Why did the Wood Stock Increase in the Galician Forestry Industry during a Time Period of Decreasing Profitability?

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Abstract

The aim of this paper is to analyze the statistical relationship between the yearly wood production of Maritime Pine and Eucalyptus and their market prices in Galicia (northwest of Spain) during the 1985-2007 period. The wood market presents an apparent contradiction from an economic point of view: forest owners accumulate growing stock during a period characterized by a decreasing profitability in the forestry sector. We attempt to explain this paradox statistically using the Granger causality test and an analysis based on the Cross-Correlation functions. The results demonstrate that the increasing forest investment is due to a decrease in wood prices in the case of *Pinus Pinaster*. There were lower prices and less wood production, so there was a higher accumulation of growing stock. On the contrary, this result does not hold for *Eucalyptus*. The decrease in price does not statistically cause a reduction in wood production. This may suggest that the accumulation of growing stock in this case could be a consequence of forest abandonment and a fast natural regeneration of this species.

JEL: C40, Q23

1. Introduction

Approximately half of the Spanish wood production occurs in Galicia, but it only covers approximately 7.5% of the total Spanish forest area.[1] Until the 1960s, agriculture and cattle farming were very important in the traditional rural economy. Migration towards urban areas together with changes in farming practices made these lands less needed for traditional purposes, so the forest owners and local authorities proceeded to plant trees. At first, the reforestation was mostly done with Maritime Pine (*pinus pinaster*) and later on with plantations of Eucalyptus (*eukaliptus globulus*) to meet the demand of the pulp industry. Currently, both species make up 85% of the wood production in this region.

Data from the Second and Third National Forest Inventories published by the Spanish Ministry of Environment shows that the volume of growing stock in Galicia has increased from 90,396 million m^3 of timber to 133,090 million m^3. The volume of Eucalyptus has increased by 122% and Maritime Pine has increased 8%. However, the profitability has decreased in this time period because of the evolution of prices and costs. On the one hand, the constant prices have decreased yearly 1.75 percent and 0.25 percent for Maritime Pine and Eucalyptus, respectively.[2] On the other hand, the forest sector demands more inputs from the industry (essentially machinery and fuel), so that the cost per cubic meter of timber sold has grown at an annual rate of 8%. As a result, the price-costs gap is reduced, and there is a decline in the profitability of forestry in Galicia.

The increasing volume of growing stock together with a decreasing profitability seems to be contradictory from an economic point of view. To be more precise,

[1] About 1,400,000 ha. Galicia and 18,500,000 ha. Spain.
[2] Data from the yearly Agricultural Statistics published by the regional authorities (Xunta de Galicia) and the National Statistics Office.

Economic Theory postulates that the reduction of profitability should be followed by a decrease in the investment in forest wood stock. Moog and Borchert (2001) found the same inconsistency in the German forestry sector. Specifically, these authors also observed an increasing volume of standing timber along with a decrease in the return on investment, but they found there is no contradiction. At first glance, it seems to be irrational since the investments should decrease when the economic expectations regarding an economic sector become worse. However, following the Land Rent Theory, they calculated the optimal rotation period using Pressler's indicating percent. The results show that the forest owners invest in standing timber by increasing rotation periods when the prices fall. Consequently, owners accumulate forest wood stock, expecting a higher price in the future. This fact validates that price is one of the most important exogenous factors if one wants to understand what is driving the owner's decision-making process. This finding confirms two main strands of the literature that analyze the forest problems from an economic perspective. The first one is centered on the estimation of timber supply (Moog, 1991), and the second one is based on the optimal rotation period (Faustmann, 1949; Kula, 1988; Quentin, 2004; Faucheux and Noël, 2001; Diaz-Balteiro, 1997; Romero, 1994). However, calculating the rotation periods implies a restriction in the analysis since it is necessary to make assumptions about the interest rate, cost, growth functions, and thinning. Moreover, sometimes the unavailability of data (prices of imported timber, pulp exports, rates of growth, etc.) does not allow researchers to estimate the supply function of wood or calculate the optimal rotation with the Faustmann Formula or Pressler's indicating percent.

