CANARY ISLAND TOMATO EXPORTS: A STRUCTURAL ANALYSIS OF SEASONALITY

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SUMMARY

The European tomato market is characterised by a constant process of dynamic adjustment toward the equilibrium. Furthermore, Canary tomato exports cause a high seasonal impact on market prices in the winter period. In these circumstances, an adequate distribution of shipments throughout the campaign could contribute to maximize producers' profits.

The goal of this paper is to analyse the seasonal pattern of Canary tomato exports to Europe throughout the first fourteen campaigns following Spanish integration into the European Union. These export levels show some degree of instability, clearly related to the changes in the European Union trade rules, and there is a long period, the summer, without exports. Moreover, we have opted by using weekly data. These factors should be taken into account in order to accurately capture the performance of exports and, specifically, the nature of their seasonal behaviour. Thus, this analysis is carried out inside the frame delimited by the structural approach to time series and the usefulness of spline functions as an alternative to standard seasonal variation models is shown.

Key words: Canary tomato exports, weekly data, seasonality, structural models, splines.

1. INTRODUCTION

The cultivation of tomatoes for export in the Canary Islands has a long tradition. In the last decades of the 20th century, the participating agents in this activity have modernized cultivation, package and marketing techniques. The driving force behind this modernisation process has been national and international competition in the European markets. The strongest competitors of Canary suppliers are Morocco and, above all, Spain mainland. Canary shares in exports to Europe in the winter period were around 40% in the analysed campaigns. However the innovative effort of the producers will not be able to support the position of Canary tomatoes in the markets indefinitely. Furthermore, it is necessary to analyse precisely the appropriate moment for sending the quantity which every market demands. In those weeks in which the Canary export shares are the highest, the growth of these exports is usually accompanied by a fall in market prices. For this reason, Canary producers should plan their shipments in order to guarantee some profit margin. From this point of view, the study of the seasonal pattern of tomato exports from the Canary Islands is highly relevant to the marketing decision-making process. In this paper, the evolution of the weekly exports to Europe of Canary Islands tomatoes is analysed in the period following Spain's entry in the European Union.

Before building an econometric model capturing the variations of this series, it is useful to point out some features of the tomato export activity in the Canary Islands. First, the seasonal pattern of Canary exports is characterised by concentration in winter and disappearance in summer. This pattern is a rational response guided by the search for profitability; there are no exports in summer because northern European countries and Canary supplies converge in this season, and so Canary tomato prices would be low. Second, the development of greenhouse technology in northern Europe, the increase in

Spain mainland supply and the third country supplies sharing the same export periods as Canary Islands product entry to the European market, have led to a growing overlap of the different supplies in spring and autumn. Finally, Spain's full integration into the CAP has brought about the abolition of the mechanisms used by European producers as custom barriers against production from the Canary Islands[1], and these changes have encouraged Canary producers to increase their exports, despite the fact that Moroccans have also benefitted from a significant reduction in these barriers[2]. From these remarks, it follows that the volumes of Canary tomatoes exported in the different weeks of the campaign have not kept stable throughout last years.

In order to model the behaviour of exports, an important task is whether these alterations are located at specific times and can be captured through modifications in deterministic components, or whether they are more continuous and random changes that can be captured by ARMA models with or without unit roots. Moreover, if the classic definition of the components of a time series is relaxed, structural models appear to be a potentially appropriate tool for handling these instabilities. Structural analysis introduce a new conceptual framework which can lead to apparently different results although, nevertheless, equivalent to those obtained through alternative models, and the techniques used in this paper can be framed inside this approach.

The use of the structural approach, the specific constraints which must be taken into account when weekly data are being studied and the existence of non-exporting periods of variable amplitude, are factors why this study can be interesting from an econometric point of view. The plan of the paper is as follows. In the next section, the data used are identified and some interesting features of their nature and preliminary processing are discussed. In case study, the properties of the series do not appear to remain the same over time. Then, structural models are an appropriate class of models to cope with this kind of situation. The basic statistical framework for handling such models is outlined in the third section. In section four, these procedures are applied to weekly series of Canary tomato exports. Section 5 presents the conclusions.

