THE RESERVATION PRICE APPROACH AND INFORMATIONALLY EFFICIENT MARKETS

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ABSTRACT

We discuss and analyse the reservation price approach and the theory of informationally efficient markets. Using the basic principles of the Faustmann formula, an equilibrium model for an informationally efficient market is stated. This model is reduced to a statistically testable expression, which is used to analyse the Danish roundwood market for the three species: Norway spruce, beech and oak. Results show large differences between the markets for the three species, and the reservation price approach is not generally applicable. The price process for Norway spruce is likely to be trend stationary indicating inefficiency, the presence of a unit root in the beech prices cannot be rejected which indicates efficiency, and the result for oak is a level stationary autoregressive process implying possible inefficiency.

Keywords: Reservation price approach, roundwood markets, unit root-tests, weak informational efficency.

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INTRODUCTION

Why are the stochastic characteristics of roundwood price processes interesting? Because knowledge of these characteristics may provide a chance of designing trading rules that could generate a supernormal profit. These trading rules are based on the simple principle of storing the roundwood in the forest when prices are low and selling when prices are high. Such economic behaviour is termed adaptive optimization, adaptive in the sense that decisions are at any time conditional on the available information.

A prerequisite for such speculation in price fluctuations is that it is possible to decide when the current price is higher (or lower) than expected future prices. As will be discussed below, this requirement is met when the price generating process is mean-reverting. However, this requirement collides with the expected behaviour of prices,

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when prices are set in an informationally efficient rational expectations market equilibrium. In such a market no trading rule should on average perform better than any other strategy — even no strategy.

First, central studies on the adaptive optimization approach known as the reservation price approach are briefly discussed. After introducing the theory of weak informational market efficiency, we show how the Faustmann-principle can encompass the theory which leads us to the formulation of a basic test model. Before turning to the empirical tests of market efficiency we discuss some relevant features of the Danish roundwood market. Tests are performed for three different tree species: Norway spruce, beech and oak, and finally, results are presented and discussed.

THE RESERVATION PRICE APPROACH

A classic issue in forest economics is when to harvest a stand. The Faustmann formula provides a widely accepted rule for the rotation age decision (Faustmann, 1849 (1995)). An important assumption in the Faustmann formula is that roundwood prices are deterministic; but instead roundwood prices are more correctly percieved as being generated by stochastic processes. Large fluctuations in roundwood prices may provide a chance to improve profits by 'playing the market' and using an adaptive behaviour to solve the classic stochastic dynamic optimization problem. Extensive research has been done in this field. Teeter & Caulfield (1991) and Brazee & Mendelsohn (1988) implicitly assume that such trading rules are possible. Lohmander (1987) finds that for a generally applicable and profitable trading rule to exist, the stochastic price process has to be stationary. A stationary process fluctuates around a deterministic level (and a 'trend stationary' process around a trend) and deviations can be recognized as above or below the expected price. Lohmander shows that the optimal harvest policy — given stationary prices — is a state dependent reservation price approach, resulting in significantly higher profits than in the deterministic case. Similar results were found by Haight (1991).

Washburn & Binkley (1990) make the link between the above research and the theory of informational efficient markets.[1] They note that the existence of profitable trading rules is inconsistent with informationally efficient markets and they find that the pine roundwood market in South-Eastern USA is weak-form efficient. Using these results Thomson (1992) and Haight & Holmes (1991) construct numerical optimization models with nonstationary prices. They find that the optimal harvest policy is price-independent when no fixed costs are present and the land value is zero; otherwise, the optimal policy is price-dependent but *not* analogous to the reservation price policy with stationary prices described above. Haight & Holmes (1991) test price series from North Carolina, USA, and find that monthly and quarterly prices are stationary and quarterly average prices are nonstationary. They point out that the nonstationarity could be an artefact resulting from the averaging of a time series of autocorrelated prices. Thus their result is ambiguous with respect to the value of the reservation price approach. Hultkrantz (1995) finds that the nonstationarity hypothesis for Swedish annual stumpage and net stumpage price series can be rejected when using the results provided by Perron (1989), and this supports the use of the reservation price approach.

