Empirical demand analysis of long-lenght roundwood (sawlogs) in Greece

Stathis KLONARIS, Garyfallos ARABATZIS***

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Abstract

In Greece and internationally, the roundwood is one of the most important forest products as it is widely used in the building and construction sector. In this study, the determination of the long-length roundwood (>2m) wholesale price is depicted in the form of an inverse demand system. The empirical application based on five species of long-length roundwood using annual auctions data provided reasonable and promising results. The quantity flexibilities suggest that prices responses to quantity changes are inelastic, whereas the Allais coefficients suggest substitutability between the different species of roundwood of long length.

Key words: demand analysis, flexibilities, long-length roundwood, wood sector, Greece.

Résumé

En Grèce et dans le monde entier, le bois rond, qui est largement utilisé dans le secteur de la construction et du bâtiment, est l'un des produits forestiers les plus importants. Dans cette étude, le processus de détermination du prix de gros des longs rondins (>2m) est décrit sous forme de système à la demande inverse. L'application empirique basée sur cinq espèces de longs rondins, et utilisant les données annuelles des ventes aux enchères, fournit des résultats satisfaisants et prometteurs. Les flexibilités des quantités semblent indiquer que les prix ne s'ajustent pas en fonction de ces changements, tandis que les coefficients d'Allais obtenus semblent indiquer que les différentes espèces longs rondins sont interchangeables.

***Mots clés**: analyse de la demande, flexibilités, longs rondins, industrie du bois, Grèce.*

1. Introduction

At world level, the production of industrial roundwood was 1 billion cubic meters in 1961 and it reached 1.7 billion cubic meters in 2005. Specifically, during the period 1990 – 2005, the same production was between 1.5 and 1.7 billion cubic meters. North and Central America have the greatest production of industrial roundwood, approximately 39.5% of the total timber production followed by Europe with roughly 28.5%. The demand of industrial roundwood like construction timber, processed wood products, paper and paperboard is rising faster in rapidly growing economies (FAOSTAT, 2007).

Generally, the consumption of wood and of its products (roundwood, sawnwood, veneer sheets, plywood, particleboard, wood pulp, paper, paperboard, etc.) presents an always increasing increased trend because of the various uses nowadays. In particular, the factors which affect the consumption of wood and its products are: a) the population, b) the Gross National Product (GNP), c) the institutional and technological changes, d) the energy cost, e) the capital availability and f) the wood and its products prices (Lefakis *et al.*, 1998). It is estimated that the increase in wood consumption (industrial and wood fuels) will be important in the future will pass from 3.4 cubic meters in 1992 to 5.5 billion cubic meters in 2010 and 6.5 billion cubic meters in 2020 (Nilsson, 1996; Stamou, 2006).

In the literature concerning the forest sector, a great number of empirical models were developed and they refer to the production (supply), consumption (demand), imports and exports of various categories of wood and of its products (Philippou and Lefakis, 1997; Tromborg *et al.*, 2000; Solberg *et al.*, 2003; Koulelis, 2005; Brodrechtova, 2008). In particular, the Global Forest Product Model (GFPM) is a model which was developed by the FAO for the production, consumption and forest products trade (imports-exports) for 180 countries and 14 commodity products during the period 1994-2010 (Tomberlin *et al.*, 1998). Kangas and Baudin (2003) made estimation for the supply and demand of wood products in 2030 in 37 European countries. They pointed out that the increase in consumption in the next two decades will be based on the dynamic development of East-European countries. However, this increase will be retarded after the economic convergence. Also, Hetemaki *et al.* (2004) investigated the wood exports and the sawlog demand for the Finnish forest sector with short-term forecasting models (univariate and multivariate time series models). Wibe (2005) constructed and used a simple linear supply and demand model. According to this model, everything is formulated and understood in the fundamental concepts of economic theory and it is easy to use in simulating various scenarios and in particular about what will happen in production consumption and forest products trade in case of demand and supply changes. In order to forecast the in-