This study uses an alternative perspective to explain the apparent contradiction in forest owners' increasing investment during a period of decreasing profitability. It directly examines the statistical relationship between price and wood production. We applied two techniques to explain this paradox statistically: the Granger Causality Test (Granger, 1969) and an analysis based on the Cross-Correlation functions. The main objective is to determine whether price is the key factor that explains the investment in forest wood stock in a period characterized by a decreasing profitability. The analysis is focused on the specific case of the Galician forestry industry during the years 1985 to 2007.

The rest of the paper is organized as follows. After this introductory section, the second section provides a description of the data and the methodology. In Section Three, the results are discussed. Finally, Section Four closes the paper with a summary of the main findings.

2. Methodology

Two alternative and complementary methods of analysis were employed to statistically study the impact of prices on the production of Maritime Pine and Eucalyptus.

The first one is based on the causality concept developed by Granger (1969). This author presented an approach for testing causality between two variables, and it has been widely applied in many econometric studies; however, it has been rarely used in forestry research. The procedure starts with the construction of simple causal models

$$x_t = \alpha_0 + \alpha_1 \cdot x_{t-1} + ... + \alpha_p \cdot x_{t-p} + \beta_1 \cdot y_{t-1} + ... + \beta_p \cdot y_{t-p} + \varepsilon_t \quad (1)$$

and

$$y_t = \mu_0 + \mu_1 \cdot y_{t-1} + ... + \mu_p \cdot y_{t-p} + \delta_1 \cdot x_{t-1} + ... + \delta_q \cdot x_{t-p} + u_t \quad (2)$$

where x_t and y_t are the two time series objects of analysis that must be stationary. The residuals of the models ε_t and u_t must be uncorrelated white-noise series. As usual in this kind of analysis, the best order p for the equations is selected by minimizing an

Information Criterion, for example, the Schwartz Criterion (Schwartz, 1978). The first equation means that the variable x_t can be expressed as a function of its own past and of the past of y_t. In the same way, the second equation determines that the variable y_t can be explained by its own past and the past of the variable x_t. Therefore, the definition of causality in the sense of Granger implies that y_t is causing x_t if it is proved that some estimated coefficient β_i, is statistically nonzero. Similarly, x_t is causing y_t if it is demonstrated that some δ_i is statistically nonzero. Moreover, if both of these events occur, a feedback relationship is said to exist between x_t and y_t. The null hypothesis of the contrast with two restrictions is that y_t does not Granger-cause x_t in the first regression

$$H_0 : \beta_1 = \beta_2 = ... = \beta_p = 0$$

and that x_t does not Granger-cause y_t in the second regression

$$H_0 : \delta_1 = \delta_2 = ... = \delta_p = 0 .$$

The statistical test used to contrast these hypotheses is the conventional F-test.

The second perspective used to analyze the empirical relationship between prices and wood production is based on the cross-correlation function (CCF). This methodology is usually applied in natural science research to detect connections between different climatic, biological, and oceanographic variables (Hurrell, 1995; Gimeno et al., 2002; Orfila et al., 2005, among others). The sample cross-correlation between two time series y_t and x_t is calculated using the expression

$$\rho_{X,Y} = \frac{C_{X,Y}(l)}{\sqrt{C_{X,X}(0)} \cdot \sqrt{C_{Y,Y}(0)}} \qquad l = 0, \pm 1, \pm 2, ... \qquad (3)$$

where

$$C_{X,Y}(l)=\begin{cases}\sum_{t=1}^{T}\left(x_t-\bar{x}\right)\cdot\left(y_{t+l}-\bar{y}\right)/T & if\ \ l=0,1,2,... \\ \sum_{t=1}^{T}\left(y_t-\bar{y}\right)\cdot\left(x_{t-l}-\bar{x}\right)/T & if\ l=0,-1,-2,...\end{cases} \quad (4)$$

Nevertheless, one must remember that the analysis using CCFs should be handled with care. If each one of the analyzed series has a very high degree of autocorrelation, then the nonzero values of the cross-correlation function do not necessarily imply a true relationship between the two time series (Katz, 1988). In other words, the presence of autocorrelation can lead to a spurious relationship between the variables and, therefore, the cross-correlation analysis would be completely wrong. Therefore, in order to avoid possible fictitious cross-correlations, it is necessary to remove all of the autocorrelation in each time series and then cross-correlate that which remains. If the identical method of removing autocorrelation is applied to each variable, the true cross-correlation between variables is preserved (DeLurgio, 1998).

