Non-industrial Private Timber Supply: What have we learned from survey data?

Jari Kuuluvainen
University of Helsinki

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“A study of forest ownership is prerequisite to the appellation ‘*forest economist*,’ or so it has been said.” (Clark Binkley, 1981)

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  - Long-run price effects
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Theoretical background to NIPF timber supply econometrics

- **Faustmann model**

  Faustmann 1849, Samuelsson, 1976, Clark, 1976, Hartman 1976 (marketable non-timber values)

- **Biomass harvesting models, household production**

  Binkley,1981 (static, non-marketable in values, micro-econometrics),

  Johansson and Löfgren 1982 (uncertainty, two period model).

  Lohmander 1983 (credit rationing, and non-separability in Fisherian two-period consumption savings framework, unpublished working paper),

  -*Koskela* 1989a, 1989b (uncertainty in perfect and imperfect capital markets),

  -*Ovaskainen* 1992 with (*in situ*, *existence*, *values*).

- **Continuous time rotation models, household production**

  Tahvonen, 1998 (Credit rationing, bequest and *in situ* values).

  Tahvonen and Salo, 1999. (In situ values, one or more stands)

Under rather general conditions:

- The effects of prices (costs and interest rate) on timber supply are ambiguous
- Owner characteristics affect the harvesting decisions.
- Age-class models: Forest age class structure matters

Empirical Studies

- **Binkley, C. 1981:**
  - Static household production model, non-marketable amenities
  - Time-series cross-section data (1947-1973), USA, logit model, harvest (0,1)

- **Loikkanen, H.A., Kuuluvainen, Salo J.** 1986.
  - NIPF harvest, Finland, Pooled time-series cross-section data, logit, OLS with selectivity and tobit models (unpublished working papers).

- **Hyberg, B.T., and Holthausen, D.M.** (1989):
  - Rotation model, non-marketable amenities
  - Cross-section data (Canada, 1980s)
  - Logit model, Harvest (0,1), Regeneration investment (0,1)

- For surveys see, Amacher et al. 2003; Beach et al. 2005; Kuuluvainen, et al. 2006

Empirical Studies

- **Prestemon, J.P., and Wear, D.M.** 2000: Household production; Inventory data,
  - Harvesting decisions by ownership categories, short and long run price responces in aggregated timber supply,. Short-run elasticities > long-run elasticities.
- **Pattanayak, S.K., Murray, B.C., and Abt, R.C,** 2002: Household production; Inventory data
  - Simultaneous determination of Timber supply, Inventory volume, Age distribution, price effects on supply
- **Bolkesjø, T.F., and Baardsen**, S.2002, Household Production; Survey data
  - Timber supply and endogenous tax rate
- **Bolkesjø, T.F., and Solberg**, B. 2003,Houshold Production; Survey data
  - Price elasticities
- **Bolkesjø, T.F., Solberg, B., and Wangen**, **K.R**. 2007: Household production; Survey data
  - Heterogeneity of NIPF timber supply, pooled, fixed, random effects, property averages. Price elasticities, Income, Wealth.

NONTIMBER PRODUCTION; SILVICULTURE, OWNER CLASSIFICATIONS

- Kline et al 1999, Kline, et al. 2004, Ovaskainen, 2006, Kendra, 2007, Majumdar, et al. 2008,

Focus of this presentation

1) **Forest owner heterogeneity and the effects of directly non-observable owner preferences (objectives) on timber suppply**.

Kuuluvainen, Karppinen and Ovaskainen (1996)

- Two period, biomass harvesting, non-marketable amenities, credit rationing
- Cross-section time-series data, Finland 1986-1990
- Pooled tobit for annual per ha harvest
- Owner objectives (preferences) effect on timber supply

2) **The effects of price on timber supply**.

- Income vs. substitution effects of prices
- Long-run vs. short-run

Kuuluvainen and Tahvonen (1999)

- Rotation model, non-marketable amenities
- Cross-section time-series data, Finland 1981-1989
- Short-run price-effects: variation of per hectare harvest over time; fixed effects
- Long run price: variation of per hectare harvest between forest owners
- Substitution effect of timber price dominates

Effects of timber price on Supply

Johansson and Löfgren 1985: Income target, Volvo effect of timber price

Kuuluvainen, 1990: Two-period model

Maximize $U = \left[u(c_1) + \beta u(c_2)\right]$

st. forest and budget constraint with binding borrowing limit.

