



THE BEHAVIOUR OF TIMBER RENTS IN SWEDEN 1909–1990

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ABSTRACT

Optimal stopping rules for timber harvesting depend on the nature of the price process. This paper examines two measures of the annual unit timber rent in Sweden; stumpage prices from 1909–1990, and unit net conversion value from 1920–1989. Allowing a postwar shift in the price level, the unit-root conjecture is rejected in a Perron test. This implies that reservation price rules can be implemented.

Keywords: Roundwood market, unit-root test, commodity prices, optimal stopping, forest economics.

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INTRODUCTION

Stock prices in several countries have been found to follow a (non-stationary) random walk process. This is consistent with the weak form of the (information) efficient market hypothesis for an asset, if speculators are risk-neutral (see LeRoy (1989)) and the volume of the capital good is given. Weak-form efficiency of a capital market (as defined by Fama (1970)) means that no trading rule based on historical prices alone can succeed on average.¹ For a produced storable good, however, a rational expectation equilibrium may imply a stationary (non unit-root) price process (Samuelson, 1971; Scheinkman & Schechtman, 1983; Williams & Wright, 1991; Deaton & Laroque, 1992).

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¹ Fama identified three levels of market efficiency. Under the semi-strong form of market efficiency, prices incorporate all publicly available information. Under the strong form, all public and private information is incorporated in asset prices.

For forest management decisions, the nature of the net price (unit timber rent) process is essential. If the logarithm of the unit timber rent follows a random walk (i.e., the net price process follows a geometric Brownian motion)², then the optimal forest management program (the harvesting schedule) is independent of the price realisation in each period (Clarke & Reed, 1989; Thomson, 1992),³ whereas if the price process is stationary it may be optimal to adopt a reservation price rule, i.e., to cut when price exceeds a specific reservation price (Norstrom, 1975; Lohmander, 1985, 1987).

This paper examines time-series data for timber rents in Sweden. The Swedish timber market has several appealing features for the investigation of long-run, time-series properties of timber rents. Sweden has had a well developed, mainly export-oriented, forest industry since the middle of the previous century. Since the switch from utilisation of old-growth forest resources to timber from managed forests was made at the turn of the century, the forest industry has been working under remarkably stable conditions. Forestry has produced a roughly equiproportional mix of sawlogs and pulpwood from two main species, Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*). The split in land ownership between forest industry (25%), private nonindustrial owners (50%), and public ownership (25%) has remained unchanged. Most timber has, therefore, been transacted on the timber market, in two different contractual frames. In stumpage sales, the purchaser pays a net price to the forest owner and bears the logging costs. In delivery sales, the seller harvests the forest. He then receives a (roadside) gross roundwood price that covers both the felling cost and the timber rent. There are, therefore, two different sources for net-price data.

² A variable is said to follow a random walk or Brownian motion when changes in the variable are white noise. Geometric Brownian motion means that relative changes are white noise. Two examples of geometric Brownian motion with drift are found in note 6. The random walk is an example of a process that has a unit root. It is not stationary. It is integrated of order 1, i.e., taking first differences gives a stationary process (the white noise).

³ It is also assumed that growth is age dependent and that there are no fix costs in harvesting.

In the present study, annual time-series data is used from both these markets; directly as stumpage prices and indirectly as unit net conversion value computed from roundwood prices and logging costs. Annual data from the beginning of the century, gathered by Streyffert (1960), make it possible to analyse stumpage prices from 1909 and unit net conversion value from 1920. For recent years, data is found in Statistical Yearbook of Forestry. The specific seasonal pattern of Swedish forestry (determined by seasonalities in tree growth; in conditions for off-road, forest-road and, previously, river-floating transportation; and in labour supply) has required price settlement for the coming logging year when it begins in August, so these net prices are really annual, and not just annual averages.

