Empirical Behavior models on timber supply using survey data

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- **Consistent estimation of long-run non-industrial forest owner timber supply using micro data**

Ibrahim M. Favada, Jari Kuuluvainen Jussi Uusivuori

2006

- **The effects of prices, owner charasteristics and ownership objectives on timber supply**

Ibrahim, M. Favada, Heimo Karppinen, Jari Kuuluvainen, Jarmo Mikkola & Corinne Stavness.

2006

MOTIVATION

Is it possible to relate empirically estimated price elasticities to the Faustmann rotation model?

	Heteroscedastic IHS tobit		
Variable	**Probability**	**Unconditional mean**	**Conditional mean**
Timber price, p,*) (cross-section)	0,982 [b] (0.411)	0,107 (0.659)	-0,875 [c] (0.470)
Timber price, $\dot{p}$,**) (cross-time)	1,570[a] (0,141)	1,253[a] (0,324)	-0,225 (0,277)

*) Dep. var. sawlogs sold, m3/ha/year, scaling age classes 60-100 area
**) Dep. var. total roundwood sold, m3/ha/year, scaling: woodlot area

Introduction

- Hartman 1976: Monetary non-timber values in the Faustmann model
- Binkley 1980: Non-timber values in forest owner's (static) utility maximization problem

- **Theoretical background for econometric models of timber supply using micro data House-hold production models,**

1) Biomass harvesting model

   Lohmander 1983 (nonseparability), Koskela 1989a, 1989b, (uncertainty, perfect and imperfect capital markets)

   Kuuluvainen, 1989, 1990 imperfect capital markets

   Ovaskainen 1992 with in *situ values*

2) Faustmann model

   Hyberg and Holthausen 1989 (incl. econometric experiments)

   Tahvonen, 1998, bequest values, imperfect capital market, *in situ* values

Conclusion: Under bequest motives, market imperfections and/or in situ values in addition to prices, costs and interest rate, owners preferences affect the harvesting decisions.

Tahvonen and Viitala 2006: Market level analysis should be based on the rotation model.

Other Approches

- Prestemon, J. P. and D. N. Wear. 2000. Linking harvest choices to timber supply. *For. Sci.* 46(3):377-389.
- Provencher, B. 1995a. Structural Estimation of the Stochastic Dynamic Decision Problems of Resource Users: An Application to the Timber Harvest Decision. *J. of Environ. Econom. and Management* 29: 321-338.
- Provencher, B 1995b. “An Investigation of the Harvest Decisions of Timber Firms in the South-East United States.” *J. Appl. Econometrics.* 10:57-74.
- Provencher, B 1997. Structural versus Reduced-Form Estimation of Optimal ptimal Stopping Problems. *American Journal of Agricultural Economics.* 79: 357-368.

Biomass harvesting model

The equilibrium condition of the basic two-period model is, (determines the optimal level of biomass stock)

$$p_2 q_1(1+F'(q_1)) = p_1 q_1 (1+r)$$

- p_1 and p_2 are timber prices
- r is the interest rate,
- q_1 is the first period timber volume after harvest, H_1
- $F'(q_1)$ is growth rate of the stand.

Faustmann rotation model

- Rotation model determines the steady state rotation age. (e.g., Johansson and Löfgren, 1985)

$$pq'(t^*) = rpq(t^*) + rV(t^*)$$

- p timber price,
- $q(t)$, volume of the stand at age t
- r interest rate,
- t^* optimal rotation age
- $V(t^*)$ maximised land value

Behavioral timber supply functions

- The behavioural timber supply function for current harvest, *H1*, of the biomass harvesting model is

$$H_1 = H(p_2/p_1, r),$$

- The behavioural equation for current harvest under perfect markets becomes of the rotation model is

