Technology diffusion, farm size structure and regional land competition in dynamic partial equilibrium

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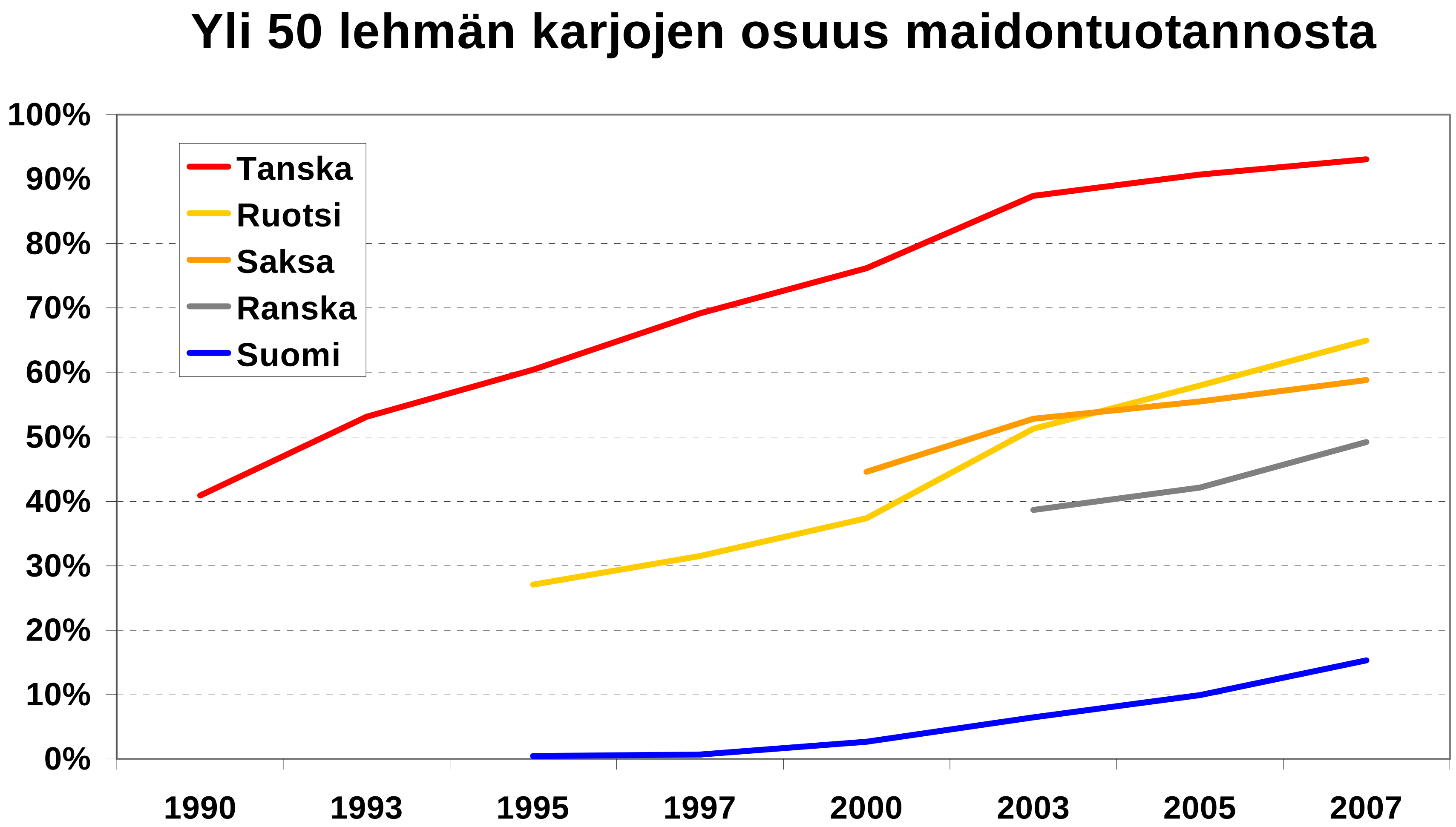
Introduction: Drivers leading to land scarcity

