TECHNOLOGY DIFFUSION, FARM SIZE STRUCTURE AND REGIONAL LAND COMPETITION IN DYNAMIC PARTIAL EQUILIBRIUM

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

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Abstract. The methodological challenge addressed here is modelling multi-regional development of agricultural production and structural change, including land competition, in a dynamic partial equilibrium setting. The model applied in this study is a dynamic recursive model simulating the development of the agricultural investments and markets annually from 1995 up to 2020. Results show that land prices play a role when animal production increases in most competitive regions and gradually decreases in less productive regions. The framework can be applied when analysing how various new techniques, practices and regulations for land use affect regional production structures.

Keywords: agricultural sector modelling, technical change, land competition, manure nutrients, agri-environmental policies.

1. Introduction

Modelling structural change together with land competition has been considered increasingly important in agricultural economics literature in recent years (Chavas 2001, Kellermann et. al., 2008). Increased land prices are expected to have a strong role in agricultural production and its regional allocation. Multiregional sector models which explicitly analyse changes in comparative advantage and production between regions are well suited to this problem, since increasing production often takes place on growing and relatively efficient farms, possibly inhibited by land scarcity.

Concentration of production on most competitive farms and regions has been 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. In earlier years land competition was not very intense in Finnish agriculture due to low level of regional concentration of animal farms and animal numbers. In such conditions the main emphasis in farmers’ decision making was how to attain economies of scale and other benefits of production specialisation on farms and regions while land was not a significant cost factor (Pietola, 1997). However land competition has intensified in the last 15 years, especially in areas where animal production has significantly increased (Lehtonen&Pyykkönen, 2005, Pyykkönen, 2006).

Changes livestock production, its input and land use intensity, as well as regional concentration of production, are seen as important determinants of land values as well as agricultural water pollution. Despite the theoretical fact that decoupling production linked agricultural subsidies should decrease input use intensity and volume of agricultural production, no or little decrease has been observed in agricultural water pollution in Finland during the last 15 years (Ekholm et. al. 2007). This observation, despite the fact that nitrogen surplus has decreased by 42 % and phosphorous surplus by 65 % in Finland 1995-2006, has been a disappointment since ambitious targets have been set for water quality improvements and significant agri-environmental subsidies have been paid for farmers in order to reach the targets (Turtola, 2007). Ekholm et. al. (2007) conclude that simultaneous changes in agricultural production (e.g. regional specialisation) and abnormal weather conditions on several years may also have counteracted the effects of agri-environmental measures. Especially the slowly decreasing phosphorous stock in agricultural soils has been indentified a major problem and hence compelling restrictions have been set to phosphorous fertilisation. This, in turn, restricts economic use of manure nitrogen and requires enlarging livestock farms to rent more land for spreading manure phosphorous.

Aim in this paper is to show, using a simplified case study example, how regional agricultural production and farm structures can be modelled in a way that not only provides (1) a consistent picture of agricultural changes with respect to overall markets and policies, but provides also (2) a major platform for analysis how regional production structures are impacted by policies, possibly promoting specific technological options in order to reach different environmental targets at reasonable costs. There may also be synergies and conflicts between different targets, which require economic analysis.

Partial analyses focusing on individual production lines, which compete on the same regional land, labour and capital resources, may not always provide a sound basis for policy recommendations. Especially regional changes in agriculture may not be driven by technical change and other (such as managerial abilities of farmers) developments in individual production lines alone, but also by comparative advantage of regions and farms. Hence a sector level analysis, entailing the overall change in agriculture, is needed when evaluating changes in the regional development of agricultural production, as well as when evaluating the potential to reduce nutrient runoff, greenhouse gas emissions, or other negative externalities, from agricultural sector.

These modelling challenges are attacked using a dynamic regional sector model of Finnish agriculture (DREMFIA; Lehtonen, 2001), which has been tailored to facilitate consistent integration between physical field scale and catchment scale nutrient leaching models. In addition to analyses of production and income effects of agricultural policies (Lehtonen 2004, 2007), this model has been earlier employed to assess the effects of alternative EU level policy scenarios on the multifunctional role of Finnish agriculture (Lehtonen et.al. 2005, 2006).

The rest of this paper is organised as follows. In the following section we present the agricultural sector model and its tailored components for structural change analysis, facilitating also links between technical change, investments and regional farmland value. This is followed by a presentation of 3 simplified policy and technology related options for relaxed land requirements imposed on new cattle house investments. Impacts of these options for dairy production and dairy farm structure are then reported on whole country and regional levels. Finally, based on the results we discuss and conclude on the theoretical consistency and empirical feasibility of the presented approach.

2. Methods

2.1. The sector modelling approach

The model applied in this study is a dynamic recursive model simulating the development of the agricultural investments and markets annually from 1995 up to 2020. The model consists of two main parts: (1) a technology diffusion model which determines annual sector level investments in different production technologies (farm types) in each region; (2) an optimisation routine simulates annual price changes (supply and demand reactions) of all major crops and animal products by maximising producer and consumer surplus subject to regional product balance, resource (land and capital) and various non-linear constraints. The major driving force in the medium- and long-term is the module of technology diffusion which takes into account cumulative gains from the earlier investments in the specific animal farm types in each region. Since alternative techniques are attributed to farm size, the technology diffusion model represents the dynamic change in farm size structure and technology. However annual price changes, including land prices, from the market simulating optimisation model affect the profitability of livestock investments. This model set-up has been applied in several studies of market changes, agricultural and agri-environmental policies.

What is a new and relevant contribution here is that the price of land, affected by all production activities regionally, is provided for technology diffusion model as dual values of the explicit regional land resource constraint from the market simulating optimisation model. Hence the regional land prices of the previous year from the market model are taken into account as a cost in the technology diffusion model (since environmental permits and agri-environmental support scheme requires explicitly and implicitly require necessary land availability when investing), which determines profitability and level of investment in different techniques in different animal production lines for the next year. Now the land cost is determined equally for each and every farm type on the basis of land areas needed for manure spreading and roughage production. This means that the livestock investment alternatives (farm size categories) are treated equally in terms of land requirements. The relative profitability of different animal farm types and production lines is not only determined by scale economies and degree of specialisation, or feed availability determined by regional roughage feed balances, but also by the land costs, affected by all agricultural activities in the region, as well as agri-environmental restrictions and policies. Hence the profitability of livestock investments decrease in those regions where land price increase, while livestock investments become more profitable in regions where land price decreases. Such dynamic recursive modelling may explain if the increase in intensive animal production regions has decelerated due to high land prices, and if land prices play a role when animal production still exists in less productive regions.

The dynamic regional sector model of Finnish agriculture (DREMFIA) is a dynamic recursive model simulating the development of the agricultural investments and markets from 1995 up to 2020 (Lehtonen 2001, 2004). The underlying hypothesis in the model is profit maximising behaviour of producers and utility maximising behaviour of consumers under competitive markets. According to microeconomic theory, this leads to welfare maximising behaviour of the agricultural sector. Decreasing marginal utility of consumers and increasing marginal cost per unit produced in terms of quantity lead to equilibrium market prices which are equal to marginal cost of production on competitive markets. Each region specialises to products and production lines of most relative profitability, taking into account profitability of production in other regions and consumer demand. This means that total use of different production resources, including farmland, on different regions are utilised optimally in order to maximise sectoral welfare, taking into account differences in resource quality, technology, costs of production inputs and transportation costs (spatial price equilibrium; Takayama and Judge 1971, Hazell & Norton 1986).

The model consists of two main parts: (1) a technology diffusion model which determines sector level investments in different production technologies; and (2) an optimization routine simulates annual price changes (supply and demand reactions) by maximizing producer and consumer surplus subject to regional product balance and resource (land and capital) constraints (Fig. 1). The major driving force in the long-term is the module of technology diffusion. However, if large changes take place in production, price changes, as simulated by the optimization model, are also important to be considered. The investment model and resulting production capacity changes is however closely linked to market model determining production (including land use, fertilisation, feeding of animals, and yield of dairy cows, for example), consumption and domestic prices. Our market model is a typical spatial price equilibrium model (see e.g. Cox and Chavas 2001), except that no explicit supply functions are specified, i.e. supply is a primal specification).

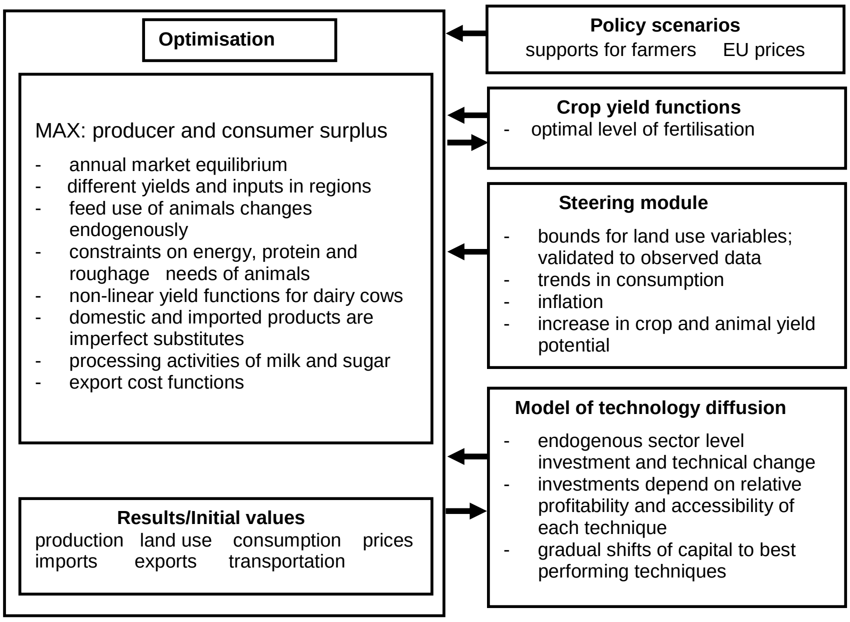

Fig. 1. Basic structure of DREMFIA sector model

Contrary to comparative static models, often used in agricultural policy analysis, current production is not assumed to represent an economic equilibrium in the DREMFIA model. The endogenous investments and technical change, as well as the recursive structure of DREMFIA model implies that incentives for changes in production affect production gradually in subsequent years, i.e. all changes do not take place instantaneously. The current situation in agricultural production and markets may include incentives for changes but these changes cannot be done immediately due to fixed production factors and animal biology. Hence, the continuation of current policy may also result in changes in production and income of farmers. However, the production in DREMFIA model will gradually reach a long-term equilibrium or steady state if no further policy changes take place.