$$H_1 = H(w/p_1, \mathrm{p}_2/\mathrm{p}_1, r),$$

$$p_2/p_1 = \dot{p} \quad \text{, price change}$$

Examples of empirical household production models

	Estimation method	Data type	Price	Income/ wealth	Inventory
Dennis 1989	Tobit model	Cross-section N=58	7.73	-2.81	1.06
Hyberg & Holthausen 1989	Logit model Pooled	Cross-section time-series N= not reported	-0.05	-0.002	None
Kuuluvainen and Salo 1991	Tobit model Pooled	Cross-section time-series N=1570, 5 years	2.16	-0.25/ (0.15, wealth)	0.40
Dennis 1990	Probit model Pooled	Cross-section time-series N=706, 11 years	3.94	-1.292	0.351
Carlén 1990	Tobit model Pooled	Cross-section time-series N=7028, 5 years	1.72 1.92[c]	None	0.84 0.84[c]
Aronsson 1990	Tobit model	Cross-section N=858	1.67[d]	None	0.16
Wear and Newman 1991	System MLE	Regional cross-section N=not reported	[e]	None	[e]
Newman and Wear 1993	System MLE	Regional cross-section N=132	[e]	None	[e]
Kuuluvainen et al. 1996	Tobit model Pooled	Cross-section time-series data N=730	0.41	-0.13/ (0.25 wealth)	0.99
Kuuluvainen & Tahvonen 1999	Tobit model, Panel, Cross-section	Cross-section time-series N=1071 (119)[n]	1.93[f] -2.90[g]	-0.31[f] 0.10[g]	Not reported
Prestemon & Wear 2000	Probit model,	Cross-section time-series N[o]: NIPF 541 Industry 268 Government 112	1.96[h] 0.12[h] 1.13[i] 0.08[i]	None	Not reported
Lee 1997	Probability of harvest, MLE	Cross-section time series, 2799	-0.0085[j] 0.0063[j]	None	None
Bolkesjø and Baardsen 2002	Tobit model, MLE, Panel	Cross-section time series data[k] N=3413 (160)[n]	0.49 0.44	-0.05 [l] -0.01 [l] 0.48 [m] 0.54 [m]	0.69 0.73

[a] Elasticities for 1973 sample based on cross-sectional data.
[b] Elasticities for based on pooled data.
[c] Probit elasticities
[d] Based on price difference

Problems in interpretation of the empirical results

- Theoretical approaches in the above empirical investigations vary:
  - Two period biomass harvesting (e.g., Aronsson, 1990, Kuuluvainen et al 1996, Bolkesjö & Baardsen 2002)
  - Static utility maximization (Binkley, 1980, Dennis 1989, 1990)
  - Cost function approach (Newman and Wear 1991)
  - Rotation model (Hyberg & Holthausen, 1989, Kuuluvainen & Tahvonen, 1999).

- Data
  - Individual cross section survey data
  - Regional cross-section data
  - Cross-section time series data

- How to interpret the estimated elasticities
  - Cross-section variation: long-run equilibrium behaviour
  - Time-series variation: short-run behaviour

  (Baltagi and Griffin, 1984, Pirotte, A. 1999)

Is it possible to relate empirical elasticities to the Faustmann rotation model?

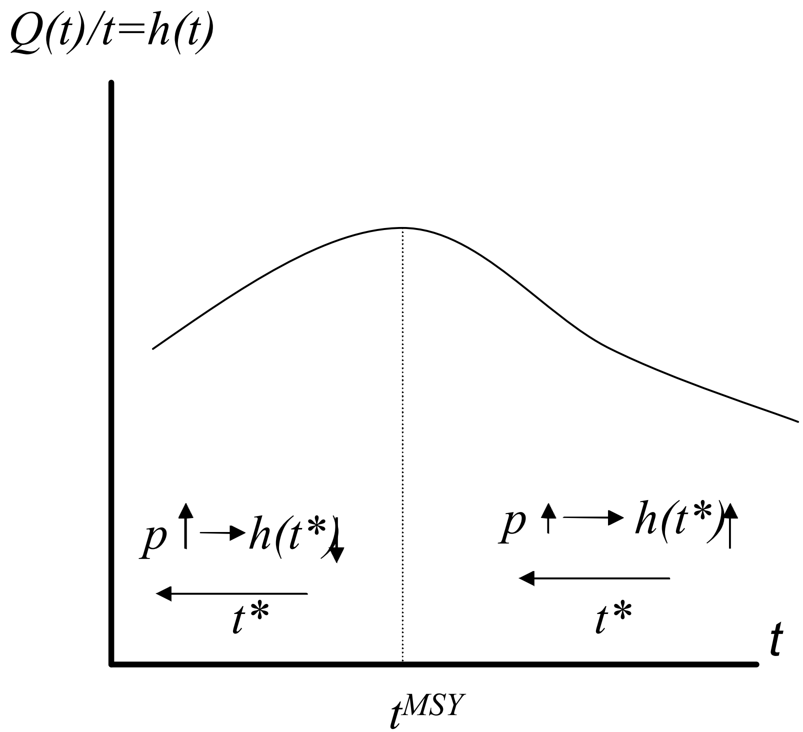
- Faustmann model is theoretically correct model for determining the optimal time to harvest an even-aged stand
  - Hyberg and Holthausen (1989) utility maximizing forest owner, test rotation model steady state comparative static effects
  - Kuuluvainen and Tahvonen (1999) forest owners life cycle utility maximization model, allowed over time variation in timber price, test steady state effects & over time adjustment (based on Tahvonen 1997).
  - Both assume perfect capital market and instantaneous utility

