Reducing the use of pesticides in Danish agriculture - macro- and sector economic analyses

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Abstract

In this paper a combined system of economic models is used to evaluate different policy scenarios for targeting aquatic quality in terms of reduced pesticide loads. Three types of scenarios are analysed

- *taxes on all pesticides*
- *taxes on herbicides*
- *pesticide-free buffer zones*

The relative cost effectiveness of the considered instruments depends on the aim of the regulation. Thus, pesticide taxes are relatively cost effective regulations, if the aim is to reduce the aggregate agricultural use of pesticides. However, if the aim is to improve the conditions for wildlife habitats etc., pesticide-free buffer zones may be a more cost effective regulation.

In addition to the above measures, increased conversion to organic farming has been evaluated as an instrument to reduce the pesticide loads. Although the latter evaluation is subject to some uncertainty, the cost effectiveness of such an initiative is undoubtedly lower than for the other three types of regulation, no matter if the cost effectiveness is evaluated against the total use of pesticides or the environmental impacts.

Preface

This working paper presents economic analyses of a range of different policy strategies to reduce the pesticide load from Danish agriculture. The range of policy measures includes tax instruments, ban on pesticide use in buffer zones and increased conversion to organic farming, and these instruments are evaluated with respect to their impacts on overall economic welfare, land allocation, pesticide intensity and agricultural production, income and employment.

The analyses have been prepared for the Danish Economic Council as an input to their analysis of various strategies to ensure the Danish water supplies, as presented by the Council in the report Danish Economy – autumn 2004.

The working paper has been prepared by research fellow Lars-Bo Jacobsen, research analyst Martin Andersen and senior research fellow Jørgen Dejgård Jensen, who has also been project leader and responsible for the final editing of the working paper.

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1. Introduction

Concerns about the impact of modern agriculture on the environment have in the past few decades resulted in strict legislation concerning the leaching of nitrogen from Danish farms and their use of pesticides. Observing the policy initiatives taken reveals these concerns[1] and throughout recent years, a number of analyses have been directed towards various aspects of environmental impacts from agriculture and the economic impacts of regulation at the farm and/or sector level, based on qualitative or quantitative economic model frameworks, which have often been more or less closely linked with environmental satellite models. Examples of such research related to nitrogen problems are Walter-Jørgensen (1998), Schou et al. (1996, 2000), Becker & Kleinhanss (1995), Linddal (1998), Vatn et al. (1996), Jacobsen et al. (2004) and Abildtrup et al. (2004), whereas Ørum (1999), Jacobsen (1999), Frandsen & Jacobsen (1999) and Jensen et al. (2002) address the issue of pesticides.

Frandsen and Jacobsen (1999) show that the cost to society of a complete or partial ban on pesticides would account to 0.82 and 0.35 percent of real GDP, respectively[2]. The scenario is calculated using an Agricultural Applied General Equilibrium model (AAGE) of the Danish economy. The advantage of using the AGE approach is that this modelling framework covers the interdependencies between the individual industries, interaction between industries and consumers and between domestic and foreign agents. The model thus covers the whole Danish economy and is characterised by a requirement that there is equilibrium in all markets. The model therefore calculates long run results of a given policy scenario.

Jacobsen et al. (2004) address the relative cost-effectiveness of different instruments to regulate the use of nitrogen and phosphorus in agriculture, including nitrogen surplus taxes, norm-based regulations and various land-based strategies to reduce leaching of nitrogen and phosphorus to the aquatic environments. On the other hand, relatively little research effort has been devoted to the cost-effectiveness of different policy instruments to regulate the use of pesticides, although Jensen et al. (2002) compare the cost-effectiveness of transferable versus non-transferable pesticide quotas.

[1] The Danish Aquatic Programme 1 and 2 implemented in 1987 and 1998 (See Jacobsen 2002). Taxes on pesticides (13-27 percent) were introduced in 1996 and increased by approximately 100 percent in 1998.

[2] This report was prepared for governmental committee commissioned to analyse pesticide use in Denmark. (The Bichel Committee 1999).

The objective of this working paper is to evaluate alternative strategies for reducing the pesticide load from Danish agriculture from a macro- and a sector-economic perspective. Furthermore, the working paper serves as documentation for the economic part of a multidisciplinary evaluation of these strategies, where the impacts of the strategies on economy, biodiversity and groundwater quality are assessed from a cost-benefit perspective coordinated by the Danish Economic Council (Det Økonomiske Råd, 2004).

This paper is organized in 5 sections. Section 2 describes the methodology and data foundation for the applied models in the analysis, including an AGE-model (Applied General Equilibrium) and an agricultural sector model. The scenarios are described in section 3 and the results are presented and analysed in section 4. Finally, section 5 concludes and discusses some perspectives from the results.

2. Methodology

Different strategies for reduction of pesticide use are evaluated economically using a combined set of economic models. The model system comprises

- an applied general equilibrium model for assessment of macro-economic effects and overall impacts on the industry structure due to different pesticide reduction strategies
- an economic agricultural sector model for assessment of agricultural land use, pesticide use and agricultural incomes due to different pesticide reduction strategies

For each type of reduction strategy considered, the two models simulate the impacts of the strategy against a baseline scenario representing a likely projection of the Danish economy and agricultural sector towards 2015-20. The two models run sequentially. Thus, in the first stage, the AGE model is run, determining macroeconomic results and results concerning prices and aggregate levels of agricultural production at a national level. In the second stage, the agricultural sector model is run, conditional on prices and agricultural output levels from the first stage, determining land allocation, pesticide intensity and agricultural income, distributed on different farm types. In the following, the data foundation as well as the two models and their linkage, are described.

2.1. Data

Data foundation for the AGE model

Analysing pesticide regulation in an AGE modelling framework requires a database that explicitly describes the production structures of each agricultural sector as well as the distribution of agricultural products for intermediate and final use, distributed between organic and conventional sectors and commodities.

The Danish Research Institute of Food Economics has produced agricultural specific input-output tables for the Danish economy for many years (Jacobsen, 1996). The process of expanding the original database is illustrated in figure 2.1. Starting from the top, the first two levels illustrate the construction of the standard AGE-database without the specific description of organic production.

Initially, the agriculture-specific input-output table of the Danish economy is constructed, basically by disaggregating those commodity accounts that are used by Statistics Denmark for constructing the agricultural sector in their official input-output table. This disaggregation is done by extensive use of various agricultural statistics and sector specific farm accounts.

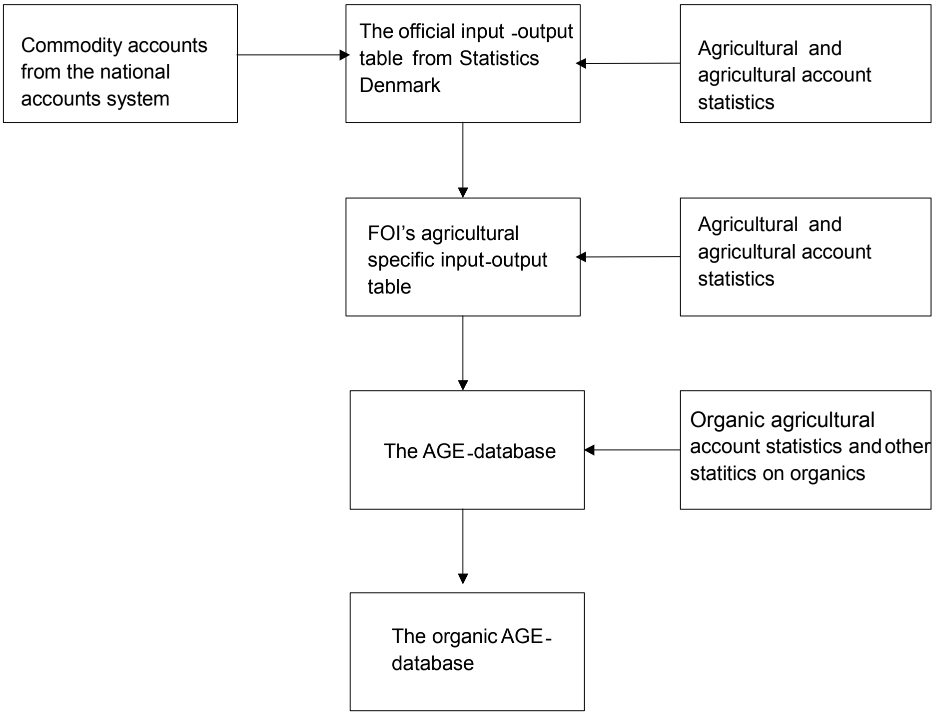
In order to analyse the development of organic farming, extensions of this work have been undertaken, resulting in a detailed description of organic farming as well as the processing of the primary products.

The second level illustrates how the agriculture-specific input-output table, together with agricultural and sector specific farm accounts, comprises the basis for construction of the AGE-database. This work involves the disaggregation of farm income into components related to the rent of capital, the return to land and the farmer's own labour input.

The third level in fig 2.1 shows that the organic AGE-database is constructed from the existing database.

The general AGE-database describes the Danish economy using an industry and commodity aggregation with 50 industries and 56 commodities, of which 10 industries and 12 commodities are related to the primary agriculture. In the organic version, the database is expanded with similar organic sectors and commodities (excluding fur farming), thus leading to 19 primary industries and 23 commodities. Moreover, a number of processing industries are also disaggregated into organic and conventional sectors, resulting in a total of 18 organic industries and 20 organic commodities. The final database thus covers 68 industries and 76 commodities (see Appendix A).

Figur 2.1 Constructing the organic AGE-database



Data for ESMERALDA

The economic behaviour of Danish farmers is represented by a large set of anonymous individual economic accounts data provided by the Danish Research Institute of Food Economics. The dataset is constructed from a stratified sample of annual farm accounts drawn from the total population of Danish farmers to obtain representativity in all relevant respects (cf. Danish Research Institute of Food Economics, 2003a).

For econometric estimation of behavioural parameters, the dataset has been divided into eight subsets according to farm type in order to obtain a reasonable degree of homogeneity. Hence, four farm types (part-time farms and full-time crop, cattle and pig farms) on two soil types (loam and sand) are distinguished. These eight farm categories are expected to reflect the main sources of variation among farms. For example, attitudes towards economic optimisation may differ between full-time and part-time farmers, because the latter often have other income sources. Fertilisation behaviour may differ between crop and livestock farms due to the self-supply with animal manure on the latter, and between cattle and pig farms due to significant differences in crop composition. Crop production behaviour may differ between loamy and sandy soils.

Part-time farms are defined as farms, where the standard labour requirement per year is less than one full-time (1,665 hours) working year. Full-time farms, where at least two thirds of the Standard Gross Margin are due to crop production are classified as crop farms, and analogously for cattle and pig farms[3]. Farms located in municipalities where more than 70 per cent of the area is loam are classified as loamy soil farms, and similarly for farms on sandy soil. Hence, farms from municipalities with less than 70 per cent of either loam or sand are not included in the data material used for econometric estimation.

These farm account data are supplemented with data on the economic returns in different agricultural lines of production as a driving force for changes in activity levels. Such data are not available at the individual level, but it is possible to construct data series for average changes in such sub-sector specific economic returns. The basis for such series is aggregate data on the economy in different agricultural sub-sectors, provided by the Danish Research Institute of Food Economics (e.g. 2003b). These data include revenues and costs per production unit (for example hectares or animal units) for the most important sub-sectors in Danish agriculture, including internal costs due to on-farm transfers between different sub-sectors.

2.2. The AAGE model

There are five types of agents in the AAGE (**A**gricultural **A**pplied **G**eneral **E**quilibrium) model: industries, capital creators, households, governments and foreigners. The current database of the model identifies 68 industries producing 76 commodities (see appendix A). For each industry there is an associated capital creator. The capital creators each produce units of capital that are specific to the associated industry.

[3] In addition, the group of pig farms include a minor share of farms, which are not specialised in one of the three categories – either because their production is relatively diversified, or because they specialise in other lines of production (e.g. poultry or furred animals).

There is a single representative household and a single government sector. Finally, there are foreigners, whose behaviour is summarised by export demand curves for Danish products, and by supply curves for imports.

AAGE determines supplies and demands of commodities through optimising behaviour of agents in competitive markets. Optimising behaviour also determines industry demands for labour and capital.

The assumption of competitive markets implies equality between the producer's price and the marginal cost in each industry. Demand is assumed to equal supply in all markets other than the labour market (where excess supply can occur). The government intervenes in markets by imposing sales taxes on commodities. This places wedges between the prices paid by purchasers and prices received by the producers. The model recognises margins (e.g. retail trade and freight) that are required for each market transaction (the movement of a commodity from the producer to the purchaser). The costs of the margins are included in purchasers' prices.