Four main areas are included in the model: Southern Finland, Central Finland, Ostrobothnia (the western part of Finland), and Northern Finland. Production in these is further divided into sub-regions on the basis of the support areas. In total, there are 18 different production regions (Fig. 2). This allows a regionally disaggregated description of policy measures and production technology. The final and intermediate products move between the main areas at certain transportation cost. Hence, the model provides a complete coverage of land use and animal production, which compete on production resources.

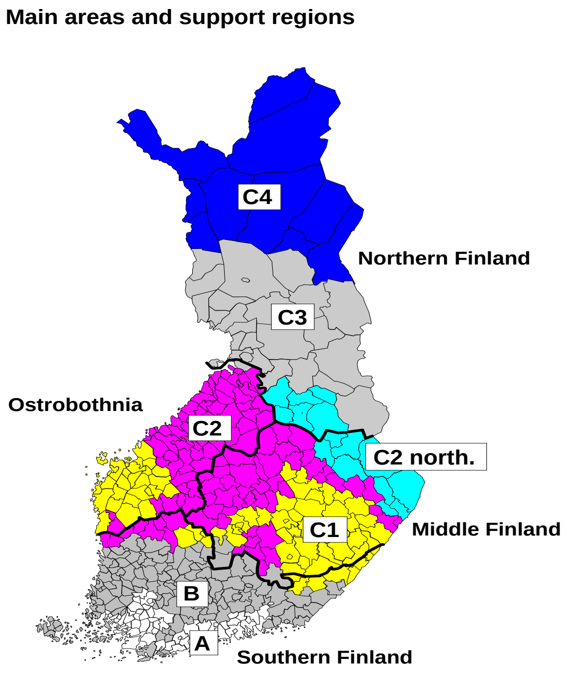

Fig. 2. Regional disaggregation of the DREMFIA sector model. There are 4 main regions split up by subsidy zones (A, B, C2-C4) and 3 small river catchments (not shown here).

2.2. Technology diffusion, investments and technical change

The purpose of the technology diffusion sub-model is to make the process of technical change endogenous. This means that investment in efficient technology is dependent on the economic conditions of agriculture such as interest rates, prices, support, production quotas and other policy measures and regulations imposed on farmers. Changing agricultural policy affects farmers' revenues and the money available for investment. Investment is also affected by public investment supports. The model for technology diffusion and technical change presented below follows the main lines of Soete & Turner (1984). The choice of this particular diffusion scheme is further motivated in Lehtonen (2001, 2004). While the set-up of Dremfia model is rather neo-classical (competitive markets simulated by maximisation of consumer and producer surplus), the model of technology diffusion allows at least temporary movements out of equilibrium path and can be therefore considered close to the core of evolutionary economics paradigm (Nelson & Winter 2002).

Let us assume that there is a large number of farm firms producing a homogenous good. Different technologies with different production costs are used and firms can be grouped on the basis of their technology. The number of technologies is *N*. Each technology uses two groups of factors of production, variable factors, such as labour (L), and fixed factors, such as capital (K). Variable factors of production may also include land rent, particularly if agricultural land can be rented on a short-term basis, or opportunity cost of land, so that crucial issue of competition for land can be included in the analysis. A particular production technique is labelled α. The rate of return on capital for firms using the α technique, under assumption of fixed exogenous input prices (w), is

$$r_\alpha = \frac{Q_\alpha - wL_\alpha}{K_\alpha}. \qquad (1)$$

The surplus available for investment—Q_α - wL_α (Q_α is the total revenue on the α technique)—is divided between all firms using the α technique. $f_{\beta\alpha}$ is the fraction of investable surplus transferred from α technique to β technique. This transfer will take place only if the rate of return on the β technique is greater than the rate of return on the α technique, *i.e.* $r_\beta > r_\alpha$. The total investable surplus leaving α technique for all other more profitable techniques is

$$\sum_{\beta : r_\beta > r_\alpha} f_{\beta\alpha} \, \sigma r_\alpha K_\alpha , \qquad (2)$$

where $\sigma < 1$ is the savings ratio (constant). To make the model soluble, a form of $f_{\beta\alpha}$ has to be specified. Two crucial aspects about diffusion and adaptation behaviour are included: first, the importance of the profitability of the new technique, and secondly, the risk, uncertainty and other frictions involved in adopting a new technique. The information about and likelihood of adoption of a new technique will grow as its use becomes more widespread with a growth in cumulated knowledge of farmers.

To cover the first point, $f_{\beta\alpha}$ is made proportional to the fractional rate of profit increase in moving from technique α to technique β, *i.e.* $f_{\beta\alpha}$ is proportional to $(r_\beta - r_\alpha)/ r_\alpha$. The second point is modelled by letting $f_{\beta\alpha}$ be proportional to the ratio of the capital stock in the β

technique to the total capital stock (in a certain agricultural production line), *i.e.* K_β/K. If β is a new innovation then K_β/K is likely to be small and hence $f_{\beta\alpha}$ is small. Consequently, the fraction of investable surplus transferred from α to β will be small. Combining these two assumptions, $f_{\beta\alpha}$ can be written as

$$f_{\beta\alpha} = \eta' \frac{K_\beta}{K} \frac{(r_\beta - r_\alpha)}{r_\alpha}, \qquad (3)$$

where η' is a constant. A similar expression can be written for $f_{\alpha\beta}$. The total investment to α technique, after some simplification, is

$$I_\alpha = \sigma r_\alpha K_\alpha + \eta(r_\alpha - r)K_\alpha = \sigma(Q_\alpha - wL_\alpha) + \eta(r_\alpha - r)K_\alpha \qquad (4)$$

where r is the average rate of return on all techniques. The interpretation of this investment function is as follows. If η were zero then (4) would show that the investment in the α technique would come entirely from the investable surplus generated by the α technique. For $\eta \neq 0$ the investment in the α technique will be greater or less than the first term, depending on whether the rate of return on the α technique is greater than r. This seems reasonable. If a technique is highly profitable, then it will tend to attract investment and conversely if it is relatively less profitable, investment will decline.

Assuming depreciations, the rate of change in capital invested in α technique is

$$\frac{dK_\alpha}{dt} = [\sigma r_\alpha + \eta(r_\alpha - r) - \delta_\alpha]K_\alpha, \qquad (5)$$

where δ_α is the depreciation rate of α technique. If there is no investment in α technique during some time period, the capital stock K_α decreases at the depreciation rate. To summarise, the investment function (4) is an attempt to model the behaviour of farmers whose motivation to invest is greater profitability but nevertheless will not adopt the most profitable technique immediately, because of uncertainty and various other retardation factors. Total investment is distributed among the different techniques according to their profitability and accessibility. The most efficient and profitable technique, which requires a large scale of production, is not equally accessible for all farmers and, thus, farmers will also invest in other techniques which are more profitable than the current technique. When some new and profitable technique becomes widespread, more information is available about the technique and its characteristics, and farmers invest in that technique at an increasing rate.

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). Let us briefly show the calibration of the diffusion model to the official statistics of farm size structure. Parameter σ has been fixed to 1.07 which means that an initial value 0.85 (*i.e.* farmers re-invest 85% of the economic surplus on fixed factors back into agriculture) has been scaled up by 26% which is the average rate of investment support for dairy farms in Finland. The η (fixed to 0.77) is then used as a calibration parameter which results in investments which facilitate the ex-post development of dairy farm structure and milk production volume. The chosen combination of the parameters σ and η (1.07:0.77) is unique because it calibrates the farm size distribution to the observed farm size structure (a new combination is chosen each year when new information on farm size structure has been obtained). Choosing larger σ and smaller η exaggerates the investments on small farms, and choosing smaller σ and larger η exaggerates the investments on large farms. Choosing smaller values for both σ and η result in too low investment and production levels, and choosing larger values for both σ and η results in overestimated investment and production levels, compared to the ex post period.

The investment function (1) shows that the investment level is strongly dependent on capital already invested in each technique. This assumption is consistent with the conclusions of Rantamäki-Lahtinen *et al.* (2002) and Heikkilä *et al.* (2004), *i.e.*, farm investments are strongly correlated with earlier investments, but poorly correlated with many other factors, such as liquidity or financial costs. Other common features, except for the level of previous investments of investing farms, were hard to find. Hence, the assumption made on cumulative gains from earlier investments seems to be supported by empirical findings.

