

# Regional Socioeconomic Impacts of Livestock Regulation

## - an Integrated Modelling Approach<sup>1</sup>

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### Abstract

This paper addresses the combination of environmental regulation and rural development using an integrated economic modelling approach. Specifically, the regional impacts of regulating livestock density at the farm level are analysed in a projected 2010 setting. This scenario is motivated by a concern for nitrogen loads on ground and surface water. The applied model framework includes a macroeconomic CGE-model, an econometric agricultural sector model and a local economic model, and consistent links have been established between these models. The analyses show that the largest relative economic impacts occur in the western parts of Denmark. This occurs in the agricultural sector, because the highest livestock densities are found in the western regions, but also at the general economic level, because agriculture is relatively important for the regional economy in these regions. However, the maximum absolute economic impact on the regional economies in terms of regional GDP is only around one per cent in the most affected region.

Keywords: economic models, livestock density regulation, regional impacts

### 1. Introduction

Danish rural municipalities have a lower disposable per capita income than the rest of the country (Madsen & Caspersen, 1998). This also applies to agricultural rural areas, although the disposable per capita income in these areas has shown growth rates above the national average since 1980 (Madsen & Caspersen, *ibid.*). At a national level, the total economic activity resulting from agricultural production, including agro-industry, contributes by 8-10 per cent of the total economic

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<sup>1</sup> This paper refers to the project “Economics and development of agriculture in rural areas”. The project is carried out in at cooperation between the Institute of Local Government Studies – Denmark (AKF) and Danish Research Institute of Food Economics (FØI). The paper builds on the report “Scenarios for Rural Areas Development – an Integrated modelling Approach” (Hasler et al (2002)). It presents an overview of the report underlining major findings.

activity (GDP, employment) (Jensen, 1998). The regions differ widely in their contribution to this aggregated result, however, and the contribution from agriculture and the related industries is low in e.g. the Capital region and relatively high in Western Jutland and the southern islands. Consequently, one can expect that changes in agricultural and environmental policies, e.g. price changes and environmental requirements, will influence the regions and municipalities differently.

At the same time, there is an increasing pressure for further regulation of agricultural activities due to problems with nitrogen pollution of ground and surface waters. One of the major contributors to these problems is the relatively high livestock density, especially in some of the regions where agriculture plays a major role. Hence, the concern for economic development in rural areas may seem to be conflicting with the concern for the aquatic environment.

The aim of the present paper is to analyse the impacts of agriculture-related environmental regulation on the regional economies, using an integrated economic modelling framework. The model framework enables consistent analysis of macro-, agricultural and local economic effects of a specific regulation scenario. The specific regulation comprises a tightening of existing requirements concerning the upper limit on livestock density, i.e. number of livestock units per hectare of agricultural land at the farm level.

As the considered tightening has not been implemented yet, it will have its' impacts in the future rather than in a historic year, like 1995. As the structural development in agriculture, as well as in Danish rural regions in general, is pretty dynamic, it is relevant to compare the impacts of the considered regulation with a projected future situation. For example, it may be expected that the economic development, amongst other trends involves a reduction of the relative importance of "rural sectors" (like the agricultural sector), an increase in "urban sectors" and an increasing role for rural regions as residential areas for urban economies. The need for having a future perspective in the analysis is furthermore stressed by the fact that the policy framework facing the agricultural sector is changing, not least at the EU level. In 1999 the EU countries agreed on a new agricultural policy reform, Agenda 2000, comprising both agricultural and regional dimensions, building on the fact that many European regions are highly dependent on agriculture. For this reason, the considered regulation is analysed in a projected 2010 setting, where a combined projection/environmental regulation scenario is compared with the results of a "pure" baseline projection, based on currently known trends and already decided policy changes.

## **2. The integrated model system – models and links**

The scenarios for development in rural areas are analysed by means of a model system comprising a national macroeconomic model (AAGE), a regionalised agricultural sector model (ESMERALDA) and a local economic model (LINE). The integrated model system and the links between the models are outlined in figure 1.

### ***2.1. The aggregate economic AAGE model***

The AAGE model<sup>2</sup> is a traditional static general equilibrium model for the Danish economy. The model is based on neoclassical theory of the behaviour of profit maximizing firms under perfect competition. Among other variables, AAGE determines domestic production, input uses and prices for a given scenario in 68 industries of which 16 primary agricultural (8 conventional and 8 organic

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<sup>2</sup> The AAGE model is based on the Australian ORANI-tradition. See Frandsen et al. (1995) for a description of a less agriculture-specific version of the model.

industries), 76 commodities of which 18 are primary agricultural (9 conventional and 9 organic industries), and finally three primary inputs; labour, capital and land.