Non-stationarity (unit root) tests have been applied previously to stumpage prices in the south-eastern part of the United States (Haight & Holmes, 1991; Hultkrantz, 1993; Washburn & Binkley, 1990, 1993). Washburn & Binkley (1990) covered monthly, quarterly, and annual data but did not use modern unit-root tests. In a comment, Hultkrantz therefore applied the *Dickey-Fuller* test to the quarterly and annual stumpage price series. However, as pointed out by Haight and Holmes, these contain quarterly and annually average prices, which implies that they are biased towards a larger autoregressive coefficient than in the underlying series for a shorter time interval. The upshot of this work is that nonstationarity can be rejected for monthly data only (and for quarterly series of opening month prices). This finding, however, may be of minor relevance to practical forest management if felling plans cannot be adjusted rapidly. Also, a weakness of the available data for the southern United States is that the time series are rather short. For instance, Haight and Holmes use data from between January 1977 and March 1988. In contrast, the Swedish time series that will be explored here are genuinely annual. This provides a time interval that in most cases would be sufficiently long for planning and completion of timber sales.

Moreover, the time span extends much beyond that of the previous works. This is important because recent studies of the power of tests for a unit root have given support to the widely held view in empirical work that long data spans are important for identifying mean reversion in

slowly decaying processes. As shown by Pierse & Snell (1995), and in other studies reviewed by them, it is data span rather than the number of observations that affects the power of unit-root tests.

The statistical properties of Scandinavian stumpage prices were first studied in Lohmander (1987), investigating the nature of the stochastic process of stumpage prices in Norway and Finland. The claim was made that prices in both countries are stationary, but, from the results, the unit root conjecture can be rejected for Finland only.⁴

THEORETICAL FRAMEWORK

A stochastic price process P_t over time t is a submartingale with respect to a sequence of information sets I_t if P_t has the following property:

$$E(P_{t+1}|I_t) \geq P_t \quad (1)$$

where E is the expectations operator. The process is a martingale if this relation holds with equality. In ex post form, the martingale and the submartingale correspond to the random walk (or Brownian motion) process and the random walk with drift, respectively. Timber rent, P_t , is the roadside (average) timber price less logging (and hauling) cost. The millside price, p_t , is the roadside price plus the cost of transport from the forest-road to the manufacturing mill. Let the difference $(p_t - P_t)$ be the unit access cost C_t . If two of these variables are integrated of order 0 (stationary or stationary around a trend), then the third one must be integrated of order 0 too. If two of them are integrated of order 1 (has a unit root), then the third one is integrated of order 0 or 1. If stationary, then the other two variables are cointegrated in the specific linear combination that yields the third variable.

Consider the (intertemporal) cutting decision problem of a forest owner. Let p_t be the net price of timber (timber price less unit logging cost), i.e., the timber rent. Let the growth rate of a forest stand (stumpage store) at time t be

⁴ The Dickey-Fuller " τ -statistic", computed from the reported estimation results, is -3.14 for Finland and -2.09 for Norway.

g_t and the capital cost and storage (maintenance) cost, expressed as proportions of stumpage price, be r_t and c_t , respectively. Also, assume that the timber rent is non-negative. The intertemporal arbitrage equilibrium condition for stumpage (Washburn & Binkley, 1990) is then:

$$P_t = E(P_{t+1}|I_t) \exp(g_t - c_t - r_t). \quad (2)$$

In logarithm form, this is:

$$\log(P_t) = \log(E(P_{t+1}|I_t)) + g_t - c_t - r_t. \quad (3)$$

Assume that the growth rate of the forest stand is a positive, continuous, monotonously decreasing function $g(a_t)$ of the rotation period of the forest. Also, assume that it can be postulated that the log of the stumpage price process is a martingale, i.e., that stumpage price follows geometric Brownian motion. Then, the arbitrage equilibrium equation can be reduced to:

$$g(a_t) = r_t + c_t. \quad (4)$$

Thus, the harvesting decision at time t depends on capital cost and storage cost, but is independent of the realisation of the stumpage price.⁵ In other words, the instantaneous stumpage supply is completely price inelastic. For non-negative timber rents and constant capital and storage cost, the supply of stumpage will be uniquely determined by the initial age distribution of trees. If the marginal access cost (logging cost) for timber varies, then timber supply will be elastic with respect to the (gross) price of timber, reflecting the variation in the volume of stumpage with non-negative timber rent as the (gross) timber price varies.

⁵ It is, perhaps, not obvious that the harvesting decision can be made in a "myopic" one-period look-ahead setting. However, Clarke & Reed (1989) prove that a "myopic look-ahead" rule will, in fact, be optimal under fairly general conditions.