To conclude on the research done, stationarity of the price process is important for the use and profitability of speculative trading rules like the reservation price approach[2]. As pointed out by Washburn & Binkley (1993) the existence of profitable trading rules necessarily implies market inefficency in the weak form. Empirical investigations do not give a clearcut result concerning the efficiency of roundwood markets. In the following section the basic concepts of the market efficiency theory are presented to enhance understanding of the above discussions.

THE THEORY OF MARKET EFFICIENCY

A large amount of research in the area of financial econometrics and market efficiency theory has addressed the question: is it possible to use trading rules to generate supernormal financial gains from trading capital assets or

[1] For a discussion see Hultkrantz (1993) and Washburn & Binkley (1993).

[2] Actually, using the cointegration framework developed by, e. g. Engle & Granger (1987) may provide models with scope for at least short-run gains to speculation.

commodities? Fama (1970, p. 383) defined an efficient market as: "A market in which prices always 'fully reflect' available information is called 'efficient". Jensen (1978) proposed a modification; he defined a market as efficient if it reflects available information to the extent where no net gain may be obtained from collecting and acting on information, i.e. using trading rules.

Fama (1970) proposed three different degrees of market efficiency depending on the kind and availability of information. Only one of them is dealt with here: weak-form informational efficiency. A market is informationally efficient in the weak form if prices at any time fully reflect the knowledge about future prices given by available information. Therefore no trading rule based on the available information can generate supernormal profits.

Fama (1970) notes that the following three conditions are *sufficient*, but *not nessecary* for establishing market efficiency. First, there are no trading costs. Secondly, all available information is costlessly available to all agents. Finally, all agents agree on the implications of current information on current prices and distribution of future prices. If these conditions are fulfilled, any changes in information and thus expectation of future prices will immediately be reflected in the current price. Note that the conditions may be relaxed to some extent without making the market inefficient, especially in the Jensen-sense. Later we will briefly discuss the conditions in relation to knowledge of the Danish roundwood market.

To perform empirical tests of market efficiency it is nessecary to specify a testable model for the process of price formation. Fama (1970) and many others base their work on the assumption that given rational expectations the market equilibrium can be stated in terms of expected return. Thus — following Fama — for a single asset we have:

$$\mathrm{E}\left(p_{t+1} \middle| \Phi_t\right) = \left[1 + \mathrm{E}\left(r_{t+1} \middle| \Phi_t\right)\right] p_t \tag{1}$$

where p_t is the price in period t, r_{t+1} is the one-period return in period $t + 1$, and Φ_t is the full public information set available to the agents at time t. Now we simplify the model by assuming the conditional expected return to be zero. Define:

$$\varepsilon_{t+1} = p_{t+1} - \mathrm{E}(p_{t+1}|\Phi_t) = p_{t+1} - p_t \tag{2}$$

Then the combined assumptions of informational market efficiency and the expected returns equilibrium have the following important implication:

$$\mathrm{E}\left(\varepsilon_{t+1}|\Phi_t\right) = 0 \tag{3}$$

Thus, the expected price change is zero ruling out trading rules based on Φ_t. These properties define the stochastic price process for the price p as a Martingale (cf. LeRoy, 1989), and the stochastic process of price changes ε as a 'fair game' with respect to the information set Φ_t available. This is recognized as the most precise and flexible description of the market efficiency theorem. If we add the assumption that ε is not only independently but also identically distributed over time, then we have the more restrictive but also often used Random Walk model. The expected return model is not implied by the market efficiency theory (Fama, 1970) but is merely a possible consequence of a necessary choice. One important implication of this model is the assumption of risk-neutral agents, as discussed by LeRoy (1989). Another important feature to be noted is that in Random Walk processes any relevant stochastic shock — including the weather — has a permanent effect.