2.3 Recursive programming model

The optimization routine is a spatial price equilibrium model which provides annual supply and demand pattern, as well as endogenous product prices, using the outcome of the previous year as the initial value. Production capacity (number of animal places available, for example), which is an upper boundary for each production activity (number of animals) in each region, depends on the investment determined at a sub-model of technology diffusion.

Feeding if animals is endogenous in the model, which means that animals may be fed using an infinite number of different (feasible) feed stuff combinations. This results in non-linearities in balance equations of feed stuffs since the number of animals and the use of feed are both decision variables. There are equations ensuring required energy, protein and roughage needs of animals, and those needs can be fulfilled in different ways. The use of concentrates and various grain-based feed stuffs in dairy feeding, however, is allowed to change only 5–10 % annually due to biological constraints and fixed production factors in feeding systems. Concentrates and grain based feed stuffs became relatively cheaper than silage feed in 1995 because of decreased grain prices and CAP payments for grain. The share of concentrates and grain has increased, and the share of roughage, such as silage, pasture grass and hay, has gradually decreased in the feeding of dairy cows. There has also been substitution between grain and concentrates (in the group of non-roughage feeds), and between hay, silage and pasture grass (in the group of roughage feeds). The actual annual changes in the use of different feed stuffs have been between 5–10%, on the average, but the overall substitution between roughage and other feed stuffs has been slow: the share of concentrates and grain-based feed stuffs in the feeding of dairy cows has increased by 1% annually since 1994.

Feeding affects the milk yield of dairy cows in the model. A quadratic function is used to determine the increase in milk yield as more grain is used in feeding. Genetic milk yield potential increases exogenously 110–130 kilos per annum per cow (depending on the region). Fertilization and crop yield levels depend on crop and fertilizer prices via empirically validated crop yield functions.

There are 18 different processed milk products, many of which are low fat variants of the same product, in the model as well as the corresponding regional processing activities. There are explicit skim milk and milk fat balance equations in the model. In the processing of 18 milk products, fixed margins representing the processing costs are used between the raw material and the final product. This means that processing costs are different for each milk product, and they remain constant over time in spite of gradually increasing inflation. In other words, it is assumed that Finnish dairy companies constantly improve their cost efficiency by developing their production organisation, by making structural arrangements (shutting down small scale processing plants) and substituting capital for labour (enlarging the processing plants), for example. Such development has indeed taken place in Finland in recent years.

All foreign trade flows are assumed to be to and from the EU. It is assumed that Finland cannot influence the EU price level. Armington assumption is used (Armington 1969). The demand functions of the domestic and imported products influence each other through elasticity of substitution. Since EU prices are given the export prices are assumed to change only because of frictions in the marketing and delivery systems. In reality, exports cannot grow too rapidly in the short run without considerable marketing and other costs. Hence, the transportation costs of exports increase (decrease) from a fixed base level if the exports increase (decrease) from the previous year. The coefficients of the linear export cost functions have been adjusted to smooth down the simulated annual changes in exports to the observed average changes in 1995–2004. In the long-term analysis the export costs play little role, however, since they change only on the basis of the last year's exports. Hence the exports prices, (the fixed EU prices minus the export costs), change only temporarily from fixed EU prices if exports change. This means that Finland cannot actually affect EU price level. In fact the export specification is asymmetric to the specification of import demand. Export prices may be only slightly and temporarily different from EU average prices while the difference between domestic and EU prices may be even significant and persistent, depending on the consumer preferences (Jalonoja and Pietola 2004).

However the export price changes due to changing export volume are relatively small and temporary compared to changes in domestic prices which are dependent on consumer preferences. In terms of maximizing consumer and producer surplus, this means that exports may fluctuate a lot and cause temporary and relatively small changes in export prices (through export costs), while the difference between domestic and average EU prices may be more or less persistent, depending on the consumer preferences. Hence, in addition to the import specification, the export specification explains why the domestic prices of milk products, as well as the producer prices of milk, remain at a higher level than the EU average prices even if Finland is clearly a net exporter of dairy products.

2.4. Links between technology diffusion and land use competition

Let us briefly discuss the role of land competition here since agricultural land is almost always required if livestock investments are to be made. Already nitrate directive of the European Union restricts the amount of nitrogen fertilisation to the maximum value of 170 kg N/ha per year. Environmental permits, required for large scale livestock production units, may pose more stringent conditions for a farm, implying more land area for manure spreading. Agri-environmental subsidy scheme in Finland poses significantly stricter requirements for manure spreading since not only nitrogen fertilisation level but also phosphorous fertilisation is given upper limits, as a condition for agri-enviromental subsidies. This phosphorous fertilisation limit is particularly compelling for pig and poultry farms since the phosphorous content of manure of pigs and poultry animals is significantly higher than that of bovine animals.

The price of land, affected by all production activities regionally, is provided as shadow values of the regional land resource constraint. When shadow price of regional land resource constraint is fed as an input price to the technology diffusion model, profitability of livestock investments decrease in those regions where land price (endogenous to the programming model) is high, while livestock investments become relatively more profitable in regions where land prices are low. Implementing a link between land prices between technology diffusion model and programming model however provides one more possibility to validate the simulated development path of regional animal production and land use to the observed ex-post development. Furthermore, regional feed use of animals, also endogenous in the programming model affects the phosphorous content in manure and hence land area required by animal production. Feeding may serve as a substitute, in a limited extend, to land area required for feed and manure spreading.

2.5. Trade of milk quotas

Milk quotas are traded within three separate areas in Finland. Within each quota trade area the sum of bought quotas must equal to the sum of sold quotas. In the model the support regions A, B and BS is one trade area (Southern Finland), support region C1 and C2 another trade area (Middle Finland – consisting of both Central Finland and Ostrobothnia regions in the model), and support areas C2P, C3 and C4 constitute a third region (Northern Finland). The price of the quota in each region is determined by the shadow value of an explicit quota trading balance constraint (purchased quotas must equal to sold quotas within the quota trading areas consisting of several production regions in the model, defined separately for each quota trading area. A depreciation period of five years is assumed, i.e. the uncertainty of the future economic conditions and the future of the quota system rule out high prices. Additional quotas and final phase-out of the EU milk quota system can be taken into account in a straightforward manner.

3. Land resource requirements to be analysed

For simplicity, the following 3 land resource requirement options described below are imposed only for dairy cows, not for pigs or poultry even if environmental regulations affect pork and poultry production even more than dairy or beef production. The reason for this choice in this illustrative model application example is that only dairy and beef are produced throughout the country in Finland, while pig and poultry production are concentrated on certain parts in southern and western Finland. However, the land demand of different agricultural production lines are indirectly taken into account in the sector model, which means that land demand is initially higher in southern and western (Ostrobothnia) Finland than in central and northern Finland (Fig. 2) with little pig and poultry production or specialised crop production.

In baseline it is simply assumed that *one dairy cow requires one hectare of farmland* because of existing specific regulations of environmental support programme. The specific regulations impose upper limits for nitrogen fertilisation (including both chemical and manure fertilisation) and require the phosphorous stock of soil to be non-increasing, e.g. in practice the annual phosphorous fertilisation is restricted to 20 kg P /ha. These conditions imply that a farmer should have 1 ha per dairycow for manure spreading, which is restricted by the phosphorous content of the manure. This means that a dairy farmer is also obliged to purchase chemical nitrogen fertiliser in order to reach high and of good quality grass silage yields (important for milk quality and farm economy), simultaneously when additional land has to be rented or contracted for manure spreading due to the phosphorous fertilisation limit.

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. This can be achieved within the phosphorous fertilisation limits if 50% of the phosphorous can be fractioned out from the manure. This may also mean that the nitrogen content of the manure can be utilised more efficiently and at least some part of the purchased nitrogen fertiliser can be avoided on a dairy farm. However we do not go to the details of thse cost savings here but merely assume that 0.5 ha of farmland is required per one dairycow when building new livestock facilities, with no additional building costs (analysed in later phases of the research project). However it is important to note here that the partial relaxation of the existing rather strict regulations do not affect all existing capacity but applies only to all new cattle house investments.

In scenario *"Liberal manure policy" (or highly efficient manure utilisation technology) (LM100)* it is assumed that no farmland is required per dairycow when investing in new cattle houses. Also in this scenario the relaxation of the existing rather strict regulations do not affect all existing capacity but applies to all new cattle house investments from 1995, i.e. in the beginning of the simulation period.

4. Results

4.1. Impacts on regional dairy investments and capital

Let us first discuss the impact of relaxed land requirements on farm size structure at the whole country level. A quick look on the relative shares of capital in different farm size categories (Figs. 3-5) would suggest that relaxed land requirements assumed in scenarios LM50 and LM100 do not have, on the aggregate, any significant impact on the structural change in the dairy sector. However, this counterintuitive result hides the regional results and is mostly affected by the equilibrium properties of the DREMFIA model. In other words, land requirements per dairy cow have relatively little impact on aggregate production (see Fig. 8 below) because of relatively inelastic domestic demand and relatively less profitable dairy exports due to export costs. Hence decreasing milk prices due to increasing output would make increasing farm size and production not attractive in all regions. The regional results (Figs. 5-7), however, provide a more detailed view.