AAGE recognises two broad categories of inputs: intermediate inputs and primary factors. Firms in each industry are assumed to choose the mix of inputs, which minimises the costs of production for their level of output. They are constrained in their choice of inputs by nested production technologies (see appendix B). For the land-using industries (see appendix A), AAGE specifies nested substitutions between:

(a) capital, labour, energy and herbicides (CLEH);
(b) land, fertiliser and insecticides (LFI);
(c) CLEH and LFI (CLEHLFI); and
(d) CLEHLFI and an aggregate of remaining intermediate inputs

For non-land using industries, substitution is allowed between capital, labour and energy (CLE) and between CLE and aggregate non-energy intermediate inputs.

The representative household buys bundles of goods to maximise a utility function subject to a household expenditure constraint. The bundles are combinations of imported and domestic goods.

Capital creators for each industry combine inputs to form units of capital. In choosing these inputs, they minimise costs subject to technologies similar to that used for current production; the only difference being that they do not use primary factors. The use of primary factors in capital creation is recognised through inputs of the construction commodity.

The government demands commodities. In AAGE, there are several ways of handling these demands, including: (i) endogenously, by a rule such as moving government expenditures with household consumption expenditure or with domestic absorption; (ii) endogenously, as an instrument which varies to accommodate an exogenously determined target such as a required level of government deficit; and (iii) exogenously. In this paper both (iii) and (i) are used. In the baseline projection, government demands are exogenous while in the scenario analyses, changes in government demand follow household consumption expenditures.

Two categories of exports are defined: traditional, which are the main exported commodities, and non-traditional. Traditional export commodities face individual downward-sloping foreign demand schedules. The commodity composition of aggregate non-traditional exports is treated as a Leontief aggregate. Total demand is related to the average price via a single downward-sloping foreign demand schedule.

For all industries, AAGE includes the standard Armington specification for imported and domestically produced inputs. This assumes that users of a given commodity regard the domestic and the imported varieties of this commodity as imperfect substitutes. The Armington assumption is also used in input demands for industry investment and in household demands for consumption.

AAGE is a system of non-linear equations. It is solved using GEMPACK, a suite of programs for implementing and solving economic models. A linear, differential version of the AAGE equation system is specified in syntax similar to ordinary algebra. GEMPACK then solves the system of non-linear equations as an Initial Value problem, using a standard method, such as Euler or midpoint. For details of the algorithms available in GEMPACK, see Harrison and Pearson (1996).

The ESMERALDA model

ESMERALDA[4] describes production, input demands, land allocation, livestock density and various economic and environmentally relevant variables on representative

[4] ESMERALDA (Econometric Sector Model for Evaluating Resource Application and Land use in Danish Agriculture). See Jensen et al. (2001) for a more detailed description of the ESMERALDA model.

Danish farms, and subsequently in the Danish agricultural sector at relevant levels of aggregation. These variables are assumed to be functions of the economic conditions facing the farms, including agricultural prices, economic support schemes, quantitative regulations etc. A basic assumption underlying the model's behavioural description is that farmers exhibit economic optimisation behaviour, which means that farmers allocate production to the lines of production with the highest return.

The model covers 15 lines of agricultural production and 11 agricultural outputs, including 7 cash crops, 2 cattle sectors, pigs and poultry. Along with these outputs, the model determines demands for 12 variable inputs in the short run. In the long run, the model determines changes in activity levels (land allocation and livestock density), input of capital and derived effects of outputs and demands for short-run variable inputs. Based on changes in prices, quantities etc., a number of economic variables can be determined: output value, variable costs, gross margin etc.

The main principle in the ESMERALDA model is to determine economic behaviour on a number of (approximately 2000) representative Danish farms, and subsequently aggregate these farm-level results to the relevant level or type of aggregation, e.g. the national, regional or municipal level or various typological farm aggregates. The economic behaviour at farm level includes determination of input composition, production intensity in individual lines of production as well as activity levels (numbers of hectares or animals) in each line of production. In each of these stages, the behavioural adjustments (e.g. adjustments to price changes) are determined by econometrically estimated behavioural parameters (e.g. price elasticities). Specifically, 8 sets of behavioural parameters have been estimated, representing 8 main farm types (part-time farms and full-time crop, cattle and pig farms on loamy and sandy soil, respectively). To each farm in the model, the most relevant of these 8 sets of parameters is attached. Behavioural parameters of the model are estimated econometrically using anonymous farm account data from 1000-2000 Danish farms per year in the period 1973/74 to 1997/98. These data comprise land use, livestock herds, labour and capital input, output revenues from different agricultural products and variable input costs at the farm level.

In ESMERALDA, the allocation of agricultural area is determined by the development in relative economic returns in different crop sectors. It is assumed that the economic return in cattle production is channelled to the returns in roughage production (fodder beets, grass in rotation, permanent grasslands and silage cereals). On the other hand, the economic returns to pig production is assumed not to affect the relative economic returns between different crops. Adjustments in land use is described in a pairwise nesting structure with corresponding farm-type dependent elasticities of transformation (part time farms and full time crop, cattle and pig farms on clay and sandy soils, respectively). See Jensen et al. (2001) for more description of the mechanisms.

Aggregation of farm results is carried out by means of an aggregation matrix, which contains aggregation factors for each model farm to each of the relevant aggregates. Hence, the aggregation matrix represents the farm structure related to the considered grouping of farms. The aggregation matrix is assumed to be independent of the economic conditions. This assumption might be considered as a restrictive one. However, a study by Wiborg et al. (1997) indicates that developments in the Danish farm structure seem to have been fairly unaffected by observed changes in prices and regulations.

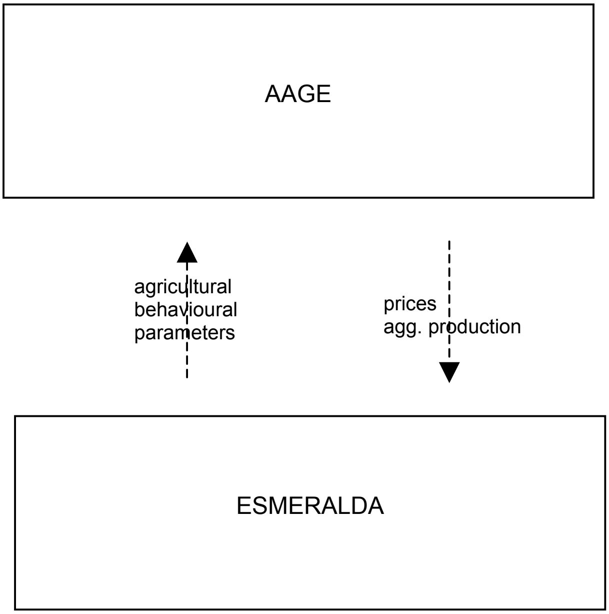
In its present version, the model can be used for economic analysis of changed conditions in the Danish agricultural sector, e.g. price changes or restrictions on the production behaviour. The "bottom-up" approach of the model yields the opportunity to distinguish economic effects between different farm types, in different regions etc.

2.3. Linking AAGE and ESMERALDA

The linkage between AAGE and ESMERALDA implies the largest possible mutual consistency in the behavioural description of the two models, but also mutual consistency in the contents of the specific scenarios analysed in the models. The former consistency implies that econometrically estimated behavioural parameters for the agricultural sector (cf. ESMERALDA) are transferred to AAGE. Provided consistency in the behavioural descriptions, the latter consistency implies that equilibrium prices from the AAGE model can be used as inputs to ESMERALDA for impact assessment in different parts of the agricultural sector, including agricultural economic consequences for different farm types. Furthermore, ESMERALDA results are adjusted in order to establish consistency between ESMERALDA and agricultural AAGE results at the national level.

The flow of results between the two models is outlined in figure 2.2.

Figur 2.2 Link between AAGE and ESMERALDA



Econometric work underlying ESMERALDA has been utilised in generating parameters for the AAGE model concerning economic behavioural parameters in the agricultural sector. A procedure for deriving behavioural parameters corresponding to the structure and functional forms applied in AAGE based on the estimation underlying ESMERALDA is described in Jensen et al. (1999). AAGE-determined agricultural price variables serve as input variables to ESMERALDA, which in turn determines agricultural production in the before-mentioned 15 lines of production, input use and value added on a large number of representative Danish farms, taking into account the variations in farm and production structure and soil type.

Because AAGE determines the interrelations between agriculture and other economic sectors, it has been chosen to adjust ESMERALDA results in order to obtain consistency with AAGE results concerning output values and gross factor income. The adjustment implies that the aggregate output of individual agricultural commodities and input use are determined by AAGE, whereas its regional distribution is determined by ESMERALDA.

Despite the efforts to ensure consistency between results from the two models, this consistency is not complete. The issue of consistency regarding the results in the current project is dealt with in section 4.3 below.

3. Scenarios

As mentioned at the outset of this working paper, the effects of different pesticide reduction strategies are evaluated against a baseline scenario, representing a likely projection of the coming 10 years' development of Danish economy and agriculture. This chapter describes these scenarios and their technical implementation in the two models.

3.1. Baseline scenario

A baseline is constructed to introduce all ongoing policy developments and known shocks to the economy so as to ensure that the policy shocks are undertaken in an economy where all known developments and shocks are accounted for.

The baseline scenario takes departure in current trends in economic growth, productivity etc. Developments in international markets are projected using an international economic model (GTAP), taking into account the effects of the EU enlargement from May 2004.

With regard to the agricultural sector, 3 policy initiatives are accounted for in the baseline projection:

- The 2003 Reform of the Common Agricultural Policy, including lower intervention prices for dairy products and beef, and decoupling of subsidies to agriculture
- The Action Plan for the Aquatic Environment III decided in April 2004, which imposes requirements on the handling of animal manure, a tax on phosphorus and regulations on the use of land
- A pesticide tax that was introduced in the 1995-2003 period

Details of the baseline scenario are given in Box 3.1.

Box 3.1 Assumptions of the baseline scenario

- Public consumption shock with actual development from 1995 to 2003, thereafter an annual increase of one percent per annum is assumed.
- Prices in foreign trade from GTAP model simulations; this also introduces effects of the enlargement of the European Union.
- Labour productivity, annual growth
  - assumed between 2.5 – 6 percent in agriculture
  - assumed 2.2 in manufacturing and 2.1 in services
- 2003 reform of the CAP
  - Intervention price cut for butter and skimmed milk powder
  - Compensatory payments to the dairy quota
  - Increase in the dairy quota
  - Full decoupling of hectare premium
  - Partly decoupling of animal premium
  - Modulation of direct support
- Action Plan for the Aquatic Environment III
  - Phosphorus taxes – Revenues return to the agricultural sector
  - Buffer zones – Compensation payments to land
  - Late crops requirements tightened
  - Manure utilisation requirements tightened
- Pesticide taxes introduce in the 1995 – 2003 period

The return to capital is assumed to be determined by the rate of return on the world market and this rate of return is assumed to be fixed throughout all scenarios. Total employment is assumed exogenous. With fixed rate of return on the world market capital is determined on the factor frontier, thus effectively determining GDP from the supply side. With capital determined on the supply side investments are also determined. Fixing the trade balance as a fraction of GDP finally determines national consumption (public and private consumption).

In the baseline scenario, public consumption is assumed truly exogenous while in the pesticide reduction scenarios public and private consumption are linked together and therefore effectively determined by the trade balance requirement.

3.2. Pesticide reduction scenarios

We introduce a number of alternative scenarios for pesticide reduction.

- *Scenario 1*. A general levy on all pesticides with the aim of reducing the total use of pesticides by 25 per cent.
- *Scenario 2a*. A levy on herbicides leading to the same welfare loss as scenario 1 (induces a reduction in the use of herbicides by 40 per cent)
- *Scenario 2b*. A soil-type differentiated levy on herbicides, with the aim of obtaining 80 per cent of the herbicide use reduction on clay soil and 20 per cent of the reduction on sandy soil, and with an economic loss corresponding to that of scenario 2a.
- *Scenario 3*. Pesticide-free buffer zones around all fields leading to the same welfare loss as scenario 1 (resulting buffer zone area amounts to 14 per cent of the total arable area)

A further "*scenario 4"* increases the area cultivated according to organic principles by 155 per cent. Due to numerical instability this scenario has not been calculated according to the same principles as the above mentioned. This scenario is briefly dealt with in appendix G.

In the pesticide reduction scenarios different policy instruments are used. In order to make results from the different scenarios comparable (and hence evaluate the relative cost-effectiveness of different instruments), all instruments are scaled to yield the same aggregate cost in terms of welfare loss, computed as the discounted change in national consumption. Thus, the effects of the scenarios are identical with regard to aggregate costs, but they differ with respect to their effects on variables like land use, pesticide use – and consequently the effects on biodiversity, ground water quality etc.