* Department of Agricultural Economics & Rural Development, Agricultural University of Athens, Athens, Greece.
** Department of Forestry and Management of the Environment and Natural Resources, Democritus Universit of Thrace, Orestiada, Greece.

dustrial roundwood demand, empirical models have been specified and estimated by many researchers. In these models, explanatory variables have been employed, such as the increase in population, the economic development, the models of final consumption, the technological advance and others specific factors (Apsey and Reed, 1995; Nilsson, 1996; Stamou, 2006). At present, despite the heavy reliance of Greece on wood imports, the empirical economic research on the domestic demand for domestic wood is modest[1]. Actually, to the authors' knowledge, there is no any study that would concern the empirical demand analysis of roundwood in Greece. The non existence of any empirical study for this product is partly due to there is not easy to find data for this certain wood category.

To fill this gap, this paper focuses on the empirical investigation of the demand for long-length roundwood in Greece for the period 1964-2005. The data which are used in this paper concern annual prices and quantities of five long-length roundwood categories (fir and spruce, pine, beech, oak and poplar & other broadleaved species). These five categories are auctioned by state forest farms (as described afterwards). The analysis allows the quantification of the responses of different species of long-length roundwood to changes in prices and expenditure. The price, scale and substitution flexibilities (which are the main outcome of empirical inverse demand systems) enable researchers to measure costs and benefits associated with changes in market or policies (either national or European). The broader contribution of this paper is to provide an improved price determination component for conducting forest and roundwood policy analysis which was the context within which the model was originally developed. Therefore, the results of the present study may be of particular interest to policy makers, domestic wood industries and forest management experts. The rest of the paper is organised as follows: in the next section, the Greek wood sector as well as the exploitation system are described. In the third and fourth sections, the theoretical framework and the empirical results are presented. We will continue by discussing the results and the paper conclusions with our closing remarks.

2. Forests and wood sector in Greece

According to the most recent census, in Greece forests cover the 25.4% of the country's total area (i.e. 3,358 thousand ha). Approximately the two thirds (65.4%) of this area belong to the state and the remaining 34.6% belong to private entities, local authorities, monasteries, and other welfare institutions (Ministry of Agriculture, 1992; Arabatzis, 2005; Koutroumanidis *et al.,*2009). The domestic production of technical wood (roundwood and sawnwood) during the period 1980-1999 ranged between 0.5 and 1 million cubic metres (only in 1998 the production was less than 0.5 million cubic metres), while the period 2000-2005 experienced a decrease in production ranging from 0.39 to 0.44 million cubic metres (Ministry of Rural Development and Food, 2006).

The long-length roundwood constitutes the most important product of Greek forests as it has a high added value and in its processing form (sawn wood, veneer, fibreboards, particleboards) it has a lot of uses in the building and construction sector and in the furniture-making sector and it considered the most important product for the economy of a country. As in Greece the evolution in these sectors is quite promising, an increase in the demand for roundwood is expected. The main sources of long-length roundwood are species like fir, black pine and beech. To be more specific, starting from 1995 an important increase of building activity was observed with a Medium Annual Rate of 6.9%. The main reasons that contributed to this increase were on the one hand the accumulated housing needs and on the other hand the progressive de-escalation of interest rates. This evolution contributes to the increase of consumer credits, which are expected to positively affect the size of the building sector and the size of consumer expenditures for accommodation will rise at about 3.4% with further demand for new residences. The evolution in the furniture-making sector will also be quite promising: it is an important customer for products deriving from roundwood processing activities (mainly sawnwood). The consumer expenditure for furniture is expected raise up to about 35% during the period 1998 – 2010. This increase is also expected to substantially influence the demand for roundwood, as furniture will absorb large quantities. After 1994, the various wood processing and constructing sectors established a positive relationship. The work for the Olympic Games and work done in the framework of the 3rd CSF (Community Support Framework) considerably increased the demand in wood products. This increase of construction activities is expected to be continued also on the occasion of the 4th CSF (Polemis, 2002).