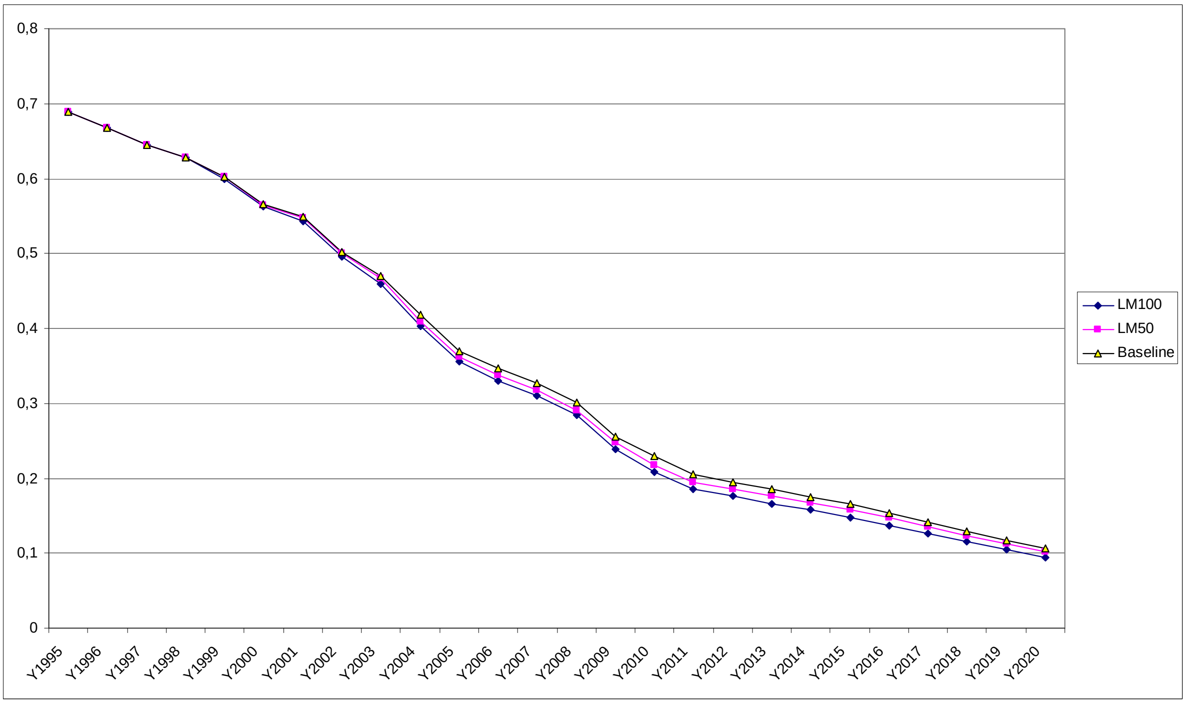

Figure 3. Share of capital on small dairy farms (1-19 cows) at the whole country level.

Figure 4. Share of capital on medium sized dairy farms (20-49 cows) at the whole country level.

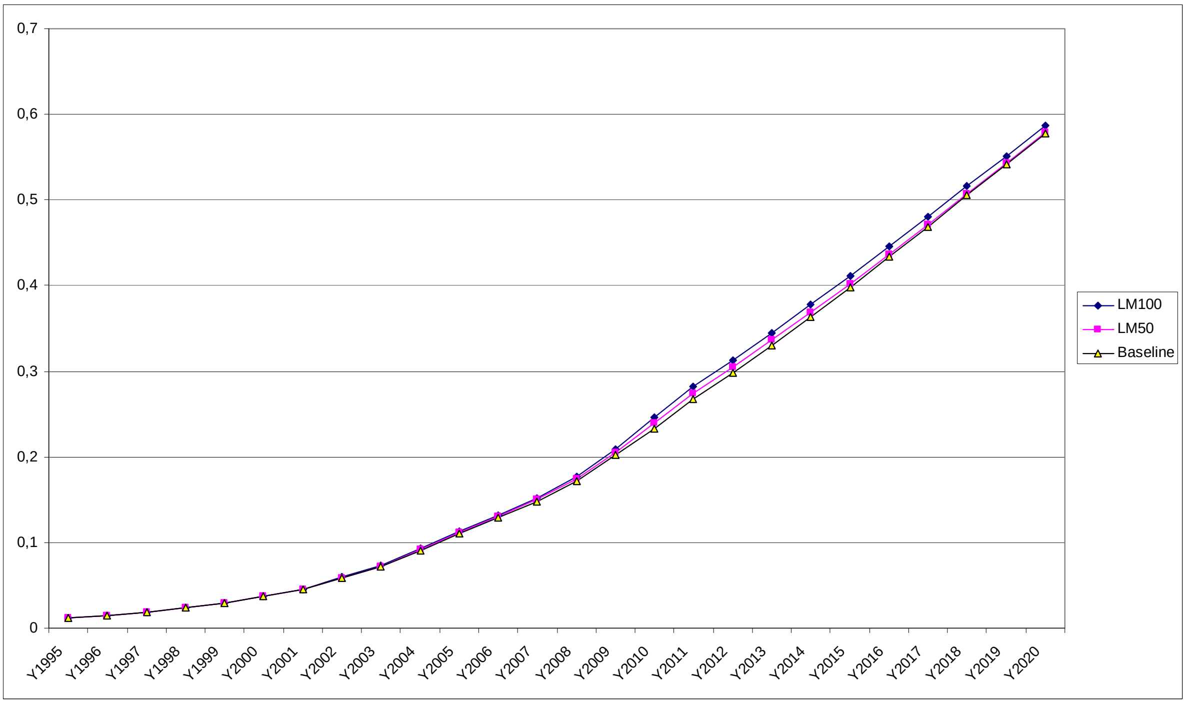

Figure 5. Share of capital on large dairy farms (>50 cows) at the whole country level.

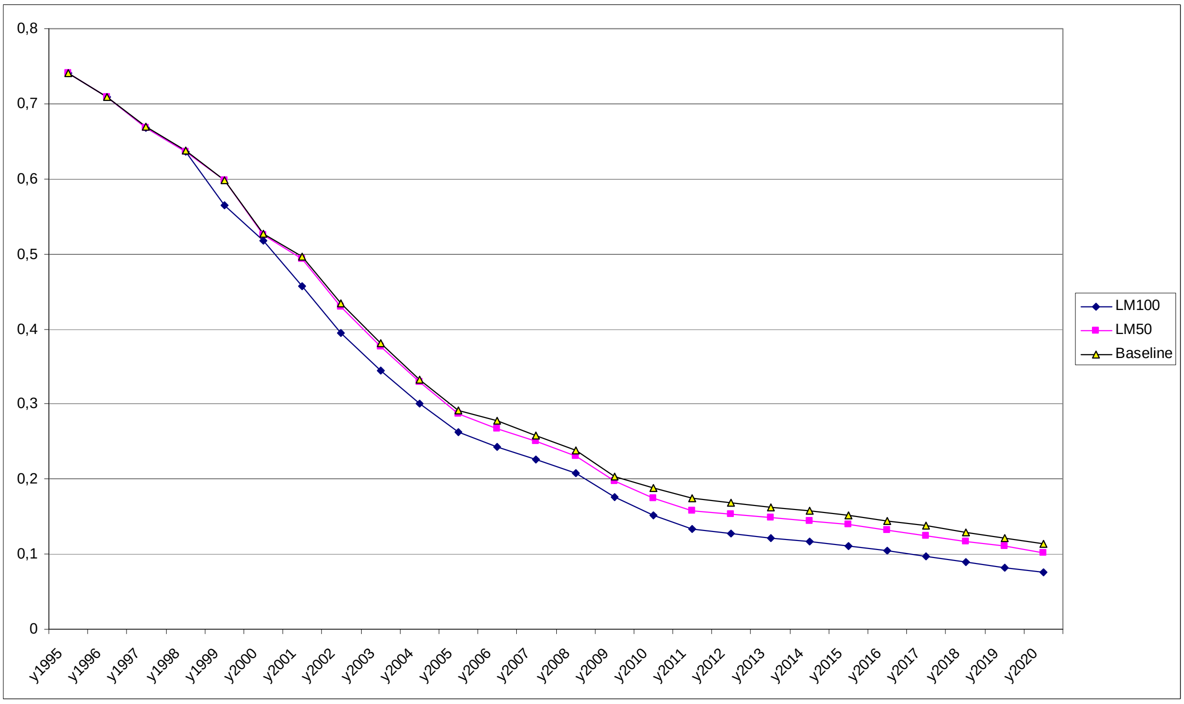

Figure 6. Share of capital on small dairy farms (1-19 cows) in northern Finland.