Scenario 1 – pesticide tax scenario

In scenario 1, a common tax rate (percentage of price) is used on all pesticides. The pesticide tax is introduced in order to ensure a decrease of 25 percent in the overall pesticide quantity index. The tax rates necessary to obtain this reduction in AAGE are displayed in the first column of table 3.1. The reason for the difference in the calculated tax rates in the pesticide scenario is that the model calculates a uniform percentage change in the existing applied taxes. As the initial tax rates are different for herbicides, fungicides and insecticides, respectively, the tax factor also differs between the three pesticide categories.

Table 3.1 Model calculated tax rates, per cent

	Pesticide	Herbicide
Fungicid	201	
Insecticid	247	
Herbicid	201	339

Scenario 2 – herbicide tax scenario

In scenario 2a, a general levy is put on the use of herbicides, leaving the taxes on fungicides and insecticides unaffected. As the scenario is scaled to yield the same economic welfare loss as scenario 1, a higher herbicide tax rate is necessary. The herbicide tax rate necessary to obtain this effect in AAGE is displayed in the second column in table 3.1.

In scenarios 1 and 2a, AAGE results concerning prices, aggregate agricultural output and aggregate use of herbicides, fungicides and insecticides are introduced into ESMERALDA as exogenous variables, which in turn drive the agricultural sector results, including land use, pesticide treatment frequency and agricultural income on different farm categories.

As AAGE does not include explicit distinction between clay and sandy soil, scenario 2b, (soil-type differentiated herbicide taxes) cannot be analysed in AAGE. On the other hand, ESMERALDA distinguishes between farms on loamy and sandy soils, and hence enables partial analysis of soil-specific taxes at the agricultural sector level. The size of the aggregate reduction in herbicide use is determined in order to obtain an economic welfare loss corresponding to the loss incurred by a 25 per cent reduction in pesticide use due to a general tax on pesticides (cf. above). As the welfare loss cannot be calculated directly for this scenario, an approximation for the extent of the herbicide reduction is determined as the one yielding the same loss in agricultural net income as a non-differentiated herbicide tax (scenario 2a).

If 80 per cent of the reduction in herbicide use should take place on loamy soil, the ratio between the soil-specific tax rates necessary to obtain the differentiated reduction in herbicide use can be determined as

$$\Delta H_L = 4 \cdot \Delta H_S$$

$$\Updownarrow$$

$$\frac{\Delta \tau_L}{\Delta \tau_S} = 4 \frac{\varepsilon_S^H \cdot H_S}{\varepsilon_L^H \cdot H_L}$$

where
H is the baseline aggregate application of herbicides on loam (subscript L) and sand (subscript S), respectively
p_H is the baseline herbicide price
τ is the herbicide tax rate (subscript according to soil type)
ε_H is the aggregate own-price elasticity of herbicides

Thus, the larger share of herbicides applied on sandy soil, the larger should be the loamy soil tax rate relative to that of the sandy soil tax rate. And the larger the price elasticity on sandy soil, compared with loamy soil, the larger should be the tax on loamy soil, relative to the tax rate on sandy soil.

Scenario 3 – pesticide-free buffer zone scenario

The AAGE model does not include buffer zones directly. In order to mimic such buffer zones, these are translated into an average change in the productivity of land. To translate results from this scenario back into an actual usage of buffer zones requires some assumptions. If the scenario does not change the aggregate land usage, total crop production falls by 2.87 percent. The average productivity loss with pesticide free production is approximately 20 percent (Frandsen and Jacobsen, 1999, Ørum, 1999) Assuming unchanged productivity on land not in the buffer zone, the fraction of land in the buffer zone can be calculated as

$$0.9713 = \beta \times 0.8 + (1-\beta) \times 1 \Rightarrow$$
$$0.0287 = (1-0.8) \times \beta \Rightarrow$$
$$\beta = 0.1435$$

That is at least 14.35 percent of total land should be allocated as pesticide-free buffer zones. This fraction increases with increased productivity of land outside the buffer zone and with the ability to change productivity inside the buffer zone.

In ESMERALDA, the allocation of land is driven by changes in the relative economic returns to land in the respective crop sectors. Thus, if the percentage change in returns to land in one crop is larger than in another crop, land will be re-allocated towards the first crop.

From a partial perspective, introduction of pesticide-free buffer zones will affect the economic returns to land on the area within the buffer zones in three ways:

- lower pesticide costs per hectare.
- lower crop yield due to the lower pesticide application
- possible replacement of pesticides with other inputs

On the other hand, introduction of buffer zones may not imply changes in production practises on the area not considered as buffer zone. These effects will most likely differ across crop sectors, and hence the percentage effects of buffer zones on economic returns will also differ. Consequently, introduction of buffer zones will affect land allocation.

Quantitative estimates of the impacts of buffer zones on economic returns in ESMERALDA's crop sectors have been obtained based on data from Danish Research Institute of Food Economics (2003b) and parameters estimated by Ørum (1999), assuming that no input substitution takes place in the buffer zones.

Table 3.2 provides such estimates under the assumption that the pesticide-free buffer zones amount to 14 per cent of the area, and that the buffer zones represent equal percentage area shares for all crops. The estimates indicate that the buffer zones will have the most serious economic implications for potatoes, whereas the economic returns to grasslands is only affected to a limited extent. Hence, these results indicate that the introduction of pesticide free buffer zones may lead to a reduction in the potato (and possibly wheat) area and growth in areas with grass and green fodder, however depending on the elasticities of transformation between the different crops.

The direct effects at the field level (reduced pesticide use and reduced crop yields), as well as the changes in the allocation of land lead to changes in the aggregate production and input use at the farm level. The change in aggregate variable X can be determined as

$$\Delta X = \left(\sum_h \alpha_h \cdot \widetilde{A}_h \cdot \widetilde{x}_h + (1-\alpha_h) \cdot \widetilde{A}_h \cdot x_h\right) - \left(\sum_h A_h \cdot x_h\right)$$

Table 3.2. Effects on economic returns due to introduction of pesticide-free buffer zones

	Spring barley	Winter barley	Wheat	Pulses	Rapeseed	Potatoes	Sugar beets	Fodder beets	Grass in rotation	Permanent grass	Silage cereals	Fallow
Normal cultivation, 2002												
Crop yield	4633	4954	6210	4470	4366	19088	18657	21784	8317	4418	8759	0
Coupled subsidies	2397	2413	2401	2694	2374	6444	43					2382
Pesticide, total	397	536	750	516	621	1643	1822	1845	35	6	328	0
Other variable inputs	2330	2485	2616	1860	2403	8178	4173	6965	3697	1746	5315	277
Gross margin I	4303	4346	5245	4788	3716	15711	12705	12974	4585	2666	3116	2105
Labour	1479	1713	1773	1553	1523	5656	4646	5153	1001	467	1130	241
Gross margin II	2824	2633	3472	3235	2193	10055	8059	7821	3584	2199	1986	1864
Pesticide-free cultivation, 2002												
Crop yield	3910	4011	4705	3634	3669	14352	16511	19278	8075	4290	7891	0
Coupled subsidies	2397	2413	2401	2694	2374	6444	43	0	0	0	0	2382
Pesticide, total	0	0	0	0	0	0	0	0	0	0	0	0
Other variable inputs	2330	2485	2616	1860	2403	8178	4173	6965	3697	1746	5315	277
Gross margin I	3977	3939	4490	4468	3640	12618	12381	12313	4378	2544	2576	2105
Labour	1479	1713	1773	1553	1523	5656	4646	5153	1001	467	1130	241
Gross margin II	2498	2226	2717	2915	2117	6962	7735	7160	3377	2077	1446	1864
Share of pesticide-free area	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14
Percentage change in gross margin	-1,62%	-2,16%	-3,05%	-1,38%	-0,49%	-4,31%	-0,56%	-1,18%	-0,81%	-0,78%	-3,81%	0,00%

Source: FØI (2003b), Ørum (1999)

where

ΔX : change in farm level variable X due to buffer zone regulation

α_h : buffer zone's share of area in crop h

$\widetilde{A}_h$: total area in crop h under buffer zone regulation

A_h : total area in crop h without buffer zone regulation

$\widetilde{x}_h$: variable x per hectare of crop h in the buffer zone

x_h : variable x per hectare of crop h on area not in buffer zone

In addition, a fourth scenario has been evaluated tentatively, namely an expansion of organic agriculture. However, as this scenario requires assumptions beyond those of the previous scenarios, the results are not strictly comparable with those of the other three reduction scenarios. Hence, results for the organic expansion scenario are presented in Appendix G.

Expected results from the analysis

In the *pesticide* tax scenario the target is a 25 percent reduction in the index of total pesticide usage. The instrument used is a uniform change in the existing pesticide taxes. This means that the change in input usage is not expected to be identical among different sectors and for the different pesticides. In general the pesticides that are more easily substituted with other inputs will be affected the most. Also those sectors having the best possibility to substitute pesticides will reduce the most. But also affecting this decision is the ability to pass on the extra cost of producing. Those sectors facing inelastic demand will in general reduce production less and hence contribute less to the overall reduction in pesticide usage while those sectors facing high elasticities in the demand for their products will reduce production more.

Reducing productivity of land has the effect of lowering the available effective land and increases the price of an effective unit of land. This means that land intensive industries will suffer more than less land intensive industries.

4. Results

In this chapter results from the analysis are presented and explained. First, we deal shortly with the baseline only focusing on the macro economic forecast of the Danish economy until 2015. Then the macroeconomic impacts of the pesticide scenarios are explained, followed by results for microeconomic impacts of the scenarios. Finally, uncertainties of the results are discussed.

4.1. Baseline scenario

The assumed changes in productivity lead to an increase in effective labour units throughout the baseline period and consequently to a total increase in GDP of 53.8 percent or an average of 2.2 percent per year. The growth leads to an increase in capital stock of 51.9 percent (2.1 percent per year).

With the assumed shocks to import and export prices the domestic price level is determined to ensure that the trade balance as a fraction of GDP remains fixed. A decrease in the terms of trade ensures this and hence real exports grow faster than real imports. With the trade balance determined and investment effectively determined by capital growth national consumption is determined, since we have an exogenous assumption on public consumption it remains to determine the growth in private consumption (2.5 percent per year).

The baseline scenario implies some changes in the agricultural sector, due to changes in foreign and domestic demands as well as changes in the supply conditions caused by e.g. environmental regulations and reforms of the Common Agricultural Policy. Table 4.2 presents some of the implications for the aggregate use of agricultural land.

The cultivated area will be reduced by 180.000 hectares in the baseline projection, due to increased demand for land for other purposes (e.g. urban growth and afforestation). The reduction in cultivated area mainly takes place for "other grains" and rapeseed, due to the decoupling of agricultural support as a result of the 2003 reform of the Common Agricultural Policy. The area with roughage is increased. The latter effect is however due to some uncertainty, as it depends on the final implementation of the reform, which allows some flexibility for member states to maintain some degree of coupling between production and subsidy payments.

Table 4.1 Macroeconomic impacts of baseline 1995 – 2015

	1995-level	Baseline		
	Bill. DKK.	Bill. DKK. 2003	Percent	Anual pct.
Real GDP	1037.7	558.8	53.8	2.2
Real private consumption	511.1	321.8	63.0	2.5
Real public consumption	260.3	81.6	31.3	1.4
Real investments	189.3	93.9	49.6	2.0
Real stocks	39.3	0.0	0.0	0.0
Real exports	296.0	176.4	59.6	2.4
Real imports	258.2	104.3	40.4	1.7
Real capital stock			51.9	2.1
Welfare	771.4	405.3	52.5	2.1

Table 4.2 Land use

1000 ha	Basis 2002	Baseline projection
Wheat	602	619
Other grains	910	789
Peas	41	7
Rapeseed	67	10
Seeds for sowing	68	68
Potatoes	14	9
Sugar beets	58	60
Other cash crops	13	13
Fodder beets	9	9
Grass, rotation	178	194
Perm. grass	180	175
Silage cereals	233	285
Fallow	226	180
Total area	2.599	2.419

This shift in land allocation, including an increase in wheat area, leads to an increase in the average treatment frequency index, as far as the use of fungicides is concerned, cf. table 4.3.

Table 4.3 Average treatment frequency index

Standard doses per hectare	Basis 2002	Baseline projection
Herbicides	0,96	0,93
Fungicides	0,45	0,59
Insecticides	0,26	0,24
Growth regulators	0,20	0,18
Total	1,87	1,93

4.2. Pesticide reduction scenarios

Macroeconomic impacts

As mentioned earlier, the pesticide reduction scenarios are compared by scaling the considered regulation instruments to the extent that their effects on economic welfare are equal to the welfare loss incurred by a general pesticide tax targeting a 25 per cent decrease in total pesticide use. This results in a decrease in total welfare by 862.1 million DKK.