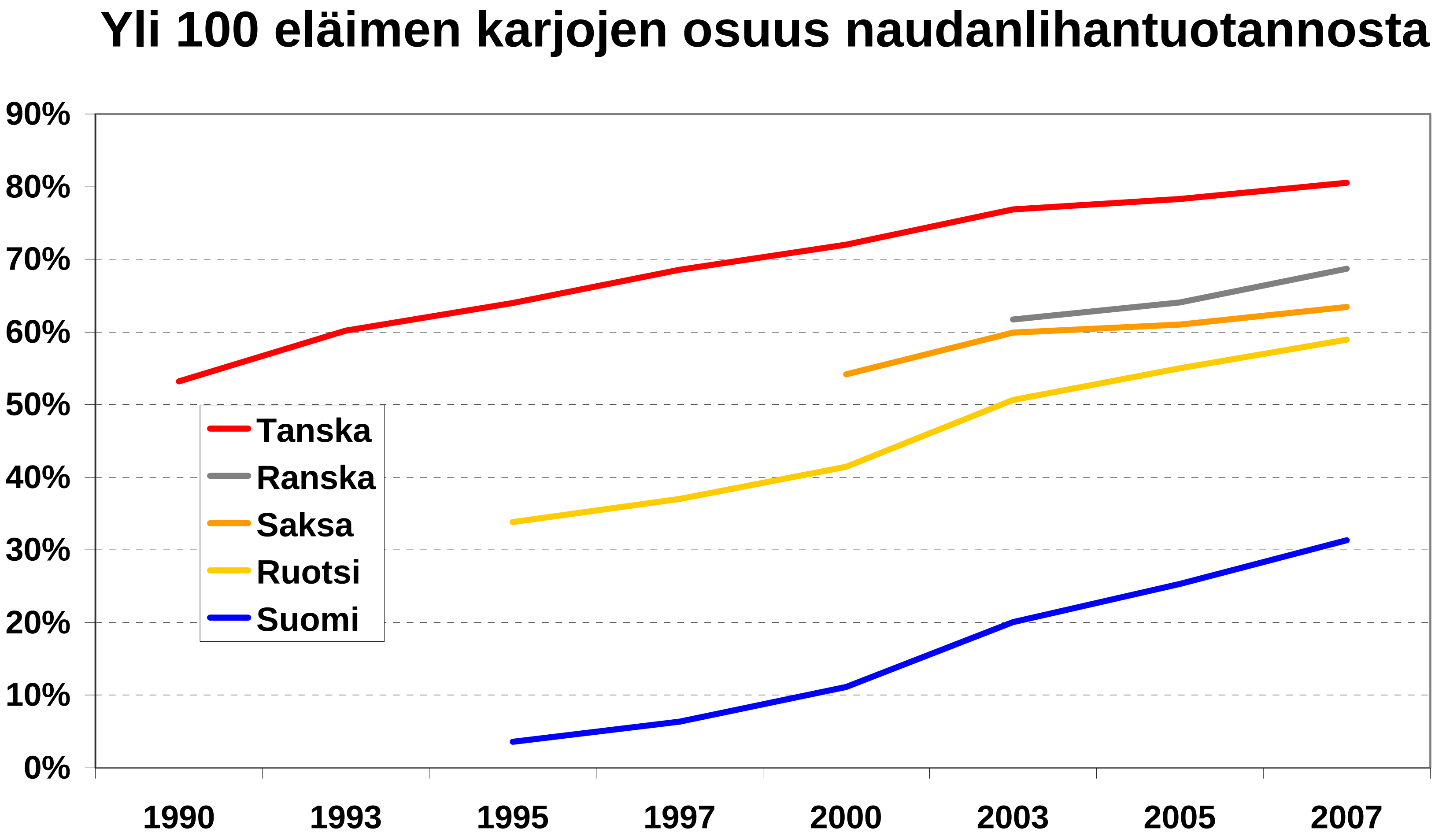
- Farm size growth
  - facilitating economies of scale and production specialisation
- Concentration of production on most competitive farms and regions
  - important for agricultural viability and profitability in Finland where farms and regional animal densities have been smaller than in neighbouring countries such as Denmark or southern parts of Sweden
- Stringent environmental regulations
  - Environmental support scheme restricts phosphorous fertilisation max 20 kg P/ha (even less on farms with high P stocks on farmland)
  - This means that 40m3 bovine manure and 25 m3 pig manure can be spread per ha
- => Land competition has intensified in Finnish agriculture in the last 15 years
  - especially in areas where animal production has significantly increased

Share of dairycows kept at farms with more than 50 cows; Denmark – Sweden – Germany – France – Finland. Source: Eurostat