Substitution and income effects under credit rationing: The effect of present timber price on harvest:

$$\frac{\partial h_1}{\partial p_1} = D^{-1}\left[u'(c_1) + h_1 u''(c_1) p_1\right] \lesseqgtr 0,$$

Kuuluvainen and Tahvonen 1999: Numerical experiments, substitution effect seemed to dominate.

Uusivuori and Kuuluvainen 2008: Substitution effect dominates if:

$$1 + \frac{m_1 + B^u}{p_1 h_1} > \frac{c_1 u''(c_1)}{u'(c_1)}$$ ≡ e, Elasticity of marginal utility

Uusivuori and Kuuluvainen 2008, Age class model with amenities.

In the equilibrium, *Substitution effect* dominates, when:

$$1+\frac{rw}{\sum_{i=1}^{n} a_i x_i p q_i - \sum_{i=1}^{n} a_i x_i k} > \frac{c u''(c)}{u'(c)} \equiv e\text{, Elasticity of marginal utility}$$

Left hand side: 1 + (Non-forest income/Forest Income).

According to *Evans*, (*Fiscal Studies*, 2005) Elasticity of Marginal Utility in developed countries is around 1.4. ($stpr=\rho+eg$)

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

Favada, Ibrahim M., Jari Kuuluvainen, Jussi Uusivuori

2007

Study on NIPF timber supply in Finland, based on survey data. Perfect capital market, Valued non-marketable forest amenities,

$Max.\ U = u(c)+A(x),$

Subject to: *forest dynamics (rotation model) and budget constraints*

Behavioral reduced form equations

Rotation, t, years, with dominating substitution effect

$$t = t(p, w, m, a, \rho, T)$$

$$- \quad + \quad + \quad + \, - \quad -$$

Harvest, under *MSY, h(t)=x(t)/t, m3/ha/y*

$$h(t) = h(p, w, m, a, \rho, T)$$

$$- \quad + \quad + \quad + \quad - \quad -$$

Interpretation of estimated effects of exogenous variables

•Cross-section variation: long-run equilibrium behavior
(Baltagi and Griffin 1984, Pirotte 1999)

Data & Econometric specification

Cross-section variation of saw log harvests of 1814 Finnish forest owners in 1994-1998.

Consistent estimation of a Tobit model

$$h_{it} = h_{it}{*} = \beta' x_{it} + u_{it} \quad \text{if } RHS > 0,$$

$$h_{it} = 0 \quad otherwise$$

Heteroscedasticity (e.g., Su and Yen 1996; Yen and Kolpin 1996)

$$\sigma_j = exp(\alpha' w_j)$$

Non-normality (Burbidge et al. 1988)

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

Expected values of the tobit model in general case

Probability (rotation)

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

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

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

Unconditional mean (Expected harvest 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, (Prob(h)): the higher the probability of harvest, the shorter the rotation (Hyberg & Holthausen, 1989)

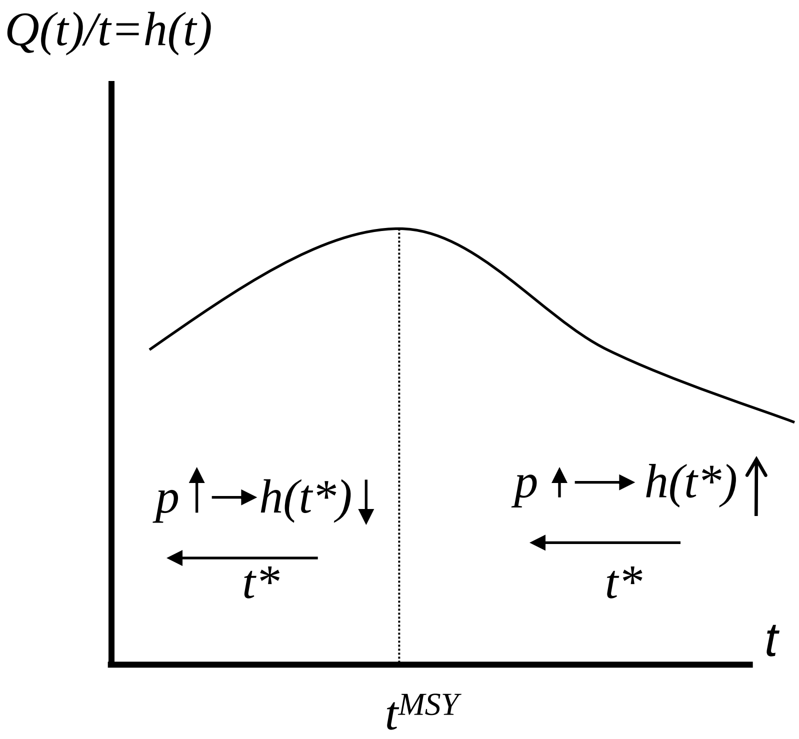
- Conditional harvest (m3/ha/year, forest owners who harvest):
  - above MSY if Prob(h) increases, conditional harvest increases,
  - under MSY if Prob(h) increases, conditional harvest decreases,