3. Theoretical Framework

As mentioned before, the wood trade supply is very inelastic in the short run and producers are virtually price-takers. Price-taking producers and price-taking consumers are linked with traders who select a price which they expect to clear the market. In practice, this means that at the auction the wholesale traders offer prices for the fixed quantities which after being augmented with a suitable margin are sufficiently low to induce consumers to buy the available quantity. The traders set the price as a function of the quantities. The causality goes from quantity to price. Hence, the use of quantity-dependent (direct) systems in modelling the demand for such commodities is inappropriate and inverse demand functions, where prices are functions of quantities, provide an alternative and fully dual approach to the standard analysis of the consumer demand (Anderson, 1980).

[1] Among others: Anagnos and Stamou 1980, 1981; Papastavrou *et al.*, 1986a, b; Philippou and Lefakis, 1997; Lefakis *et al.,* 1998; Fousekis *et al.*, 2001.

The reason is that given a predetermined quantity the price must adjust in order to clear the market (Barten and Bettendorf, 1989).

Until the late 1980s, inverse demand systems were typically specified in an *ad hoc* manner (Freebain and Rausser, 1975; Arzac and Wilkinson, 1979). Over the last few decades, the search for better specification of direct demand systems has paid great attention to the choice of functional forms (translong, Rotterdam and AIDS models). Since then, based on the above-mentioned approaches to the consumer behaviour, various specifications of inverse demand systems (dual and differential) have been formally derived and applied to commodities such as meat, fish, fresh fruits and vegetables (Eales and Unnevehr, 1994; Barten and Bettendorf, 1989; Rickertsen, 1998; Fousekis and Revell, 2002). The Inverse Almost Ideal Demand System (IAIDS hereafter), developed by Eales and Unnevehr (1994), is so far the most used model in the empirical work.

To derive an inverse demand system, one can start either from the direct utility function and exploit the Wold's identity (which can yield ordinary inverse demands), or start from the distance (transformation) function and exploit the Shephard's theorem (which yields compensated inverse demand function) (Moschini and Vissa, 1992). Usually, preferences are represented by a distance function, characterizing the amount by which all quantities consumed must be changed proportionally to attain a particular level of utility. This means that it gives the proportional «distance» along a ray from the origin by which quantities must be reduced or increased to reach a particular indifference surface. The differentiation of the distance function with respect to the quantity of a particular good yields a compensated inverse demand function for that good.

The inverse of a Marshallian demand function can be expressed in terms of normalized prices (price divided by income or total expenditure) as a function of quantities (Deaton, 1979). In this respect, the distance function (an inverse representation of the direct utility function) provides the theoretical framework for deriving inverse demand systems and their properties (Anderson, 1980; Deaton, 1979). Starting with the PIGLOG cost function of the AIDS system (Deaton and Muellbauer, 1980) and interchanging the price variable (p) with quantity (q), an analogous expression for the distance function can be specified as:

$$\log D(y,q) = (1 - U) \log A(q) + B(q) \qquad (1)$$

where D denotes the distance function, u indicates utility and $A(q)$ and $B(q)$ are homogenous functions given by

$$\log A(q) = a_0 + a_i \log q_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\gamma_{ij} \log q_i q_j \qquad (2)$$

and

$$\log B(q) = \log A(q) + \beta_0 \prod_j q_j^{\beta_j} \qquad (3)$$

Eales and Unnevehr (1994) and Moschini and Vissa (1992) followed this approach and developed an inverse AIDS model. The expenditure share w_i of a good i is given by:

$$w_i = a_i + \sum_{j=1}^{n}\gamma_{ij} \log(q_j) + \beta_i \log(Q) \qquad (4)$$

where q_j is the quantity of good j. The quantity index *log(Q)* is defined by:

$$\log(Q) = a_0 + \sum_{k=1}^{n} a_k \log(q_k) + \frac{1}{2}\sum_{k=1}^{n}\sum_{j=1}^{n}\gamma_{kj} \log(q_k)\log(q_j) \qquad (5)$$