$$U = u(c)+u(x),$$

$$t^* = t^*(\underset{\mp}{p},\ \underset{+}{\dot{p}},\ \underset{\pm}{w},\ \underset{+}{m},\ \underset{+}{a},\ \underset{\mp}{\rho},\ \underset{-}{T})$$

Optimal rotation and timber supply

Optimal rotation and timber supply in the long run



Once-and-for-all increase in the price of timber substitution effect dom:s

Once-and-for-all changes in other variables can be studied analogously

(Uusivuori & Kuuluvainen 2006, substitution effect dominates with most relevant utility fns)

Optimal rotation and harvest

Rotation

$$t^* = t^*(\underset{\mp}{p},\ \underset{+}{\dot{p}},\ \underset{\pm}{w},\ \underset{+}{m},\ \underset{+}{a},\ \underset{\mp}{\rho},\ \underset{-}{T})$$

Harvest, e.g., under *MSY,* assuming dominating substitution effect, Uusivuori & Kuuluvainen 2006

$$h(t) = h(\underset{-}{p},\ \underset{+}{\dot{p}},\ \underset{+}{w},\ \underset{+}{m},\ \underset{+}{a},\ \underset{-}{\rho},\ \underset{-}{T})$$

Empirical results

- **Hyberg and Holthausen** (1989):
  - Cross-section data (Canada, 1980s)
  - Logit model, Harvest (0,1), Regeneration investment (0,1)
  - Evidence supporting rotation framework (timber price ?)

- **Kuuluvainen and Tahvonen** (1999)
  - Cross-section time series data, Finland 1981-1989)
  - Tobit model for mean annual (unconditional) per hectare harvest
    - short run (fixed effext tobit model for over time variation):

$$h_{ti} = \beta_{0\mathrm{i}} + \beta_1 p_{tj} + \beta_2 m_{ti} + \beta_3 \rho_{\mathrm{ti}} + \phi \Delta v_{t-1,\mathrm{i}} + e_{\mathrm{it}},$$

    - long run (OLS for cross section variation)

$$\beta_{0i} = \theta_0 + \theta_1 v_{0i} + \theta_2 \overline{p}_j + \theta_3 \overline{m}_i + \theta_4' Z_i + \varepsilon_i$$

Consistent estimation of long-run non-industrial forest owner timber supply using micro data

Ibrahim M. Favada, Jari Kuuluvainen and Jussi Uusivuori

2006

Cross-section variation of sawlog trade of ca. 1800 Finnish forest owners in 1994-1998.