The procedure followed here starts by assuming that each one of the time series under study follows an autoregressive process with additive Gaussian noise. Consequently, the method involves the fit of a p-order autoregressive model (AR(p)) for x_t of the form

$$x_t=\alpha_0+\alpha_1 x_{t-1}+.......+\alpha_p x_{t-p}+e_t \quad (5)$$

and a q-order autoregressive (AR(q)) for y_t

$$y_t=\mu_0+\mu_1 y_{t-1}+.......+\mu_p y_{t-q}+u_t \quad (6)$$

where x_t and y_t are the original time series that show autocorrelation, $\{\alpha_i\}_{i=0}^{p}$ and $\{\mu_j\}_{j=0}^{q}$ are the coefficients that must be optimally estimated in order to get non-autocorrelated residuals $\{e_t\}_{t=1}^{T}$ and $\{u_t\}_{t=1}^{T}$. Finally, the residuals in (5) and (6) will be the filtered series to be cross-correlated.

3. **Data description**

3.1 Profitability and growing stock

Figure 1 shows that the price for Maritime Pine and Eucalyptus started rising from 1988-1990[3]. However, since 1994 the timber prices have declined. On the other hand, Figure 1 also shows that the average production cost per cubic meter sold by the forestry sector has considerably increased. As a result, it can be inferred that the profitability of both species decreased since timber prices do not compensate for production cost increases.

[Figure 1]

In spite of the profitability deterioration, Table 1 shows that the volume of standing timber for all species has increased by 42,694 million of m^3, which represents a growth of approximately 50%. This fact constitutes an apparent contradiction from an economic point of view since the forest owners in Galicia have invested in timber during a period characterized by a decreasing profitability.

[Table 1]

3.2 Wood prices and wood production

In order to explain the apparent contradiction, which is the object of this study, the statistical relationship between price and wood production is explored. The price and production data for Maritime Pine and Eucalyptus were obtained from the Yearly Agricultural Statistics published by the regional government (Xunta de Galicia). Figures 2 and 3 depict the annual evolution of wood production and prices in Galicia for both species.

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[3] Price data were obtained from the Yearly Agricultural Statistics published by the regional government (Xunta de Galicia). Cost data came from the Spanish Ministry of Environment.

[Figure 2 and 3]

4. Results

In order to apply the Granger Causality Test, it is first necessary to statistically verify that the time series are stationary. For this purpose, the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) design by Kwiatkowski et al. (1992) is used for testing stationary. The results, reported in Table 2, show that both time series, price and wood production, are stationary. Given this result, it is feasible to apply the Granger Causality Test.

[Table 2]

Table 3 shows the null hypothesis to be contrasted and the values and p-values of the test. As can be seen, the test presents a p-value of 0.827 for Eucalyptus, which implies that the null hypothesis cannot be rejected. That is, the price does not have a causal effect on wood production for this forest species. On the other hand, for the Maritime Pine, the test displays a p-value of 0.051. Therefore, the null hypothesis that price does not have a causal effect on wood production is rejected. Moreover, an analysis of the sensitivity of the results reveals that the test is robust to different number of lags considered in the analysis.

[Table 3]

Regarding the use of cross-correlation functions, the first step is to remove the autocorrelation existing in the original, using an AR(p). Figure 4 depicts the choice of the optimal order of the autoregressive. In all cases, the optimum order that minimizes the Akaike Information Criterion is p=1, and the residuals obtained after filtering the original data did not exhibit significant autocorrelations.

[Figure 4]

Therefore, the residual series can be used in the analysis to detect significant cross-correlations not due to co-temporality. Specifically, the residuals of the prices were cross-correlated with each one of the residuals of the wood production.

Figure 5 and Figure 6 show graphically the sample cross-correlation function for the Maritime Pine and Eucalyptus cases, respectively. Moreover, these figures also display the intervals of confidence necessary to examine the statistical significance of the cross-correlation coefficients. The intervals are empirically constructed by means of a Montecarlo simulation. To do so, 1,000 time series were randomly generated with the same characteristics as a random white variable and with the same standard deviation as the residuals of the price series. Then, each one of these artificial variables was cross-correlated with the residual series of wood production. An empirical distribution of each cross-correlation coefficient for each lag was computed. Using this empirical distribution, a confidence interval with a specific significant level is built; in this case the significance is determined to be 95%.