2. DATA

This section is concerned with the series of weekly exports of Canary tomatoes (measured in 6 kg boxes) to European markets from the 1986/1987 harvest until the 1999/2000 harvest[3]. Each campaign is considered to start on week 27 of a year and

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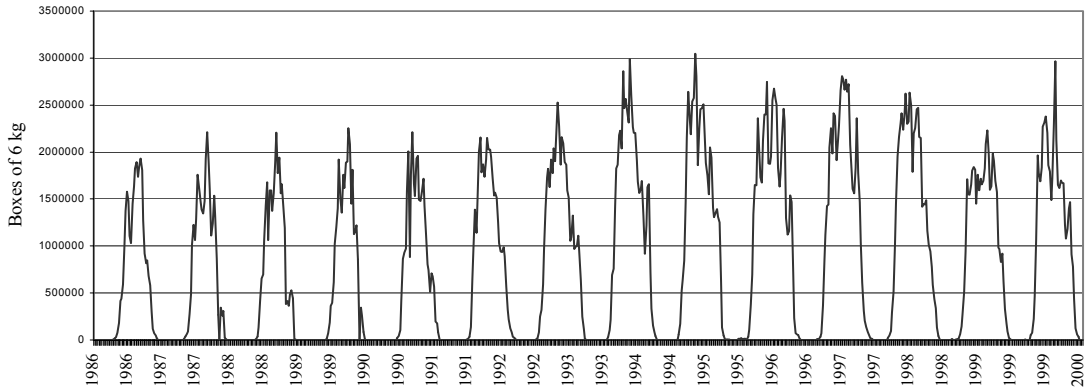
[1] In practice, the reference price system did not allow Canary produce to enter European markets from the month of April onwards of each year. This system was replaced by another, more flexible system of supply prices, introduced in July 1991. From the 1st January 1993, the abolition of supply price system meant a liberalisation of Canary exports to the European Community, with the exception of the maintenance of the complementary mechanism applied to exchanges, of very little impact. For a detailed explanation of these protection mechanisms, see Cáceres (2000: 292-305).

[2] Since the signing of the Protocol between Morocco and the EU in 1988, and until the full integration of Spain in the CAP, Moroccan production entered European markets under similar conditions to Canary production. The 1994 GATT agreements constituted a hardening of the access conditions for Moroccan produce, but these conditions became null and void as a result of the EU-Morocco trade agreements of 1995 and 1996. See Cáceres (2000: 278-281, 308-312).

[3] Export statistics have been obtained from weekly data published by the provincial exporter associations of Santa Cruz de Tenerife (ACETO) and of Las Palmas (FEDEX) in their export season reports. In the weeks where these sources did not register any data, they have been assigned a zero value.

conclude in week 26 of the following year. Figure 2.1 shows a plot of this series and we will refer to it as $\{y_t\}_{t=1,...,728}$, hereafter[4].

Figure 2.1. Canary Tomato Exports to Europe (1986/1987 to 1999/2000)



The statistical analysis of these data is not an easy task. The first problem is that because there is not an integral number of weeks in the year, the number of observations in the year varies between 52 and 53. Hence, the week of one year and the same week of the following year do not fall on exactly the same period of a year. Bearing in mind that there is a long period —the summer— without observations and the fact that the campaigns appear to begin one week later when there are 53 observations corresponding to a year, we have decided to move forward by one week the starting point of the campaign in these cases.

In figure 2.1 a rising movement that begins in October and finishes in January or February, followed by another downward movement that continues until May or June, is observed campaign by campaign. Thus, changes of seasonal behaviour are not significant enough to justify considering that *summer become winter* as it could be possible if that behaviour were dominated by the non stationary stochastic seasonal component. However, three periods differing by the extent of the campaign and the export levels in some weeks of the campaign can be distinguished. The full integration into the European Union since the first of January 1993, and the consequent abolition of reference/supply prices, brought about a significant export boost[5]. The general growth in exports in this second period is interrupted in 1996, coinciding with the introduction of a trade agreement between the EU and Morocco[6]. Despite the changes observed in the growth rate and the average weekly levels of exports, the seasonal pattern is more or less regular, with maximum and minimum levels almost always located around the same weeks of the harvest.

Therefore, and as a preliminary hypothesis, it could be assumed that there are a stable seasonal component around a stochastic trend component. This behaviour could be

[4] The case taken into account in this paper requires weekly data in order to avoid that the interest seasonal cycles go unnoticed by the degree of temporal aggregation. In fact, export association register their shipments abroad on a weekly basis, which shows that the week is a period of time which economic agents consider appropriate to perceive the market reactions and to be able to act in consequence.