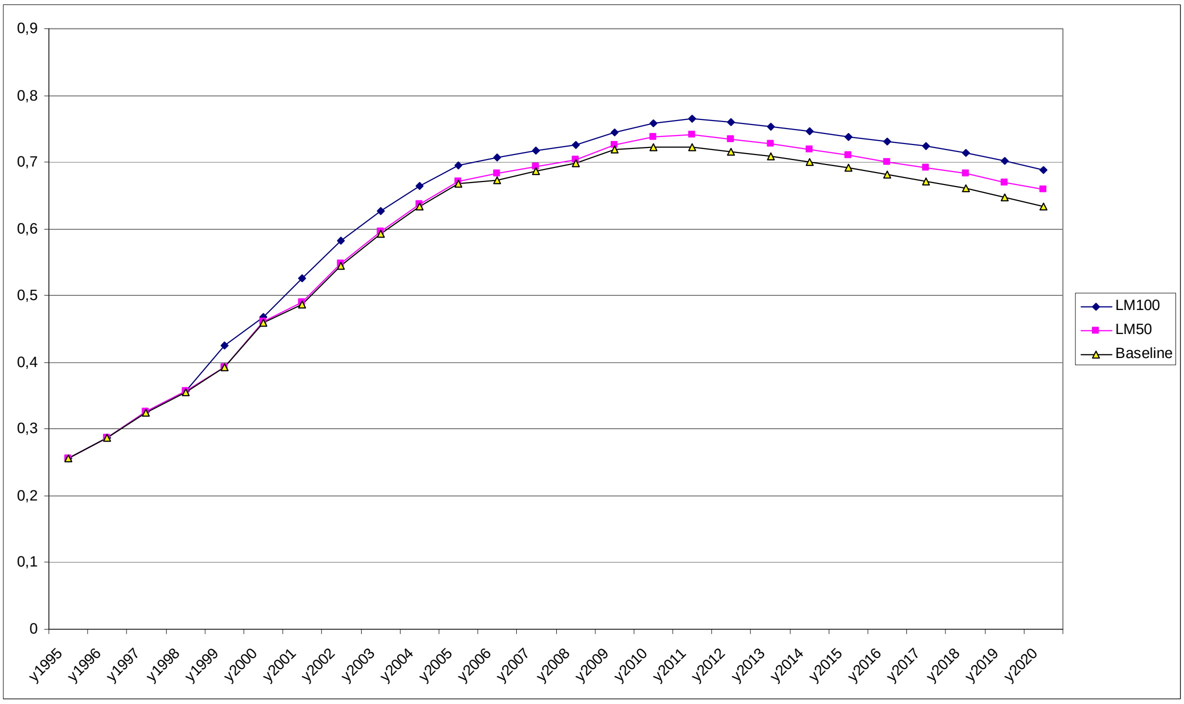

Figure 7. Share of capital on medium sized dairy farms (20-49 cows) in northern Finland.

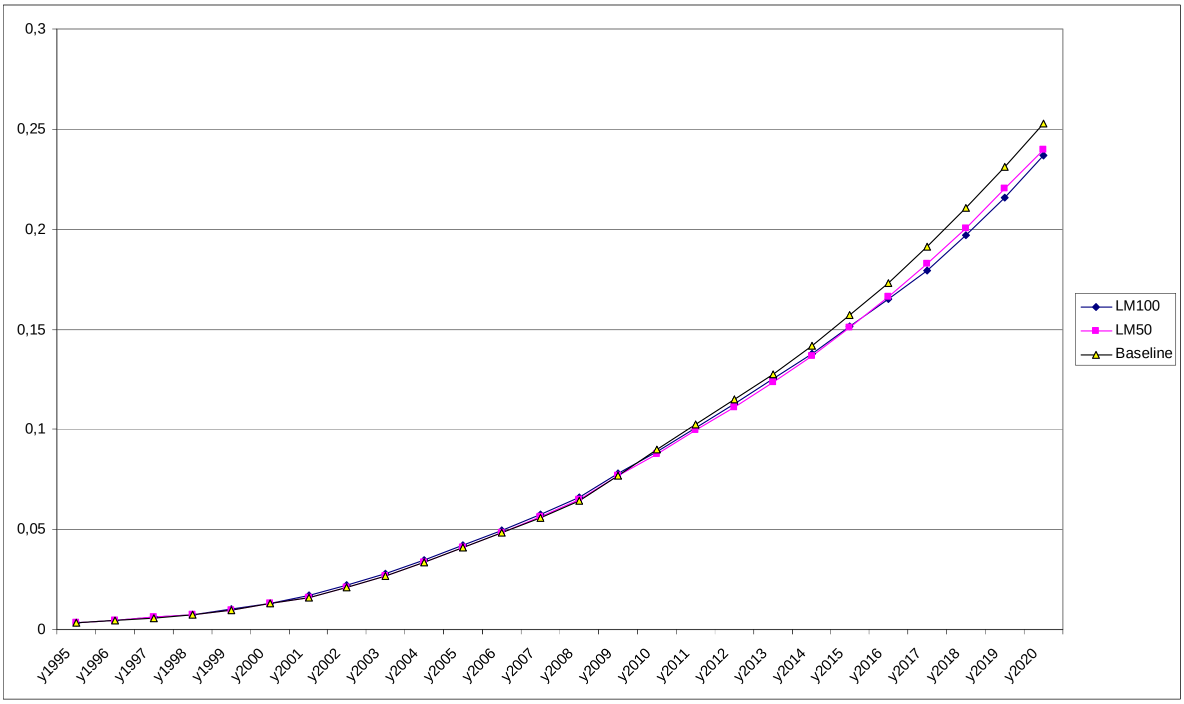

Figure 8. Share of capital on large dairy farms (>50 cows) in northern Finland..

Figures 3-5 would suggest rather steady and constantly increasing share of large farms of total capital and production, and that would justify a view that land requirements play little role in the structural change in dairy sector, on the aggregate. That would mean that land scarcity, or existing compelling environmental regulations, were not really a problem for dairy sector development. While this may hold in areas where land is not scarce, the model results depicted in figures 6-8 show that in northern Finland, where national subsidies per litre of milk are the highest and land is scarce due to topography and soil types, a relaxation of the land requirements would significantly promote structural change in the dairy sector up to 2020. Especially one should note that small dairy farms, producing little investable surplus due to low productivity, have long dominated the milk output in northern Finland. It is also unlikely that small farms can immediately invest and enlarge their size up to 50 cows (according to the parameters of the technology diffusion model calibrated using official farm structure statistics). Hence an increasing share of capital is necessary on medium sized farms before the capital investments in large farms can substantially increase. Since feed crop yields are low in northern Finland, land scarcity is already inhibiting farm size growth, and any relaxation of the stringent environmental land requirements for dairy investments are likely to be a hindrance for structural development in the long run. Hence technological innovations improving the utilisation of manure nutrients, possibly through fractioning out phosphorous from manure could most likely promote structural development and provide economic benefits for farmers in the north. The same kind of reasoning and results (not shown here for brevity) are valid in Ostrobothnia (western Finland) region where, unlike in northern Finland, production has gradually increased due to milk quota trade.

4.2. Impacts on regional milk production volumes

Equilibrium reasoning, i.e. decreasing marginal consumer utility and producer profits with increasing production volume, in other words inelastic domestic demand and relatively high export costs, would suggest that land requirements have relatively little impact on the aggregate milk production in Finland (Fig. 9.). Rather the result show a temporary decline in production due to decreasing real prices of dairy products in the EU due to milk quota expansion and later full elimination (real prices of milk assumed to decrease by 15% at the EU while Armington assumption would imply a slightly higher producer prices in Finland (Lehtonen (ed.) 2007)). At the whole, land scarcity due to environmental reasons would not seem to play any big role.

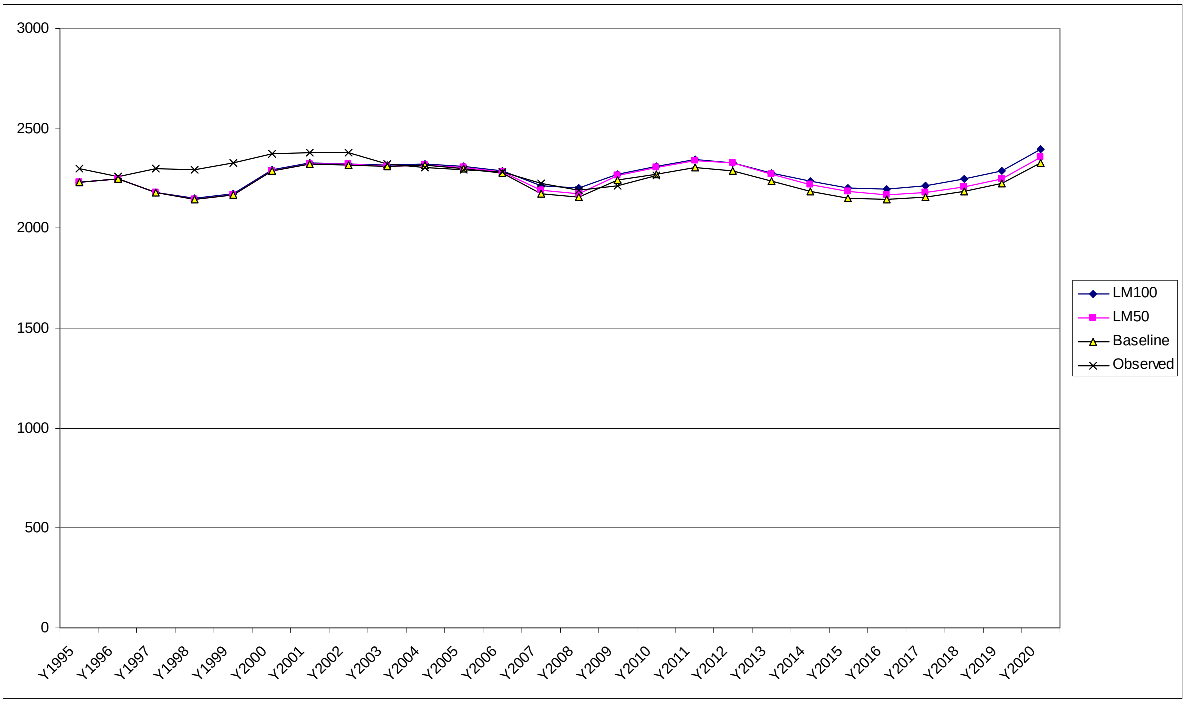

Figure 9. Milk production volume (million litres) in Finland.