[Figure 5 and 6]

Analyzing Figure 5, one can observe that the price is positively cross-correlated with the wood production of Maritime Pine at lag 2, and no significant cross-correlations to other lags are detected. These results verify the existence of a positive statistically significant relationship between price and wood production. On the other hand, examining Figure 6, one can see that there is no statistical relationship between price and wood production in the case of Eucalyptus.

Both the Granger Test and the cross-correlation analysis reveal that price has a statistically significant impact on wood production for Maritime Pine. This finding suggests that when prices are low, the production temporally goes down. The forest owners increase the rotation period, expecting higher prices and better profitability in the future. Therefore, the decreasing profitability observed in the Galician forestry sector jointly with a growth in volume of standing timber does not contradict Economic Theory.

On the contrary, for the Eucalyptus, the Granger Test and the cross-correlation analysis corroborate that price does not have a statistically significant impact on wood production. Price was not a determinant variable in the Galician forest owners´ decision-making process on wood production with Eucalyptus as it was for Maritime Pine. Then the stock increase is not caused by a decline of wood production associated with the existence of low prices. Owners do not invest in old forest timber expecting a higher price in the future. The question to be answered is still why the Eucalyptus stock has increased during the time period under analysis.

There are at least two possible influential factors. The first factor is that the growing stock could be caused by better investment conditions for Eucalyptus than for other species (growing rate, low maintenance and regeneration costs, and subsidies). Consequently, the owners expanded the Eucalyptus plantations, transforming bare land, substituting Eucalyptus for other forest species, or reforesting land previously devoted to agricultural uses. Another explanation for the observed growing stock could be the abandonment of agricultural or forest land that is occupied by the natural expansion of Eucalyptus without the active intervention of the forest owners.

4. Conclusions

This study presents statistical evidence that verifies a connection between price and volume of cuts for Maritime Pine in Galicia, Spain. Decreasing prices together with increasing costs, i.e., decreasing profitability, postponed the felling. By using a novel approach in the analyses of the forest sector, we have found for the Maritime Pine that the forest owners invest in standing timber by increasing rotation periods when the prices fall. As a consequence of this, owners accumulate forest wood stock, expecting a higher price in the future. These findings are in line with previous results in the forest economics literature. First, one main strand of forest economics, which is the estimation of timber supply, postulates that price decreases imply a decrease of wood production and vice versa. Second, Moog and Bochert (2001), based on the literature about the optimal rotation period, have explained that price decreases are followed by increases in the volume of growing stock and vice versa.

On the other hand, this hypothesis does not hold for Eucalyptus. Although the data show an increase in volume of growing stock and a price decrease, there is no statistical interaction between price and cutting volume. Therefore, the forest owners do not take the price into account to modify the cutting age or optimal rotation period. The observed increase in volume of growing stock is not caused by higher rotation because the owners accumulate forest wood stock, expecting a higher price in the future. Instead the better conditions for investment or the abandonment of agricultural and forest land could explain the growing stock of *Eucalyptus*. Therefore, growing stock does not appear in the form of old forest but as reforestation of agricultural land and substitution of forest species.

Eucalyptus is a very low-demand species in terms of regeneration and maintenance costs. Additionally, the species has a very high growth rate in the Atlantic region of the

Iberian Peninsula, and growers have received subsidies from the Galician, Spanish, and European governments to grow it. All these are advantages for the forest owners and could have influenced the profitability and the expansion of Eucalyptus. The observed growing stock of Eucalyptus could even have been caused, at least partially, by the natural expansion of this species and as a consequence of the abandonment of agricultural and forest land. In this sense, this paper opens a research avenue that will require further effort and data in order to quantify the advantages of Eucalyptus and discover the causes of this connection. The explanation of the results is out of the scope of this research.