[5] Already from the 1991/1992 campaign, surely as a response to the new trade situation of the Canary Islands with regard to the European Union since July 1991 (reference prices were substituted by supply prices), the campaigns, that often finished in early May, continued until June.

[6] See footnote 2.

modelled by a set of structural change assumptions in the deterministic components related to changes in trade rules. However, in this paper structural models are used as a tool which can capture the instabilities of the different components of the series through statistical criteria and without the researcher establishing, at least beforehand, such defined variation patterns. This methodology is briefly explained in the next section.

3. STRUCTURAL TIME SERIES MODELS

The analysis of time series is based on the stochastic process theory, originally built on the assumption of stationarity. However, few economic time series are stationary. Indeed, the greater availability of data in the last years and, especially, the possibility of constructing longer series with higher frequency of observations, make evident the difficulties in asserting as true the assumption of a fixed behaviour pattern over time. In this sense, it would be more appropriate to assume that the statistical properties of most of the socio-economic series show an evolutionary nature.

The traditional time series paradigm is one in which it is assumed that a series can be reduced to stationarity by differencing or detrending. However, modelling the stationary transformation is not the best way of identifying the salient features of a series. In a structural time series model, the source of non-stationarity is not eliminated and the aim is to present the stylised facts of a series in terms of a decomposition into stochastic components which have a direct interpretation[7].

A univariate structural time series model can be formulated as $y_t = \mu_t + \psi_t + \gamma_t + \varepsilon_t$, t=1,...,T, where μ_t, ψ_t and γ_t are the trend or level component, the cycle and the seasonal component, and ε_t is the irregular component, which reflects non-systematic movements in the series. This model must be flexible enough to allow it to respond to changes in the behaviour of the series. Therefore, a structural model needs to be set up in such a way that its components are regarded as being driven by random disturbances.

The salient characteristics of the time series shown in figure 2.1 are a trend and a seasonal pattern, but a cycle is not observed. The cyclical component should be in a model if there are reasonably strong grounds for believing one to be present; then, in order to capture these characteristics, the so-called basic structural model could be used, which can be formulated as follows

$$y_t = \mu_t + \gamma_t + \varepsilon_t,\ \varepsilon_t \sim NID(0,\ \sigma_\varepsilon^2)$$

where the notation $NID(0,\ \sigma_\varepsilon^2)$ denotes a normally distributed, serially independent, random variable with mean zero and variance σ_ε^2; the level component is assumed to be generated by the random walk $\mu_t = \mu_{t-1} + \beta_{t-1} + \eta_t$, where $\beta_t = \beta_{t-1} + \zeta_t$, $\eta_t \sim NID(0, \sigma_\eta^2)$ and $\zeta_t \sim NID(0, \sigma_\zeta^2)$[8]; and the seasonal component can be modelled by two ways. If there

[7] For a detailed explanation of these models, see Harvey (1989) and Harvey (1993). See also Durbin and Koopman (2001).

[8] It is assumed that the underlying level of the process is a stochastic process whose value at time t, μ_t, is the result of adding to the value of the component at time t-1, μ_{t-1}, a certain random increase, β_{t-1}, and a random disturbance term, η_t. Of course, the level or the slope may not possess a stochastic nature and, moreover, the slope may not be present.

$$g(w)=\begin{cases} g_{1,0}+g_{1,1}w & , \quad w_0 \le w \le w_1 \\ g_{2,0}+g_{2,1}w+g_{2,2}w^2+g_{2,3}w^3, & w_1 \le w \le w_2 \\ g_{3,0}+g_{3,1}w+g_{3,2}w^2+g_{3,3}w^3, & w_2 \le w \le w_3 \\ g_{4,0}+g_{4,1}w+g_{4,2}w^2+g_{4,3}w^3, & w_3 \le w \le w_4 \end{cases}$$

with $w_0 = 1$ and $w_4=52$. The spline g(w) must satisfy following conditions:

