rest of the model's parameters (Chow 1984). In the present case, another alternative was used, fixing (as is done in Hackl and Westlund 1996) the elements $\mathbf{a}_{0|0}$ and $\Sigma_{0|0}$ at the MCO values obtained by estimating the model with constant parameters (and without dummy variables) over the complete sample period.[19]

With respect to the elements of the matrix $\mathbf{Q}$ (known as hyperparameters), there are two possible routes. They may be estimated by a maximum likelihood method (Chow 1984), or fixed beforehand as proposed again by Hackl and Westlund (1996), to avoid problems of lack of identification and large oscillations in the estimates of the state variable parameters. In the present case, the second option was followed:[20] fixing the elements (their values) q_{ii} of the matrix $\mathbf{Q}$ beforehand, by taking $\mathbf{Q}=\mathbf{I}$.[21]

5.3. Ex-Post Forecasting Analysis

As was noted in Section 5.1, all the models were estimated (in general) for the period 1970–90, leaving out the last five years (1991–95) in every case as the period on which to carry out an experiment of ex-post forecasting. Thus, the forecasts made with the structural models are based on real values of the explanatory variables, and these forecasts were compared with the observed values of the endogenous variables for the years under consideration. To measure the degree of goodness of the forecasts, four known statistics based on symmetric loss functions were used, the mean error (ME), the mean absolute error (MAE), the root mean square error (RMSE), and the inequality coefficient (U) of Theil (1966).[22] The results of the ex-post simulation carried out with the two types of model used ($\mathbf{Q}=\mathbf{0}$, i.e., the model with fixed parameters and dummy variables; and $\mathbf{Q}=\mathbf{I}$, i.e., fixing the hyperparameters beforehand) are presented in Table 5.

19. We recognize that, if one wants to fix the initial values instead of estimating them, either of the other two initialization methods considered is more orthodox and correct than that used here. In one of the cases, the small sample size did not allow us to discard certain observations at the start of the sample period. In the second, we believed it advisable to give an initial value by incorporating information a priori, since with so few observations a diffuse initialization value could give rise to trajectories with large fluctuations from one period to the next originated by a poor choice of the initial point.

20. The model in which the hyperparameters were estimated by maximum likelihood yielded generally poorer results than the model where they were fixed beforehand. This may be due to the problems of identification of such parameters caused by the small sample size.

21. Wolf (1987) considers a range of matrices of the type $\mathbf{Q}=\mathrm{E}_{0|0}$ for 0.0, 0.01, 0.05, 0.10 and 0.25, representing in order lesser to greater variability in the state variables and interaction amongst the same.

22. The U statistic is the ratio of the RMSE of the forecasts obtained with the estimated model and the random walk model. This statistic has a straightforward interpretation: if $U<1$ the forecasts of the model are better than the naive forecasts, and if $U>1$ they are worse.

Table 6 shows an overall summary by branches of activity of the results from Table 5; thus, 65.3% of the best results correspond to the model with fixed parameters and dummy variables, and 34.7% to the fixed Q=I. Table 5 shows how the overall results in two out of the seven sectors under study (construction and transport and communications) are better in the model with Q=I than the other option. Subsequently, one observes from the comparison of the statistics that there is no dominance of the time-varying parameter models over the fixed parameter models.

Table 7 shows a summary of the results from Table 5 for every one of the five years taken as the limit in order to perform the simulation experiment. The results confirm that only in one (the second) of the five considered years does the model with Q=I provide a better forecast than the model with dummy variables. For the remaining years, the model with dummy variables accounts for between 24% and a 35% of the