- Unconditional harvest (m3/ha/year, all forest owners):
  - above MSY, if Prob(h) increases, unconditional harvest increases
  - above MSY, if Prob(h) increases, unconditional harvest decreases

  Backward bending supply curve

Rotation and timber supply

Optimal rotation (*t**) and timber supply *h*(*t**) in the long run,



Once-and-for-all increase in the price of timber when substitution effect dominates

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

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

Favada, Ibrahim M., Jari Kuuluvainen, Jussi Uusivuori 2007

Elasticities of continuous variables.

	Heteroscedastic IHS tobit		
Variable	**Prob***	**Uncond**	**Cond**
Timber price	0.982 [b]	0.107	-0.875 [c]
	(0.411)	(0.659)	(0.470)
Reforestation cost	0.602	1.750 [a]	1.148 [a]
	(0.419)	(0.371)	(0.127)
Average timber price change	-0.035	0.014	0.049 [c]
	(0.022)	(0.040)	(0.030)
Nonforest income	0.017	0.120 [b]	0.103 [b]
	(0.027)	(0.059)	(0.045)
Timber stock	0.275 [b]	0.092	-0.182
	(0.109)	(0.174)	(0.115)
Owner's age	-0.527 [a]	-0.189	0.338 [c]
	(0.184)	(0.228)	(0.173)
Age class > 100 yr.	-0.015	-0.134 [b]	-0.119 [b]
	(0.026)	(0.063)	(0.053)

*Prob = probability, Uncond = unconditional level, Cond = conditional level
a 1%, b 5%, c 10%

The Effects of Timber Prices, Ownership Objectives and Owner Characteristics on Timber supply

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

2009

Time-section variation in stumpage price and per hectare harvest,
Cross-section variation in other variables incl. *owner objectives*
Survey data 1814 Finnish forest owners in 1994-1998.
Rotation