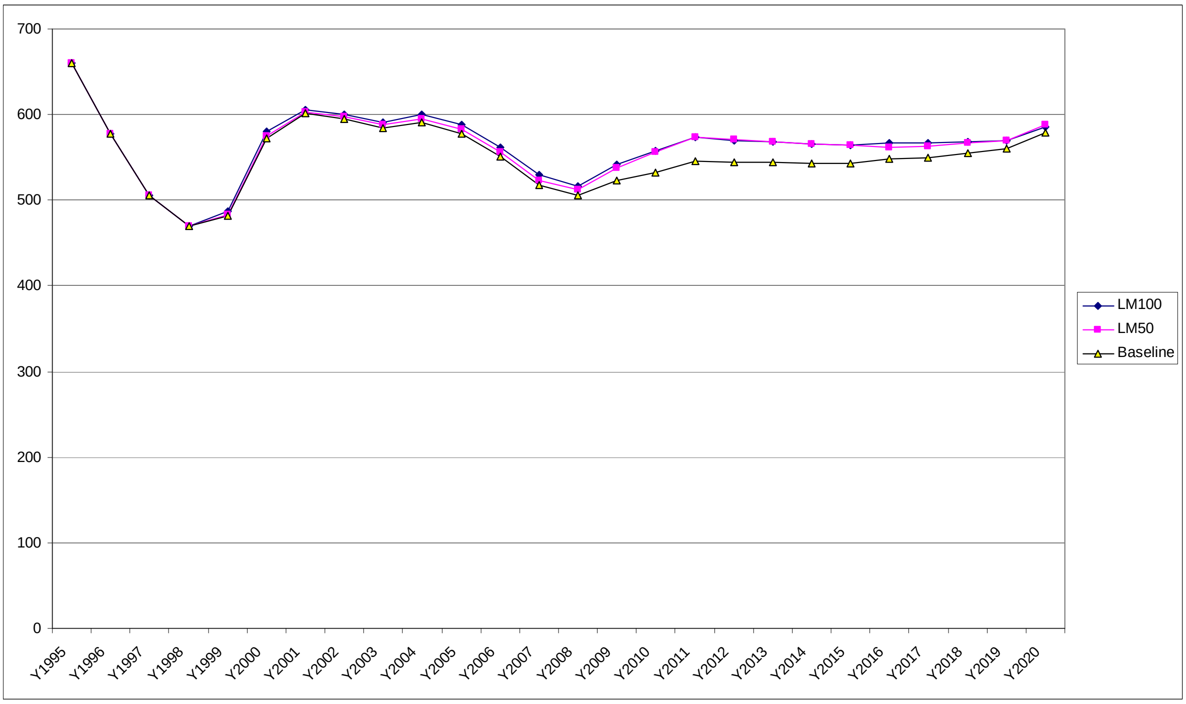

Figure 10. Milk production volume (million litres) in southern Finland.

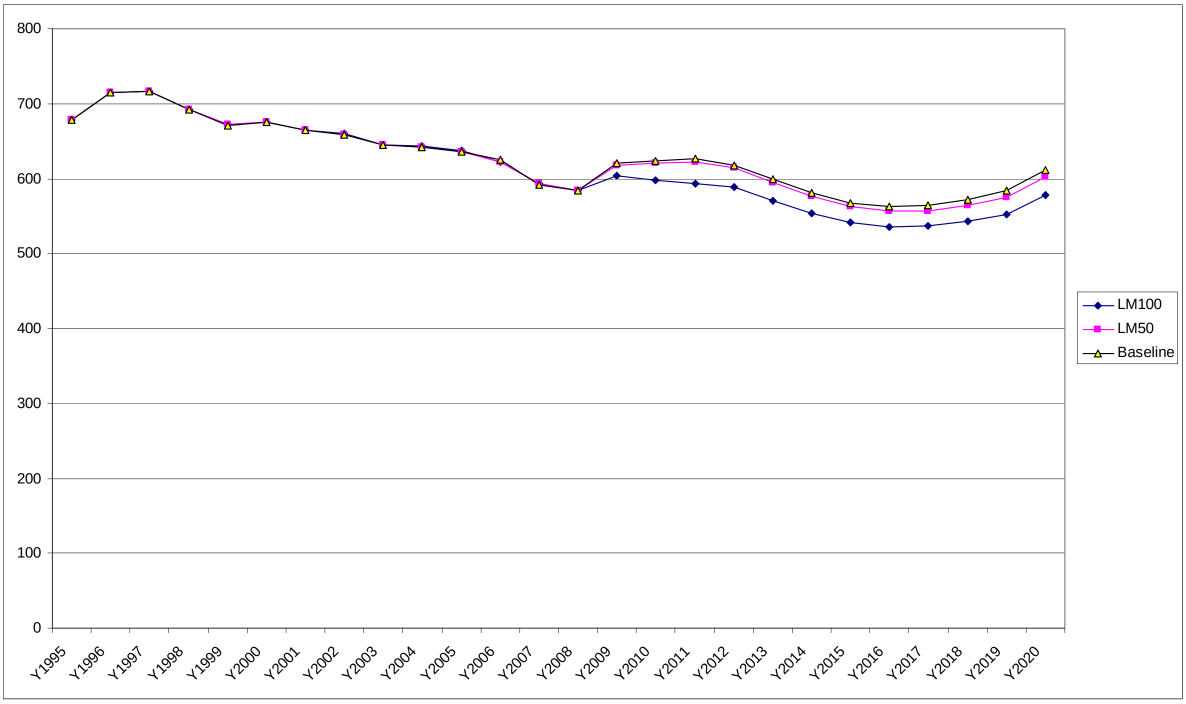

Figure 11. Milk production volume (million litres) in central Finland.

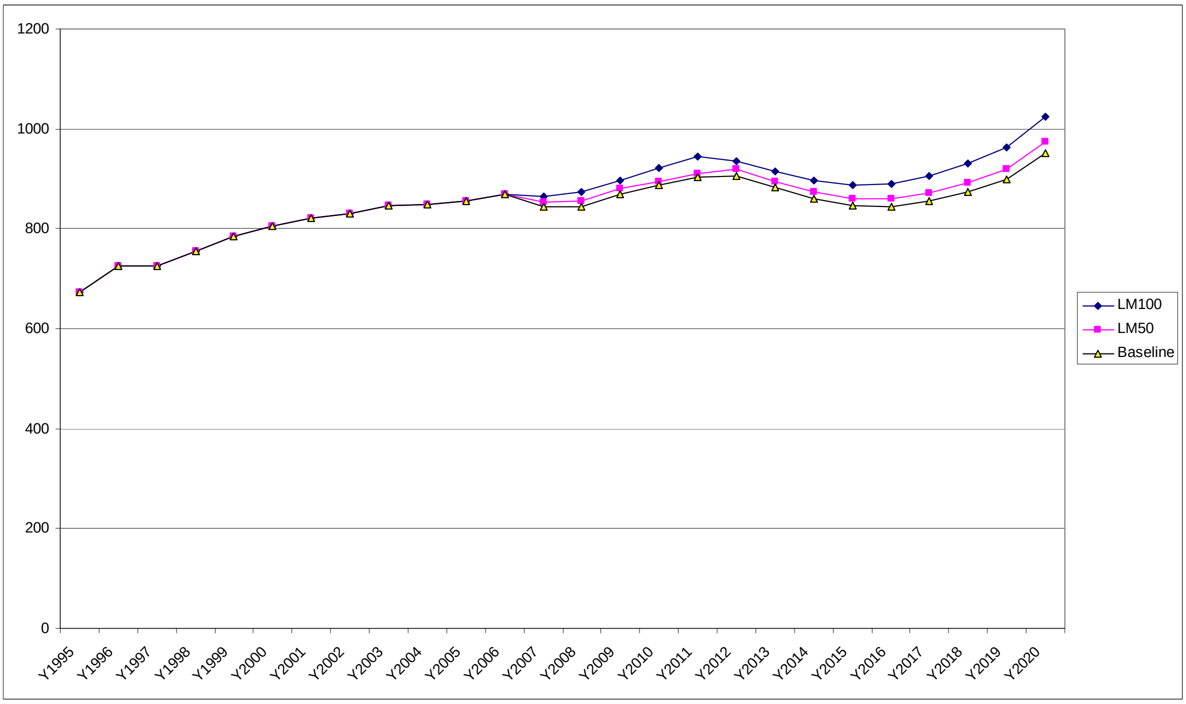

Figure 12. Milk production volume (million litres) in Ostrobothnia (upper western) Finland.