To summarize, this is what we have learned about the Galician forestry sector (North-Atlantic coast of the Iberian Peninsula) regarding the relationship between development of volume of growing stock and the behavior of wood producers:

i) Because there is no data (prices of imported timber, pulp exports, rates of growth) we cannot estimate the supply function of wood nor calculate the optimal rotation with the Faustmann Formula or Pressler's indicating percent.

ii) We used the Granger Causality Test and cross-correlation, widely used in the literature to assess the link between variables, to test whether the variable price affects wood production for the two main species in the Galician forestry sector.

iii) We found a relationship between price and the supplied quantity of timber for the Maritime Pine. The finding shows that decreasing profitability of this forestry product and increasing volume of standing timber are not contradictory, that is, owners accumulate forest wood stock, expecting a higher price in the future.

iv) Regarding the Eucalyptus, we did not find a Granger causal relationship or cross-correlation for price and wood production. For this species, prices do not cause changes in the wood production, so the forest owners do not invest in standing timber, changing the optimal rotation period. That is, owners do not accumulate wood stock, expecting higher prices in the future.

v) Consequently, the increase of the volume of growing stock is not based on the increase of the standing timber of old forest.

vi) For the Eucalyptus, the increasing volume of standing timber is due to the substitution of species and/or the expansion of forest lands caused by better investment conditions (growing rate, subsidies, costs, etc.) or the abandonment of forest and agricultural land.

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Figure 1: Costs and prices of Maritime Pine and Eucalyptus