Consistent estimation: Heteroscedastcity (e.g., Su and Yen 1996; Yen and Kolpin 1996) , non-normality (Burbidge et al. 1988)

Heteroscedasticity

$$\sigma_j = \exp\left(\alpha' w_j\right),$$

Non-normality

$$h_j^T = \log\left[\Omega h_j + (\Omega^2 h_j^2 + 1)^{1/2}\right] \Big/ \Omega = \sinh^{-1}\left(\Omega h\right) / \Omega,$$

Expected values of the tobit model in general case

Probability (rotation)

$$Pr(h>0)=\Phi\left(\frac{x'_j\beta}{\sigma_j}\right)$$

Expected conditional mean (m3/year, forest owners on the market)

$$E(h\mid h>0)=\Phi\left(\frac{x'_j\beta}{\sigma_j}\right)^{-1}\cdot\int_0^\infty\left\{\frac{h_j}{\sigma_j\left(1+\Omega^2 h_j{}^2\right)^{1/2}}\cdot\frac{1}{(2\pi)^{1/2}}\cdot exp\left[-0{,}5\left(\frac{h(\Omega)-x'_j\beta}{\sigma_j}\right)^2\right]\right\}dh_j$$

Expected unconditional mean (m3/year, all forest owners)

$$E(h)=\int_0^\infty\left\{\frac{h_j}{\sigma_j\left(1+\Omega^2 h_j{}^2\right)^{1/2}}\cdot\frac{1}{(2\pi)^{1/2}}\cdot exp\left[-0{,}5\left(\frac{h(\Omega)-x'_j\beta}{\sigma_j}\right)^2\right]\right\}dh_j$$

Yen, Liu and Koplin, 1996

Interpretation

- Normal forest, oldest stands harvested first

- Probability of harvest: the higher probability of harvest, the shorter the rotation

- Conditional harvest:
  - above MSY if Prob(h) increases, conditional harvest increases,
  - under MSY if Prob(h) increases, conditional harvest decreases,

- Unconditional harvest
  - above $MSY,$ if Prob(h) increases, unconditional harvest increases
  - above $MSY,$ if Prob(h) increases, unconditional harvest decreases

  Backward bending supply curve

Descriptive statistics of the sample mean (standard errors in parentheses) (From Survey Data (1994-1998), Finnish Forest Research Institute, by Karppinen, Hänninen, Ripatti, 2000)

Variable	Description	Full sample N=1860	Positive harvests	Zero harvests*
Continuous variables				
β_1	Timber price, FIM	203.718 (19.814)	207.281 (22.412)	202.476 (18.668)
β_2	Timber price change, %	7.533 (11.786)	7.548 (12.465)	7.528 (11.541)
β_3	Reforestation cost, FIM	1489.991 (304.387)	1547.246 (294.583)	1470.048 (305.243)
β_4	Nonforest income, 1000 FIM	181.895 (155.051)	181.796 (151.288)	181.930 (156.353)
β_5	Timber stock, m^3	116.987 (40.491)	123.311 (36.862)	114.784 (41.459)
β_6	Owner's age, yr.	55.893 (12.865)	54.345 (12.481)	56.432 (12.953)

Table 3. Maximum likelihood estimates of the tobit models (standard errors in parentheses; [a] significant at 1%, [b] significant at 5% and [c] significant at 10%).

Variable	Heteroscedastic IHS tobit (1)	Homoscedastic IHS tobit (2)	Heteroscedastic tobit (3)	Standard tobit (4)
Constant	-49.123[a]	-44.933[a]	-98.009[a]	-107.222[a]
	(8.050)	(5.504)	(17.668)	(12.982)
Timber price	0.142[a]	.0.065[b]	0.206[b]	0.135[b]
	(0.041)	(0.027)	(0.092)	(0.065)
Reforestation cost	0.002	0.008[a]	-0.002	0.018[a]
	(0.002)	(0.002)	(0.005)	(0.004)
Timber price change	-0.158[b]	-0.049	-0.439[a]	-0.065
	(0.063)	(0.046)	(0.143)	(0.112)
Nonforest income	-0.003	0.002	-0.014	0.007
	(0.004)	(0.002)	(0.009)	(0.006)
Timber stock	0.065[a]	0.037[a]	0.216[a]	0.065[b]
	(0.015)	(0.011)	(0.032)	(0.027)
Owner's age	-0.259[a]	-0.152[a]	-0.540[a]	-0.333[a]
	(0.040)	(0.029)	(0.088)	(0.070)
Age class > 100 yr.	0.100	-0.076	0.563[a]	-0.206
	(0.097)	(0.079)	(0.189)	(0.194)
Tax	6.987[a]	6.992[a]	15.376[a]	16.629[a]
	(0.765)	(0.768)	(1.676)	(1.794)
Occupation	6.995[a]	6.680[a]	14.102[a]	14.098[a]
	(0.760)	(0.756)	(1.696)	(1.797)
Ω	0.068[a]	0.070[a]		
	(0.005)	(0.005)		
Log-likelihood	-11415.66	-11437.77	-11863.45	-11931.09
Expected mean sales (m^3/ha/yr.)	5.350	5.512	6.349	6.701
Probabilty of harvest	0.227	0.230	0.209	0.212

Table 4. Elasticities of continuous variables.