EFFICIENCY ON THE ROUNDWOOD MARKET

In this section we show how the a stochastic analogue to the Faustmann-principle can encompas the Martingale model for prices. Any mature stand may be considered a living storage. The facts that it is alive and grows have the important consequence that net storage costs may be very low for longer periods, which makes storage of roundwood on the stump highly attractive. The theory of storage (Williams & Wright, 1991) provides an explanation for the existence and use of storage in the commodity markets. It states that in an efficient commodity market with storable commodites there exists a rational expectations equilibrium:

$$p_t = \mathrm{E}\left(p_{t+1}|\Phi_t\right)e^{-(c+r)} \tag{4}$$

where p is the price, c is the relative cost of storage, and r is the relative capital cost. Again, agents are assumed to form rational expectations and information Φ_t is freely available. Furthermore, storage is supposed not to be exhausted and commodities are allowed to flow freely in and out of storage. The first of these two last conditions may seem reasonable for roundwood markets; its importance for the behaviour of commodity prices has been analysed in many studies, e.g. Deaton & Laroque (1992) and Danthine (1977). In general, exhaustion of storage may cause severe excess demand leading to the well-known temporary explosive rises in price — which make the overall price process seem stationary. The second assumption does not seem reasonable for storage on the stump: once felled the roundwood has left the storage forever. Calamities like windthrow may invalidate this assumption, typically causing the price to drop. But if we regard these as problems of minor importance we may accept an equilibrium model like (4), and commodity markets should be informationally efficient. If roundwood owners expect future prices to rise they will withhold roundwood from the market, causing the present price to rise until equilibrium is restored.

If we assume a pulse harvesting strategy optimal and relevant we can consider a whole stand to be the commodity traded. Assuming agents to possess rational expectations and using basic principles from the Faustmann formula we may assume the following equilibrium on an informationally efficient market:

$$p_t \cdot Q_t \cdot e^{c+r} = \mathrm{E}_t\left(p_{t+1} \middle| \Phi_t\right) \cdot Q_t \cdot e^{g} \tag{5}$$

Here Q is the roundwood volume in the stand, c represents real storage costs pr. unit of roundwood including land rent, r is the real capital cost, and g is the deterministic age-dependent growth[3] in volume per roundwood unit. The price p is real price. For the mature stand at the optimal rotation age the expected marginal real value production $g \cdot Q_t \cdot \mathrm{E}(p_{t+1})$ equals the marginal real costs $(c + r) \cdot Q_t \cdot p_t$. In this study we make no attempt to model fluctuations in any components of (5), except of course for the price. Instead

[3] If there is a deterministic change in value of the stand due to increasing dimension, this aspect could also be included in g.

we assume g, c, and r to be constant so that for the mature stand g equals $(c + r)$, which is the well-known criterion for optimal rotation age in a deterministic environment. Using this line of reasoning (5) is reduced to:

$$E_t(p_{t+1}|\Phi_t) = p_t \tag{6}$$

where p is the real price. Of course, there may be fluctuations in r, c, and g. But since e^g / e^{c+r} should fluctuate around 1 over time our assumptions do not seem unreasonable. Thus, the Faustmann principle can encompass the simple Martingale model, which is the basic model in this study. Further elaboration on the model and the tests is postponed to allow for comments on some empirical data and questions.

THE DANISH MARKET

The most important feature of the Danish market is the system of negotiated recommended prices, which have existed since the end of last century. The market is to some extent a market of 'opposite monopolies' since two organizations representing suppliers and demanders are negotiating prices centrally. The outcome of the negotiations are sets of recommended prices for the different tree species and assortments. If both organizations have the same information and agree on its implications for the market price, then the market will be efficient. Thus the system of negotiated prices does not exclude an efficient market, nor does it guarantee efficiency. Both sides must agree on the present and future aggregate supply and demand curves to find an efficient price. If such information is surpressed for, e.g. strategic reasons, price-setting may be inefficient. The fact that an agreement is not always made indicates the possibility of inefficiency. However, it is the individual agents who makes the actual deals, and though they can be expected to conform with the negotiated prices, the loose and uncertain definitions of roundwood qualities give room for deviations from the negotiated prices. Thus, it is relevant to outline the profile of the agents on both the supply and demand side.