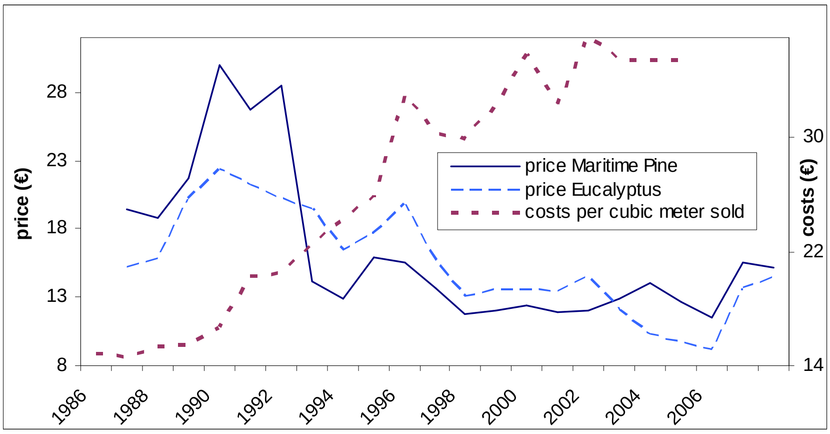


Figure 2: Price and production of Maritime Pine

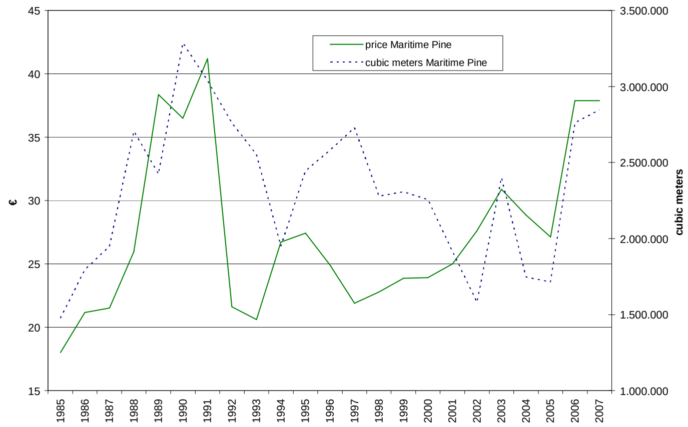


Figure 3: Price and wood production of Eucalyptus

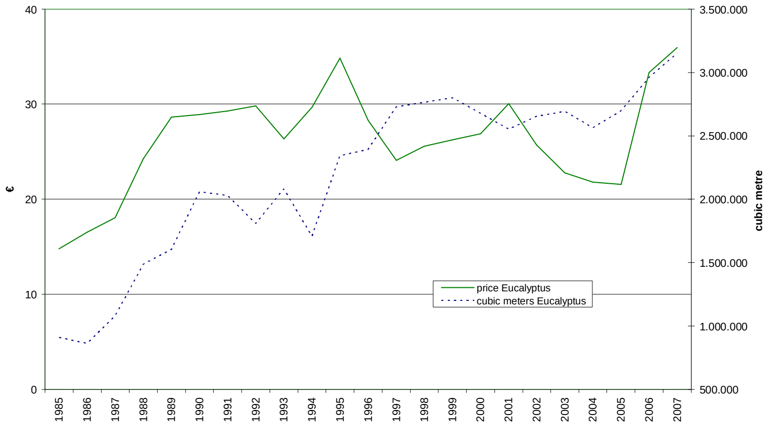
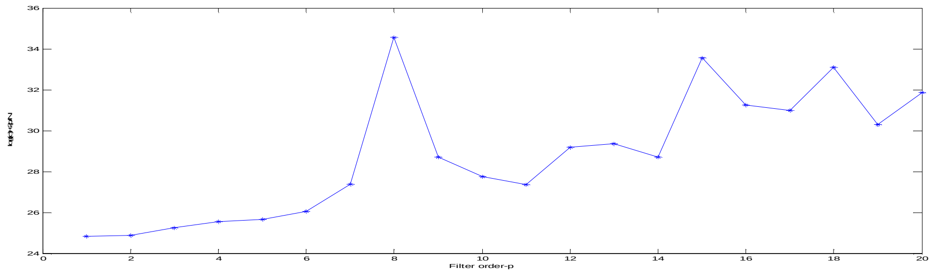
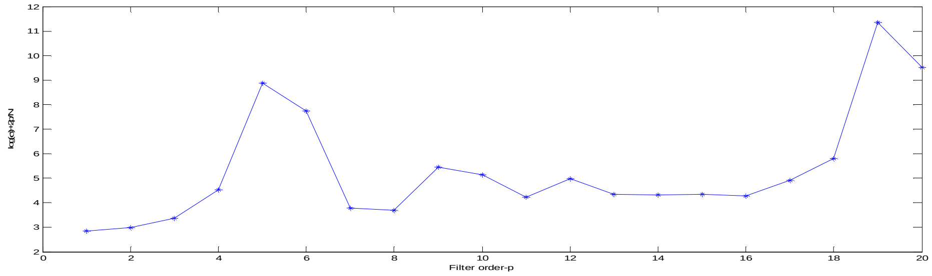


Figure 4: Choice of the optimal order of the autoregressive

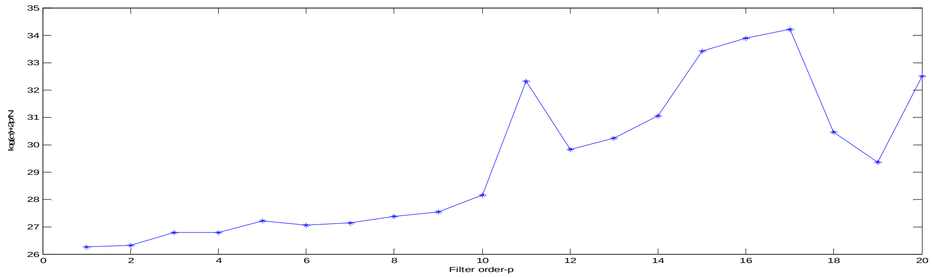
a) Eucalyptus wood production



b) Eucalyptus wood price



c) Pine wood production



d) Pine wood price

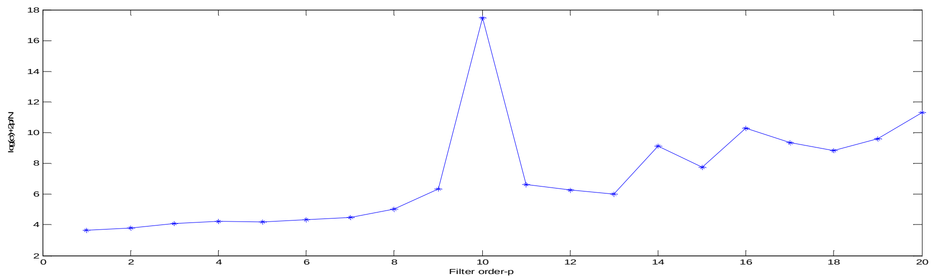


Figure 5: Sample cross-correlation between residuals of the wood price and the residuals of the wood production for the Maritime Pine case.