The arbitrage equilibrium (4) is equivalent to the Faustmann-Pressler-Ohlin rule for the optimal rotation period under deterministic conditions (in the one-rotation case, i.e., disregarding the value of bare land). A more general analysis of this case in continuous time has been made by Clarke & Reed (1989) and in discrete time by Thomson (1992). Besides assuming that stumpage price follows geometric Brownian motion, they allow for a stochastic age-dependent growth process.⁶ The analysis confirms the above conclusion that, in the absence of fix costs, the level of the current timber rent (provided it is positive) is irrelevant to the forest owner in his decision on whether to cut now or later. In the Wicksellian wine-ageing case (the one-rotation problem), the optimal stopping (cutting) rule resembles the Wicksellian deterministic solution, except a modification of the rate of interest. The one-rotation tree should be cut when the expected relative growth rate (the deterministic part of the growth function) is equal to the rate of interest less a variance term. The latter term is shown to be half the sum of the variances and covariance of the price and growth processes. Clarke and Reed extend this to the case of a risk-averse forest owner and show that the usual risk-cost term will be added to the risk-free rate of interest. The case of the on-going forest, with subsequent rotations, turns out to be more tricky, but they are able to derive a similar modified Faustmann-Pressler-Ohlin rule in the case where price is the only stochastic variable. A general feature of these results is that the optimal cutting age is independent of the current timber rent.

Thus, martingale stumpage prices give (modified) Faustmann-Pressler-Ohlin management. Returning to equation (3), we see that the opposite implication also holds: If equation (4) is valid, then in arbitrage (rational expectations) equilibrium, the stumpage price will be a martingale.

⁶ Clarke & Reed (1989) define the "biological asset's" aggregate intrinsic value as $R_t = P_t X_t$ and:

$$\begin{aligned} d \ln P_t &= \alpha dt + \sigma_{\ln P} dw_{\ln P} \\ d \ln X_t &= g_t dt + \sigma_{\ln X} dw_{\ln X} \end{aligned}$$

where P_t is price and X_t is volume at time t . $w_{\ln P}$ and $w_{\ln X}$ are standard Wiener processes, $\sigma_{\ln P}$ and $\sigma_{\ln X}$ are constant variances, g_t is the deterministic component of proportional growth and α is a constant drift term in the price equation.

However, assume that it can be postulated that the timber rent process is integrated of order 0. This means that the elasticity of expected future prices with respect to the current price (cf. Scheinkman & Schechtman, 1983, p. 433) is less than one. For example, assume that rent follows this process:

$$\log(P_{t+1}) = \alpha + \beta \log(P_t) + u_t, \quad 0 \leq \beta < 1, \quad (5)$$

and

$$E(u_t | I_t) = 0, \quad (6)$$

where α and β are constants (i.e., we allow the process to be stationary around a deterministic trend).

Arbitrage equilibrium (eq. (2)) now gives the following forest management rule:

$$g(a_t) - c_t - r_t = (1 - \beta) \log(P_t) - \alpha. \quad (7)$$

Clearly, the rotation age is now also dependent on the current price realisation, P_t . Differentiation with respect to P_t and a_t yields:

$$\frac{da_t}{dP_t} = \frac{(1 - \beta)}{g'_t P_t} < 0, \quad (8)$$

where $g'_t = \partial g_t / \partial a_t$. This means that the short-run supply curve has a positive slope (an increase in timber rent leads to a reduction of the volume of the growing stock) even if the marginal access cost is constant.

The implications for optimal forest management of stationary (possibly around a deterministic trend) prices have been worked out by Lohmander (1985, 1987, 1988); related works are Norstrom (1975), Löfgren & Ranneby (1983), Brock, Rotschild, & Stiglitz (1988), Brazee & Mendelson (1988), and Haight (1991). Under stationary prices, the optimal cutting rule can be expressed as a reservation price,

i.e., the felling decision (and therefore the short-term supply of timber) will depend on the current stumpage price.