Two-thirds of the Danish forest area belong to non-industrial private owners and one-third is state forest. Sizes of private and company estates and the area in different

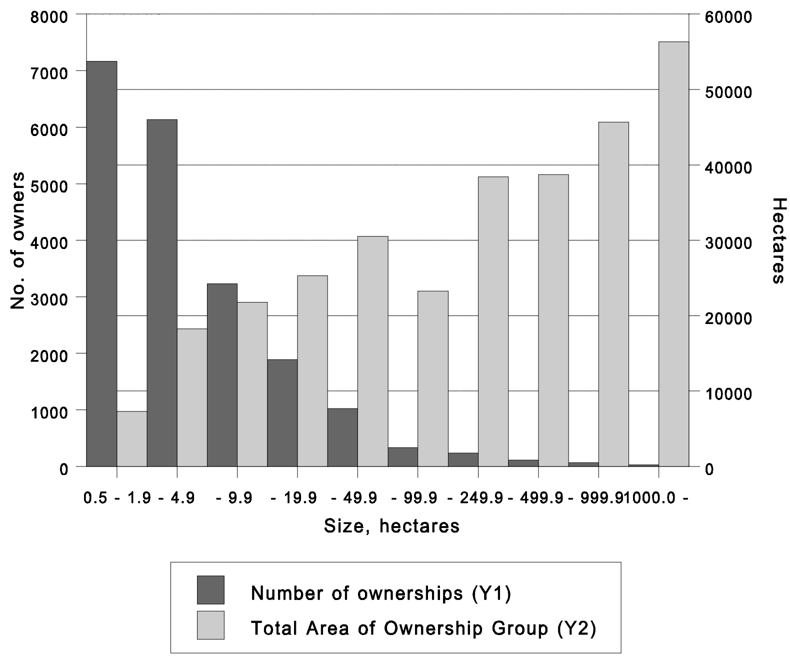

FIGURE 1. FOREST OWNERSHIP IN DENMARK.
Private and company estates, number and area grouped by size (Danmarks Statistik 1994).

size groups are shown in Figure 1. It is obvious that most estates have little economic importance for the forest owner. Therefore, even though information may be available at low cost it may not be collected. And even if information is collected forest owners may not agree on its implications for their present supply due to differences in objectives. For some estates the forest is used to smooth fluctuations in income from agricultural activities. In other cases the estates are financially stressed to an extent where the cost of speculation outrules any attempt to speculate. For small estates the timing of cuttings might be determined by factors like a new car or an anniversary. Finally, costs of rescaling logging capacity may represent transaction costs likely to inhibit market efficiency. These large differences in forest owner characteristics may affect the market efficiency.

The demand side agents are perceived to be more homogenous and rational. The sawmills consumed 678,000 m^3 in 1992 with imports covering 138,000 m^3 (Landbrugsministeriet, 1994). With half of the total variable costs coming from purchase and transportation of roundwood and a low rate of value-adding, the profit margin in the wood industries — and the sawmills in particular — is sensitive to price variations. Thus, demand agents are likely to collect information and to agree on its implications for the present price as they are under competitional stress. Therefore one could expect a high degree of efficiency on the roundwood market induced by the demand side agents, who need to have prices reflect the market accurately for the double purpose of keeping down costs and obtaining the resources needed. Again, rescaling processing capacity may represent transaction costs which could inhibit efficiency in the short run.

The possibility of import and export affects the price-setting on the Danish market. There is no severe institutional restriction on the free trade of roundwood, at least on the roundwood market of northern Europe. Assuming an efficient commodity arbitrage price differences between countries must be transitory which in turn implies that the efficiency of the Danish market will depend on the efficiency of the surrounding market, as the Danish market for roundwood is small. An inefficient price setting in the surrounding market would dictate an inefficient price setting in the Danish market and vice versa.

In sum we find that there are reasons to expect efficiency as well as inefficiency in the Danish market when evaluating the conditions put forth by Fama. The supply side agents are very diverse and may cause inefficiency, while the demand side agents are more likely to act according to rational expectations of future prices. The fact that prices are negotiated centrally may offset any inefficiency caused by the possible lack of rational expectations in the diverse group of supply side agents. Finally, the efficiency of the Danish market may to a large extent depend up on the efficiency of the surrounding market.