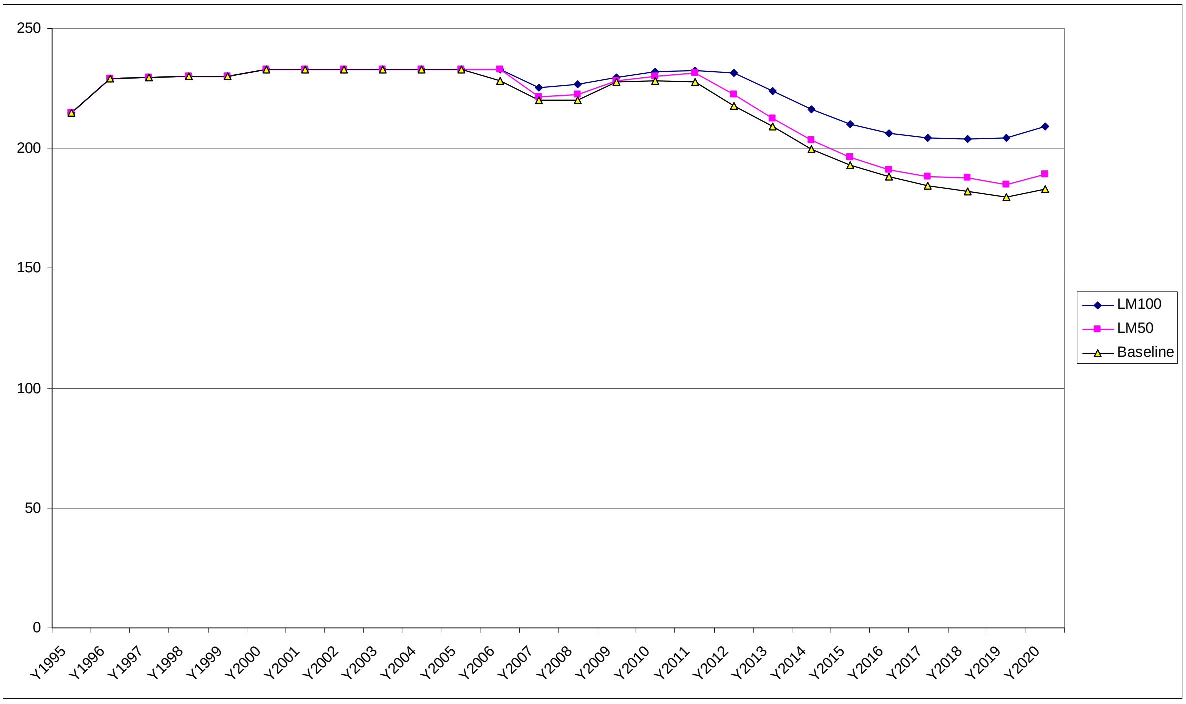

Figure 13. Milk production volume (million litres) in northern Finland.

However the regional milk production development depicted in Figures 10-13 shows that relaxation of land requirements (possibly due to technological innovations providing solutions for the phosphorous accumulation in agricultural soils) would clearly lead to higher production of milk in Ostrobothnia region and northern Finland (increasing comparative advantage) compared to the baseline, while production in sourthern Finland would increase only slightly (due to land competition witk pork, poultry and specialised crop production), and to a decreasing production central Finland, compared to baseline. Hence regions with lower than average animal densities would loose some of their earlier comparative advantage.

4.3. Impacts on regional farmland prices

First it should be recognised that the land price, taken as an annual shadow value of the land resource constraints, shows only the agricultural value of land, not the actual value of land comprising from a set of different values (Pyykkönen 2006). Second, the land price, i.e. the value of an additional unit of the regional land resource in the optimisation model, must be considered a rather volatile marginal indicator of the profitability of agriculture and farmland scarcity (high farmland prices) or abundance (zero or low marginal values of land) in general in the region. Hence the existing production and land use structure in the region affects the changes in farmland value, affected by the technological options described above. In regions with abundance of farmland any relaxation of the land resource required per a dairy cow is likely to decrease land prices even further if land requirements per dairy cow are to be relaxed.

Land prices seem to be largely unaffected by the land requirement alternatives, described in ch. 3, up to year 2010. However the relaxation of land resource requirement per dairy cow seem to have rather diverse effects on farmland values in different regions after 2010. In southern Finland there are more alternatives for dairy and beef production than in other regions. For this reason the impact of the studied options are relatively small. Nevertheless, the relaxed land requirements for dairy investments drive down the land prices in 2009 – 2016 (less demand for farmland), while relaxed land requirements push up the land prices, i.e. the marginal value of land in the sector model in the longer term due to recovering and slightly expanding dairy production.

In central Finland the land prices seem to be largely unaffected in the long run. In Ostrobothnia region (western Finland) the dairy farm size and production structure is developing most favourably and there increasing dairy production (at the expense of other regions) drive up the land prices (marginal value of land) in the long run. Even if land was not required at all for dairy investments, the (roughage) feed requirement will drive up land prices in the long run.

In northern Finland the significant national subsidies for milk lead to gradually increasing land values already in the baseline, partly due to the fact that technological change and farm size growth with scale economies provide more economic surplus for farmland even if the overall milk production volume in northern Finland were on the decrease. In fact the milk production increases in one dominant sub-region inside northern Finland, and there land scarcity push up land prices, while in other sub-regions milk production decreases as well as land prices. Hence the high land values simulated reflect the land scarcity (due to hardly avoidable feed requirements) in some parts, not everywhere in northern Finland.

However the initial proposition that relaxing land requirements from dairy investments will promote farm size growth and structural change seems to hold in northern Finland. That will also drive up the marginal value of land, since more milk is produced, land is still needed due to feed requirements.

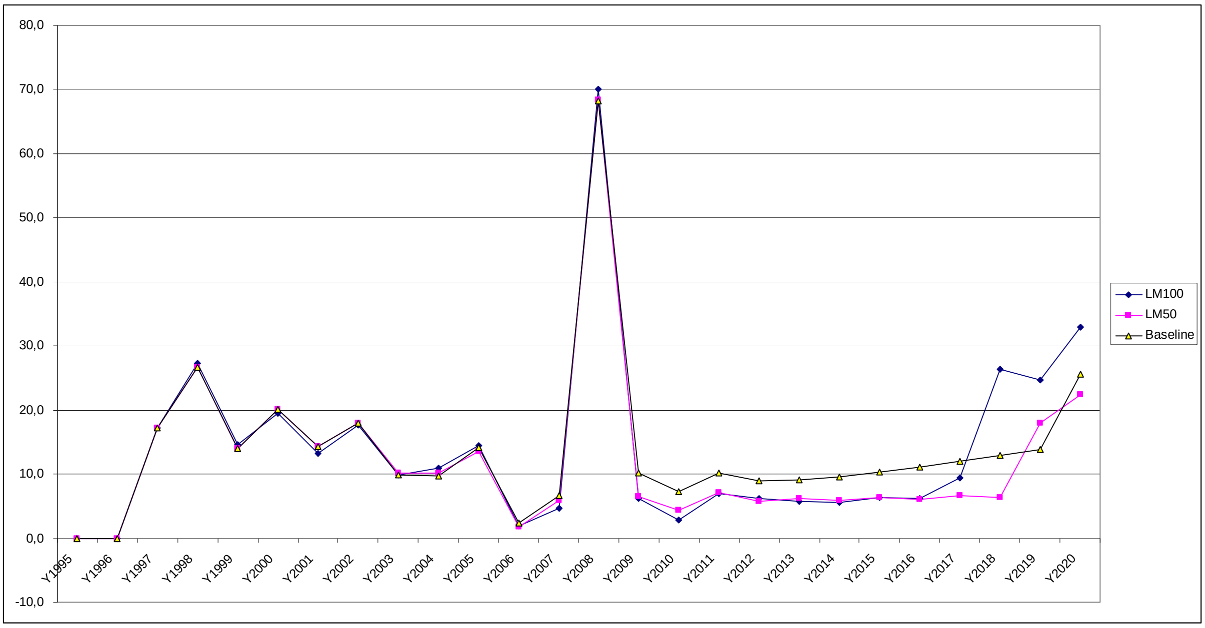

Figure 14. Marginal value of land (shadow price of land resource constraint) in southern Finland.

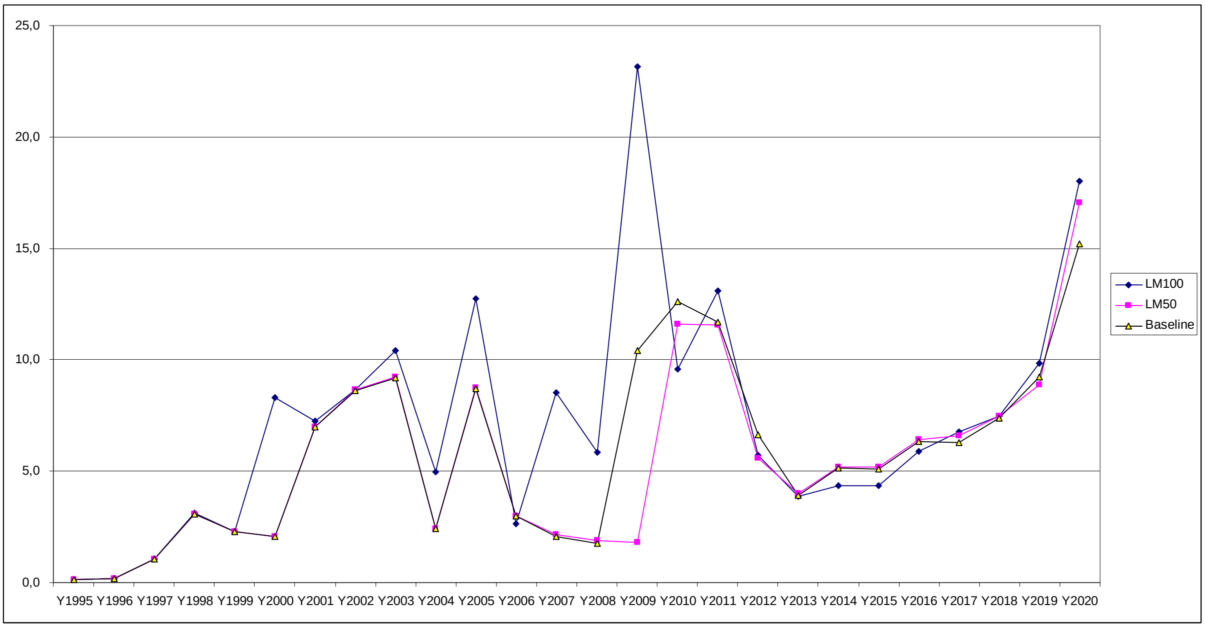

Figure 15. Marginal value of land (shadow price of land resource constraint in eur/ha) in central Finland.