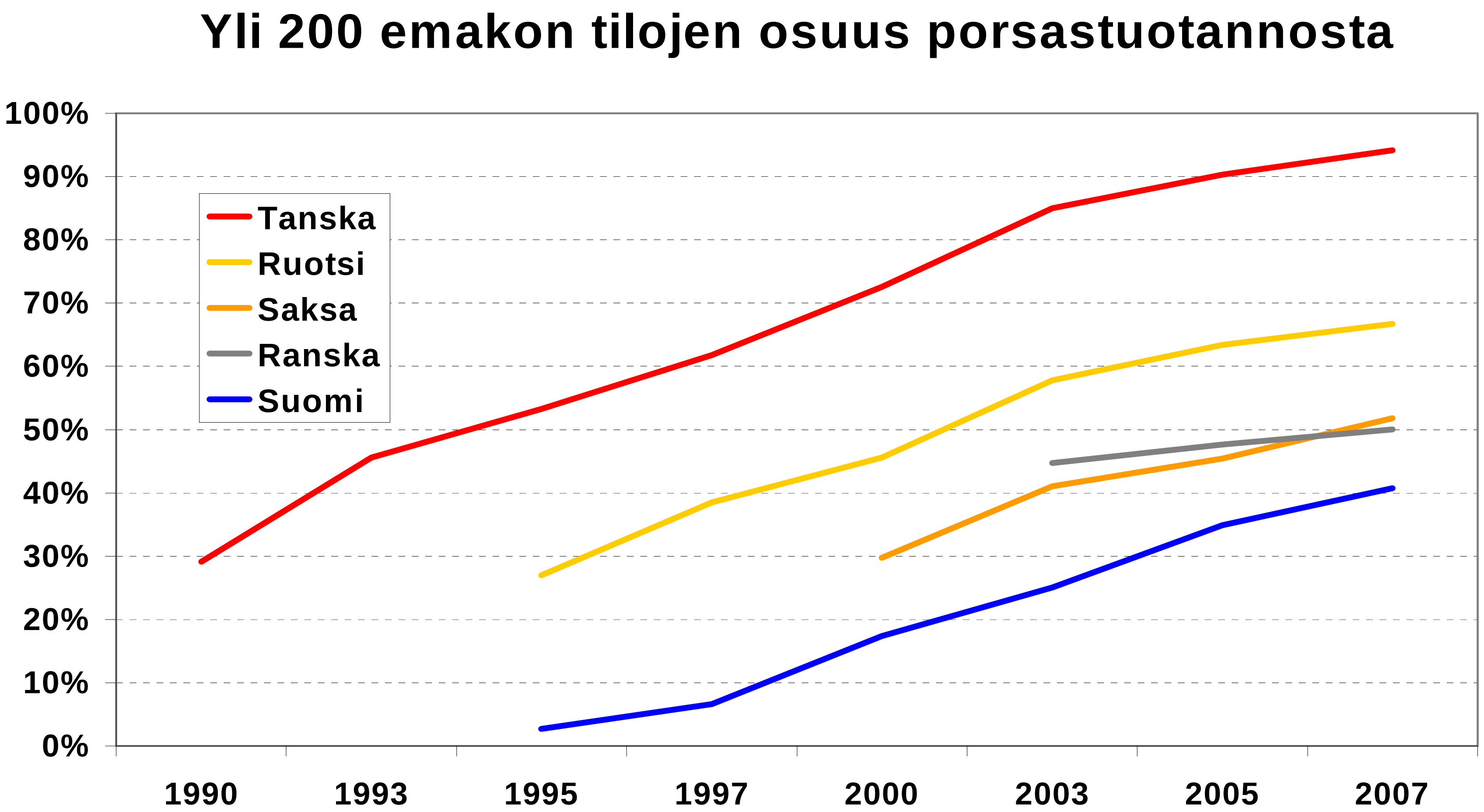
Lähde: Eurostat

Share of bulls kept at farms with more than 100 animal; Denmark – Sweden – Germany – France – Finland. Source: Eurostat



Lähde: Eurostat

Share of piglets grown at farms with more than 200 sows; Denmark – Sweden – Germany – France – Finland. Source: Eurostat



Lähde: Eurostat

Phosphorous can be fractioned out from manure

- There are at least two main techniques for this (mechanical and chemical fractioning removing solid organic material from slurry)
- Dry matter content in manure slurry and in liquid and solid fractions of slurry, after mechanical treatment:

	Dry matter content
Unhandled slurry from bovine animals	5,5%
Unhandled slurry from pigs	3,5%
After mechanical treatment -liquid (rich in N) -solid (rich in P)	 2-3% 30-35%

Benefits and consequences of manure processing

- Fractioning out phosphorous (P) from manure may
  - improve the use of manure nutrients since P surplus can be divided between land parcels ;
  - Part of P stock can be sold or transported to other farms at reasonable costs
  - decrease the land area needed for manure spreading
  - Decrease the manure transportation since liquid manure with less phosphorous can be used in larger volumes per hectare
  - => reduction of purchased fertiliser at livestock farms
- Manure fractioning could benefit significantly those profitable livestock farms which could increase production but cannot due to land scarcity and high land prices

Farm size growth will continue –
What if land constraints were relieved?
What would be the effects on farm size growth, production and its regional concentration?
What would be the value of less binding land constraint for agricultural sector?

Research methods

- We study these issues by integrating regional land values as input prices in investment model - technology diffusion scheme in Dremfia sector model
- We simply define land requirements due to manure spreading requirements (20 kg P/ha) as input cost per each animal place in new cattlehouses
- This means that shadow value of regional land constraints in Dremfia is provided as land input price for the technology diffusion model for the next year
  - We accept one year lag in land values to enter investment decisions
- Explicit land price may change the profitability of investments and hence investments

The structure of DREMFIA sector model
- based on mathematical programming

*Max u=r*X-cX*

-Φ[X'ΩX]1/2

Optimisation

MAX: producer and consumer surplus

- annual market equilibrium
- different yields and inputs in regions
- feed use of animals changes endogenously
- constraints on energy, protein and roughage needs of animals
- non-linear yield functions for dairy cows
- domestic and imported products are imperfect substitutes
- processing activities of milk and sugar
- export cost functions

Results/Initial values

production land use consumption prices
imports exports transportation

Policy scenarios

supports for farmers EU prices

Crop yield functions

- optimal level of fertilisation

Steering module

- bounds for land use variables; validated to observed data
- trends in consumption
- inflation
- increase in crop and animal yield potential

Model of technology diffusion

- endogenous sector level investment and technical change
- investments depend on relative profitability and accessibility of each technique
- gradual shifts of capital to best performing techniques

Research methods

- Dynamic recursive model of Finnish agriculture (DREMFIA) includes 18 production regions and 2 major coupled parts:
  - (1) a technology diffusion model which determines sector level investments in different production technologies
  - (2) a price endogenous optimisation routine which simulates annual production decisions (within the limits of fixed factors) and price changes, *i.e.* supply and demand reactions, by maximising producer and consumer surpluses subject to regional product balance and resource (land and capital) constraints

Microeconomic model of technology diffusion drives medium and long-term development

- Investments I_α in each alternative technique α depend on absolute and relative profitability as well as spread of each technique, which represents accessibility, farmers' knowledge and risk of each technique
- K_α = capital in technique α; Q_α = production linked revenue for technique α; L_α = variable factors of production; w = input prices; δ_α = depreciation rate of α technique, r_α = rate of return of technique α; r = general interest rate in the economy; σ = savings rate (share of economic surplus to fixed factors which is re-invested in agriculture), includes investment supports ; η = farmers' propensity to invest in alternative techniques (calibration parameter)

$$r_\alpha = \frac{Q_\alpha - wL_\alpha}{K_\alpha}.$$

$$I_\alpha = \sigma r_\alpha K_\alpha + \eta(r_\alpha - r)K_\alpha = \sigma(Q_\alpha - wL_\alpha) + \eta(r_\alpha - r)K_\alpha$$

$$\frac{dK_\alpha}{dt} = [\sigma r_\alpha + \eta(r_\alpha - r) - \delta_\alpha]K_\alpha$$