THE DATA

The data for the present study are extracted from a data base on Danish roundwood prices for Norway spruce, beech and oak (Riis *et al.,* 1995). The three time series used here cover the period 1911–1992 and are aggregations of weigthed average prices of all assortments typically occuring, when harvesting mature stands of the three tree species Norway spruce, beech and oak. In accordance with the expected return models we use net prices, however it was found that gross prices possess the same stochastic properties. The above-mentioned price negotiations imply prices are set in advance of every logging season. The averaging should therefore not hide a systematic price development or trend within the year but may occasionally contain price adjustments for some assortments due to additional negotiations in the logging season. The prices are most correctly regarded as genuinly annual data.

THE TEST FOR MARKET EFFICIENCY

As mentioned earlier our basic specification of the market efficiency hypothesis is the simple Martingale model presented in (6). Basically, we test the hypothesis of a weak-form efficient Danish roundwood market by testing the hypothesis that the roundwood price time series is generated by a random walk, i.e. it is a test for $\rho = 1$ in the model:

$$p_t = \rho p_{t-1} + \varepsilon_t \tag{7}$$

where p is the price and ε is assumed i.i.d. $N(0, \sigma^2)$. In model (7) the OLS-estimator of ρ will be downward biased, especially when ρ is close to 1 (Dickey & Fuller, 1976). This is avoided by reformulating the model by subtracting p_{t-1} from both sides. To allow for different error structures an Augmented Dickey Fuller-test is applied as suggested by Said & Dickey, (1984). We start from a very general model, i.e. the model to be estimated is:

$$\Delta p_t = \mu + \beta t + (\rho - 1) p_{t-1} + \sum_{i=1}^{k} \gamma_i \Delta p_{t-i} + \varepsilon_t \tag{8}$$

If the coefficient for p_{t-1} is significantly negative, then ρ in (7) is significantly less than one and the price process is stationary. The estimator of $(\rho-1)$ has a 'Dickey-Fuller'-distribution (see Fuller, 1976). A general to specific procedure is used in each case, attempting to reduce (8) to simpler models, note that it may reduce to (7). Likelihood ratio statistics are provided by Dickey & Fuller (1981). This procedure allows alternative models, e.g. 'trend-stationary' models, to suggest themselves.

As shown by Perron (1989) a shift in level or trend (or both) in a stationary process may cause ordinary unit root tests to identify the process as nonstationary. Perron suggests alternative models and tests provided there *a priori* is a reason to expect such shifts at specific points in time. If we alter the model and allow a simultaneous shift in level and trend the model is:

$$\Delta p_t = \alpha + \beta t + (\rho - 1) p_{t\text{-}1} + \theta DU_t + \omega DT_t + \delta D(TB)_t + \sum_{i=1}^{k} \gamma_i \Delta p_{t\text{-}1} + \varepsilon_t \quad (9)$$

where DU_t is a dummy for a shift in level (DU_t = 1 if t > time of break (TB), and 0 otherwise) and DT_t is a dummy for a shift in trend (DT_t = 0 if $t < TB$, and $t - t_0$ otherwise). $D(TB)_t$ is a dummy for the shift between systems ($D(TB)_t$ = 1 at TB, and 0 otherwise). The latter is included as suggested by Perron (1989) and allows for the presence of a discontinuity at the time of break under the null (see Figures 2 and 3). Note that (9) may reduce to (7) and that a broader family of trend stationary models may suggest themselves. Model (9) is used in this study to allow for the possibility of a structural break in the functioning of the market. Such a structural break occured in 1953 when post-war market regulations were cancelled. This intervention could represent an event exogenous to the 'day-to-day' functioning of the economic dynamics underlying our basic model. Therefore, we try to catch the effect with the dummy variables. This way the hypothesis of informational efficiency can find support if prices on both sides of the break behave like random walks. Tests for stationarity in (9) is performed using Perron's tables for the t-statistic of (ρ–1). The series and the estimated trends from model (9) are shown in Figures

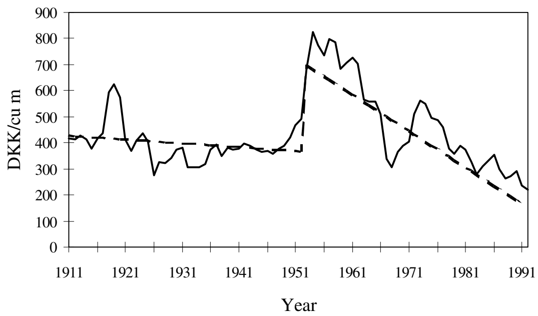

FIGURE 2. REAL NET SAWLOG PRICES FOR NORWAY SPRUCE.