a) continuity of the spline

$$g_{1,0}+g_{1,1}w_1 = g_{2,0}+g_{2,1}w_1+g_{2,2}w_1^2+g_{2,3}w_1^3$$
$$g_{2,0}+g_{2,1}w_2+g_{2,2}w_2^2+g_{2,3}w_2^3 = g_{3,0}+g_{3,1}w_2+g_{3,2}w_2^2+g_{3,3}w_2^3$$
$$g_{3,0}+g_{3,1}w_3+g_{3,2}w_3^2+g_{3,3}w_3^3 = g_{4,0}+g_{4,1}w_3+g_{4,2}w_3^2+g_{4,3}w_3^3$$
$$g_{4,0}+g_{4,1}(w_4+1)+g_{4,2}(w_4+1)^2+g_{4,3}(w_4+1)^3 = g_{1,0}+g_{1,1}w_0$$

b) continuity of its first derivative

$$g_{1,1} = g_{2,1}+2g_{2,2}w_1+3g_{2,3}w_1^2$$
$$g_{2,1}+2g_{2,2}w_2+3g_{2,3}w_2^2 = g_{3,1}+2g_{3,2}w_2+3g_{3,3}w_2^2$$
$$g_{3,1}+2g_{3,2}w_3+3g_{3,3}w_3^2 = g_{4,1}+2g_{4,2}w_3+3g_{4,3}w_3^2$$
$$g_{4,1}+2g_{4,2}(w_4+1)+3g_{4,3}(w_4+1)^2 = g_{1,1}$$

c) continuity of its second derivative[23]

$$2g_{2,2}+6g_{2,3}w_2 = 2g_{3,2}+6g_{3,3}w_2$$
$$2g_{3,2}+6g_{3,3}w_3 = 2g_{4,2}+6g_{4,3}w_3$$

If it is assumed that w_1, w_2 and w_3 are known, this representation involves the coefficients $g_{1,0}$, $g_{1,1}$, $g_{2,0}$, $g_{2,1}$, $g_{2,2}$, $g_{2,3}$, $g_{3,0}$, $g_{3,1}$, $g_{3,2}$, $g_{3,3}$, $g_{4,0}$, $g_{4,1}$, $g_{4,2}$ and $g_{4,3}$. They cannot be chosen freely, but must satisfy the above conditions, and we are left with four degrees of freedom. We have opted by writting the parameters of the vector $G_{10x1} = (g_{1,0}, g_{1,1}, g_{2,0}, g_{2,1}, g_{2,2}, g_{2,3}, g_{3,0}, g_{3,1}, g_{3,2}, g_{3,3})'$ as functions of $g_{4,0}$, $g_{4,1}$, $g_{4,2}$ and $g_{4,3}$, which are the finally estimated parameters[24]. Taking into account the approach to the problem, the set of above mentioned conditions can be written in a matrix form such as WG=R, where

[23] Given the linear specification in the first segment, neither $\nabla^2 g_1(w_1) = \nabla^2 g_2(w_1)$ nor $\nabla^2 g_4(w_4+1) = \nabla^2 g_1(w_0)$ conditions have been taken into account.

[24] Another option consists in demanding that the spline satisfies extra conditions. For example, the spline function can be forced to cross the knots.

$$W_{10x10}=\begin{bmatrix} 1 & w_1 & -1 & -w_1 & -w_1^2 & -w_1^3 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & w_2 & w_2^2 & w_2^3 & -1 & -w_2 & -w_2^2 & -w_2^3 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & w_3 & w_3^2 & w_3^3 \\ -1 & -w_0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & -1 & -2w_1 & -3w_1^2 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 2w_2 & 3w_2^2 & 0 & -1 & -2w_2 & -3w_2^2 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 2w_3 & 3w_3^2 \\ 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 2 & 6w_2 & 0 & 0 & -2 & -6w_2 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 2 & 6w_3 \end{bmatrix}$$

$$R_{10x1}=\begin{bmatrix} 0 \\ 0 \\ g_{4,0}+g_{4,1}w_3+g_{4,2}w_3^2+g_{4,3}w_3^3 \\ -g_{4,0}-g_{4,1}w_4-g_{4,2}w_4^2-g_{4,3}w_4^3 \\ 0 \\ 0 \\ g_{4,1}+2g_{4,2}w_3+3g_{4,3}w_3^2 \\ -g_{4,1}-2g_{4,2}w_4-3g_{4,3}w_4^2 \\ 0 \\ 2g_{4,2}+6g_{4,3}w_3 \end{bmatrix}$$