	Heteroscedastic IHS tobit			Standard tobit		
Variable	Prob*	Uncond	Cond	Prob	Uncond	Cond
Timber price	0.982 [b]	0.107	-0.875 [c]	0.674 [b]	0.868 [b]	0.195 [b]
	(0.411)	(0.659)	(0.470)	(0.323)	(0.416)	(0.093)
Reforestation cost	0.602	1.750 [a]	1.148 [a]	0.670 [a]	0.863 [a]	0.193 [a]
	(0.419)	(0.371)	(0.127)	(0.145)	(0.186)	(0.042)
Timber price change	-0.035	0.014	0.049 [c]	-0.012	-0.015	-0.003
	(0.022)	(0.040)	(0.030)	(0.021)	(0.027)	(0.006)
Nonforest income	0.017	0.120 [b]	0.103 [b]	0.030	0.038	0.009
	(0.027)	(0.059)	(0.045)	(0.026)	(0.033)	(0.007)
Timber stock	0.275 [b]	0.092	-0.182	0.188 [b]	0.242 [b]	0.054 [b]
	(0.109)	(0.174)	(0.115)	(0.079)	(0.101)	(0.023)
Owner's age	-0.527 [a]	-0.189	0.338 [c]	-0.457 [a]	-0.589 [a]	-0.132 [a]
	(0.184)	(0.228)	(0.173)	(0.096)	(0.124)	(0.028)
Age class > 100 yr.	-0.015	-0.134 [b]	-0.119 [b]	-0.035	-0.045	-0.010
	(0.026)	(0.063)	(0.053)	(0.033)	(0.042)	(0.009)

*Prob = probability, Uncond = unconditional level, Cond = conditional level

The effects of prices, owner charasteristics and ownership objectives on timber supply

Ibrahim, M. Favada, Heimo Karppinen, Jari Kuuluvainen, Jarmo Mikkola & Corinne Stavness.
2006

Over time variation in stumpage price and per hectare total harvest,
Cross-section variation owner characteristics and owner objectives
Ca. 1814 Finnish forest owners in 1994-1998.