Validating farm size distribution

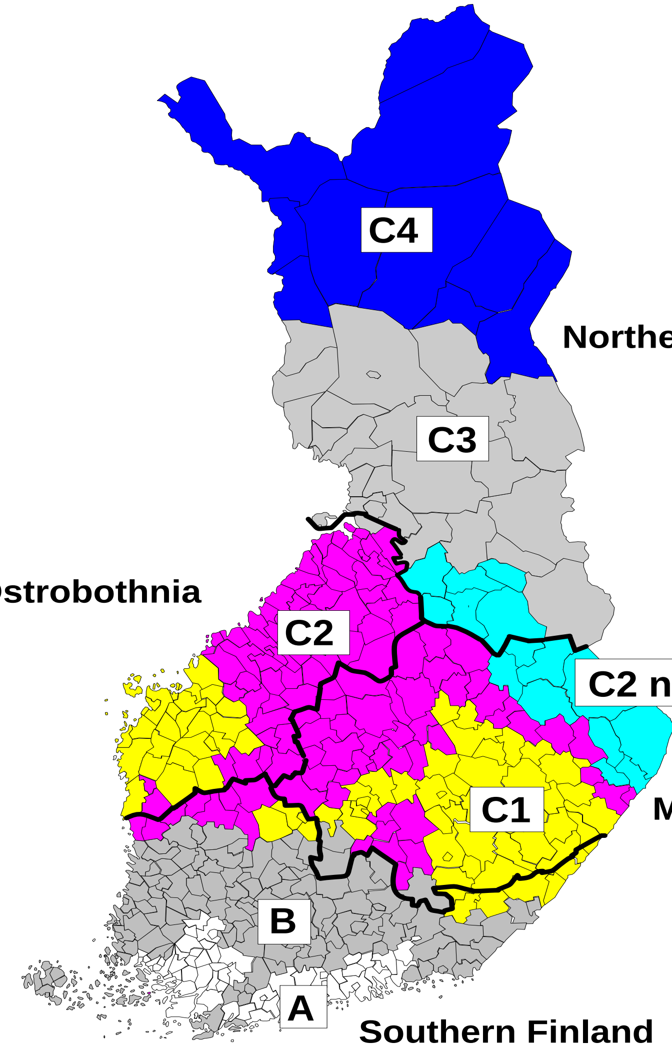
- Three dairy techniques (representing α techniques) and corresponding farm size classes have been included in the DREMFIA model: farms with 1-19 cows (labour intensive production), farms with 20-49 cows (semi-labour intensive production), and farms with 50 cows or more (capital intensive production).
- The chosen combination of the parameters ($\sigma:\eta$) (1.17:0.87) is unique because it calibrates the farm size distribution to the observed farm size structure (2008)

Other characteristics

- Armington assumption
- Endogenous investments and technical change in animal production
  - Explicit sunk costs and capital depreciation
- Use of variable inputs, such as fertilisers and feed stuffs, are dependent on agricultural product prices and fertiliser prices through production functions
- Milk quotas, which constrain milk production at farm, region and country level, are traded within three separate areas

- Land can be substituted in a rather limited extent by other inputs, due to restrictions on manure phosphorous
  - Increasing purchased feed (concentrates) decreases feed area but increases P content in manure and hence manure spreading area at a farm!