The nature of the stumpage price process is therefore of crucial importance to forest managers. From a theoretical perspective, one would want to know whether a stationary stumpage price process can be upheld in an economy where forest owners and timber purchasers have rational expectations. For an exchange economy (i.e., no production is undertaken) with risk-neutral agents, Lucas (1978) has shown that the price process will be a martingale. However, with risk aversion, this is no longer generally true (LeRoy, 1989). Moreover, in a production economy, with risk-neutral agents, the rational equilibrium price process may be stationary. This was first shown by Samuelson (1971) for a simple (wheat) production economy. In his model, production in each period is stochastic and the produced good can be stored from one period to another. Scheinkman & Schechtman (1983) extend this model by allowing the possibility of raising production by increase in effort. They show that the (point) elasticity of price expectations with respect to the current price is less than one and may be zero for high enough prices. Finding that this work has analytically explored the basic storage model as far as possible, Williams & Wright (1991) turn to a numerical dynamic programming model for a deeper understanding of the issues involved. A basic feature of their model is that it is ergodic, i.e., if the current value of one of the variables, such as price, is far from the mean of the infinitely long sequence, the expected path for that variable returns to the steady-state mean. However, as in the analytically solved models, the model produces an autoregressive price structure because storage spreads unusually high or low excess demand over several periods. In an experiment with land prices, the authors show that in samples of typical length such as 20 or 30 periods, a price series from the model may be misidentified in a unit-root test as a pure random walk.

TESTING FOR UNIT ROOT

In this section, we will test the conjecture that the timber net-price process has a unit root. This conjecture implies a unit β -coefficient in equation 5. If β is equal to one and

equation 6 holds, in a regression of the residuals on any subset of the information set I_t , then clearly the reservation price approach can be dismissed. If, however, β is below one, then the net-price process has no unit root.

A first empirical counterpart for the timber rent is stumpage price. National sample data for prices in stumpage sales has been recorded by the Swedish National Board of Forestry since 1955 (see Statistical Yearbook of Forestry, various issues). Stumpage prices for sales from public lands have been published in the Swedish Official Statistics since 1909 (collected in Streyffert, 1960, p. 163). A stumpage price series for the period 1909–1990 has therefore been constructed by chaining the elder data set to the newer. The second source for timber rent data is the unit net conversion value of timber, computed from roundwood price and felling cost data. For the period 1920–1955, Swedish Official Statistics data (Streyffert, 1960, p. 164) for delivered sales of roundwood from public lands is used. This series is chained to national data for 1955–1990 calculated by the National Board of Forestry (Statistical Yearbook of Forestry, various issues).

Both annual stumpage price and unit net conversion value are weighted averages of rents for different timber qualities in different parts of the country. Streyffert (1960, p. 106) however, computed unit net conversion values for different qualities in different regions 1909–1958. These show a close resemblance to each other and to the national average. Also, at least during later years, the variation in the composition of the total cut has been relatively stable.⁷ A problem with the unit net-conversion value data before 1975 is that cutting costs in self-employed forest work by individual forest owners are not based on a primary source, but on harvesting cost data from large-scale forestry. However, this is a minor problem only. Until the beginning of the 1970's, small-scale forestry and large-scale forestry used essentially the same (chain-saw) technology.⁸ More important, large-scale logging operations were supplied and purchased, in free competition, to small forest owners, so the

⁷ From 1977 to 1987, the share of saw timber in the total roundwood consumption varied between 43 per cent (1987) and 49 per cent (1977 and 1982).

⁸ Large-scale forestry, with specialised forest workers, had higher productivity but the opportunity cost of labour was probably lower on average in self-employed work.

marginal cost of self-employed forest work cannot have deviated greatly from large-scale cutting costs.

These price series have been deflated with the Swedish Consumer Price Index (from 1935) and its predecessor, the Living Cost Index.

The unit-root tests will be performed on real net prices transformed to the logarithmic scale. The null hypothesis is thus that the real net price of timber follows geometric Brownian motion. An important reason for this is that observations generated with a logarithmic model are non-negative. This also means that the variance of the stochastic component is assumed to be proportional in size to the observed price.

The most commonly used unit-root tests are the *Dickey-Fuller (DF)* and *augmented Dickey-Fuller (ADF)* tests. The *DF*-test has more power when the stochastic component is white noise, but the *ADF*-test, including lagged differential terms in the test equation, has to be used if there is serial correlation. Since these tests have fairly low power, i.e., a high probability of making Type-II errors, several other test methods have been proposed.