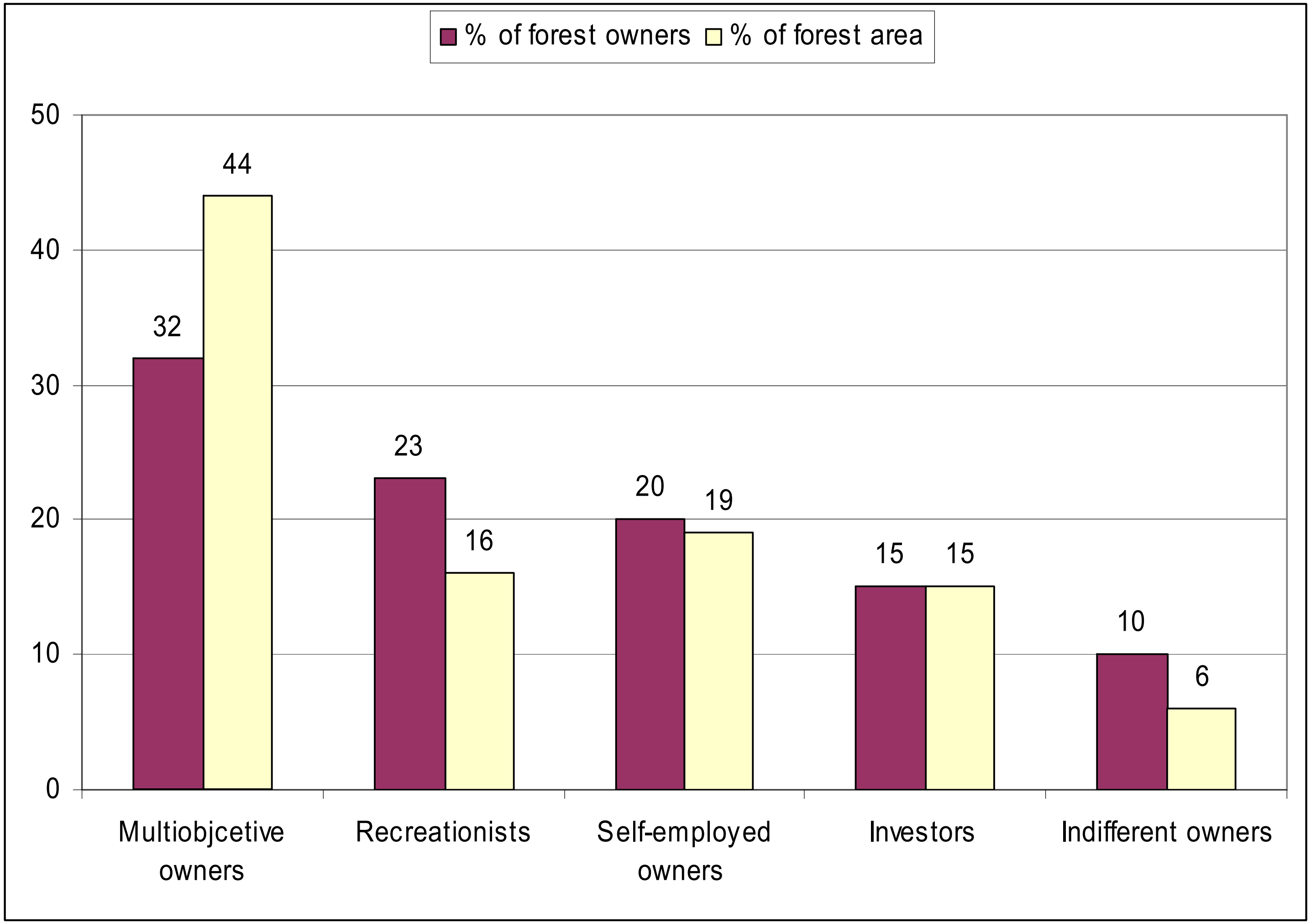
Consistent estimation: Heteroscedastcity (e.g., Su and Yen 1996; Yen Liu and Kolpin 1996) , non-normality (Burbidge et al. 1988)

Table 2. Forest owner groups based on ownership objcetives. K-means cluster analysis.

Owner group	n	Economic security & reg. sales income	Non-timber benefits	Self-employment opportunities
		Mean of PC score (standard deviation)		
Multiobjective owners	927	0.821 (0.526)	0.382 (0.536)	0.542 (0.525)
Recreationists	754	-0.716 (0.722)	0.929 (0.540)	-0.465 (0.707)
Self-employed owners	586	-0.592 (0.816)	-0.601 (0.726)	0.986 (0.588)
Investors	453	0.860 (0.543)	-0.592 (0.786)	-0.934 (0.896)
Indifferent owners	331	-0.796 (0.596)	-1.313 (0.871)	-0.926 (0.715)
	Σ 3051			
F statistic				
P- value				

Elasticities of continuous variables [a] significant at 1%, [b] significant at 5% and [c] significant at 10%).

	Heteroscedastic Ihs tobit			Standard tobit		
Variable*	Prob	Uncond	Cond	Prob	Uncond	Cond
Price	1.570[a] (0.141)	1.253[a] (0.324)	-0.317 (0.277)	1.590[a] (0.156)	2.071[a] (0.202)	0.481[a] (0.046)
Age	-0.168[b] (0.075)	0.429[b] (0.169)	0.597[a] (0.136)	-0.040 (0.088)	-0.053 (0.114)	-0.012 (0.026)
Income	0.033 (0.021)	0.210[a] (0.040)	0.177[a] (0.051)	0.053[b] (0.023)	0.069[b] (0.029)	0.016[b] (0.007)
Regen. costs	0.140 (0.103)	1.247[a] (0.187)	1.387[a] (0.234)	0.399[a] (0.120)	0.519[a] (0.157)	0.121[a] (0.036)
Fores land area	-0.046[a] (0.011)	-0.280[a] (0.023)	-0.326[a] (0.033)	0.112[a] (0.015)	0.146[a] (0.020)	0.034[a] (0.005)
Timber volume	0.291[a] (0.055)	0.449[a] (0.085)	0.158[a] (0.030)	0.295[a] (0.062)	0.384[a] (0.081)	0.089[a] (0.019)