Main areas and support regions

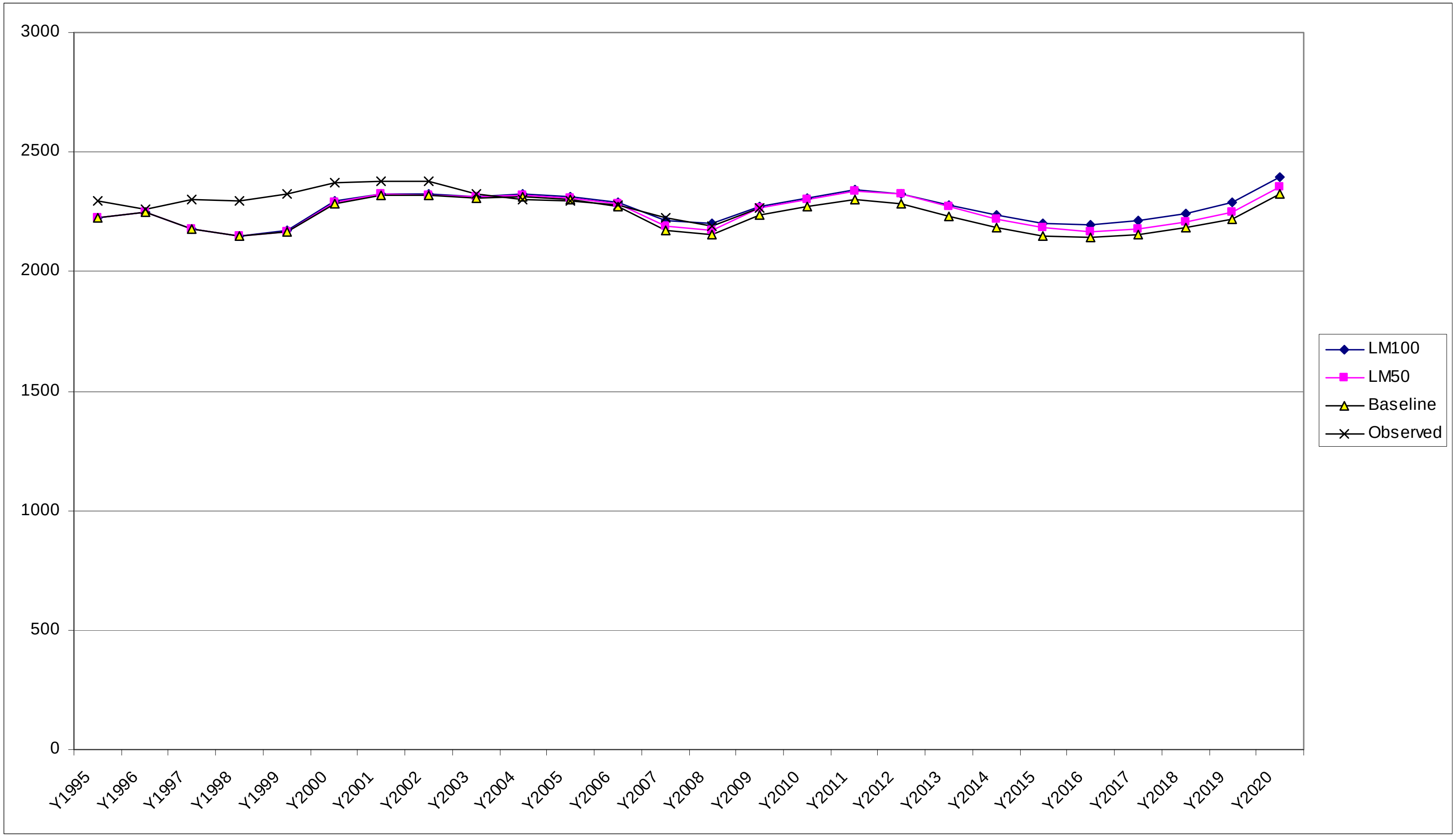


MAATALOUDEN TALOUDELLINEN TUTKIMUSLAITOS

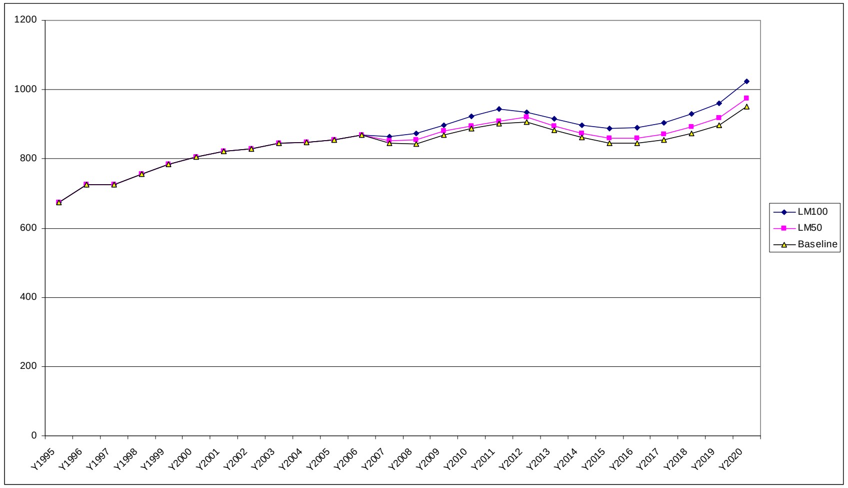
3 land resource requirement options were analysed:

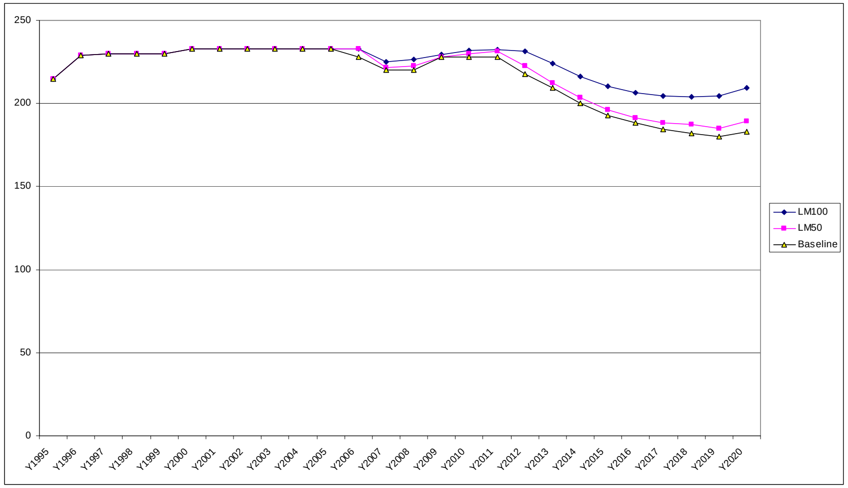
- *In* ***baseline*** it is simply assumed that *one dairy cow requires one hectare of farmland* because of existing specific regulations of environmental support programme
- In scenario *"**Less stringent manure policy" (LM50)*** it is assumed that only 0.5 hectare per dairy cow place is required when investing in a new cattle house
- ***"Liberal manure policy" (LM100)*** (*or highly efficient manure utilisation technology)* it is assumed that **no farmland** is required per dairycow when investing in new cattle houses.
- All these optional policies are assumed to start 1995

Do less stringent land requirements for dairy investments increase dairy production in Finland? If not, why not?