The pesticide tax and the horizontal herbicide tax scenarios show similar macroeconomic effects. The introduced taxes reduce competitiveness in agriculture reducing demand for land, labour and capital resulting in a downward pressure on the economic return to these factors. Since land is used only in agriculture it is not surprising to see the large effect on the price of agricultural land. The effect on the land price shows a relatively large difference between the two scenarios, an indication that the herbicide tax has relatively smaller effect on the competitiveness of the agricultural sector than the general pesticide tax.

Except for international trade the macroeconomic effects in the buffer zone (land productivity) scenario are similar to those in the two tax scenarios. The reason for the difference in trade is the way export is modeled. A large fraction of the Danish export is described by a common export function, this export is termed non-traditional export and the commodity composition of this aggregate is treated as a Leontief aggregate, where total demand is related to the average price of the aggregate via a single downward-sloping demand schedule. In all three scenarios, the sign of total exports in table 4.4 is dominated by the result for non-traditional exports and the difference is thus explained by the reason for differences in non-traditional exports.

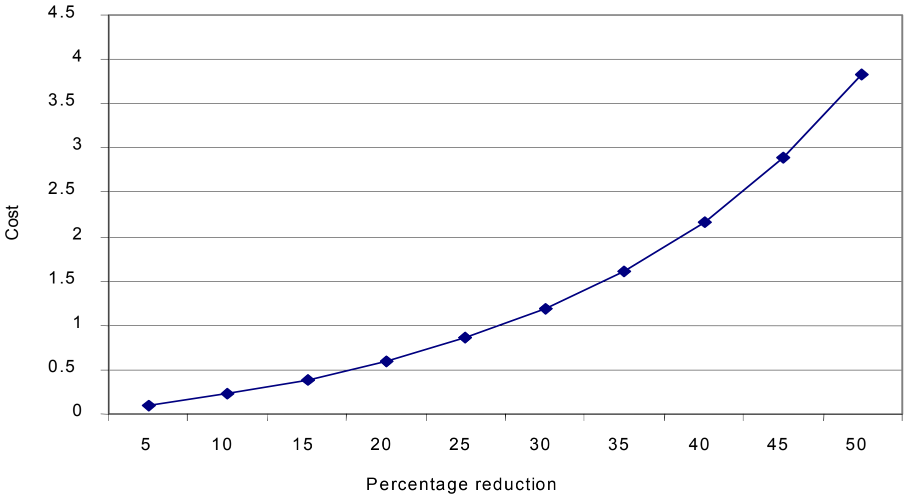
In the two tax scenarios, relative large price increases of a few agricultural products in the group of non-traditional exports lead to an increased average price of non-traditional exports and consequently a decrease in export volumes. In the land productivity scenario, price increases of agricultural products in the group of non-traditional export commodities are more modest and are outweighed by decreased prices of other commodities in the aggregate, thus leading to a decrease in the average price and an increase in the export volume.

As a sensitivity analysis concerning the overall abatement cost of increased pesticide taxes (scenario 1) the total welfare costs have been calculated for different tax levels (c.f. Figure 4.1). The figure shows a pattern of increasing marginal costs. This reflects an assumption that the range of possible actions in order to adjust to the higher pesticide price level becomes narrower, the higher is the tax rate. Similar patterns could be expected for the herbicide tax and buffer zone scenarios.

Table 4.4 Macroeconomic impact 2015, measured in 2003 currency

	2003-Level	Pesticide taxes		Herbicide taxes		Productivity of land	
	Billion DKK	Million DKK	Percent	Million DKK	Percent	Million DKK	Percent
Real GDP	1899.8	-799.0	-0.04	-760.3	-0.04	-703.4	-0.04
Real private consumption	991.1	-611.2	-0.06	-611.2	-0.06	-611.2	-0.06
Real public consumption	406.8	-250.9	-0.06	-250.9	-0.06	-250.9	-0.06
Real investments	337.0	7.1	0.00	18.2	0.01	-112.5	-0.03
Real stocks	46.7	0.0	0.00	0.0	0.00	0.0	0.00
Real exports	562.2	-59.7	-0.01	-33.1	-0.01	642.7	0.11
Real imports	431.5	-245.0	-0.06	-240.5	-0.06	313.2	0.07
Real capital stock			-0.05		-0.05		-0.04
Welfare		-862.1	-0.06	-862.1	-0.06	-862.2	-0.06
GDP deflator			-0.11		-0.10		-0.08
Consumer price index			-0.08		-0.08		-0.06
Price of investment goods			-0.10		-0.09		-0.06
Consumer real wage			-0.19		-0.18		-0.12
Price of agricultural land			-7.05		-3.16		-1.26

Figur 4.1 Model calculated abatement cost of pesticide reduction, Bill. DKK



Agricultural production and exports

Both the general pesticide tax and the herbicide tax increase unit cost in sectors using land, and hence reduce the production level and demand for land, labour and capital in these sectors. In the long run, prices of these factors must fall and most for land since this factor is fully and only used in agriculture.

The immediate effect of introducing lower productivity of land reduces effective input of land and thus results in lower production, ceteris paribus. This results in an increase in unit cost and thus a need for a production adjustment.

Industries can also be indirectly affected by the introduced instruments through higher input prices for intermediate inputs produced by sectors directly affected by the policy instrument. The final result for these industries is a weighted result of increased prices for some intermediates and the lowered factor prices of primary factors.

Industries not affected negatively by the policy instrument (directly or indirectly) face lower factor prices and are thus able to expand production at lower unit cost. Individual industry results are generally a result of changed factor priced and the intensity of use of these factors in each industry.

In the following, only policy scenario results for the primary agricultural sector are dealt with. Detailed results, including baseline results, for all industries are given in appendix C.

The first striking result of the pesticide tax is the relatively large decrease in horticultural production. The reason is that horticulture uses very little land compared to other sectors. When the taxes result in decreased land price, land intensive sectors have the ability to maintain their competitiveness. On the other hand, horticulture faces the pesticide tax, but at the same time the land price reduction has very little effect on the sector's profitability.

The introduced taxes benefit pig production even though there is an increase in the price of cereals (a major input). The reason is that the lover factor prices dominate the effect on unit cost.

Table 4.5 Impacts on agricultural production and exports, per cent

	Pesticide tax		Herbicide tax		Buffer zone	
	Production	Exports	Production	Exports	Production	Exports
Cereals	-1.59	-8.68	-1.44	-7.94	-9.01	-40.23
Rapeseed	-0.48	0.26	-1.61	-0.01	-0.21	0.08
Potatoes	-2.43	-0.07	-0.51	-0.05	0.13	0.23
Sugar beets	0.00	-0.07	0.00	0.05	0.00	0.23
Roughage	0.00	0.00	-0.14	0.00	0.00	0.00
Beef	-0.05	0.19	-0.03	-0.10	0.00	0.21
Milk	0.00	0.00	0.00	0.00	0.00	0.00
Pork	0.22	-0.07	016	-0.05	-0.22	0.23
Poultry	0.12	-0.07	0.10	-0.05	0.00	0.23
Furred animals	0.19	0.21	0.17	0.18	0.08	0.07
Horticulture	-9.69	-13.00	-10.30	-13.83	0.36	0.51

The herbicide tax results in the same overall mechanism. but compared to the general pesticide tax. a herbicide tax affects sectors which are relatively intensive in herbicides more and favours sectors more intensive in the other pesticides e.g. potatoes production (fungicides). compared with the general pesticide tax.

In contrast to the two tax scenarios. horticulture increases its production (0.36 percent) in the buffer zone scenario. This effect arises because horticulture is the agricultural sector with the lowest share of land in production. At the same time. horticulture does not use any input from the other land using sectors. therefore it gains from lower price of capital and labour.

Pig production. not directly affected by the shock. looses because of an increased price of cereals. which dominates the price decreases of factor inputs. in contrast to the tax scenarios. The major looser in this scenario is production of cereals due to its relatively high usage of land.

Employment

Employment results are much in line with the overall production results and the overall results for agricultural employment are alike in the three scenarios resulting in a decrease in employment of approximately 1.000 fulltime persons in the agri-food industries.

Table 4.6 Table 4.6 Effects on employment in the agricultural-industrial complex. Fulltime employed persons

	1995	Baseline	Changes from baseline		
			Pesticide taxes	Herbicide tax	Land prod
Cereal	21222	11761	-30	75	-1051
Oilseed	2785	5470	100	58	-13
Potatoes	1629	1838	31	6	3
Sugarbeet	2222	1410	29	19	2
Roughage	5833	3603	53	98	1
Cattle	22893	13476	11	25	7
Pig	17217	8388	22	17	-14
Poultry	950	696	2	1	0
Fur	2221	1333	3	3	2
Horticulture	10843	15762	-1330	-1402	62
Total primary agriculture	**87815**	**63737**	**-1109**	**-1101**	**-1002**
Processing cattle meat	3860	2528	-1	0	0
Processing pig meat	17586	14688	39	30	-25
Processing poultry meat	1213	841	3	2	0
Dairy	9547	6624	2	3	3
Sugarrefinaries	1573	1042	1	1	1
Processing	**33779**	**25723**	**44**	**37**	**-21**
Total	***121594***	***89460***	***-1066***	***-1064***	***-1023***

Agricultural sector results

Land use

The consequences of the pesticide reduction scenarios for land use are displayed in table 4.7.

A general tax on all pesticide types will strike relatively hard on the economic returns to wheat production. because wheat is relatively intensive in pesticides. Hence. the pesticide tax will lead to a change in the composition of grain production – from wheat towards grains with lower pesticide intensity. mainly spring barley. The increase in potato area may seem surprising. as potatoes are relatively intensive in pesticides. especially fungicides. However. the tax induces a price increase for potatoes. which makes the loss of economic returns to land in potato production relatively lower than for other crops[5].

[5] It should be mentioned that this finding is subject to some uncertainty, as there is some deviation in the potato area effect in the two models.

Table 4.7 Land use

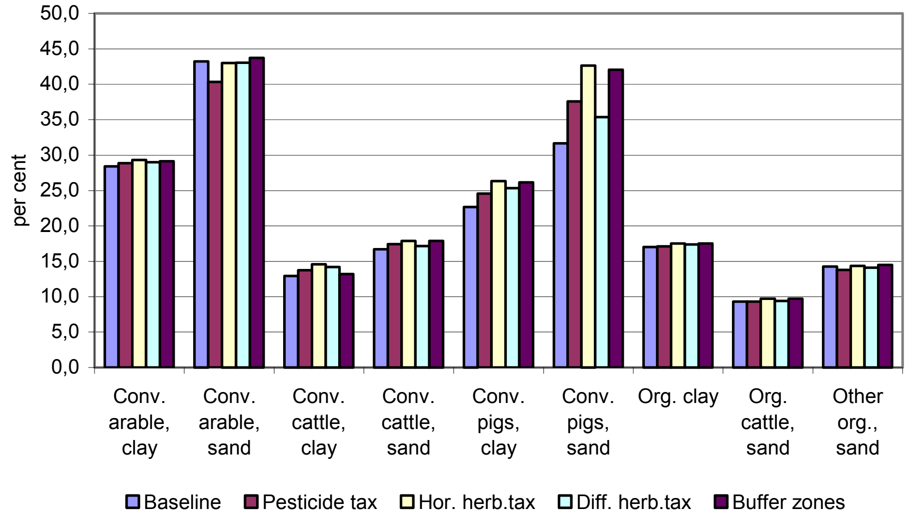
1000 ha	Baseline projection	1. Pesticide tax	2a. Herbicide tax	2b. Differentiated herbicide tax	3. Pest.-free buffer zones
Wheat	619	571	534	582	540
Other grains	789	819	876	822	873
Peas	7	9	9	11	7
Rapeseed	10	13	13	15	11
Seeds for sowing	68	68	67	68	67
Potatoes	9	24	8	10	7
Sugar beets	60	59	60	58	61
Other cash crops	13	13	13	13	13
Fodder beets	9	8	8	8	9
Grass. rotation	194	194	194	194	194
Perm. grass	175	175	174	175	175
Silage cereals	285	286	285	285	285
Fallow	180	181	180	180	180
Total area	2.419	2.419	2.419	2.419	2.419

In the horizontal herbicide tax scenario (scenario 2a). the shift in grain area is even stronger. but in this case the relative economic returns to potato production is not affected significantly and thus the potato area only changes slightly. The soil-type differentiated herbicide tax scenario (scenario 2b) furthermore leads to conversion of sugar beet area towards other crops. Sugar beets are almost exclusively cultivated on clay soil and are also relatively herbicide-intensive. Thus. a large herbicide tax for farms on clay soil will affect the economic returns to sugar beet cultivation relatively seriously. In contrast. the changes in the composition of grain area are more moderate than in scenario 2a.