TABLE 5

Forecasting Performance of the Models in the Ex-post Simulations 1991–1995

	ME		MAE		RMSE		U	
Horizon (years)	Q=0	Q=I	Q=0	Q=I	Q=0	Q=I	Q=0	Q=I
AGRICULTURE								
1	**0.002**	0.107	**0.002**	0.107	**0.002**	0.107	**0.017**	0.818
2	−0.065	0.049	0.065	0.054	0.075	0.073	0.587	0.567
3	−0.066	**−0.039**	**0.066**	0.077	**0.073**	0.083	**0.607**	0.692
4	−0.135	−0.164	0.135	0.164	0.155	0.177	1.269	1.455
5	−0.118	−0.145	0.118	0.145	0.142	0.169	1.138	1.360
ENERGY								
1	0.057	0.058	0.057	0.058	0.057	0.058	2.959	3.072
2	**0.009**	−0.025	**0.042**	0.043	**0.043**	0.050	**3.166**	3.676
3	**−0.056**	−0.164	**0.062**	0.164	**0.078**	0.171	**4.300**	9.402
4	−0.068	−0.127	**0.068**	0.127	**0.083**	0.151	**2.667**	4.848
5	−0.080	−0.147	**0.080**	0.147	**0.091**	0.169	**3.208**	5.975
CONSTRUCTION								
1	−0.005	**0.002**	0.005	**0.002**	0.005	**0.002**	0.199	**0.089**
2	−0.016	−0.007	0.016	**0.007**	0.017	**0.010**	0.898	0.576
3	−0.013	−0.012	0.013	0.013	**0.015**	0.016	0.799	0.874
4	−0.010	0.008	**0.010**	0.011	0.013	0.014	0.629	0.676
5	−0.004	0.065	**0.011**	0.065	**0.014**	0.066	**0.310**	1.460
MANUFACTURING INDUSTRY								
1	**0.012**	−0.027	**0.012**	0.027	**0.012**	0.027	**0.338**	0.803
2	0.026	0.011	0.026	0.024	0.028	0.026	1.075	1.012
3	0.041	0.056	0.041	0.056	0.044	0.061	2.033	2.836
4	0.022	0.045	0.036	0.045	0.038	0.055	1.919	2.763
5	**0.000**	0.012	0.041	**0.035**	0.045	**0.041**	2.532	**2.311**

Table 5 continued next page

TABLE 5 (*continued*)

SALES-ORIENTED SERVICES								
	ME		MAE		RMSE		U	
Horizon (years)	Q=0	Q=I	Q=0	Q=I	Q=0	Q=I	Q=0	Q=I
1	0.003	**−0.002**	0.003	**0.002**	0.003	**0.002**	0.164	**0.086**
2	**0.011**	0.016	**0.011**	0.016	**0.013**	0.017	**0.664**	0.874
3	**0.011**	0.027	**0.011**	0.027	**0.012**	0.029	**0.401**	0.949
4	**0.003**	0.020	**0.011**	0.021	**0.013**	0.024	**0.337**	0.645
5	**−0.005**	−0.009	**0.016**	0.018	**0.019**	0.025	**0.569**	0.724

TRANSPORT AND COMMUNICATIONS								
	ME		MAE		RMSE		U	
Horizon (years)	Q=0	Q=I	Q=0	Q=I	Q=0	Q=I	Q=0	Q=I
1	**−0.018**	−0.031	**0.018**	0.031	**0.018**	0.031	**0.928**	1.612
2	0.006	**−0.002**	**0.016**	**0.016**	0.018	**0.017**	0.569	**0.549**
3	0.009	**0.001**	0.014	**0.012**	0.016	**0.014**	0.356	**0.307**
4	0.012	**0.011**	**0.017**	**0.017**	**0.018**	**0.018**	0.256	**0.253**
5	0.009	**0.008**	**0.014**	**0.014**	0.016	**0.015**	0.188	**0.182**

NON-SALES-ORIENTED SERVICES								
	ME		MAE		RMSE		U	
Horizon (years)	Q=0	Q=I	Q=0	Q=I	Q=0	Q=I	Q=0	Q=I
1	−0.004	−0.005	0.004	0.005	0.004	0.005	0.248	0.301
2	−0.001	−0.002	0.003	0.003	0.003	0.003	0.135	0.159
3	**0.007**	0.009	**0.007**	0.009	**0.008**	0.010	**0.444**	0.558
4	**0.005**	0.007	0.015	0.015	0.019	0.018	0.565	0.541
5	0.003	0.003	**0.012**	**0.012**	0.017	**0.015**	0.473	0.414

NOTES: ME = mean error; MAE =mean absolute error; RMSE = root means square error; U = coefficient of inequality of Theil (1996).

TABLE 6
Best Overall Results by Sector Derived from Table 5.

Branches	Q=0	Q=I
Agriculture	15 (75%)	5 (25%)
Energy	20 (100%)	0 (0%)
Construction	10 (47,6%)	11 (52,4%)
Manufacturing Industry	13 (65%)	7 (35%)
Sales-oriented Services	16 (80%)	4 (35%)
Transport and Communications	8 (33,3%)	16 (66,7%)
Non-sales-oriented Services	16 (64%)	9 (36%)
TOTAL	**98**	**52**
PERCENTAGE	**65,3%**	**34,7%**

NOTES: This summary-table compute the best model (Q=0 or Q=I) based on the goodness of fit for the predictions. If any of the statistics are coincident, those will be computed as the best results; this explains that the total number of cases is over 20 for some sectors.

TABLE 7

Best Overall Results by Years in the Results Shown in Table 5.