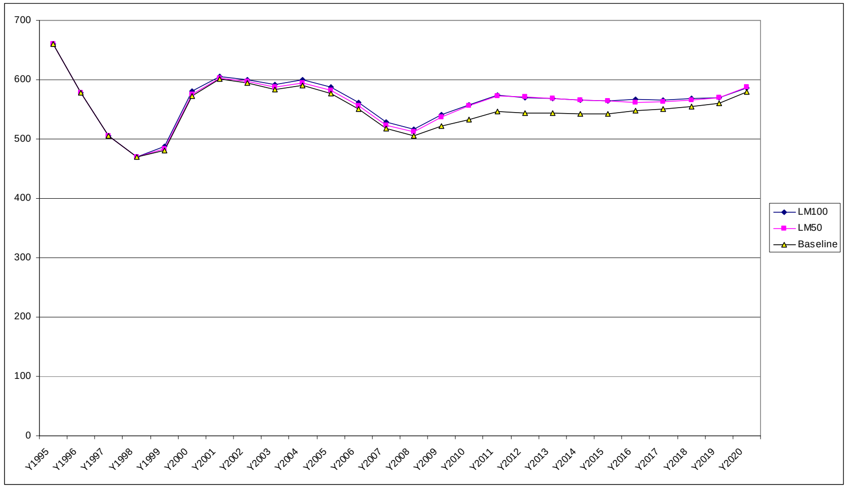


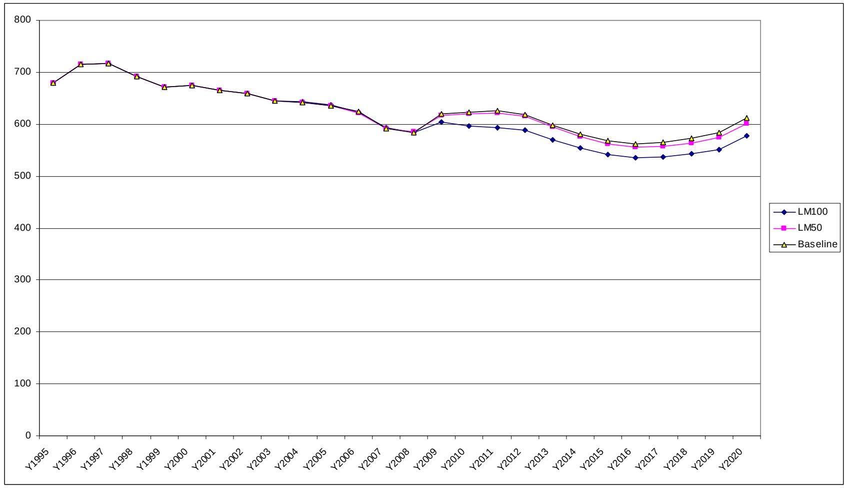
Milk production volume (million litres) increases in Ostrobothnia (western Finland; left) and in Northern Finland (right) if land requirements per animal place in new cattlehouses could be relieved



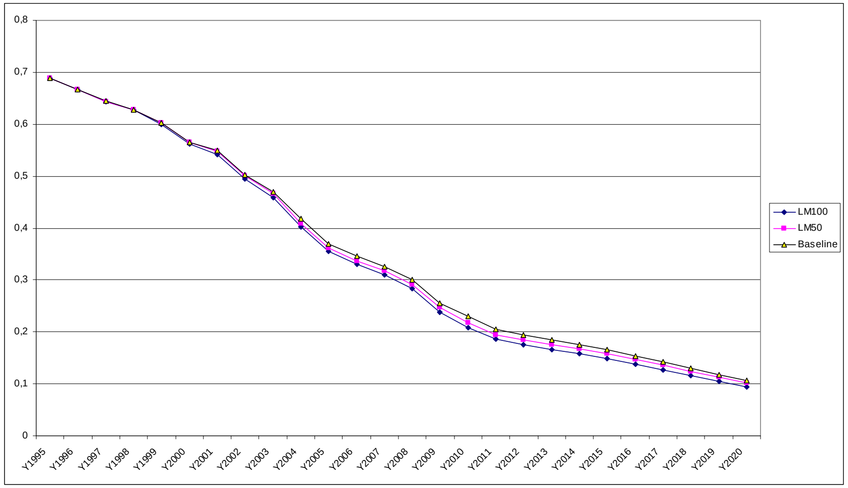


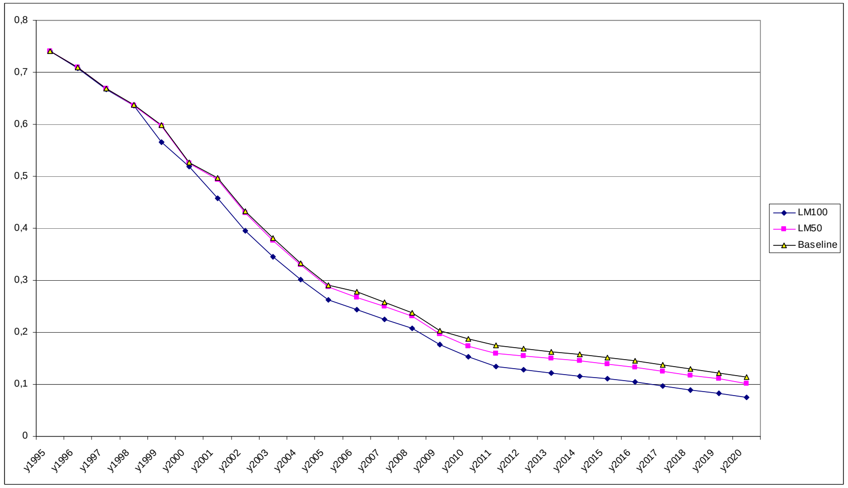
Milk production volume (million litres) *decreases* in Southern Finland; left) and in Central Finland (right) if land requirements per animal place in new cattlehouses could be relieved