Equation (1), with the geometric quantity index for *log(Q)*, is an approximate system in the sense that it provides a first-order local approximation to any arbitrary inverse demand system. Therefore, it is termed a linear approximate inverse demand system (LAIDS). Similar to the Rotterdam inverse demand system by Barten and Bettendorf (1989), LAIDS also satisfies the minimum flexibility criteria by Diewert's definition. Further, the restrictions implied by microfoundations can be imposed without any *a priori* implication for the substitution possibilities among commodities. Since the sum of shares across ***i*** is unity by definition, the parameters of (4) and (5) must satisfy the following adding up restrictions $\sum_i \alpha_i = 1 \;\; \sum_i \gamma_{ij} = \sum_i \beta_i = 0$ while the restriction of homogeneity $\sum_j \gamma_{ij} = 0$ and symmetry $\gamma_{ij} = \gamma_{ji}$ can be easily imposed or tested.

It should be noted that equation (4) together with the quadratic expression for *log(Q)* in (5) are not dual to the AIDS system. Therefore, they cannot represent the same preference structure. As such, the system is nonlinear in parameters. But the interesting aspect of this model is that it can be made linear by replacing the quadratic expression of *log(Q)* with an appropriate index[2]. From an empirical stand point, *log(Q)*, the scale which adjusts the quantities consumed to meet the particular utility level, can be assumed to be exogenous. In our analysis, this is facilitated by a geometric quantity index for the scale quantity,

$$\ln Q^* = \sum_i w_i \log q_i \qquad (6)$$

Due to the fact that differently from prices quantities are not collinear, Moschini and Vissa (1992) mentioned that this index is not invariant to the choice of the units of measurement and hence it was suggested to scale quantities by dividing through by the means. The adequacy of the linear

[2] Deaton and Muellbauer (1980) provide intuitive reasoning for using Stone's price index for linearizing the AIDS system. Although the same argument does not apply here, Moschini and Vissa (1992) have shown that a geometric index provides a good approximation to the quadratic expression in (2).

approximation however, is an empirical question. In two empirical studies (Eales and Unnevehr, 1994; Rickertsen, 1998), the use of linear approximation performed quite well.

To capture shifts of demand curve due to policy change, a dummy variable was added in the model which takes the value of one after the year 1987. Thus the form of model that was employed for the estimation of the parameters and flexibilities is given by the following equation:

$$w_i = a_i + \delta_i D + \sum^{n} \gamma_{ij} \ln q_j + \beta_i \ln Q^* \quad (7)$$

With inverse demand models, sensitivities are typically measured by flexibilities (Houck, 1965). Price flexibilities defined as the percentage changes in normalized prices (prices divided by the total expenditure) caused by a 1-percent change in the consumption of that good. Furthermore, the scale flexibilities defined as percentage change in the normalized price of that good in response to the proportionate increase in the consumption of all goods.

Given Slutsky and Antonelli matrices are generalized inverses of one another, quantity elasticities derived from the inverse demand system are analogous to price elasticities derived from a direct demand system. However, empirical differences arise between the two estimates due to econometric artefacts of different dependent variables, price in the indirect and quantity in the direct demand functions. While the scale elasticities derived from the inverse demand specification behave like the income elasticities of the direct demand system in terms of establishing properties of the demand system, empirically they are difficult to compare as the scale effect accounts for the scalar movement along the distance function to compensate for a change in the consumption bundle, while the income effect accounts for income compensation necessary from a change in relative prices through the effect on expenditures (Anderson, 1980).