Therefore, $G=W^{-1}R$. If W^{-1} is expressed by

$$W^{-1}{}_{10x10}=\begin{bmatrix} a_{1,1} & a_{1,2} & \cdots & a_{1,10} \\ a_{2,1} & a_{2,2} & \cdots & a_{2,10} \\ \vdots & \vdots & \ddots & \vdots \\ a_{10,1} & a_{10,2} & \cdots & a_{10,10} \end{bmatrix}$$

and g_r, r=1, ..., 10, are defined in such a way that $g_1=g_{1,0}$, $g_2=g_{1,1}$, $g_3=g_{2,0}$, $g_4=g_{2,1}$, $g_5=g_{2,2}$, $g_6=g_{2,3}$, $g_7=g_{3,0}$, $g_8=g_{3,1}$, $g_9=g_{3,2}$ and $g_{10}=g_{3,3}$, then

$$g_r=a_{r,3}(g_{4,0}+g_{4,1}w_3+g_{4,2}w_3^2+g_{4,3}w_3^3)+a_{r,4}(-g_{4,0}-g_{4,1}w_4-g_{4,2}w_4^2-g_{4,3}w_4^3)$$
$$+a_{r,7}(g_{4,1}+2g_{4,2}w_3+3g_{4,3}w_3^2)+a_{r,8}(-g_{4,1}-2g_{4,2}w_4-3g_{4,3}w_4^2)+a_{r,10}(2g_{4,2}+6g_{4,3}w_3)$$

and, rearranging terms,

$$\begin{aligned} g_r &=(a_{r,3}-a_{r,4})g_{4,0}+(w_3a_{r,3}-w_4a_{r,4}+a_{r,7}-a_{r,8})g_{4,1} \\ &+(w_3^2a_{r,3}-w_4^2a_{r,4}+2w_3a_{r,7}-2w_4a_{r,8}+2a_{r,10})g_{4,2} \\ &+(w_3^3a_{r,3}-w_4^3a_{r,4}+3w_3^2a_{r,7}-3w_4^2a_{r,8}+6w_3a_{r,10})g_{4,3} \\ &=\alpha_{r,0}g_{40}+\alpha_{r,1}g_{41}+\alpha_{r,2}g_{42}+\alpha_{r,3}g_{43};\ r=1,...,10 \end{aligned}$$

Now, the spline can be formulated as a function of $g_{4,0}$, $g_{4,1}$, $g_{4,2}$ and $g_{4,3}$ in the following way

$$g(w)=\begin{cases}(\alpha_{1,0}g_{4,0}+\alpha_{1,1}g_{4,1}+\alpha_{1,2}g_{4,2}+\alpha_{1,3}g_{4,3})+ & \\ (\alpha_{2,0}g_{4,0}+\alpha_{2,1}g_{4,1}+\alpha_{2,2}g_{4,2}+\alpha_{2,3}g_{4,3})w & , \quad \text{si } w_0 \le w \le w_1 \\ (\alpha_{3,0}g_{4,0}+\alpha_{3,1}g_{4,1}+\alpha_{3,2}g_{4,2}+\alpha_{3,3}g_{4,3})+ & \\ (\alpha_{4,0}g_{4,0}+\alpha_{4,1}g_{4,1}+\alpha_{4,2}g_{4,2}+\alpha_{4,3}g_{4,3})w+ & \\ (\alpha_{5,0}g_{4,0}+\alpha_{5,1}g_{4,1}+\alpha_{5,2}g_{4,2}+\alpha_{5,3}g_{4,3})w^2+ & \\ (\alpha_{6,0}g_{4,0}+\alpha_{6,1}g_{4,1}+\alpha_{6,2}g_{4,2}+\alpha_{6,3}g_{4,3})w^3 & , \quad \text{si } w_1 \le w \le w_2 \\ (\alpha_{7,0}g_{4,0}+\alpha_{7,1}g_{4,1}+\alpha_{7,2}g_{4,2}+\alpha_{7,3}g_{4,3})+ & \\ (\alpha_{8,0}g_{4,0}+\alpha_{8,1}g_{4,1}+\alpha_{8,2}g_{4,2}+\alpha_{8,3}g_{4,3})w+ & \\ (\alpha_{9,0}g_{4,0}+\alpha_{9,1}g_{4,1}+\alpha_{9,2}g_{4,2}+\alpha_{9,3}g_{4,3})w^2+ & \\ (\alpha_{10,0}g_{4,0}+\alpha_{10,1}g_{4,1}+\alpha_{10,2}g_{4,2}+\alpha_{10,3}g_{4,3})w^3, & \quad \text{si } w_2 \le w \le w_3 \\ g_{4,0}+g_{4,1}w+g_{4,2}w^2+g_{4,3}w^3 & , \quad \text{si } w_3 \le w \le w_4 \end{cases}$$