Stippled line is estimated trend.

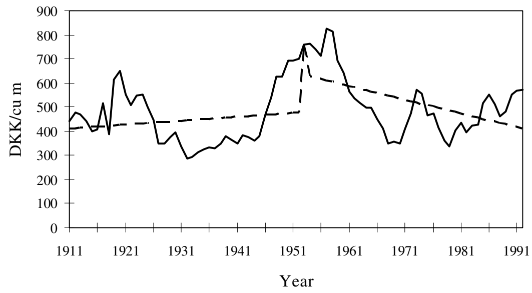

FIGURE 3. REAL NET SAWLOG PRICES FOR BEECH.
Stippled line is estimated trend.

2–4. Prices are real 1992 net prices.

RESULTS

First the analyses were made with respect to the ADF-model (8). The results for the three tree species are summarized in Table 1.

For Norway spruce and beech the test result is a random walk version of (8), where H_0: $(\rho-1) = 0$ is maintained. For Norway spruce $k = 2$ and for beech prices $k = 0$ in (8). As the results show, neither of the '$\rho-1$'-coefficients are significantly different from zero. In other words, we cannot reject the null hypothesis of a unit root and hence nonstationarity. A different result is found for the oak price series. As can be seen the coefficient is significantly different from zero, and the nonstationarity hypothesis for oak prices is rejected. More precisely, the price of oak is found to be generated by a level stationary autoregressive process with one significant lagged price change, i. e. $k = 1$ in (8).

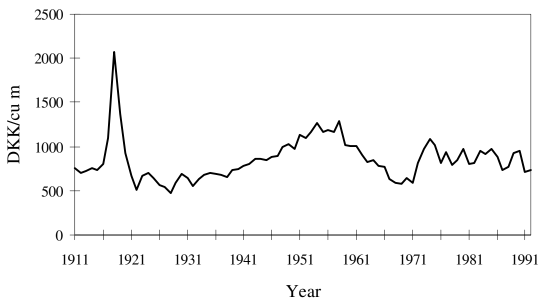

FIGURE 4. REAL NET ROUNDWOOD PRICES FOR OAK.

TABLE 1. RESULTS OF ADF-TESTS.
Unit root analysis of real 1992 prices of Norway spruce, beech and oak sawlogs, 1911–1992. Critical values from Fuller (1976).

SPECIES	COEFFICIENT OF (ρ–1)	'T-STATISTIC' OF (ρ–1)	CRIT. VALUE, 5 %	CRIT. VALUE, 1 %
Norway spruce	– 0.010	– 0.775	– 1.944	– 2.592
Beech	– 0.004	– 0.288	– 1.944	– 2.592
Oak	– 0.322	– 3.814**	– 2.898	– 3.513

Next the Perron-procedure is used. As indicated by the above results it is only relevant to perform this alternative stationarity analysis for Norway spruce and beech. We estimate model (9) and test the nonstationarity hypothesis against the alternative that the price is generated by a trend stationary process. The test results are summarized in Table 2.

The results are different between species. We reject the hypothesis that roundwood prices of Norway spruce possess a unit root, instead they seem to be trend stationary with a shift in trend and level in 1953. The dummy variables have t-statistics above 3. The trend stationarity implies that the market efficiency hypothesis is rejected. Roundwood prices of beech are found to be nonstationary and the t-statistics of the dummy variables and lagged changes are all close to zero. This result supports the above conclusion, that the price process for beech is well described by a random walk. Perron (1989) emphasizes that the power of his procedure is probably low. The length of the time series used here should to some extent reduce this problem.