To reduce the risk of accepting a false null hypothesis, one would wish to use a long time series. However, an important consideration in designing a test for sample data from a long period, as in this case, is the possibility that structural changes have occurred. As is shown by Perron (1989), a one-time break in a stationary time-series that affects its level, drift, or both, will reduce the power of the *DF* and *ADF* tests. For such cases, Perron derives an extended test, adding one or two dummy variables to the test equation.

A brief look at the plots of our two timber-rent series, displayed in Figures 1 and 2, yields the suggestion that such a break, if any, may be found between the pre-1945 and post-1945 levels. It seems that post-war net prices have generally been higher than before and during the war. A possible explanation for this is a shift in bargaining power between forest owners and forest industry. Public war-time regulations to help substitution from imported fuels to wood fuels overcame the free-rider problems that had been severe obstacles to the organisation of forest owners in the

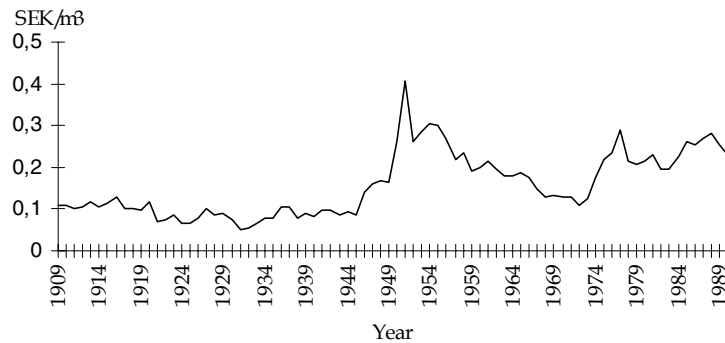


FIGURE 1. REAL STUMPAGE PRICE, 1909–1990.

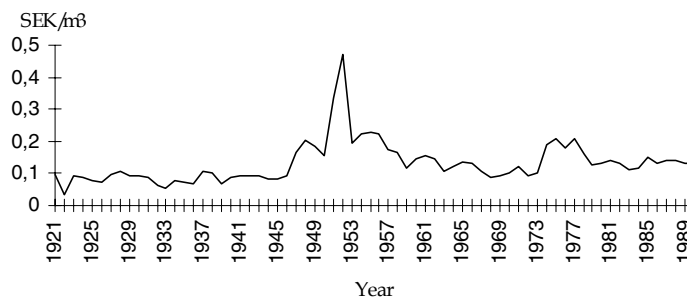


FIGURE 2. REAL UNIT NET CONVERSION VALUE, 1920–1990.

1920's and 1930's. Membership in the forest owner's movement therefore increased considerably during the war. From the end of the war, two-thirds of the quarter of the million nonindustrial forest owners were selling their timber through the regional forest owners' associations. There was also another important change. The end of the war marked the transition of the Swedish economy from a dual to a unified labour market. The previously lower wage level for rural labour caught up to the urban (manufacturing industry) level. This was among others reflected in a rapid transition in forestry from complete reliance on man and horse power to use of engines (most important the chain saw), and in large migration from the forest regions. As the purchase of delivery-sale roundwood is a joint purchase of labour and timber, this change may have had ramifications on the timber market as well.

The unit-root tests have been made with Perron's method for a possible one-time break in level. A dummy variable (zero 1909–1945, unity thereafter) has been included in the test equations (critical τ -values are found in Perron, 1989, Table IV.B). As in Haight & Holmes (1991) study of stumpage prices in southern United States, the additional lagged differences (up to six lags) were found to be not significantly different from zero and are therefore not included in the final test equations.

The regression results for the test equations are found in Table 1. The two net-price variables come out with fairly similar results. The post-war dummy variable gets significant positive coefficients, thus supporting the impression that was held from ocular inspection of the plots. The estimated autoregression coefficients are 0.75 for stumpage prices and 0.5 for unit net conversion value. The Perron-test τ -coefficients reveal that these coefficients are different from unity at the 5 and 1 percent significance level, respectively. Both equations also indicate negative drift (the intercept).