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

$$+ \quad + \quad + \quad + \quad - \quad -$$

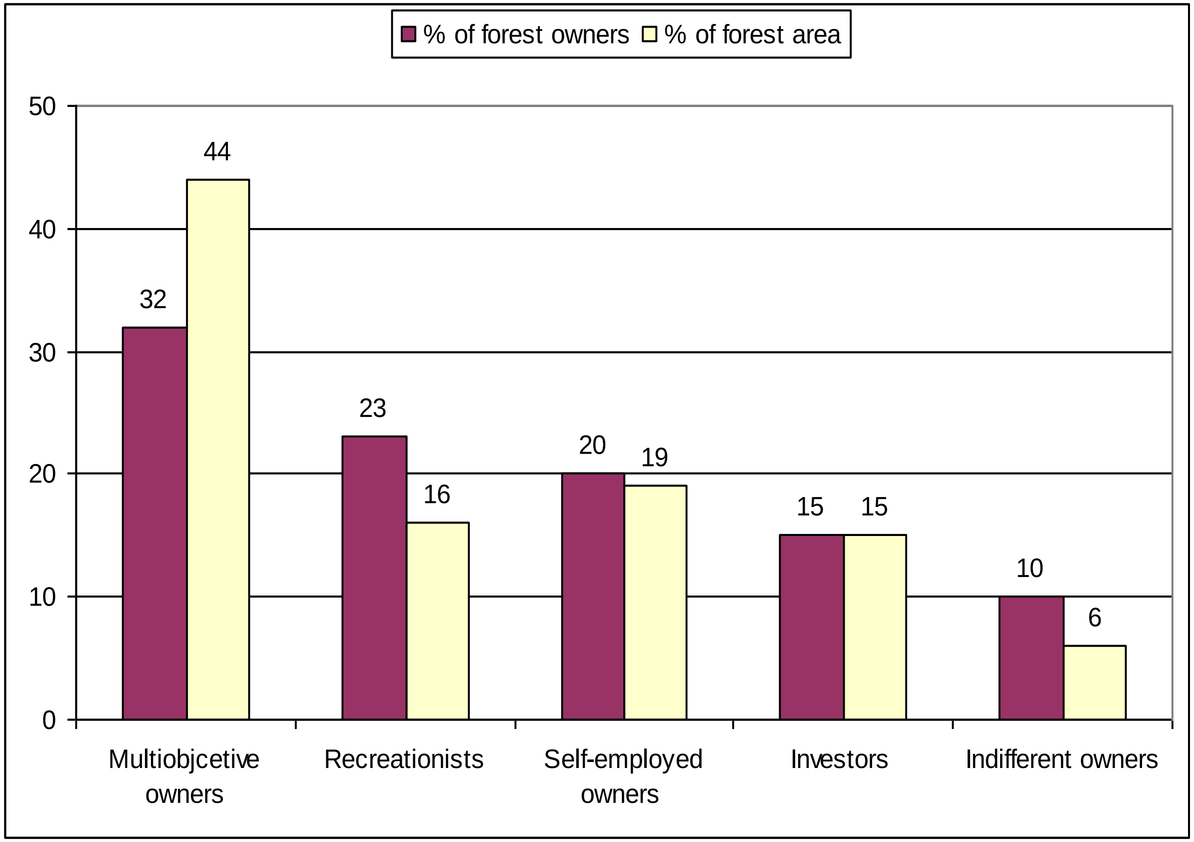
Harvest m3/ha/year, under MSY

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

$$+ \quad + \quad + \quad + \quad - \quad -$$

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

Forest owner groups based on ownership objectives. K-means cluster analysis was based on principle component scores. Principle component analysis was used to condense the information of 21 statements concerning the objectives of forest ownership of the interviewed forest owners.



Timber supply elasticities of continuous variables [a] significant at 1%, [b] significant at 5% and [c] significant at 10%) in the short-run, Finnish panel data 1995-1998**.**

	Heteroscedastic IHS tobit model		
Variable*	**Prob**	**Uncond**	**Cond**
Price	1.570[a] (0.141)	1.253[a] (0.324)	-0.317 (0.277)
Age	-0.168[b] (0.075)	0.429[b] (0.169)	0.597[a] (0.136)
Income	0.033 (0.021)	0.210[a] (0.040)	0.177[a] (0.051)
Regen. costs	0.140 (0.103)	1.247[a] (0.187)	1.387[a] (0.234)
Fores land area	-0.046[a] (0.011)	-0.280[a] (0.023)	-0.326[a] (0.033)
Timber volume	0.291[a] (0.055)	0.449[a] (0.085)	0.158[a] (0.030)

Effects of owner objectives, Favada et al. 2009 (Kuuluvainen et al. 1996) [a] significant at 1%, [b] significant at 5% and [c] significant at 10%,

	Heteroscedastic Ihs Het. Tobit		
Variable*	**Probality of harvest**	**Unconditional mean harvest**	Conditional mean harv.
Multiobjective owners as reference group			
Investors$_i$	-0.053[a] (0.012)	-0.858[a] (-1.10) (0.184)	-1.223 [a] (0.277)
Recreationists$_i$	-0.122[a] (0.011)	-1.905[a] (-1.01) (0.178)	-2.804[a] (0.292)
Self employed$_i$	-0.013 (0.010)	-0.216 (-0.77) (0.176)	-0.298 (0.245)
Indifferent$_i$	-0.133[a] (0.014)	-1.938[a] (Na) (0.191)	-3.013[a] (0.349)

*Probability of harvest=change in probability between belonging to group and not belonging, Uncondtional harvest= change mean harvest in m3/ha/y for all observations, and Conditional mean harvest= change in conditional mean harvest m^3/ha/y harvest for $h(t)$>0, other variables measured at their means.

Table 8. Elasticities and discrete effects by ownership objective groups calculated using the estimated parameters of the heteroscedastic IHS model
([a] significant at 1%, [b] significant at 5% and [c] significant at 10%).