Horizon (years)	1		2		3		4		5	
Branches	Q=0	Q=I	Q=0	Q=I	Q=0	Q=I	Q=0	Q=I	Q=0	Q=I
Agriculture	4	0	0	4	3	1	4	0	4	0
Energy	4	0	4	0	4	0	4	0	4	0
Construction	0	4	0	4	3	2	3	1	4	0
Manufacturing Industry	4	0	0	4	4	0	4	0	1	3
Sales-oriented Services	0	4	4	0	4	0	4	0	4	0
Transport and Communications	4	0	1	4	0	4	2	4	1	4
Non-sales-oriented Services	4	0	4	2	4	0	2	3	2	4
PERCENTAGE	**71%**	**29%**	**42%**	**58%**	**76%**	**24%**	**74%**	**26%**	**65%**	**35%**

best results. Therefore, this experiment demonstrates that the model Q=I is a preferred alternative. Finally, with respect to the U statistic of Theil (1966), in the case of the energy sector, the two models' forecasts are systematically worse than the naive random walk model. In the remaining sectors, the two models' forecasts generally perform better than the random walk model.

6. SUMMARY AND CONCLUSIONS

It is necessary to place this work in its real context: a small and unstable regional economy with a poor database quality. The designers of this type of model know that it is usual to obtain a model with an unknown source of misspecification. However, the steps followed in this work could provide a general framework to make a regional prediction model, starting from a exploratory data analysis (specification of a "soft" model), and then proceeding with the development and testing of a formal model. It was not the intention to suggest that the specified model was a definitive model; the aim was rather to make it possible to get predictions while the database quality was being improved.

Further the model was specified in a way to minimize the demand for both unavailable and hard-to-access regional variables drawing on the fundamental ideas of the "economic base" models but implemented using the framework provided by cointegration theory. This theory distinguished between long-term economic relationships and short-term dynamics by introducing error correction models that formed the analytical basis of the econometric model built in this paper. The result was a model with an unknown source of misspecification, since the results showed that, in the case of Extremadura, structural instability existed for both the long and the short term. Hence, standard econometric methods would not have been applicable in this case. The parameters were allowed to vary throughout the sample period, the most common method used is to introduce dummy variables that interact with the original variables, thus allowing changes in the slopes and/or the intercept. Another alternative used was to allow the regression coefficients to vary at random, endowing the resulting model with a greater flexibility than in the fictitious variable case.

In the long term, the introduction of fictitious variables was sufficient to pick up the changes in regimes that occurred during the sample period. In the short term, however, the instability was far greater, requiring the introduction of either dummy variables or allowing the parameters to vary randomly. In the forecasting analysis that was carried out, the fixed parameter model (with dummy variables) yielded better results than those revealed with the other approach.

Nevertheless, the resulting stochastic time-varying parameters model can be claimed to provide a feasible methodological option that should be taken into account when forecasting small and unstable regional economies. The generality of this finding cannot be demonstrated since only one successful case study was explored. Further, this kind of model has the advantage of incorporating future changes about the values of the parameters into the forecasts, which cannot be handled with the dummy variables model. In addition, it should be mentioned that the stochastic parameters model has not been used in this case under optimal conditions, due to lack of data.[23]

Finally, some recommendations can be provided in terms of a set of general steps to be followed in the construction of a prediction model for a small and unstable regional economy subject to a poor available database quality. First, exploratory data analysis should be employed to uncover patterns and structures and to propose hy-

23. As it is known, these types of models that essentially correspond to an error-learning mechanism, need a great number of observation in order to properly function.

potheses about both the basic and non-basic sectors and the intersectoral dependences. Second, co-integration theory would appear to be an attractive option to contrast the proposed long-term relations. Generally, it is expected that the regional basic sectors will follow a similar evolution to the corresponding national sectors; for the non-basic sectors, a long-term relation will probably exist with either one or several indicators of the level of total internal demand in the region. Third, some parametric stability tests should be applied (based on the calculation of Wald sequential statistics) to detect the presence of possible break points in each of the equations of long-term behavior. Fourth, if structural change is detected, fictitious variables may be needed to approximate it. Fifth, the short-term equations should be specified using variables that explain the short-term deviations of the situation from equilibrium. Thereafter, the short-term equations should be estimated and the presence of breaking points in each of the equations of short-term behavior should be explored. Finally, if the null hypothesis of stability is rejected, the dummy variables to be introduced in each of the equations of short-term behavior should be identified, and/or allow the regression coefficients to vary at random. Obtaining predictions from both approaches will provide the opportunity to select the prediction considering either additional information or the judgment of the forecaster.

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