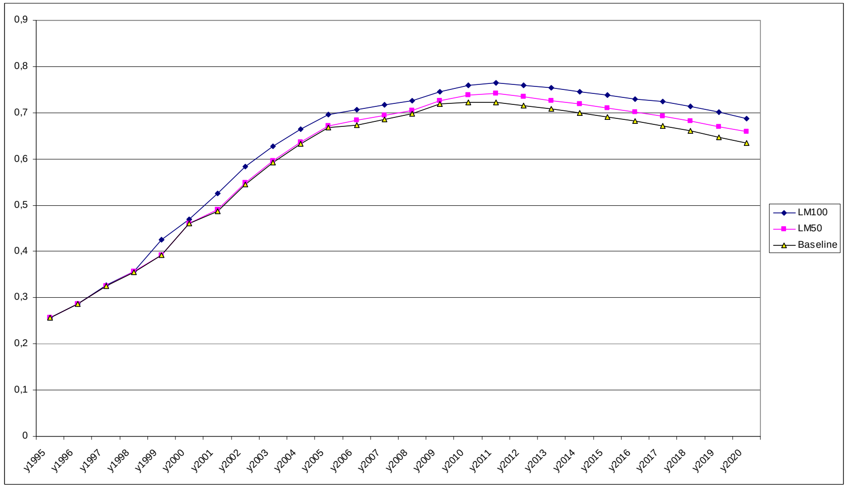


Share of capital on small dairy farms (1-19 cows) in the whole country (left) and in northern Finland (right)

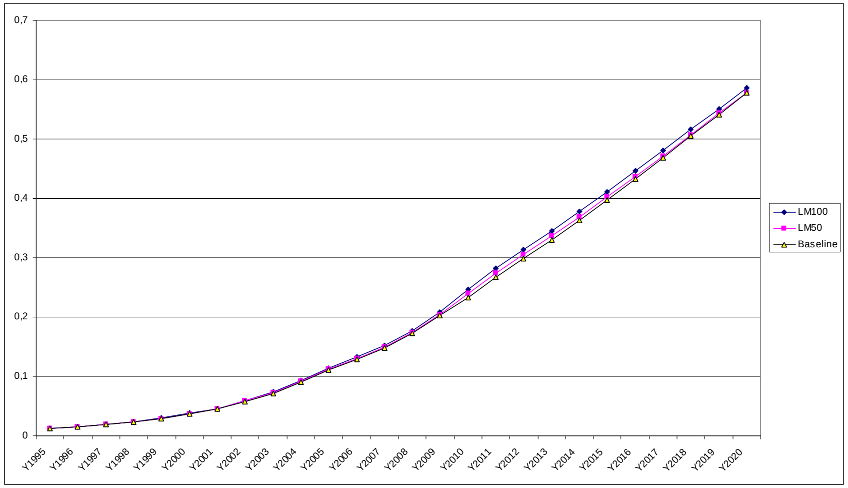


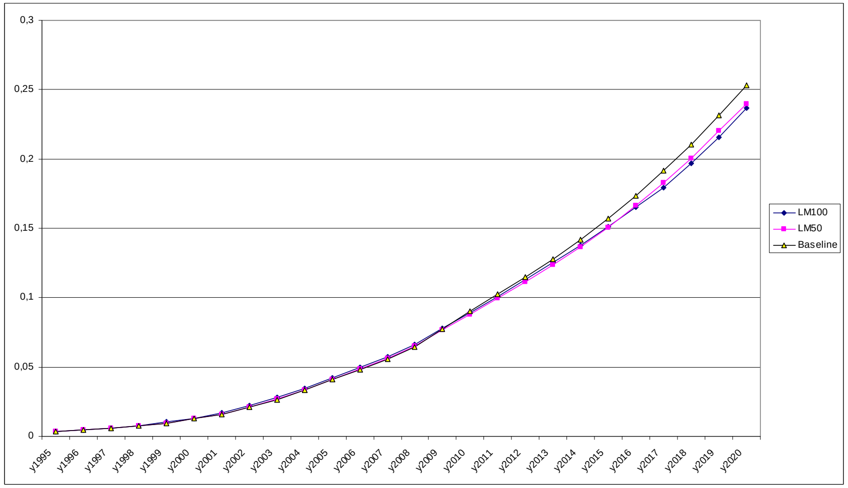


Share of capital on medium sized dairy farms (20-49 cows) at the whole country level (left) and in northern Finland