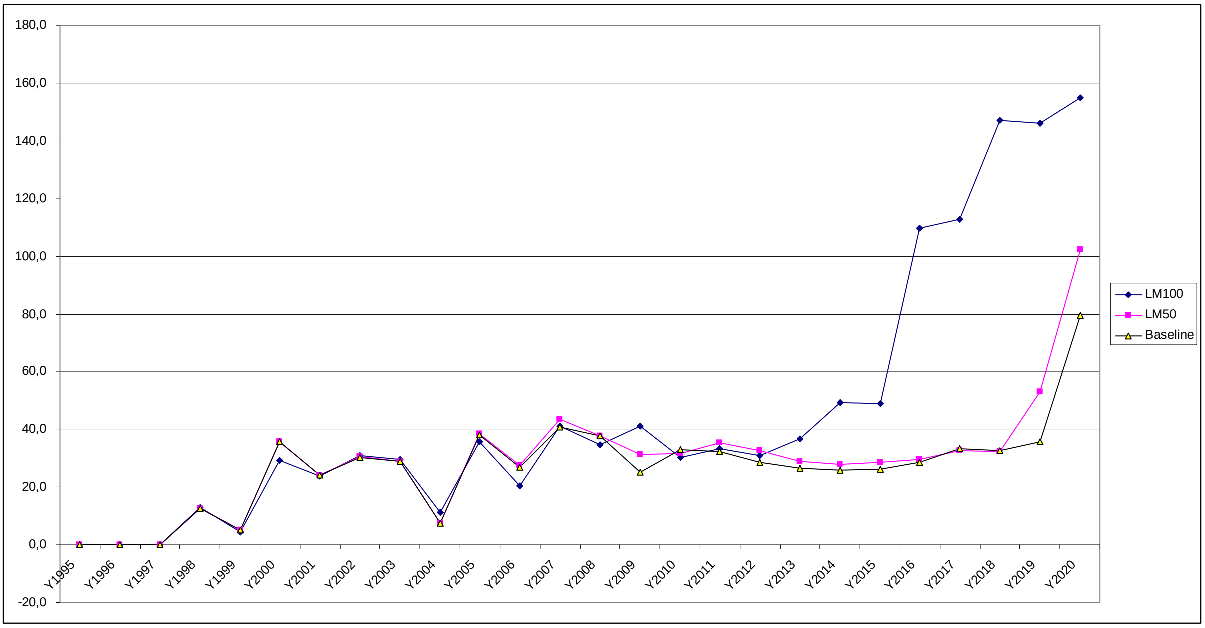

Figure 16. Marginal value of land (shadow price of land resource constraint in eur/ha) in Ostrobothnia (western Finland).

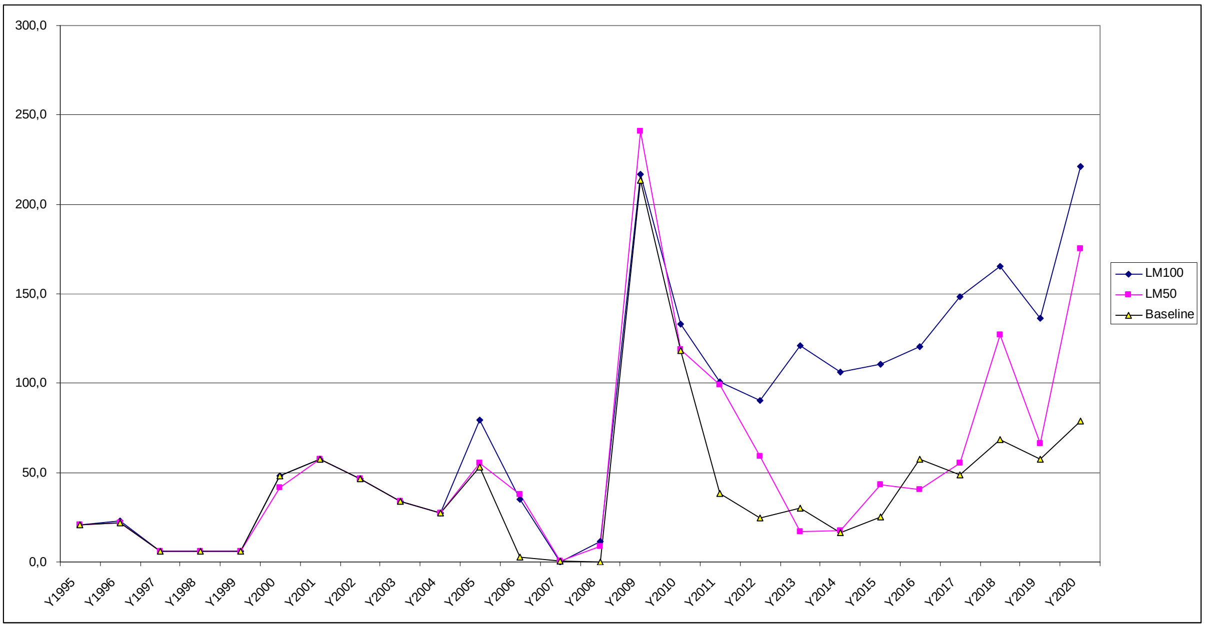

Figure 17. Marginal value of land (shadow price of land resource constraint in eur/ha) in norrthern Finland.

5. Discussion and conclusions

The simulated land values are increasing both ex post and ex ante (considering 2009 situation) in northern Finland and Ostrobothnia region where the actual farmland area has been on the increase. In fact the farmland available in Finland increased by 5% during 1995-2006, and most part of this increase did take place in northern Finland and Ostrobothnia (Regina et. al. 2009) where subsidy entitlements for the new cleared farmland, and various related institutional difficulties, has become a significant political issue. Further clearance of farmland from forest land is expected in intensive livestock production regions, is soil types are favourable close to the enlarging farms. On the other, land demand remains weak in regions where livestock production is decreasing such as many remote and sparsely populated parts of central and also northern Finland where crop production is not that attractive alternative for livestock production as in southern Finland.

It must be recognised that the production development, and hence the development of regional production level and structure as well, is dependent on the exogenous parameters of the DREMFIA model, like the opportunity cost of labour, inflation of input prices, and general interest rate. Since the exogenous variables are the same in all policy scenarios, however, they are not likely to affect the relative changes in production development between the policy scenarios.

It is also worth remembering also here that the technology diffusion sub-model is crucially based on the cumulative gains in the process of gradually increasing farm size at the local level. Small initial farm size, or any significant interruption in the process of farm size growth and improved labour efficiency, may lead to increased regional concentration of production over time. This means that agriculture at weaker agricultural areas is likely to deteriorate, at least if markets become less favourable due to e.g. milk quota abolition, while production at the national level can be considered more competitive if the production is allowed to concentrate on relatively most competitive areas. The multi-regional sector model presented and discussed in this study explains increasing concentration of production in areas such as Ostrobothnia. This development is confirmed by observed patterns of production concentration.

On the other hand the optimisation approach employed in the market model facilitate explicit treatment of physical quantities, description of inputs (kg/ha, animal), and their substitution (such as imperfect substitution between chemical fertiliser and manure used as fertiliser; utilisation for plants). This makes the approach suitable for model integrations and interdisciplinary research. The richness of the optimisation approach also lies in duality, i.e the use of dual variables (shadow prices) of explicit resource constraints and balance equations (interpreted as prices). Hence the approach taken can be made efficient in terms of utilisation of different kind of data used in validation. Land price linkage between technology diffusion model and multi-regional market model also provides one more possibility to validate the simulated development path of regional animal production and land use to the observed ex-post development. However, the observed farmland prices are very different from the simulated farmland prices, since unlike real land prices, the model used in the simulations includes only agricultural value for farmland. Our core result here is that relaxed land requirements for new cattlehouse investments may not decrease, but drive up the marginal value of land in the long-term, since more milk is produced, and land is still needed due to feed requirements. Hence relieved land requirements may decrease regional land prices only temporarily.

In technology diffusion model one may also include new technological alternatives and their locally suitable variations which may provide environmental benefits and change the relative profitability of investments in different production lines and techniques. The coupling of the technology and market model components, including land resource constraints, provides a platform for many interesting analysis. For example, one may consistently analyse impact of certain technologies, such as biogas plants and methods for fractioning phosphorous out of manure, making both nitrogen and phosphorous fractions easier to be used as fertilisers in desired quantities on field plots. Such techniques may change the land use intensity, nutrient flows, and relative profitability of investments in different farm types. In practical terms, the model and its components need to be tuned to the data, and there are many options for that in optimisation approach.

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