The uncompensated and compensated price flexibility, f_{ij} and f_{ij}^* as well as scale flexibility f_i are calculated as:

$$f_{ij} = -\delta_{ij} + \frac{\gamma_{ij}}{w_i} + \frac{\beta_i}{w_i}\left(\alpha_j + \sum_k \gamma_{kj} \ln q_k\right) \quad (8)$$

$$f_{ij}^* = f_{ij} - w_j f_i \quad (9)$$

$$f_i = -1 + \frac{\beta_i}{w_i} \quad (10)$$

where δ is the Kronecker delta and is equal to 1 for i=j and 0 otherwise.

Green and Alston (1990) have shown that the AIDS price elasticity formula is inappropriate when the linear approximation is used. Therefore, Chalfant's formula (1987) should be employed in calculating price elasticities and the analog to Chalfant's formula is used to calculate flexibilities:

$$f_{ij} = -\delta_{ij} + \frac{\gamma_{ij}}{w_i} + \frac{\beta_i w_j}{w_i} \quad (11)$$

Interpretation of flexibilities can be made in a manner similar to elasticities. A commodity is said to be inflexible if a 1% increase in consumption of that commodity leads to a greater than 1% decrease in the marginal consumption value of that commodity (its normalized price). Likewise, we will refer to commodities with scale flexibilities less (greater) than -1 as scale inflexible (flexible). Commodities are termed gross q-substitutes if their cross-price flexibility is negative, cross q-complements if it is positive. Moreover, scale flexibilities are less than -1 for necessities and greater than -1 for luxuries. At the margin, normalized price is proportional to marginal utility. Therefore, as consumption of all goods increases 1%, the marginal utility of necessities declines more than proportionately and the marginal utility of luxuries declines less than proportionately.

4. The Empirical Results

We model the demand for long-length roundwood as a five-commodity demand system which includes q_1: «*fir & spruce»,* q_2: «*pine»,* q_3: *beech»,* q_4: «*oak»* and q_5: «*poplar & other broadleaved».* The selection of products involves the assumption of weak separability (Deaton and Muellbauer, 1980). Under this assumption, it may be thought that the timber industry allocates, at a first stage, aggregate expenditure over primary composite goods such as fuel wood, pulp wood, small size roundwood and split wood, roundwood <2m and long-length roundwood >2m. Next, the timber industry may be thought to allocate the given expenditure for long-length roundwood (oak, fir and spruce, beech, pine and poplar and other broadleaved). Weak separability is very common in applied demand analysis (Mochini and Vissa, 1992; Barten and Bettendorf, 1989; Rickertsen, 1998).

In order to incorporate the impacts of the changes that have been made in the provision of forest products by the state forest farms in Greece since 1987, dummy variables were used with the value of 0 for 1986 and 1 for the after-1986 period.

Since structural demand systems, such as the Inverse AIDS (IAIDS) model, are singular, only four equations were specified (the poplar & other broadleaved equation was dropped and its parameters were obtained residually). In order to test the theoretical restrictions of homogeneity and symmetry, the unrestricted model was initially estimated by using SUR estimation[3] and then the theoretical restrictions of homogeneity and symmetry were imposed. Likelihood ratio test (LRT) was employed in order to test the theoretical restrictions and the test results are given in the Table 1. According to Table 1, both of theoretical restrictions are accepted by the data.

[3] For the estimations, the computer program SHAZAM 10 was employed. The maximum likelihood ensures that results are robust to the equation dropped.

Table 1 – *Hypothesis tests for theoretical restrictions.*

Null	Alternative	LRT	DF*	Critical value at 5%	Conclusion
Homogeneity	No-restrictions	3.92	4	9.49	Accepted
Symmetry	No-restrictions	6.65	10	18.31	Accepted