See also Lindroos, 2004

Average discrete effects ([a] significant at 1%, [b] significant at 5% and [c] significant at 10%).

	Heteroscedastic Ihs het. Tobit			Standard Tobit		
Variable*	Prob	Uncond	Cond	Prob	Uncond	Cond
farmer$_i$	0.072[a] (0.010)	1.313[a] (0.203)	1.745[a] (0.268)	0.047[a] (0.011)	1.060[a] (0.246)	1.048[a] (0.237)
tax$_i$	0.069[a] (0.009)	1.238[a] (0.170)	1.663[a] (0.231)	0.082[a] (0.009)	1.884[a] (0.215)	1.855[a] (0.205)
Inv$_i$*(ref.multiob-jective owners*	-0.053[a] (0.012)	-0.858[a] (0.184)	-1.223 [a] (0.277)	-0.049[a] (0.012)	-1.064[a] (0.248)	-1.127[a] (0.276)
Recr$_i$	-0.122[a] (0.011)	-1.905[a] (0.178)	-2.804[a] (0.292)	-0.077[a] (0.011)	-1.651[a] (0.233)	-1.769[a] (0.265)
empl$_i$	-0.013 (0.010)	-0.216 (0.176)	-0.298 (0.245)	0.000 (0.011)	0.005 (0.252)	0.005 (0.255)
indiff$_i$	-0.133[a] (0.014)	-1.938[a] (0.191)	-3.013[a] (0.349)	-0.092[a] (0.014)	-1.909[a] (0.277)	-2.150[a] (0.353)

*Prob=change in probability between belonging to group (e.g., *farmer*$_i$=1) and not belonging (e.g., *farmer*$_i$=0), Uncond= change in unconditional mean, and Cond= change in conditional mean m^3/ha/y harvest respectively, other variables measured at their means.

Continuous time Faustmann model

- Timber supply $h(t)=h(t)(p, \dot{p}, r, w, Z)$

Long run, p, and short run, $\dot{p}$, price elasticities of timber supply, 1995-1998, survey data, ca 1800 forest owners in Finland (Favada et al. 2006, Favada et al. 2006)

	Heteroscedastic IHS tobit		
Variable	**Prob***	**Uncond**	**Cond**
Timber price, p, (cross-section)	0,982 [b] (0.411)	0,107 (0.659)	-0,875 [c] (0.470)
Timber price, $\dot{p}$, (cross-time)	1,570[a] (0,141)	1,253[a] (0,324)	-0,225 (0,277)

Prob=probability of harvest, Uncond=mean annual per hectare harvest for all observations, Cond.=mean harvest for observations with positive harvest
a, b, c, sinificant at 1%, 5%, 10% risk

Conclusions

- In the long run, the rotation model cannot be rejected:
  - In regions with higher prices shorter rotation are used with smaller annual per hectare harvests of those in the market (scaled with 60-100 age class hectares).
  - The effect on mean (unconditional) annual harvest of regional price not significant statistically

Conclusions

- In the short run, the rotation model cannot be rejected:
  - When prices increase over time, more forest owners and/or more hectares of forest land come to the market, probability of harvest increases
  - Also per hectare mean annual harvest increases (scaled with the wood lot forest land area) statistically significantly, per hectare annual harvest of those in the market may decrease
  - Many owner and forest characteristics affect timber supply, "Recreationists" and "Indifferent" owners sell ca. 2 m3/ha/y less than multiobjective owners and 1 m3/ha/y less than investors
  - Non farmer forest owners sell clearly less than farmers