DISCUSSION

As ambiguous as the discussion on the possible efficiency of the Danish roundwood market was so are the results of the empirical analyses. The perhaps most interesting result

TABLE 2. RESULTS OF PERRON-TESTS.
Unit root analysis of real 1992 prices of Norway spruce and beech sawlogs, 1911–1992 with a structural break in 1953. Critical values from Perron (1989).

SPECIES	COEFFICIENT OF (ρ–1)	'T-STATISTIC' OF (ρ– 1)	CRIT. VALUE, 5 %	CRIT. VALUE, 2.5 %
Norway spruce	– 0.339	– 4.419*	– 4.24	– 4.53
Beech	– 0.086	– 1.509	– 4.24	– 4.53

of the analyses is large differences found between the markets for the different species, which cause us to discuss the results by species.

With regard to Norway spruce the ADF-procedure maintains the null hypothesis of a nonstationary process, but using the Perron-procedure we find that the price process is trend stationary. This result implies that the Danish market for Norway spruce roundwood may be inefficient. The result may be found attractive as it does not imply that events like excessive windthrow, pest outbreaks etc. causing excess supply have an eternal effect on prices as a Random Walk would imply. In this model only one event has a long lasting effect on prices, viz. the deregulation of the roundwood market in 1953. But in other aspects the result rises explanatory problems. As always, trend variables do not directly suggest a particular interpretation related to a specific economic theory. Instead they must be interpreted as substitutes for other explanatory variables that for some reason are not included in the model. Explanations like decreasing administration costs, technology change, etc. are among the plausible explanations. An obvious explanatory problem — or rather challenge — is what causes rejection of informational market efficiency? Is it induced by the central price negotiations or by other factors?

With respect to the roundwood prices for beech we cannot reject the hypothesis that they follow a random walk, thus giving the strongest support to the efficiency hypothesis. The deregulation in 1953 had no effect on the beech roundwood prices which is also evident from Figure 3. The may be that the post-war regulations were managed much more strictly for Norway spruce than for beech and oak. Substantial price changes were allowed during the regulation period for the two broadleaved species. This allowed an incremental adjustment to market forces; after the deregulation in 1953 Norway spruce prices increased to the level of competing Swedish products. Finally, we reject the presence of a unit root in the roundwood prices for oak which seem to be generated by a level stationary autoregressive process. The significance of this result is strong, providing the strongest rejection of informational market efficiency. The stability of the result was investigated in different ways, e. g. the estimation period was shortened to include only prices from 1920 — thereby excluding some large outlayers during World War I caused by extensive demand for wooden ships. The result was robust to these investigations, but shortening the period further affected the result towards accepting the null. However, there is no legitimate reason for excluding later observations that are not outliers.

CONCLUSIONS

We have discussed and tested the hypothesis of weak informational market efficiency for three different tree species on the Danish roundwood market. The results discussed above show very different conclusions, depending — it seems — on the species analysed. There are indications of both market efficiency and market inefficiency even-though the agents on the market are the same.

The ambiguity may have several explanations. First of all the result indicates that the Danish roundwood market could be perceived as three separate markets with different characteristics. If we assume that these differences exist, they indicate that the efficiency of the different markets is determined by non-common factors. These may be, e.g. differences in export/import potentials and the overall economic importance of the species. Another possible reason for the ambiguity is the low power of the procedures available and used. With regard to the analysis of Norway spruce one might say, that you could get the result you want, depending on your choice of model. However, this reasoning does not hold when you include the analyses of the broadleaved species. Finally, we conclude that the results presented do not rule out potentials for a profitable use of trading rules like the relevance of the reservation price approach on the Danish roundwood market. There may be scope for increasing profits on, e.g. the roundwood market for oak, using adaptive trading rules. Note however, that a general introduction and availability of such trading rules should affect the market towards efficiency and thereby eliminate the expected profit. If we use Jensen's (1978) definition of market efficiency as being a market where prices reflect information to the point where benefits from acting on information do not exceed the marginal costs of acquiring and acting on this information, the problem of efficiency is widened and simple tests are not adequate. Instead, the question of efficiency could be investigated with models where agents forecast roundwood prices and act on these forecasts. Then the answers will depend on assumptions about management flexibility costs — assumptions that do not enter the present analyses.

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