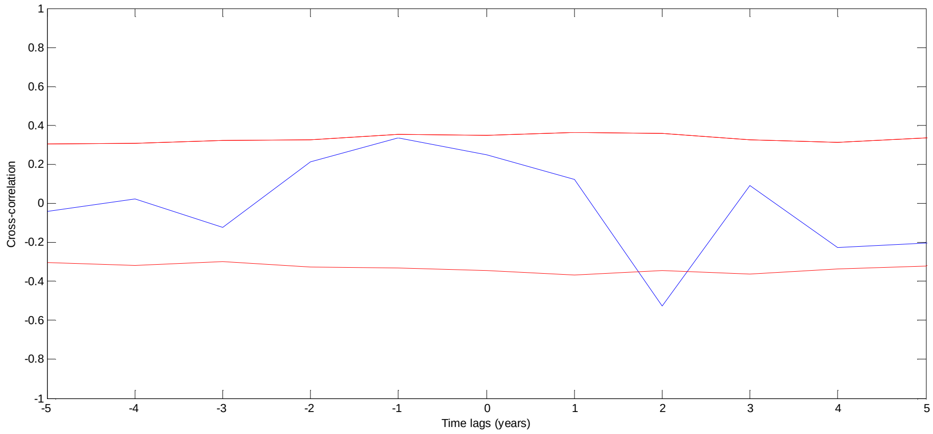


Figure 6: Sample cross-correlation between residuals of the wood price and the residuals of the wood production for the Eucalyptus case.

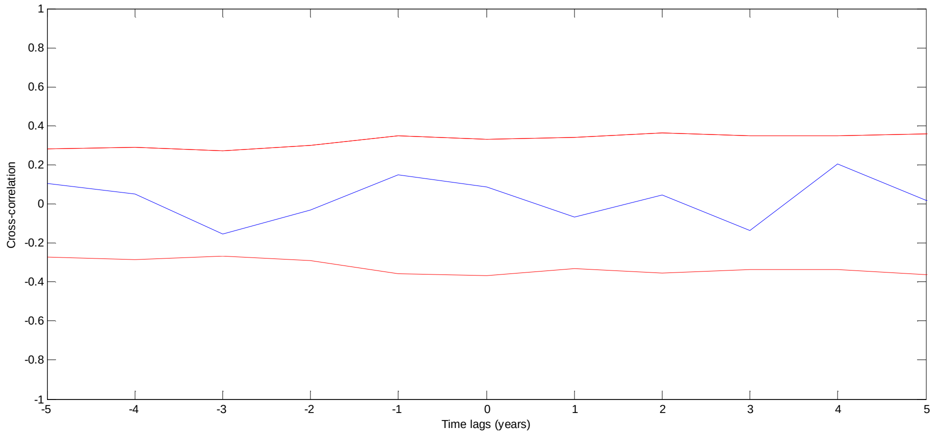


Table 1: Growing stock in Galicia 2nd and 3rd NFI (million of m^3)

	2nd NFI	3rd NFI	Increase
Maritime Pine	45,444	49,150	3,706
Eucalyptus	15,998	35,537	19,539
All species	90,396	133,090	42,694

Source: 2nd and 3rd NFI (Ministry of Environment).

Table 2. KPSS Stationary Test

	Eucalyptus	**Maritime Pine**	**P-value**
Null hypothesis**: price stationary**			
Equation with constant	0.24 (2)	0.15 (2)	0.73
Equation with constant and tendency	0.12 (2)	0.09 (2)	0.21
Null hypothesis**: production stationary**			
Equation with constant	0.64 (3)	0.11 (2)	0.73
Equation with constant and tendency	0.13 (3)	0.10 (2)	0.21

Nota: The p-values were calculated following Kwatkowski *et al*. (1992). The number of lags are shown in brackets according to the Newey-West Criterium using Bartlett Kernel.

Table 3. Granger Causality Test for Eucalyptus and Maritime Pine

	Eucalyptus		**Maritime Pine**	
Null Hypothesis	**F-test**	**P-value**	**F-test**	**P-value**
Production does not cause Granger price	0.616(7)	0.756	5.018(4)	0.001
Price does not cause Granger production	0.433(7)	0.827	4.303(1)	0.051

Note: In brackets the lag length based on the Akaike Information criterion and on the no correlation serial of the residuals