that is,

$$g(w)=\left[(\alpha_{1,0}g_{4,0}+\alpha_{1,1}g_{4,1}+\alpha_{1,2}g_{4,2}+\alpha_{1,3}g_{4,3})+(\alpha_{2,0}g_{4,0}+\alpha_{2,1}g_{4,1}+\alpha_{2,2}g_{4,2}+\alpha_{2,3}g_{4,3})w\right]D_{1,w}$$
$$+\begin{bmatrix}(\alpha_{3,0}g_{4,0}+\alpha_{3,1}g_{4,1}+\alpha_{3,2}g_{4,2}+\alpha_{3,3}g_{4,3}) \\ +(\alpha_{4,0}g_{4,0}+\alpha_{4,1}g_{4,1}+\alpha_{4,2}g_{4,2}+\alpha_{4,3}g_{4,3})w+(\alpha_{5,0}g_{4,0}+\alpha_{5,1}g_{4,1}+\alpha_{5,2}g_{4,2}+\alpha_{5,3}g_{4,3})w^2 \\ +(\alpha_{6,0}g_{4,0}+\alpha_{6,1}g_{4,1}+\alpha_{6,2}g_{4,2}+\alpha_{6,3}g_{4,3})w^3\end{bmatrix}D_{2,w}$$
$$+\begin{bmatrix}(\alpha_{7,0}g_{4,0}+\alpha_{7,1}g_{4,1}+\alpha_{7,2}g_{4,2}+\alpha_{7,3}g_{4,3}) \\ +(\alpha_{8,0}g_{4,0}+\alpha_{8,1}g_{4,1}+\alpha_{8,2}g_{4,2}+\alpha_{8,3}g_{4,3})w+(\alpha_{9,0}g_{4,0}+\alpha_{9,1}g_{4,1}+\alpha_{9,2}g_{4,2}+\alpha_{9,3}g_{4,3})w^2 \\ +(\alpha_{10,0}g_{4,0}+\alpha_{10,1}g_{4,1}+\alpha_{10,2}g_{4,2}+\alpha_{10,3}g_{4,3})w^3\end{bmatrix}D_{3,w}$$
$$+\left[g_{4,0}+g_{4,1}w+g_{4,2}w^2+g_{4,3}w^3\right]D_{4,w}$$

where $D_{i,w}=\begin{cases}1, w_{i-1}\le w<w_i \\ 0, \text{in other case}\end{cases}$, i=1,2,3, and $D_{4,w}=\begin{cases}1, w_3\le w\le w_4 \\ 0, \text{in other case}\end{cases}$, and rearranging terms

$$g(w)=g_{4,0}\begin{bmatrix}(\alpha_{1,0}+\alpha_{2,0}w)D_{1,w}+(\alpha_{3,0}+\alpha_{4,0}w+\alpha_{5,0}w^2+\alpha_{6,0}w^3)D_{2,w} \\ (\alpha_{7,0}+\alpha_{8,0}w+\alpha_{9,0}w^2+\alpha_{10,0}w^3)D_{3,w}+D_{4,w}\end{bmatrix}$$
$$+g_{4,1}\begin{bmatrix}(\alpha_{1,1}+\alpha_{2,1}w)D_{1,w}+(\alpha_{3,1}+\alpha_{4,1}w+\alpha_{5,1}w^2+\alpha_{6,1}w^3)D_{2,w} \\ (\alpha_{7,1}+\alpha_{8,1}w+\alpha_{9,1}w^2+\alpha_{10,1}w^3)D_{3,w}+wD_{4,w}\end{bmatrix}$$
$$+g_{4,2}\begin{bmatrix}(\alpha_{1,2}+\alpha_{2,2}w)D_{1,w}+(\alpha_{3,2}+\alpha_{4,2}w+\alpha_{5,2}w^2+\alpha_{6,2}w^3)D_{2,w} \\ (\alpha_{7,2}+\alpha_{8,2}w+\alpha_{9,2}w^2+\alpha_{10,2}w^3)D_{3,w}+w^2D_{4,w}\end{bmatrix}$$
$$+g_{4,3}\begin{bmatrix}(\alpha_{1,3}+\alpha_{2,3}w)D_{1,w}+(\alpha_{3,3}+\alpha_{4,3}w+\alpha_{5,3}w^2+\alpha_{6,3}w^3)D_{2,w} \\ (\alpha_{7,3}+\alpha_{8,3}w+\alpha_{9,3}w^2+\alpha_{10,3}w^3)D_{3,w}+w^3D_{4,w}\end{bmatrix}$$
$$=g_{4,0}X_{0,w}+g_{4,1}X_{1,w}+g_{4,2}X_{2,w}+g_{4,3}X_{3,w}$$