	Multiobjective [d] (n = 3165)		**Recreationists (n = 1945)**		**Self-employed (n = 1850)**		**Investors (n = 1320)**		**Indifferent (n = 790)**	
Variable	**Prob**	**Mean**	**Prob**	**Mean**	**Prob**	**Mean**	**Prob**	**Mean**	**Prob**	**Mean**
Timber price	1.341[a]	0.981[a]	1.776[a]	1.480	1.735[a]	0.813	1.193[a]	1.773[b]	1.870[a]	2.211[b]
	(0.185)	(0.354)	(0.458)	(0.931)	(0.254)	(0.705)	(0.365)	(0.865)	(0.324)	(1.069)
Owner' age	0.228[b]	-0.005	0.175	0.613	-0.156	-0.076	-0.278	0.185	-0.035	-0.305
	(0.103)	(0.202)	(0.259)	(0.511)	(0.143)	(0.356)	(0.189)	(0.438)	(0.191)	(0.555)
Nonforest income	0.035[c]	0.080[c]	0.123	0.356[b]	-0.107[b]	-0.011	0.026	0.154	-0.059	0.148
	(0.020)	(0.045)	(0.081)	(0.173)	(0.052)	(0.118)	(0.059)	(0.142)	(0.089)	(0.190)
Regeneration cost	-0.101	1.057[a]	1.049[a]	1.915[a]	0.409[b]	1.012[b]	-0.072	0.811	0.889[b]	2.314[b]
	(0.132)	(0.273)	(0.344)	(0.627)	(0.201)	(0.443)	(0.295)	(0.697)	(0.418)	(1.061)
Forestland	-0.012	-0.346[a]	-0.024	-0.259[a]	0.002	-0.481[a]	-0.011	-0.541[a]	-0.030	-0.738[a]
	(0.008)	(0.035)	(0.043)	(0.093)	(0.020)	(0.078)	(0.034)	(0.103)	(0.027)	(0.138)
Timber stock	0.404[a]	0.645[a]	0.005	0.007	0.113	0.180	0.705[a]	1.029[a]	-0.032	-0.053
	(0.072)	(0.115)	(0.165)	(0.226)	(0.104)	(0.166)	(0.153)	(0.224)	(0.216)	(0.355)
Discrete effects										
Farmer	0.069[a]	0.913[a]	0.076[a]	2.337[a]	0.075[a]	1.430[a]	0.016	0.314	0.080[a]	1.658[a]
	(0.017)	(0.235)	(0.026)	(0.922)	(0.018)	(0.381)	(0.022)	(0.439)	(0.025)	(0.567)
Site value Tax	0.111[a]	1.470[a]	0.062[a]	1.792[a]	0.054[a]	1.003[a]	0.081[a]	1.692[a]	0.093[a]	1.973[a]
	(0.015)	(0.216)	(0.018)	(0.587)	(0.019)	(0.361)	(0.021)	(0.480)	(0.029)	(0.678)
Probab. of harvest [e]	0.373		0.137		0.294		0.214		0.316	
Expect sales, all	3.019		2.725		3.409		2.910		3.894	
Expected sales, >0	8.094		19.891		11.595		13.598		12.323	

[d] Prob=probability, Mean= unconditional level of mean harvest for all observations.

Conclusions

- Using Finnish data, the model of utility maxising NIPF owner cannot be rejected,
- Owner characteristics and objectives have measurable effects on average harvest and on elasticities of other variables
- However, e.g.,

    -Favada et al. (2007, 2009): cross-section effects of prices smaller in absolute terms than time-section the effects, (see Kuuluvainen and Tahvonen 1999, numerical results).

    -Bolkejø et al. (2002,2003,2006): cross-section effects larger in absolute terms than time section.

Conclusions

•Rotation and biomass-harvesting lead to similar empirically testable hypotheses,

•Effects age class structure? (Pattanayak et al 2002)

•More informative empirical modeling would require information on both the harvested stands and on the owner of the stand: Inventory & Survey data

•Aggregated supply, e.g., the effects of endogenous forest investments and timber production area should be studied

"Too sharp a division of labor between theoretical and experimental work can lead to mutual misunderstanding, even in the so-called exact sciences; in softer disciplines, it is bound to bring about a total impasse." (Leontief, 1985)

American Economic Review: Articles where empirical analysis based on data generated by the authors initiative (Leontief, 1982)

3/1972-12/1976	3/1977-12/1982
0.8%	1.4%

In the *CJFR*, *For. Sci* & *JEEM*, 1/2000-8/2009:

46 articles on NIPF forest owner behavior, theoretical and/or numerical analysis on decision making in forest management, and analysis on timber/wood supply using aggregated data.

12 % (6) of these studies used econometric analysis based on *survey* or *inventory* data.

(Search: "Timber supply or nonindustrial private* or rotation*")*

”Meta Conclusions”

- We know rather well how forest owners should behave, but far less well how they actually do behave.

- Interaction between theoretical (forest economics and management) and empirical forest economists for policy relevant positivist results on actual NIPF owner behavior is required.