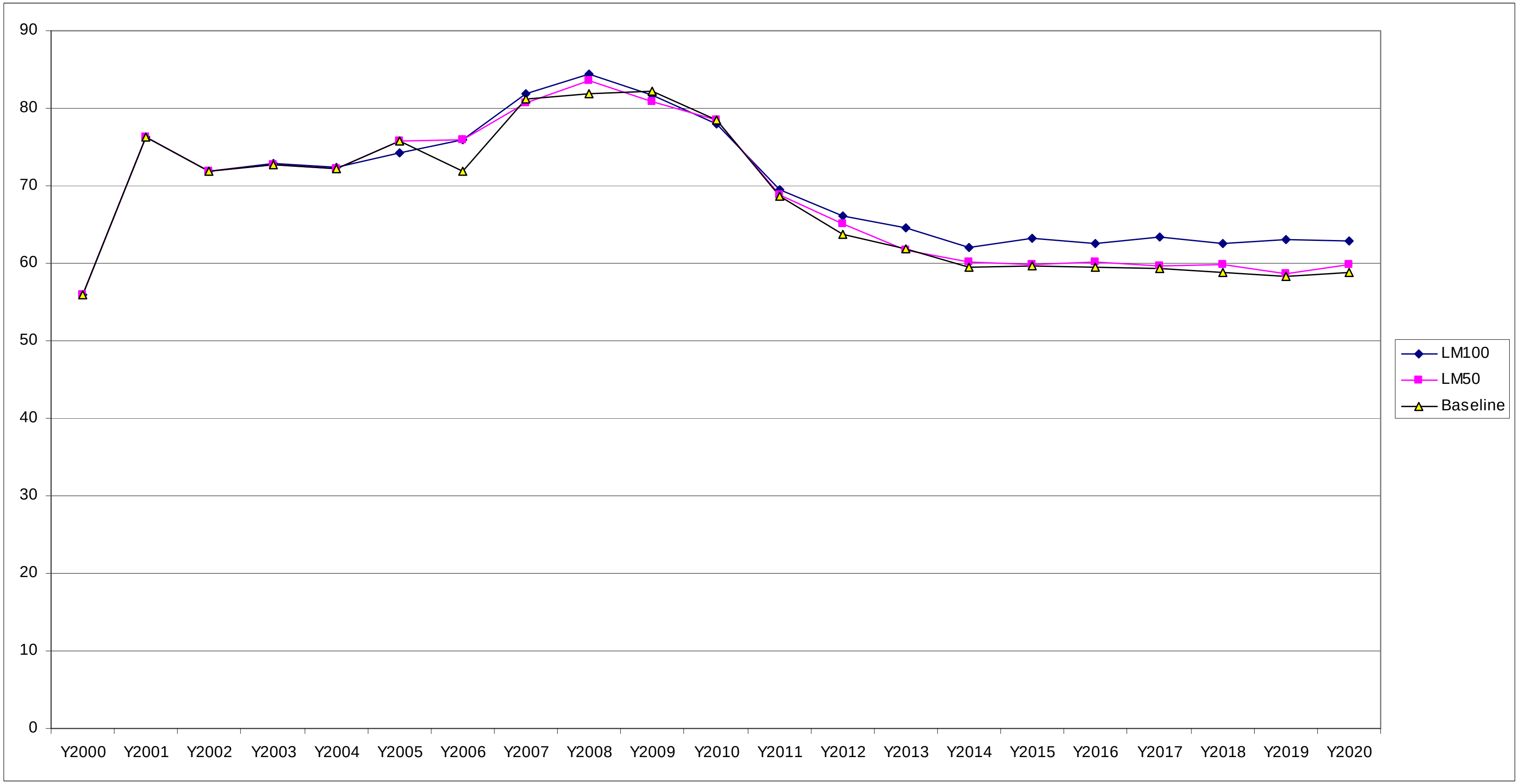


Share of capital on large dairy farms (>50 cows) in the whole country (left) and in northern Finland (right)



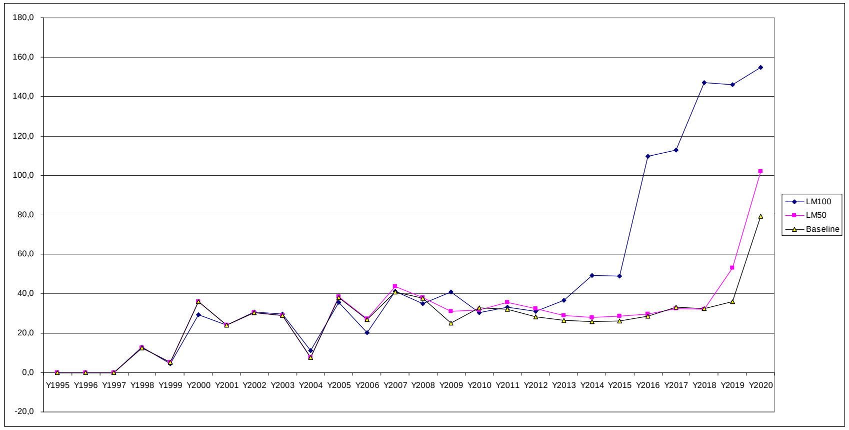


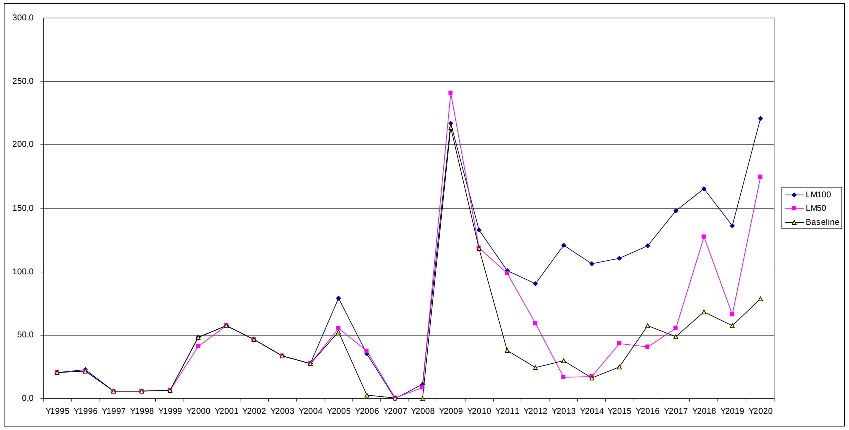
Farm income would stay at a higher level in northern Finland if land requirements per animal place in new cattlehouses could be relieved



Marginal value of land (eur/ha) in Ostrobothnia (western Finland; left) and in northern Finland (right)

- weighted averages of shadow values of land constraints in the sector model, not comparable to actual land prices





Discussion and conclusion

- Dairy producers in Western and Northern Finland would benefit relatively most on less stringent land requirements for dairy investments
- Milk production volume in northern Finland would stay at 10-20% higher level compared to the baseline where production decreases
- Farm income in Northern Finland would be 6-9% higher
  - It is taken into account that overall subsidy cannot increase in C-support regions (overall)
- Small impacts on overall milk production volume and farm income
- It is worth considering how competitive advantage is affected by land requirements (or manure processing), and what are the likely consequences for regional production
- Less stringent land requirements would relieve the increase in land prices only temporarily in regions where livestock production is increasing
  - However the land prices are likely to increase in the long-term if production is increasing
  - No change in land prices in regions where livestock production is at a decreasing trend already (southern Finland)
- The coupling of the technology and market model components, including land resource constraints, provides a platform for many interesting analysis
  - Manure processing techniques may change the land use intensity, nutrient flows, and relative profitability of investments in different farm types