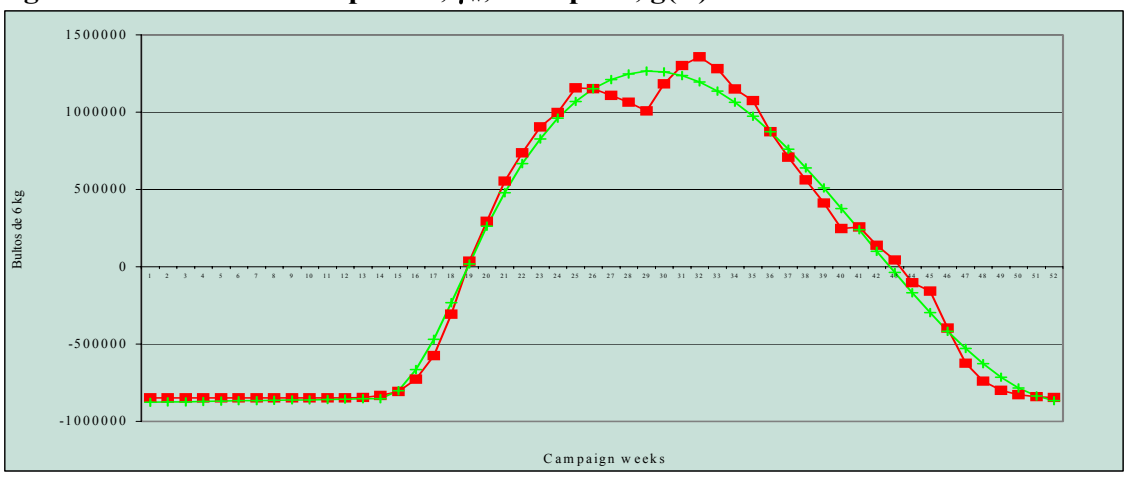
The variables $X_{i,w}$, i=0,1,2,3, can be incorporated into the structural model of the previous subsection as exogeneous variables, replacing the standard dummy variable seasonal component. However, given that $X_{0,w}$ is a unit vector, the structural model which can be estimated is (model 2)

$$y_t = \mu_t + g_{41}X_{1,t} + g_{42}X_{2,t} + g_{43}X_{3,t} + \lambda_{51,90}I_{51,90} + \varepsilon_t$$

where $X_{1,t}$, $X_{2,t}$ and $X_{3,t}$ are column vectors of dimension 728x1[25] defined in such a way that $X_{i,t} = X_{i,w}$, i=1, 2, 3, if the observation at time t corresponds to week w of the campaign.

In our case, the location of w_1, w_2 and w_3 is not known in advance. Thus, these coefficients must be treated as parameters to be estimated. One way to estimate the resulting model is to see this as a nonlinear model and estimate it using iterative methods. However, as pointed out by Nielsen (1998: 46-47), experience shows that iterative estimation procedures lead to local minima and, generally, better results are obtained through heuristic methods involving successive adjustments in which it is assumed that locations are known. In this sense, the decision has been adopted to select the combination of locations that minimises the residual sum of squares in the estimation of the regression model $\gamma_w = g_{40}X_{0,w} + g_{41}X_{1,w} + g_{42}X_{2,w} + g_{43}X_{3,w} + \varepsilon_w$, where γ_w is the estimated seasonal component in the previous subsection. Following this criterion, the chosen combination is w_1=14, w_2=20 and w_3=35, and the resulting spline is the one shown in figure 4.2.1.