*: DF denotes Degree of Freedom

Table 2 – *Inverse AIDS model – Estimations results.*

	Fir & Spruce	Pine	Beech	Oak	Poplar & other broadleaved
Constant	0.1862*	0.2642*	0.1116*	0.0383*	0.3997*
s.e[a].	0.014771	0.015246	0.007362	0.005630	0.020992
lnq_1	0.1089*	-0.0447*	-0.0188*	-0.0009	-0.0446*
s.e.	0.007063	0.006154	0.003321	0.002346	0.007588
lnq_2	-0.0447*	0.1647*	-0.0455*	-0.0120*	-0.0625*
s.e.	0.006150	0.012369	0.005960	0.003487	0.010054
lnq_3	-0.0188*	-0.0455*	0.0932*	-0.0001	-0.0289*
s.e.	0.003321	0.005960	0.005059	0.002058	0.004857
lnq_4	-0.0009	-0.0120*	-0.0001	0.0147*	-0.0017
s.e.	0.002346	0.003487	0.002058	0.001945	0.003506
lnq_5	-0.0446*	-0.0625*	-0.0289*	-0.0017	0.1377*
s.e.	0.007587	0.010054	0.004857	0.003506	0.013470
Expenditure	-0.0057	0.0220*	0.0156*	-0.0062**	-0.0540*
s.e.	0.010763	0.009924	0.005336	0.003992	0.021430
D	-0.0332*	-0.0242**	-0.0288*	-0.0073	0.0936*
s.e.	0.014207	0.015186	0.007556	0.005604	0.019800
$\bar{w}_i$	0.22	0.29	0.15	0.22	0.03
R‡	0.88	0.90	0.91	0.65	-

a.: standard errors, *(**) Statistically significant at 5%(10%) level.

The estimated parameters with homogeneity and symmetry to be imposed in the model are presented in Table 2. Sixteen out of twenty-two estimated parameters are statistically different from zero at the 5 percent level. The estimated system appears to have a high explanatory power since the computed system R^2 is 0.99. However, this statistic is frequently very high and should be interpreted with caution (Berndt, 1991). For this reason, the R^2 coefficients for the four estimated equations are reported in the last row of Table 1 and their computed value are 0.88, 0.90, 0.91 and 0.65 respectively indicating the good performance of the system. The conformity of the estimated model with the demand theory was further tested by checking the semi-definiteness of the Antonelli substitution matrix. Its five eigenvalues are -0.000018, -0.12343, -0.32043, -0.36494, and -0.41243 implying that the underlining distance function is concave, as stipulated by the economic theory. Moreover, the change of the exploitation system of state forests in 1987 had statistically significant effect on all species of roundwood except oak. An explanation is that oak, in spite of taking the 33% of the overall area of Greek forests, only produces a small quantity of roundwood. Also, this effect was negative for all the species of long-length roundwood but poplar & other broadleaves due to substantial quantities of poplar wood are produced by private plantations of poplar which were established in the framework of European Regulations.

5. Results and Analysis

Tables 3 and 4 present information on the price and scale flexibilities computed from the IAIDS parameter estimates. Average (i.e. computed at the mean budget shares) uncompensated price and expenditure flexibilities are shown in Table 2, while compensated price flexibilities are presented in Table 3.

Starting with the price flexibilities (Table 3), it may be observed that, on average, aggregate demand for long-length roundwood of all wood categories is inelastic to its own quantity changes. More precisely, in the case of fir & spruce, a 1% rise in the consumed quantity is estimated to cause a *ceteris paribus* average reduction of 0.52% to the marginal consumption value of this wood (its normalized price) during the period 1964-2005. Similarly, in the case of the remaining wood categories (pine, beech, oak and poplar & other broadleaves), a 1% rise of the supplied quantity of the each, will lead to a reduction of their normalized price equal with 0.42%, 0.36%, 0.34% and 0.61% respectively.

Average scale flexibilities (also appearing in Table 3) indicate that on average and for the period examined, if the consumption of all wood categories increases by 1%, the marginal utilities of pine and beech decline by 0.93% and 0.89% respectively. In contrast, for the remaining three long-length roundwood categories (fir & spruce, oak and poplar & other broadleaves), their marginal utility will decrease by 1.03%, 1.28% and 1.08% respectively if the consumption of all categories increases by 1%.