As a way of exposing the results, Figure 3 has been constructed from the estimated equations. It shows the expected relative change in timber rents in per cent given the sample data each year. For a forest stand that happens to

TABLE 1. REGRESSION RESULTS

Estimates of the Perron (Perron, 1989, Model A) auto-regressive equation for log real stumpage price in Sweden, 1909–1990, and log real net conversion value of timber in Sweden, 1920–1989. Zero regressors of lagged first-differences, t-values in parentheses.

DEPENDENT VARIABLES	INDEPENDENT VARIABLES			
	Intercept	First lag	Dummy	τ
Stumpage price	–0.615 (–3.71)	0.748 (11.13)	0.225 (3.40)	–3.74*
Unit net conversion value	–1.225 (–4.69)	0.516 (5.08)	0.307 (3.40)	–4.77**

* Significantly different from 1 at the 5 percent level.

** Significantly different from 1 at the 1 percent level.

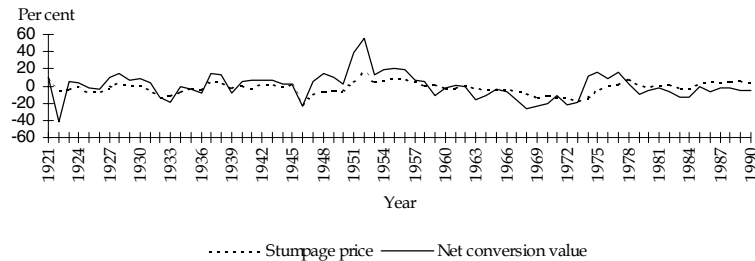


FIGURE 3. EXPECTED RELATIVE CHANGE IN TIMBER RENT 1921–1990, PERCENT.

fulfil equation (4), i.e., for which the left hand side of equation (7) is zero, the sign of this expected change tells whether to fell the trees at once (negative sign) or delay the harvesting decision (positive sign). The two net-price variables give the same signal for this case in 46 out of 70 years with overlapping data. Somewhat disturbing, the signs were different in the six most recent years. As is shown in Table 2, a *Cochrane-Orcutt* regression of the expected relative change in stumpage price on the expected relative change in unit net conversion value shows a strong correlation between these two variables, but expected relative changes in stumpage prices are generally more moderate.

TABLE 2. RESULTS FROM COCHRANE-ORCUTT REGRESSION

Regression results from Cochrane-Orcutt regression of expected relative increase in stumpage prices on expected relative increase in unit net conversion value, 1921–1989, t-values in parentheses.

DEPENDENT VARIABLE	INDEPENDENT VARIABLES		
	Intercept	Stumpage price	ρ
Unit net conversion values	-0.017 (-1.06)	0.259 (6.77)	0.697 (7.54)
\bar{R}^2	0.67		
DW	2.13		

DISCUSSION

The empirical question of whether (the logarithm of) the net price of timber follows a random walk has important implications for the optimal timing of timber harvests. Evidence from the southern United States indicates that stumpage prices when given on a monthly interval are stationary. However, *Dickey-Fuller* tests for quarterly series (Haight & Holmes, 1991; Hultkrantz, 1993) and annual series (Hultkrantz, 1993) do not allow rejection of the unit root conjecture.⁹ As shown by Haight & Holmes (1991), however, this may be an artefact of averaging of an underlying series of autocorrelated prices. This inconclusiveness is disappointing since, as emphasised by Washburn & Binkley (1993) there may be substantial information and transaction costs preventing forest managers from adjusting felling plans from one month to another. The finding in this study, rejecting unit root in two long series of genuinely annual timber rents, give a more clear support to the reservation price approach.

Another interesting result is the negative intercept in the test equations, implying a negative drift component. Streyffert (1960) concluded from data from 1909–1958 that there has been a positive trend in net prices. Based on this analysis, a common practice among forest professionals in analysing the economics of long-term silvicultural investments in the 1960's and 1970's was to add a price increase rate of one or two percent per year to the increase in revenues attributable to forest growth. Our results indicates that the existence of such a positive drift in the net price may have been a forgone conclusion from an one-time post-war increase in the timber-rent level.

⁹ Non-stationarity in quarterly Southern Pine stumpage prices is falsified in one out of 13 different states in the southern U.S. and in a pooled approach (Hultkrantz, 1993).

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