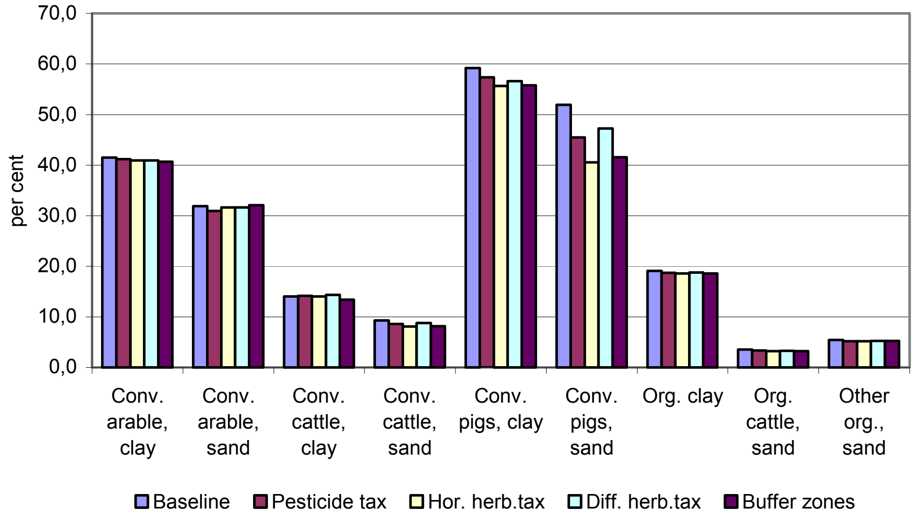
Introduction of pesticide-free buffer zones will also have relatively large consequences for the economic returns to land in wheat production. due to the high pesticide intensity in wheat production. It will thus become less attractive to cultivate wheat. compared with other grains. if a share of the area should be cultivated without using pesticides. This leads to a change in the composition of grain area.

Figures 4.2-4.4 illustrate selected land use effects of the pesticide reduction scenarios for spring cereals. winter cereals and other pesticide-intensive crops (peas. oilseeds. seeds for sowing and root crops) on different farm types. In general. the major differences across scenarios occur on pig farms. and to a lesser extent on cattle farms. whe-

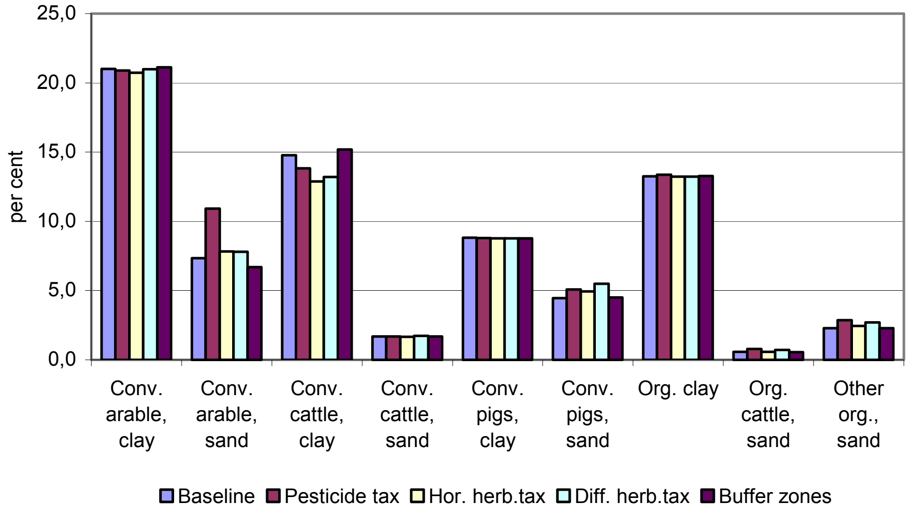
Figur 4.2 Spring cereals. per cent of area grown on different farm types



Figur 4.3 Winter cereals. per cent of area grown on different farm types



Figur 4.4 Other pesticide-intensive crop. per cent of area grown on different farm types



reas the impacts for arable farms are quite similar across scenarios. Land use on organic farms is not affected significantly by the pesticide reduction measures. as these measures only affect farms using pesticides.

Pesticide treatment frequencies

The Treatment Frequency Index (TFI) measures the intensity of pesticide treatment on the areas that are potentially treated with pesticides. TFI is defined as

$$TFI = \frac{\text{number of standard doses}}{\text{area relevant for pesticide treatment}}$$

ESMERALDA does not contain information about physical quantities of individual pesticides at the farm level. For this reason. official information about average TFI's at the crop level (Miljøstyrelsen. 2003) is applied as an approximation. These data are reproduced in appendix D (Basis 2002). Hence. in the model analysis it is assumed that the area with a specific crop is given the same pesticide treatment on all farms in 2002 (for example. a hectare of wheat gets 1.2 treatments of herbicides and 0.64 of fungicides). Changes in e.g. price relations in the scenarios affect these treatment frequencies according to the price elasticities of the model.

Resulting aggregate treatment frequency indices are displayed in table 4.8 for herbicides. fungicides. insecticides and growth regulators. respectively. Detailed results for individual crops are given in Appendix D.

At an aggregate level (across crops). the average treatment frequency index is affected through changes in pesticide intensities for individual crops. as well as through changes in the allocation of land.

Table 4.8 Average treatment frequency index

Standard doses per hectare	Baseline projection	1. Pesticide tax	2a. Herbicide tax	2b. Differentiated herbicide tax	3. Pest.-free buffer zones
Herbicides	0.93	0.64	0.54	0.75	0.75
Fungicides	0.59	0.47	0.54	0.56	0.48
Insecticides	0.24	0.16	0.24	0.24	0.21
Growth regulators	0.18	0.16	0.16	0.17	0.13
Total	1.93	1.43	1.48	1.73	1.57

The pesticide tax scenario leads to a reduction in the average treatment frequency index of 25 per cent. which is mainly a result of the target reduction of this scenario. The decrease is larger for herbicides and insecticides than for fungicides. which is related to the above-mentioned increase in potato area. Compared with the general pesticide tax scenario. a non-differentiated herbicide tax leads to a larger reduction in the average treatment frequency index of herbicides and a smaller reduction for fungicides and insecticides. as expected.

A soil-type differentiated tax on herbicides leads to a lower reduction in the average treatment frequency index than the non-differentiated herbicide tax. This is because the two tax scenarios have been scaled in order to equalize the costs induced by them (the reduction in agricultural gross factor income). As the marginal effectiveness of the tax is decreasing. the marginal herbicide-reducing effect of a high tax rate on clay soil becomes less than the marginal herbicide-reducing effect of a low tax rate on sandy soil. As the areas on clay and sandy soil are of a similar magnitude. this leads to a lower total reduction in average treatment frequency index for herbicides. and thus for the total treatment frequency index.

Introduction of pesticide-free buffer zones around the fields lead to a lower average treatment frequency index for two reasons. First. because 14 per cent of the cultivated area is not treated with pesticides and second. because the intervention leads to re-allocation of the cultivated area. cf. above. Compared with the baseline scenario. the average treatment frequency index is reduced by 19 per cent.

As the TFI is affected both by the use of pesticides and the area potentially relevant for pesticide treatment. changes in this may provide a rather imprecise indication of the total quantity of pesticides applied. Table 4.9 shows the impacts of the reduction scenarios on the total quantity of pesticides. For example. the buffer zone scenario leads to a 19 per cent decrease in the total quantity of pesticides. compared with the baseline projection.

Table 4.9 Index for pesticide quantity (baseline = 1.00)

	Baseline	Pesticide tax	Herbi-cide tax	Diff. herbi-cide tax	Pest.-free buff. zone
Herbicides	1.00	0.69	0.58	0.81	0.80
Fungicides	1.00	0.80	0.92	0.96	0.82
Insekticides	1.00	0.66	1.04	1.03	0.88
Growth regulators	1.00	0.89	0.89	0.95	0.77
Total	1.00	0.74	0.77	0.90	0.81

Nitrogen balance effects

The impacts of the pesticide regulation scenarios on the aggregate nitrogen balance have also been evaluated. In general. these impacts are fairly limited. The pure effect of land re-allocation leads to an increase at 0.5-1 per cent of the baseline nitrogen surplus. The increases are highest in the non-differentiated herbicide tax and the buffer zone scenarios. Crop yield reductions induced by the pesticide interventions may reduce the removal of nitrogen with crops. but also reduce the application of nutrients in the respective crop sectors. The net crop yield effect on nitrogen surplus will be a reduction in the nitrogen surplus. due to decreasing marginal productivity of nutrients in crop production. Finally. input substitution effects may affect the nitrogen balance. but these effects are rather weak. Thus. the overall effect of the pesticide reduction scenarios on the nitrogen surplus is small.

Economic results

As mentioned above. the ESMERALDA analyses are coordinated with the AAGE analyses. However. the two models are not mutually consistent in all respects. and deviations between the two sets of model results may occur. In the analyses at hand. such deviations are largest with regard to economic effects. as the coordination has mainly taken place with regard to the effects of the scenarios on pesticide/herbicide use. Table 4.10 shows the impacts of the pesticide reduction scenarios on the Danish Economic Accounts for Agriculture.

Table 4.10 Economic results for agriculture

million DKK	Baseline projection	1. Pesticide tax	2a. Herbicide tax	2b. Differentiated herbicide tax	3. Pest.-free buffer zones
Crop output	12.896	12.989	12.976	12.950	12.533
Livestock output	42.866	42.915	42.914	42.914	42.741
Other output	1.123	1.123	1.123	1.123	1.123
Total output	56.886	57.026	57.013	56.987	56.398
Crop-related costs	7.334	7.240	7.298	7.476	7.189
Livestock-related costs	16.085	16.383	16.378	16.186	16.009
Other variable costs	6.740	6.795	6.743	6.732	6.759
Total variable costs	30.159	30.418	30.419	30.393	29.958
Agricultural gross income (GFI)	26.726	26.608	26.594	26.594	26.440
Change in agricultural GFI		-118	-132	-132	-286

According to AAGE. the interventions lead to increased prices of conventional agricultural products. These price increases appear to outweigh the decrease in average crop yields per hectare. as a result of the taxes introduced in the ESMERALDA analysis. Thus. the monetary value of the gross output becomes larger as a result of the taxes. but it reflects a lower produced quantity. At the same time. costs in agricultural production increase due to the intervention. mainly due to higher feed prices. In total. the pesticide levy leads to a loss of agricultural gross income at 118 million DKK. while the non-differentiated herbicide tax leads to a loss at 132 million DKK.

The soil-type differentiated herbicide tax leads to a corresponding economic loss for agriculture. but the effects on production costs are composed differently. Hence. the tax leads to a larger increase in crop-related costs. because this tax intervention mainly affects crop farmers. which dominate farming on clay soil. On the other hand. the increase in livestock-related costs becomes lower. because livestock farms are predominantly localised on sandy soils. where the taxation is relatively mild.

Whereas the economic consequences of the three tax scenarios are similar to some extent. the economic impacts of the buffer zone scenario deviate somewhat. The price effects are different and the intervention leads to a drop in both gross output and crop-related production costs. In total. the loss of agricultural income becomes 286 million DKK. which is more than in the tax scenarios. reflecting the more limited possibility of adjustment in this scenario.

4.3. Discussion of the results from AAGE and ESMERALDA

As mentioned in previous chapters. the analyses in this working paper are carried out using two separate economic models. Although the focus differs between the two models. they exhibit some degree of overlap in their list of output variables. e.g. aggregate land allocation and use of pesticides. The results concerning these variables reported in tables 4.7-4.9 stem from the ESMERALDA analysis. For comparison. corresponding results from AAGE are given in Appendix F.

As the structures of the two models are substantially different. the mutual consistency between their results is however not perfect. although both models estimate the land use effects of the pesticide reduction scenarios to be moderate. For example. AAGE estimates more negative effects of the regulations on the cereal area than does ESMERALDA. On the other hand. ESMERALDA tends to estimate more negative effects on the area with other cash crops than AAGE.

Whereas there are some differences between the two models' results concerning land use effects. the estimated effects on pesticide use are more similar in the two models. which is also a result of the fact that the linkage of the two models has focused specifically on ensuring high consistency with respect to pesticide use.