Table 4 presents the compensated quantity flexibilities. The negative signs of the compensated own–quantity

Table 3 – *Compensated price flexibilities.*

	Uncompensated price flexibilities (f_{ij})					
	Fir & Spruce	Pine	Beech	Oak	Poplar & other broadleaved	Expenditure (f_i)
Fir & Spruce	-0.84*	0.11*	0.07*	0.22*	-0.05*	-0.49*
s.e.	0.01386	0.01823	0.01498	0.03565	0.00901	0.07102
Pine	-0.01	-0.64*	-0.08*	-0.32*	-0.01	-1.05*
s.e.	0.01178	0.02844	0.02225	0.04443	0.01004	0.05057
Beech	-0.02	-0.13*	-0.38*	-0.53*	0.00	-1.06*
s.e.	0.01714	0.03295	0.04433	0.06468	0.01595	0.06902
Oak	-0.03*	-0.19*	-0.19*	-0.77*	-0.01	-1.19*
s.e.	0.00758	0.01441	0.01460	0.03125	0.00643	0.03187
Poplar & other broadleaved	-0.22*	-1.38*	-1.51*	0.10	-0.67*	-0.72*
s.e.	0.02916	0.15920	0.15617	0.08104	0.03276	0.09329

s.e.: Standard errors. *(**) Statistically significant at 5%(10%) level

flexibilities for the five wood products ensure the concavity of the underling distance function[4]. The positive sign indicates gross complementarity, while the negative sign indicates gross substitution relationships between wood products (Hicks, 1956). Regarding cross price relationships among the woods examined, Table 3 indicates complementarity in all cases. Substitutability appears in the cases of pine for beech and pine for oak, but this relationship does not appear to be statistically significant.

Barten and Bettendorf (1989) argue that the cross-quantity compensated (Antonelli) effects in differential systems are imperfect indicators of the relationships among goods. This is because the homogeneity restriction, along with the negative semi-definiteness of the Antonelli matrix, entails dominance of positive cross-quantity compensated effects (i.e. dominance of complementarity). As they point out, a slightly superior indicator has been proposed by Allais (1943). Allais essentially worked with the transformation of the Hessian matrix such that the result is invariant under the monotone transformation of the utility function and can be considered to reflect interactions within the preference order independently of how it is represented. He also proposed a measure of the intensity of interaction namely:

$$\alpha_{ij} = \frac{a_{ij}}{\sqrt{a_{ii}a_{jj}}} \qquad (12)$$

where

$$a_{ij} = f^*_{ij} / w_i w_j - f^*_{rs} / w_r w_s + (f_i / w_i - f_r / w_r) + (f_j / w_j - f_s / w_s) \qquad (13).$$

In Eq. (13) *r* and *s* refer to some standard pair of goods *r* and *s*. The scalar $\boldsymbol{\alpha}$ makes $\alpha_{rs} = 0$. Thus, $\alpha_{ij} > 0$ indicates that *i* and *j* are more complements than r and s, while $\alpha_{ij} < 0$ reflects that *i* and *j* are stronger substitutes than *r* and *s*. Clearly $\alpha_{ij} = 0$ means that *i* and *j* have the same type of interactions as *r* and *s*. Allais coefficients for the five long-length roundwood products in Greece are reported in Table 5. We have selected as standard pair the interaction between «*Pine*» and «*Poplar & other broadleaves*». Diagonal entries of the table by construction are -1 consistent with the notion that a good is its own perfect substitute. All Allais interactions appear to be negative by expressing the intuitive idea that all long-length roundwood products considered here as substitutes. The highest degree of substitutability appears in the case of *pine* for *oak*, given a change in their auctioned quantities. By contrast, the lowest degree