Figure 4.2.1. Seasonal component, γ_w, and spline, g(w)



γ_w _____ g(w) _____

For these locations, the exogenous variables $X_{1,t}$, $X_{2,t}$ and $X_{3,t}$ have been calculated and the structural model (model 2) has been estimated jointly. Estimating this model gives the results shown in table 4.2.1 and figure 4.2.2[26].

[25] Note that there are 14 campaigns with 52 weeks each.

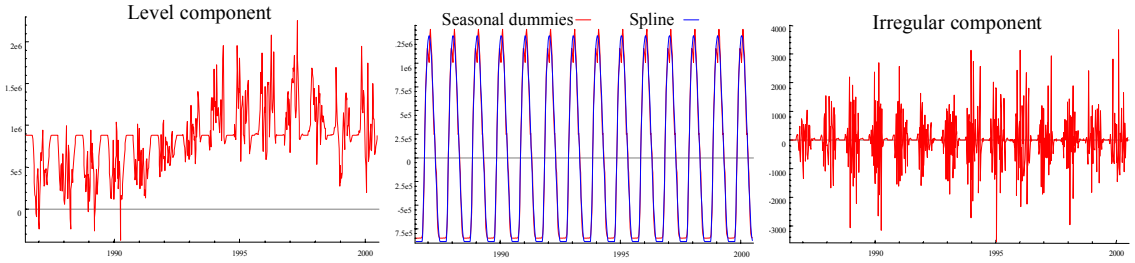
[26] In the same graph are shown the estimates of the seasonal component modelled by both approaches: standard dummy variables and spline. The estimates of the spline has been obtained from the estimated regression coefficients for $X_{1,t}$, $X_{2,t}$ and $X_{3,t}$. The intercept of the spline has been calculated in such a way that the average estimated seasonal effects are zero. The estimates of level component have also been properly corrected so that this intercept is not captured simultaneously in the trend and seasonal components.

Table 4.2.1. Parameter estimates for model 2

$\hat{\sigma}_{\varepsilon}^2$	$\hat{\sigma}_{\eta}^2$	$\hat{\mu}_T$	$\hat{\lambda}_{51,90}$	$\hat{g}_{4,1}$	$\hat{g}_{4,2}$	$\hat{g}_{4,3}$
1.2566×10^{8}	4.7561×10^{10}	-1.7447×10^{7}	-1.01×10^{6}	1.6201×10^{6}	-42514	342.51
(0.026)	(1.0000)	(-3.5585)	(-6.5234)	(4.3557)	(-4.7534)	(4.9412)

The signal-noise ratios have been shown in brackets in the case of estimations of the variances of unobservable components and t statistics in the case of the remaining estimated parameters.

Figure 4.2.2. Estimated components of model 2



As can be noted in figure 4.2.2, the spline formulation captures the seasonal variations in a fairly similar manner to the standard dummy variable method and, therefore, it can be concluded that both formulations are two equivalent ways of modelling the seasonal pattern.

In our case, the spline was not the only way of handling the seasonal pattern, but it has been used to illustrate its methodological worth. Nevertheless, sometimes it is not possible to estimate the seasonal component using seasonal dummy variables or trigonometric terms, due to computing troubles related to the excessive length of the seasonal period and the consequent high dimension of the parameters vector to be estimated. In these cases, the splines become a more valuable tool. However, when this is the case, the choice of the optimum spline could not be carried out using the procedure put forward in this paper and it would be necessary to determine the location of join points by means of heuristic adjustments starting from the observation of the original series or, perhaps, once some of its components have been filtered.

5. CONCLUSIONS

The study of the series of Canary tomato exports using structural models shows the instability of what, in the classic approach to time series, is defined as trend component, whose behaviour has been adequately characterised by a random walk plus noise model. On the other hand, the non-stochastic nature of the seasonal pattern has been properly handled using a standard dummy variable method and by means of a periodic spline, which are equivalent ways of modelling this pattern.

The main economic conclusion obtained from the previous analysis is that the seasonal pattern is stable. Hence, it would be true to say that, even though the economic agents involved in the production and exports of Canary tomatoes have reacted to changes in market rules, this response has not brought about a significant modification of the weekly distribution of exports over the campaign.

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