It should however be noted that the results from the two models are not strictly comparable for various reasons. First. the area modelled in AAGE includes horticulture. and hence includes the impacts of changes in the horticultural area on the land use in agriculture. as opposed to ESMERALDA. which does not include this cross-effect between the two land-using sectors. Second. whereas ESMERALDA considers the adjustment to the imposed regulation within e.g. the projected farm structure. AAGE assumes full adjustment. including adjustments in the farm structure as well as adjustments in the rest of the economy. Third. the assumed structure of substitution between different production factors. e.g. between land and various pesticides. as well as the behavioural parameters describing this substitution. is different in the two models. although attempts have been made to ensure some consistency in this respect.

As the regulation effects on pesticide use are quite similar and the effects on land use are quite moderate in both sets of model results. the combined use of the two models. where AAGE provides macro-economic results and ESMERALDA provides disaggregated results on land allocation and pesticide use. is considered to be reasonable for the current purpose.

It should however be noted that the correspondence between economic results in the two models is weaker than for physical results. because the linking procedure implies that inconsistencies between the two models are accumulated in these economic results. Economic results from AAGE have been used as an anchor for the analysis. as AAGE provides the measure closest to an aggregate welfare loss.

5. Concluding remarks

From the analyses above. a number of lessons can be learned concerning cost effective regulation of agriculture's use of pesticides in Denmark.

A general tax on all pesticides is the most cost effective means to obtain a reduction in the aggregate use of pesticides – among the policy measures investigated in the present analysis. On the other hand. if the objective is to mainly reduce the use of herbicides. a general tax on herbicides is the most cost effective policy measure. This finding confirms standard theory on regulation. stating that regulation should to targeted as precisely as possible towards the problem that the regulation should solve.

Geographical targeting of regulation (in casu: herbicide tax differentiated according to soil type) is less cost effective than a horizontal tax on herbicides. when cost effectiveness is measured against the aggregate reduction in the use of herbicides. However. if there are geographic differences in the environmental strains caused by herbicides. a "milder". but geographically targeted regulation may incur benefits that are as large as those from a "stronger" horizontal regulation (or larger).

Also pesticide-free buffer zones appear more expensive per reduced unit of pesticide use. However. the relative cost effectiveness of the considered instruments depends on the aim of the regulation. Thus. the cost effectiveness of buffer zones is relatively low. if the aim is to reduce the aggregate agricultural use of pesticides. However. if the aim is to improve the conditions for wildlife etc.. pesticide-free buffer zones may be a more cost effective regulation. because such buffer zones address habitats close to the field borders. Thus. the positive effects of regulation on e.g. biodiversity may be stronger for such regulation than for a horizontal measure incurring larger aggregate reductions in pesticide use.

Organic agriculture has been evaluated as a strategy to reduce pesticide use in agriculture. Although results from the organic agriculture scenario are not strictly comparable with results from the other scenarios. they strongly indicate that such a strategy is relatively expensive. if the only objective is to reduce pesticide use. It should however be kept in mind that organic farming may incur a number of other benefits (e.g. animal welfare) besides the lower use of pesticides.

It should be noted that the model analyses presented in this paper are subject to some uncertainty. because the two models are not fully mutual consistent. However. despite this uncertainty. the above conclusions are considered to be fairly robust.

As has been discussed above, the relative cost effectiveness of the considered regulations depends on the environmental dimension against which the costs are measured. In the present analysis, two environmental dimensions with regard to pesticides have been quantified: pesticide quantity (measured by a quantity index) and pesticide intensity (measured by TFI). However, both these indicators may be considered as indirect (and imperfect) measures of the effects that attract general concern (e.g. conditions for biodiversity, groundwater and surface quality or human health). In a recent report from the Danish Economic Council (Det Økonomiske Råd, 2004), an attempt has been made to link the present results with analyses of impacts on wildlife and groundwater quality.

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Appendix A

Table A.1 Industries and commodities in Organic-AAGE

	Industries			Commodities	
*#	1-2	Cereal	*	1-2	Cereal
*#	3-4	Oil seeds	*	3-4	Oil seeds
*#	5-6	Potatoes	*	5-6	Potatoes
*#	7-8	Sugerbeets	*	7-8	Sugerbeets
*#	9-10	Roughage	*	9-10	Roughage
*	11-12	Meat cattle and milk producers	*	11-12	Meat cattle
*	13-14	Pigs	*	13-14	Milk
*	15-16	Poultry	*	15-16	Pigs
	17	Hunting and fur farming. etc.	*	17-18	Poultry
*#	18-19	Horticulture		19	Hunting and fur farming. etc.
	20	Agricultural services. etc.	*	20-21	Horticulture
	21	Forestry		22	Agricultural services. etc.
	22	Fishing		23	Forestry
	23	Extraction of coal. oil and gas		24	Fishing
*	24-25	Cattle-meat products		25	Extraction of coal. oil and gas
*	26-27	Pig-meat products	*	26-27	Cattle-meat products
*	28-29	Poultry-meat products	*	28-29	Pig-meat products
	30	Fish products	*	30-31	Poultry-meat products
*	31-32	Processed fruit and vegetables		32	Fish products
	33	Processed oils and fats	*	23-34	Processed fruit and vegetables
*	34-35	Dairy products		35	Processed oils and fats
*	36-37	Starch. chocolate products. etc.	*	36-37	Dairy products
*	38-39	Bread. grain mill and cakes	*	38-39	Starch. chocolate products. etc.
*	40-41	Bakery shops	*	40-41	Bread. grain mill and cakes
*	42-43	Sugar factories and refineries	*	42-43	Bakery shops
	44	Beverage production	*	44-45	Sugar factories and refineries
	45	Tobacco manufacture	*	46-47	Beverage production
	46	Textile. wearing apparel and leather		48	Tobacco manufacture
	47	Manufactured wood and glass products		49	Textile. wearing apparel and leather
	48	Paper products and publishing		50	Manufactured wood and glass products
	49	Oil refinery products		51	Paper products and publishing
	50	Basic chemicals		52	Oil refinery products
	51	Fertiliser		53	Basic chemicals
	52	Agricultural chemicals nec		54	Fertiliser
	53	Non-metallic building material		55	Agricultural chemicals nec
	54	Metal products		56	Non-metallic building material
	55	Machinery and non-transport equipment		57	Metal products
	56	Transport equipment		58	Machinery and non-transport equipment
	57	Electricity		59	Transport equipment
	58	Gas		60	Electricity
	59	Steam and hot water		61	Gas
	60	Construction		62	Steam and hot water
	61	Motor vehicles service		63	Construction
	62	Wholesale trade		64	Motor vehicles service
	63	Retail trade		65	Wholesale trade
	64	Freight transport		66	Retail trade
	65	Financial and property services		67	Freight transport
	66	Transport and communication services		68	Financial and property services
	67	Public services		69	Transport and communication services
	68	Dwelling ownership		70	Public services
				71	Dwelling ownership
				72	Coal imports
				73	Manure
				74	Fungicide
				75	Insecticides
				76	Herbicide

* Both conventional and organic product/production. # Land using industries

Appendix B

Figur B.1 Nesting structure

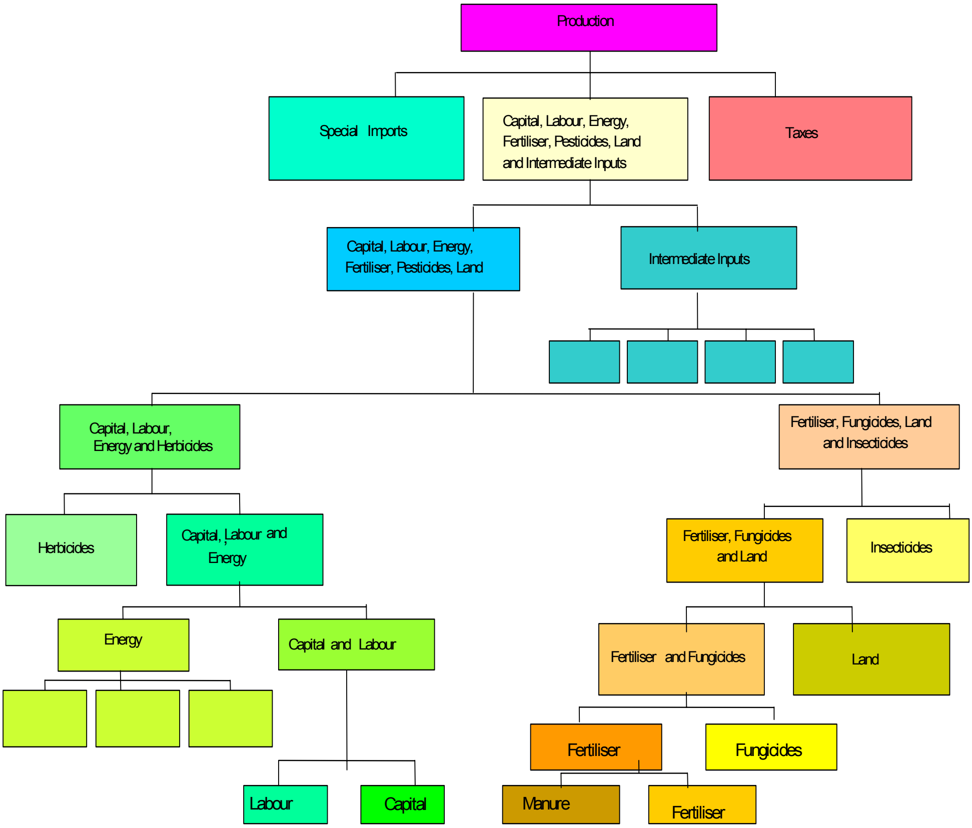

Table C.11Baseline

	Produktion	Eksport	Pris
Cereal	-15.38	-65.98	-17.48
Oil seeds	162.98	337.15	-25.74
Potatoes	55.28	114.96	-31.71
Sugerbeets	0.00	114.94	22.62
Roughage	0.74	0.00	-30.97
Meat cattle	1.42	113.49	-1.24
Milk	1.50	0.00	-16.58
Pigs	25.53	114.97	-28.33
Poultry	22.72	114.95	-28.95
Hunting and fur farming. etc.	-0.29	-13.67	-26.87
Horticulture	176.22	294.45	-39.41
Agricultural services. etc.	23.57	0.00	-31.22
Forestry	0.00	114.96	36.38
Fishing	-30.00	-35.92	34.20
Extraction of coal. oil and gas	3.56	6.34	14.56
Cattle-meat products	-5.61	-22.15	-13.34
Pig-meat products	24.32	12.40	-29.92
Poultry-meat products	4.36	-4.51	-30.28
Fish products	-24.00	-32.39	-11.60
Processed fruit and vegetables	56.25	113.66	-26.65
Processed oils and fats	69.28	114.96	-27.32
Dairy products	1.22	-24.45	-22.82
Starch. chocolate products. etc.	37.52	37.42	-28.15
Bread. grain mill and cakes	63.82	114.66	-29.52
Bakery shops	25.76	0.00	-30.37
Sugar factories and refineries	-8.39	-63.35	-11.04
Beverage production	81.78	114.96	-29.80
Tobacco manufacture	94.75	114.96	-27.80
Textile. wearing apparel and leather	34.64	17.79	-30.22
Manufactured wood and glass products	83.82	114.96	-28.22
Paper products and publishing	73.79	114.96	-30.89
Oil refinery products	-30.66	-38.28	3.44
Basic chemicals	61.33	49.41	-29.42
Fertiliser	57.14	114.96	-27.14
Agricultural chemicals nec	35.64	23.63	-25.12
Non-metallic building material	66.95	114.96	-30.23
Metal products	63.05	42.60	-28.44
Machinery and non-transport equipment	63.11	53.47	-29.98
Transport equipment	75.48	52.86	-29.90
Electricity	49.79	114.96	-25.05
Gas	73.57	114.96	-17.57
Steam and hot water	41.12	0.00	-28.67
Construction	52.75	114.96	-31.35
Motor vehicles service	62.58	0.00	-29.81
Wholesale trade	56.63	114.96	-31.71
Retail trade	51.52	0.00	-32.17
Freight transport	55.66	0.00	-28.74
Financial and property services	52.69	114.96	-32.04
Transport and communication services	88.63	133.41	-28.81
Public services	36.16	114.96	-33.06
Dwelling ownership	70.11	0.00	-29.85
Coal imports	0.00	0.00	0.00
Manure	10.77	0.00	-23.32
Fungicide	22.26	0.00	-39.29
Insecticides	21.64	0.00	-39.88
Herbicide	36.91	0.00	-31.23