Table 4 – *Uncompensated price and expenditure flexibilities.*

	Fir & Spruce	Pine	Beech	Oak	Poplar & other broadleaved
Fir & Spruce	-0.75*	0.22*	0.13*	0.43*	-0.03**
s.e.	0.00816	0.01162	0.01192	0.01509	0.00803
Pine	0.18*	-0.41*	0.06*	0.13*	0.04*
s.e.	0.00952	0.03049	0.02152	0.03115	0.00936
Beech	0.17*	0.10*	-0.24*	-0.08*	0.04*
s.e.	0.01518	0.03348	0.04524	0.04748	0.01497
Oak	0.17*	0.07*	-0.02*	-0.26*	0.04*
s.e.	0.00612	0.01544	0.01513	0.02288	0.00604
Poplar & other broadleaved	-0.16*	0.18*	0.14*	0.41*	-0.63*
s.e.	0.03329	0.04468	0.04579	0.05796	0.03091

s.e.: Standard errors. *(**) Statistically significant at 5%(10%) level

Table 5 – *Allais coefficients.*

	Fir & Spruce	Pine	Beech	Oak	Poplar & other broadleaved
Fir & Spruce	-1	-0.15	-0.24	-0.64	-0.14
Pine		-1	-0.58	-1.38	0.00
Beech			-1	-0.47	-0.29
Oak				-1	-0.41
Poplar & other broadleaved					-1

[4] This is a sufficient condition but not the necessary one.

of substitutability appears in the case of *fir & spruce* for *poplar & other broadleaves*. The almost same degree of substitutability appears in the cases of *pine* for *beech*, *fir & spruce* for *oak* and *beech* for *oak*.

6. Concluding remarks

This study empirically investigates the Greek demand for five major species of long-length roundwood (fir and spruce, pine, beech, oak and poplar and other broadleaves) by using yearly data from auctions of forest products covering the period between 1964 and 2005. Since the quantity is predetermined, the inverse almost ideal demand system was employed as the most appropriate model. The results of this study may be further used within market models of supply and demand that are frequently used for policy analysis or welfare changes.

The theoretical restrictions of homogeneity and symmetry were accepted by the data and the conformity of the estimated model with the demand theory was further tested by checking the semi-definiteness of the Antonelli substitution matrix.

The own-quantity flexibilities are substantially lower than one (in absolute value terms) suggesting inelastic responses of normalized prices to own-quantity changes for the five species of long-length roundwood.

According to the estimated scale flexibilities, a 1% increase in the supply of all species of long-length roundwood will lead to a decrease of normalized price for all species of long-length roundwood. Finally, all Allais interactions appear to be negative, a fact that expresses the intuitive idea that all the long-length roundwood products can be considered as substitutes.

Knowledge of the structure of the Greek wood market, as regards the various forest species, contributes towards the adoption of the best decisions, at a local, regional and national level.

More specifically, at a local and regional level (forest state farms), this knowledge is of decisive importance as regards the right time to supply the wood to the market and therefore in specifying the best period for felling and harvesting. It is also useful in order to determine the overall production level required for the following year, the methods to be used for supplying the wood, and the conventional terms for wood trading.

As it is known, the setting up of the forest policy, i.e. the decision-making and organization of developmental programs on forestry in the long term, is based on the future trend of supply, demand and price evolution of various forest products.

There is an urgent need to adopt a forest policy on a local, regional and national level that will a) upgrade the structure and form of the productive forests in Greece, b) significantly increase the number of forest areas, c) improve the network of forest roads, d) modernize felling methods and e) improve the terms and conditions for the trade of products, thus contributing to an increase in the competitiveness of the Greek wood sector.

According to our results, an increase in the supply of various goods of roundwood will lead to very small reduction of their prices. Thus, taking into account that the demand for forest products and especially for roundwood is daily increasing, whereas their supply does not seem to substantially grow, the foundation of a more intensive management of forests, a more efficient use of timber and an increase in grants for various developmental forestry programs will be beneficial first for the Greek economy reducing the exchange flow and secondly for the economy of rural and mainly of marginal areas increasing the employment for the local people and the residents of such areas. The annual employment of these people in the forestry sector significantly contributes to improve their standards of living, keep them in homes they live in and to stabilize the economy of mountainous regions.

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