Table C.2 Pesticide taxes

	Produktion	Eksport	Pris
Cereal	-1.59	-8.68	0.11
Oil seeds	-0.48	0.26	4.28
Potatoes	-2.43	-0.07	7.80
Sugerbeets	0.00	-0.07	-0.40
Roughage	0.00	0.00	0.40
Meat cattle	-0.05	0.19	0.10
Milk	0.00	0.00	-0.04
Pigs	0.22	-0.07	-0.08
Poultry	0.12	-0.07	-0.13
Hunting and fur farming. etc.	0.19	0.21	-0.10
Horticulture	-9.69	-13.00	1.85
Agricultural services. etc.	-0.27	0.00	-0.11
Forestry	0.00	-0.07	-0.03
Fishing	0.00	-0.10	0.04
Extraction of coal. oil and gas	0.01	0.10	-0.04
Cattle-meat products	-0.09	-0.12	0.03
Pig-meat products	0.23	0.38	-0.10
Poultry-meat products	0.28	0.35	-0.09
Fish products	0.13	0.17	-0.04
Processed fruit and vegetables	-0.23	-0.05	0.40
Processed oils and fats	-0.38	-0.07	0.85
Dairy products	-0.01	-0.02	-0.05
Starch. chocolate products. etc.	-0.29	-0.40	0.13
Bread. grain mill and cakes	-0.04	-0.06	-0.05
Bakery shops	-0.05	0.00	-0.06
Sugar factories and refineries	0.10	0.88	-0.25
Beverage production	-0.04	-0.07	-0.06
Tobacco manufacture	-0.06	-0.07	-0.08
Textile. wearing apparel and leather	0.24	0.36	-0.09
Manufactured wood and glass products	0.02	-0.07	-0.09
Paper products and publishing	0.00	-0.07	-0.12
Oil refinery products	-0.01	0.08	-0.03
Basic chemicals	0.24	0.29	-0.07
Fertiliser	1.50	-0.07	-0.05
Agricultural chemicals nec	-6.45	-7.56	2.45
Non-metallic building material	-0.04	-0.07	-0.11
Metal products	0.30	0.35	-0.09
Machinery and non-transport equipment	0.31	0.40	-0.10
Transport equipment	0.30	0.39	-0.10
Electricity	-0.09	-0.07	-0.10
Gas	-0.27	-0.07	-0.09
Steam and hot water	-0.10	0.00	-0.11
Construction	-0.04	-0.07	-0.12
Motor vehicles service	-0.08	0.00	-0.10
Wholesale trade	-0.04	-0.07	-0.13
Retail trade	-0.05	0.00	-0.14
Freight transport	-0.05	0.00	-0.11
Financial and property services	-0.03	-0.07	-0.13
Transport and communication services	0.15	0.37	-0.09
Public services	-0.06	-0.07	-0.15
Dwelling ownership	-0.06	0.00	-0.10
Coal imports	0.00	0.00	0.00
Manure	0.24	0.00	5.68
Fungicide	-13.40	0.00	-12.28
Insecticides	-9.73	0.00	-4.67
Herbicide	-10.13	0.00	-9.72

Table C.3 Herbicide taxes

	Produktion	Eksport	Pris
Cereal	-1.44	-7.94	0.10
Oil seeds	-1.61	0.01	6.05
Potatoes	-0.51	-0.05	1.53
Sugerbeets	0.00	-0.05	-0.12
Roughage	-0.14	0.00	1.59
Meat cattle	-0.03	0.10	0.07
Milk	0.00	0.00	0.00
Pigs	0.16	-0.05	-0.04
Poultry	0.10	-0.05	-0.08
Hunting and fur farming. etc.	0.17	0.18	-0.08
Horticulture	-10.30	-13.83	1.98
Agricultural services. etc.	-0.31	0.00	-0.11
Forestry	0.00	-0.05	-0.02
Fishing	0.00	-0.10	0.04
Extraction of coal. oil and gas	0.01	0.10	-0.04
Cattle-meat products	-0.04	-0.04	0.02
Pig-meat products	0.17	0.29	-0.07
Poultry-meat products	0.23	0.29	-0.07
Fish products	0.13	0.16	-0.03
Processed fruit and vegetables	-0.15	-0.03	0.26
Processed oils and fats	-0.49	-0.05	1.20
Dairy products	0.00	0.03	-0.03
Starch. chocolate products. etc.	-0.02	0.00	0.01
Bread. grain mill and cakes	-0.03	-0.04	-0.05
Bakery shops	-0.04	0.00	-0.05
Sugar factories and refineries	0.08	0.43	-0.12
Beverage production	-0.03	-0.05	-0.09
Tobacco manufacture	-0.05	-0.05	-0.07
Textile. wearing apparel and leather	0.23	0.35	-0.09
Manufactured wood and glass products	0.04	-0.05	-0.09
Paper products and publishing	0.01	-0.05	-0.12
Oil refinery products	-0.01	0.08	-0.03
Basic chemicals	0.24	0.29	-0.07
Fertiliser	0.26	-0.05	-0.06
Agricultural chemicals nec	-1.21	-1.43	0.46
Non-metallic building material	-0.04	-0.05	-0.10
Metal products	0.30	0.34	-0.08
Machinery and non-transport equipment	0.30	0.39	-0.10
Transport equipment	0.30	0.38	-0.10
Electricity	-0.10	-0.05	-0.10
Gas	-0.27	-0.05	-0.09
Steam and hot water	-0.10	0.00	-0.11
Construction	-0.04	-0.05	-0.12
Motor vehicles service	-0.08	0.00	-0.10
Wholesale trade	-0.05	-0.05	-0.13
Retail trade	-0.05	0.00	-0.13
Freight transport	-0.04	0.00	-0.11
Financial and property services	-0.03	-0.05	-0.13
Transport and communication services	0.14	0.36	-0.09
Public services	-0.06	-0.05	-0.15
Dwelling ownership	-0.06	0.00	-0.10
Coal imports	0.00	0.00	0.00
Manure	0.14	0.00	2.30
Fungicide	-1.18	0.00	0.49
Insecticides	-0.78	0.00	1.32
Herbicide	-9.19	0.00	-15.92

Table C.4 Land productivity

	Produktion	Eksport	Pris
Cereal	-9.01	-40.23	0.60
Oil seeds	-0.21	0.08	0.04
Potatoes	0.13	0.23	-0.09
Sugerbeets	0.00	0.23	0.23
Roughage	0.00	0.00	-0.06
Meat cattle	0.00	0.21	0.02
Milk	0.00	0.00	0.04
Pigs	-0.22	0.23	0.19
Poultry	0.00	0.23	0.08
Hunting and fur farming. etc.	0.08	0.07	-0.03
Horticulture	0.36	0.51	-0.05
Agricultural services. etc.	-1.39	0.00	-0.08
Forestry	0.00	0.23	0.05
Fishing	0.00	-0.05	0.02
Extraction of coal. oil and gas	0.01	0.02	-0.01
Cattle-meat products	-0.02	0.04	0.00
Pig-meat products	-0.23	-0.27	0.09
Poultry-meat products	-0.05	-0.03	0.02
Fish products	0.07	0.11	-0.02
Processed fruit and vegetables	0.09	0.23	-0.02
Processed oils and fats	0.15	0.23	-0.02
Dairy products	0.01	0.06	0.00
Starch. chocolate products. etc.	0.08	0.14	-0.03
Bread. grain mill and cakes	0.11	0.23	-0.05
Bakery shops	-0.03	0.00	-0.06
Sugar factories and refineries	-0.01	-0.20	0.08
Beverage production	0.06	0.23	-0.05
Tobacco manufacture	0.12	0.23	-0.05
Textile. wearing apparel and leather	0.14	0.22	-0.06
Manufactured wood and glass products	0.14	0.23	-0.06
Paper products and publishing	0.07	0.23	-0.08
Oil refinery products	-0.03	0.04	-0.01
Basic chemicals	0.18	0.22	-0.06
Fertiliser	-2.03	0.23	-0.04
Agricultural chemicals nec	-1.48	-1.63	0.52
Non-metallic building material	-0.02	0.23	-0.07
Metal products	0.19	0.22	-0.05
Machinery and non-transport equipment	0.18	0.25	-0.06
Transport equipment	0.19	0.25	-0.06
Electricity	-0.01	0.23	-0.06
Gas	0.00	0.23	-0.05
Steam and hot water	-0.04	0.00	-0.06
Construction	-0.05	0.23	-0.08
Motor vehicles service	-0.07	0.00	-0.06
Wholesale trade	0.00	0.23	-0.08
Retail trade	-0.05	0.00	-0.09
Freight transport	0.04	0.00	-0.07
Financial and property services	-0.03	0.23	-0.09
Transport and communication services	0.09	0.23	-0.06
Public services	-0.06	0.23	-0.09
Dwelling ownership	-0.06	0.00	-0.07
Coal imports	0.00	0.00	0.00
Manure	0.00	0.00	0.00
Fungicide	-3.04	0.00	-2.65
Insecticides	-2.92	0.00	-2.41
Herbicide	-1.40	0.00	-0.39

Appendix D Detailed pesticide treatment results

Table D.1 Crop specific herbicide treatment frequency index

	Basis 2002	Baseline projection	1. Pesticide tax	2a. Herbicide tax	2b. Differentiated herbicide tax	3. Pest.-free buffer zones	4. Organic
Spring barley	0.75	0.75	0.53	0.43	0.62	0.63	0.72
Winter barley	1.20	1.27	0.74	0.60	0.95	1.06	1.22
Wheat	1.20	1.24	0.78	0.70	0.97	1.01	1.18
Pulses	2.82	2.41	1.80	1.62	2.13	1.94	2.25
Rapeseed	1.19	1.05	0.71	0.72	1.00	0.88	0.97
Potatoes	2.10	2.10	1.24	1.21	1.67	1.85	1.98
Sugar beets	2.14	2.04	1.61	1.49	1.65	1.70	1.97
Fodder beets	2.14	2.00	1.63	1.58	1.97	1.69	1.94
Grass in rotation	0.05	0.05	0.04	0.04	0.04	0.04	0.05
Permanent grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Silage cereals	0.75	0.71	0.62	0.52	0.66	0.59	0.68
Fallow	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: Danish Environmental Protection Agency (2003)

Table D.2 Crop specific fungicide treatment frequency index

	Basis 2002	Baseline projection	1. Pesticide tax	2a. Herbicide tax	2b. Differentiated herbicide tax	3. Pest.-free buffer zones	4. Organic
Spring barley	0.27	0.34	0.25	0.33	0.33	0.30	0.34
Winter barley	0.64	0.84	0.59	0.80	0.82	0.74	0.86
Wheat	0.64	0.84	0.60	0.79	0.81	0.72	0.86
Pulses	0.06	0.07	0.05	0.06	0.07	0.06	0.07
Rapeseed	0.07	0.09	0.06	0.08	0.09	0.07	0.09
Potatoes	7.49	8.52	7.00	8.22	8.38	7.58	8.62
Sugar beets	0.08	0.10	0.07	0.09	0.09	0.08	0.10
Fodder beets	0.08	0.11	0.08	0.12	0.11	0.10	0.11
Grass in rotation	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Permanent grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Silage cereals	0.27	0.37	0.27	0.41	0.38	0.33	0.37
Fallow	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: Danish Environmental Protection Agency (2003)

Table D.3 Crop specific insecticide treatment frequency index

	Basis 2002	Baseline projection	1. Pesticide tax	2a. Herbicide tax	2b. Differentiated herbicide tax	3. Pest.-free buffer zones	4. Organic
Spring barley	0.28	0.31	0.19	0.31	0.31	0.27	0.30
Winter barley	0.17	0.19	0.11	0.19	0.19	0.17	0.19
Wheat	0.17	0.19	0.12	0.19	0.19	0.16	0.19
Pulses	0.98	1.13	0.76	1.14	1.15	0.98	1.12
Rapeseed	0.93	1.03	0.61	1.05	1.08	0.90	1.02
Potatoes	0.73	0.80	0.65	0.81	0.81	0.69	0.78
Sugar beets	0.28	0.27	0.22	0.28	0.28	0.23	0.28
Fodder beets	0.28	0.27	0.15	0.28	0.27	0.23	0.27
Grass in rotation	0.02	0.02	0.01	0.02	0.02	0.02	0.02
Permanent grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Silage cereals	0.28	0.26	0.18	0.27	0.26	0.22	0.26
Fallow	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: Danish Environmental Protection Agency (2003)

Table D.4 Crop specific growth regulator treatment frequency index

	Basis 2002	Baseline projection	1. Pesticide tax	2a. Herbicide tax	2b. Differentiated herbicide tax	3. Pest.-free buffer zones	4. Organic
Spring barley	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Winter barley	0.20	0.15	0.14	0.15	0.15	0.13	0.15
Wheat	0.20	0.16	0.15	0.16	0.16	0.14	0.16
Pulses	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rapeseed	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Potatoes	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sugar beets	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fodder beets	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grass in rotation	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Permanent grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Silage cereals	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fallow	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: Danish Environmental Protection Agency (2003)

Appendix E. Results from organic farming scenario

Table E.1 Land use

1000 ha	Baseline projection	4. Organic
Wheat	619	607
Other grains	789	784
Peas	7	7
Rapeseed	10	10
Seeds for sowing	68	67
Potatoes	9	9
Sugar beets	60	58
Other cash crops	13	13
Fodder beets	9	9
Grass. rotation	194	205
Perm. grass	175	177
Silage cereals	285	294
Fallow	180	181
Total area	2.419	2.419

Table E.2 Average treatment frequency index

Standard doses per hectare	Baseline projection	4. Organic
Herbicides	0.93	0.93
Fungicides	0.59	0.63
Insecticides	0.24	0.25
Growth regulators	0.18	0.17
Total	1.93	1.98

Appendix F. AAGE results concerning land and pesticide use

Land usage

Comparing change in land use it is interesting to note that compared to change in production horticulture substitutes out of land in the pesticide tax scenario (becomes less land intensive) whereas the sector becomes more land intensive in the herbicide tax scenario. The reason can be found in the nesting structure of the model (appendix B). Herbicide is included in an aggregate of land. labour and capital while the other types of pesticides are include in an aggregate including land. This means that in the herbicide scenario the aggregate that includes herbicide increases in price while the price of the aggregate that include land falls. In the general pesticide tax scenario both aggregates are affected by the tax but the aggregate that contains land is affected the most and hence horticulture substitutes out of land.

Table F.1 Change in land usage

	Change compared to baseline		
	Pesticide taxes	Herbicide taxes	Land prod
Cereal	-1.1	-1.2	-2.7
Oilsee	4.5	3.3	6.2
Potatoes	-6.2	2.1	6.8
Sugar beet	7.0	13.0	6.5
Roughage	5.0	3.0	6.7
Horticulture	-12.2	-7.0	6.6

Pesticide usage

Table F.2

Baseline

	Cereals	Oilsed	Potatoes	Sugarbeet	Roughage	Horticulture	Total
Fungicide	-23.4	52.7	45.9	-8.8	-11.6	129.6	-1.3
Insecticide	-15.7	61.9	32.8	-4.3	-18.5	98.1	-4.8
Herbicide	-26.5	65.0	31.5	-9.4	-23.0	100.0	6.2
Total	-22.6	63.2	43.5	-8.4	-21.7	106.9	1.2

Pesticide taxes

	Cereals	Oilsed	Potatoes	Sugarbeet	Roughage	Horticulture	Total
Fungicide	-22.0	-25.5	-21.9	-25.8	-30.0	-34.0	-23.7
Insecticide	-9.6	-9.7	-27.5	-7.2	-32.0	-38.7	-15.0
Herbicide	-21.7	-29.1	-28.7	-16.3	-39.1	-42.9	-30.0
Total	-18.9	-25.3	-23.0	-14.6	-37.1	-40.2	-25.0

Herbicide taxes

	Cereals	Oilsed	Potatoes	Sugarbeet	Roughage	Horticulture	Total
Fungicide	-1.4	3.6	1.0	11.9	2.1	-8.5	-1.5
Insecticide	-2.0	3.4	0.1	11.6	0.4	-10.0	-0.2
Herbicide	-28.8	-39.5	-40.1	-23.9	-51.2	-54.3	-39.7
Total	-12.2	-32.1	-7.9	-18.8	-41.7	-43.7	-24.0

Productivity of land

	Cereals	Oilsed	Potatoes	Sugarbeet	Roughage	Horticulture	Total
Fungicide	-8.9	0.6	0.5	0.3	0.2	0.0	-4.9
Insecticide	-8.9	0.4	0.8	0.1	0.8	0.6	-4.7
Herbicide	-9.1	0.2	0.1	0.1	0.0	0.4	-2.0
Total	-8.9	0.3	0.5	0.1	0.2	0.3	-3.5

Appendix G. Scenario 4 – increased land under organic cultivation

Introduction

As mentioned in the body of this paper a fourth scenario reducing the usage of pesticide through increased conversion to organic farming has been considered. Results from this scenario are presented independently from the other three because the specific implementation of this scenario calls for some caution when comparing results with the other three scenarios.

Scenario specification

In the three scenarios in the main part of this paper the computed scenarios result from changing truly exogenous variables to achieve a given welfare change. In the pesticide tax scenarios taxes on pesticides are changed and in the buffer zone/land productivity scenario we change the average productivity of land. A comparable scenario for organic farming would be to exogenously change the subsidy for farming organically. It turns out that this is impossible because the change is so large that the model runs into numerical difficulties.

The welfare loss induced by the organic farming scenario arises from lower productivity in organic production compared to conventional production. In order to reach the same welfare loss as in the other scenarios. a subsidy should increase profitability such that the inflow of land would more than double the size of the organic sector. The simulation runs into numerical instability and actually breaks down when only the subsidy instrument is applied. with unchanged consumer preferences and unchanged position of foreign demand schedules.

To remedy this problem. changes in the preferences of domestic and foreign consumers have been implemented by changing the position of the foreign and domestic demand functions such that the demand for conventional products falls while the demand for organic products increases. i.e. we assume changes in the consumer preferences. The reason for caution when comparing this scenario with the other three arises from the fact that the scenarios are compared through measures of welfare which have a strong connection to the specification to the utility function and thus consumer demand.

The organic farming scenario is specified by:

- An increased subsidy to land used for organic purposes

- Increased domestic and foreign demand for organic products
- Decreased domestic and foreign demand for conventional products in a magnitude that offsets the effect on organic demand on the total demand for a product.

Macroeconomic impacts

The macroeconomic impacts are in line (by construction) with the three scenarios in the main part of the paper with a reduction in real GPD of 0.04 per cent. a real drop in consumption by 0.06 per cent and a reduction in welfare of 862.1 million DKK.

Table G.1 Macroeconomic impact of increased conversion to organic farming

	2003-Level	Organic farming	
	Billion DKK	Million DKK	Percent
Real GDP	1899.8	-789.1	-0.04
Real private consumption	991.1	-611.2	-0.06
Real public consumption	406.8	-250.9	-0.06
Real investments	337.0	236.2	0.07
Real stocks	46.7	0.0	0.00
Real exports	562.2	-320.8	-0.06
Real imports	431.5	-181.7	-0.04
Real capital stock			0.01
Welfare		-862.1	-0.06
GDP deflator			-0.01
Consumer price index			-0.01
Price of investment goods			-0.01
Terms of Trade			0.01
Consumer real wage			-0.02
Price of agricultural land			0.99

Sector impacts

For most commodities. the impact on production exports and prices are as could be expected. The scenario results in two main effects. First. the subsidy to organic land generally improves the profitability in organic farming (moving the supply curve downwards). resulting in an inflow of land and increased production at a lower price. However. the production increase varies according to market possibilities for the individual product. Secondly. the applied shocks to demand generally increase the willingness to pay for organic products (moving the demand curve upwards) and thus result in increased production and prices of organic products.

The combination of these two effects leads to increased production while the sign of the price effect is undetermined since it depends on. which of the two above effects dominates in the determination of the price. Results for organic products in table G.2 all show this pattern with one exception. Some of the numbers in the table are of a rather large magnitude. but this only reflects a very low initial value.

The result for oilseed contradicts the above explanation since production goes *down* while the price is *increased.* This is a result of a third important factor – namely competition on factor markets. Agricultural enterprises compete for land until returns to land are equalized between enterprises. For oilseed producers this is important. since they supply their product to conventional processing industries and hence are not influenced by the changes in demand for organic products. The increased demand results in increased return to land. Since all sectors compete for land. this must also be true for oilseed – the result is an increase in unit cost and an upward movement in the supply curve. while the demand curve is unaffected. resulting in a decrease in production and an increase in price such that the return to land in oilseed production are increased and equal to that of the other sectors.

The effects of the organic farming scenario on aggregate land use are displayed in table G.3. Compared with the baseline projection. the organic farming scenario leads to a shift from cash crops towards fodder crops. because a major share of the conversion takes place in dairy farming and organic dairy farms have larger demand for fodder crop area than do conventional dairy farms. which is also reflected in the aggregate production results in table G.2. Nonetheless. the impacts on aggregate land use are relatively small. as a doubled organic area still only contributes around 10 per cent of the total agricultural area in the organic farming scenario.

An increased conversion to organic farming also leads to changes in the use of pesticides. The effect is measured by means of two indicators in table G.4. The pesticide Treatment Frequency Index (TFI) was introduced in chapter 4 and the results indicate that this indicator is weakly increased due to the organic farming scenario. Although this result may seem puzzling. there is a clear explanation for it. TFI is defined as the total number of applied doses divided by the total area relevant for pesticide treatment. As the organic area is deducted from this area. increased organic area as such does not affect the average pesticide intensity on the treated areas. However. a change in the crop composition on conventional farms due to the conversion may affect the average treatment intensity.

Table G.2 Production. export and prices effects in primary agriculture

	Production	Exports	Price
Conventional cereal	-15.3	-58.7	1.0
Organic cereal	1552.4	360034.8	-8.6
Total cereals	*-0.21*	*357.46*	*0.93*
Conventional oilseed	-0.56	0.38	0.24
Organic oilseed	-32.37	-34.43	2.27
Total oilseed	*-9.58*	*-3.35*	*0.81*
Conventional potatoes	-2.66	0.38	-0.12
Organic potatoes	81.00	0.38	-2.80
Total potatoes	*-0.36*	*0.38*	*-0.19*
Conventional sugar beet	-0.21	0.38	-8.45
Organic sugar beet	260.19	-44.88	7.33
Total sugar beet	*0.00*	*0.38*	*-8.44*
Conventional roughage	-2.48	0.00	0.31
Organic roughage	46.06	0.00	13.64
Total roughage	*2.33*	*0.00*	*1.63*
Conventional cattle	-9.76	0.38	4.93
Organic cattle	69.44	315.43	-11.03
Total cattle	*-3.87*	*10.70*	*3.74*
Conventional milk	-9.76	0.00	3.14
Organic milk	69.43	0.00	-2.94
Total milk	*0.00*	*0.00*	*2.39*
Conventional swine	-1.53	0.38	0.28
Organic swine	252.24	117.65	-9.17
Total swine	*-0.78*	*0.41*	*0.25*
Conventional poultry and eggs	-2.87	0.38	0.12
Organic poultry and eggs	132.14	49.30	-5.36
Total poultry and eggs	*5.69*	*0.39*	*-0.23*
Fur farming	0.06	0.06	0.04
Conventional horticulture	-2.92	-2.61	-0.02
Organic horticulture	111.14	112.07	-0.73
Total Horticulture	*3.27*	*3.25*	*-0.06*

Table G.3 Land use in organic scenario

1000 ha	Baseline	Organic
Wheat	619	607
Other grains	789	784
Peas	7	7
Rapeseed	10	10
Seeds for sowing	68	67
Potatoes	9	9
Sugar beets	60	58
Other cash crops	13	13
Fodder beets	9	9
Grass. rotation	194	205
Perm. grass	175	177
Silage cereals	285	294
Fallow	180	181
Total area	2.419	2.419

Another indicator of the impacts on pesticide use is an aggregate quantity index. which represents the change in the total amount of pesticides applied in agriculture. In line with a priori expectations. the organic farming scenario leads to a reduction in total pesticide use at some 7 per cent. However. for herbicides. the reduction is even larger. while the reduction in the use of fungicides is fairly moderate.

Table G.4 Pesticide intensity and use in the organic farming scenario

	Treatment Frequency Index		Quantity index (Baseline 2010 = 1.00)	
	Baseline	Organic	Baseline	Organic
Herbicides	0.93	0.93	1.00	0.90
Fungicides	0.59	0.63	1.00	0.98
Insecticides	0.24	0.25	1.00	0.94
Growth regulators	0.18	0.17	1.00	0.88
Total	1.93	1.98	1.00	0.93

Organic farming scenario - concluding remarks

In sum. increased organic farming to an extent that induces a welfare loss comparable with those of the considered scenarios in the body of the paper leads to relatively moderate changes in the use of pesticides compared with the effects in the other scenarios. Whereas e.g. horizontal herbicide tax or a buffer zone scenarios lead to reductions in pesticide use in the area of 20 per cent. an increased conversion to organic farming at a comparable welfare cost leads to less than half the reduction in pesticide use. Thus. if pesticide abatement is the only objective. increased conversion to organic farming is not a cost-effective strategy. However. it should be noted that apart from the absence of pesticides in production. organic farming has other attributes such as lower nutrient intensity. animal welfare. etc.

It should also be stressed that comparison of the organic farming scenario with the other pesticide regulation scenarios should be done with care. as the assumptions about consumer preferences in the organic farming scenario differs from those of the other scenarios.

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