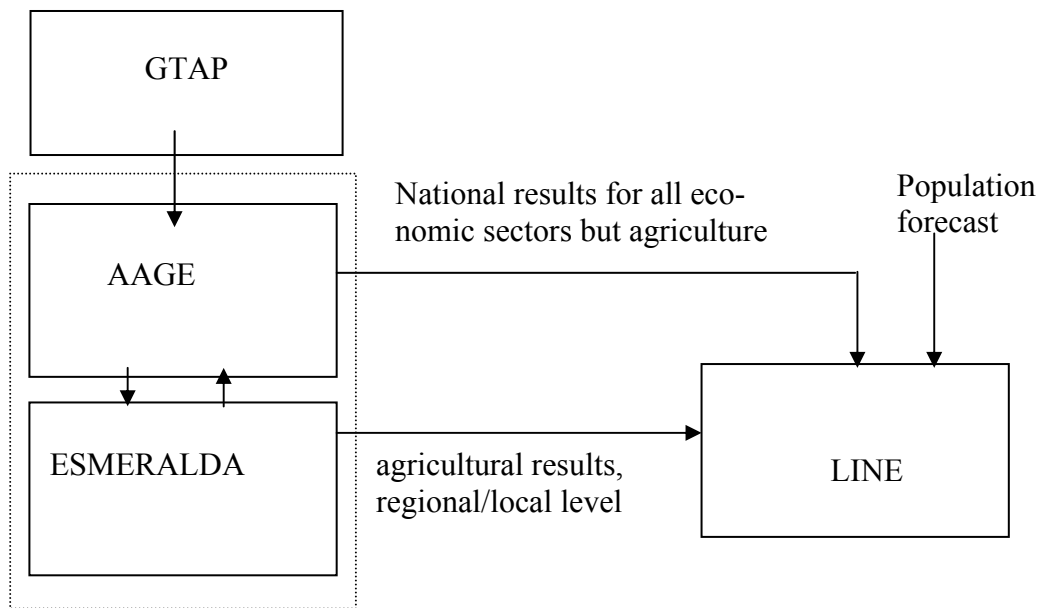


Figure 1. Model linkages

The firms' input demands are determined due to a CES-technology. All primary inputs (labour, capital and land) are assumed to be fully utilised. Thus, the model does not determine changes in e.g. employment – changes in the demand for labour are reflected in changes in real wage rates. The model's description of private consumption utilises the theory of utility maximizing households, where the distribution of total consumption is based on the linear expenditure system.

The term 'general' implies that 'everything depends on everything'. Compared with more partial model approaches, general equilibrium models are hence characterised by the fact that effects on one market affect the other markets and economic activities in one sector depend on and influence economic activities in other sectors.

Thus, in principle the model comprises the entire Danish economy, i.e. all markets and economic agents. The model is also characterised by equilibrium in all markets due to an assumption of perfectly flexible price and wage adjustments. These assumptions imply that the model assesses the long term effects of shocks to the economy, where all adjustment costs have been taken.

The AAGE model contains a description of a range of important instruments in the Common Agricultural Policy in the European Union. Thus, the milk production in AAGE is determined by the milk quota. Animal premiums in the cattle sector are also represented in the model. Hectare premiums to cereals, oilseeds and protein crops are modelled as subsidies to the remuneration of land.

As the AAGE model is not a projection model, the baseline of the model is based on the general macroeconomic development determined by other sources, including the globally oriented GTAP model, official long term projections, etc. From the GTAP model, AAGE uses changes in export and import prices facing Danish producers and consumers. From the official long term projections, levels of GDP and other macroeconomic variables are obtained and introduced to AAGE.

## ***2.2. ESMERALDA – An agricultural sector model***

ESMERALDA<sup>3</sup> describes production, input demands, land allocation, livestock density and various economic and environmentally relevant variables on representative 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 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 7 variable inputs in the short run. In the longer 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 representative Danish farms, and subsequently aggregate these farm level results to the relevant level or type of aggregation, e.g. the national, regional or municipality level or various typological farm aggregates. The economic behaviour at the 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).

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.

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. The regional economic model LINE***

LINE<sup>4</sup> is an interregional macroeconomic model for Danish municipalities. In the present version, LINE is used as a top-down and post-model with AAGE and ESMERALDA forming the framework for the calculations. The equilibrium in the regional economy is calculated on the basis of

- a) AAGE-forecast of the exogenous variables in LINE – making LINE a top-down model - and
- b) ESMERALDA results on the regional production in the agricultural sector determining production activity in the sector in LINE – making LINE a post model.

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<sup>3</sup> 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

<sup>4</sup> A comprehensive documentation of LINE can be found in Madsen et al (2001); this description serves as a brief introduction to the model and the version of LINE, which has been used in the present context.

On the basis of inputs from AAGE and ESMERALDA, LINE establishes an equilibrium in the commodity markets in each municipality and for each commodity. The equilibrium in the commodity markets is calculated in a number of round by round calculations with the regional demand-production model in LINE. After a sufficient number of rounds the demand and supply of each commodity are in balance and a solution is obtained. The round by round calculations with the demand-production model can be presented as a “real circle”.

The core of the real circle is the demand-production block in LINE. The demand-production block in LINE has two dimensions: a horizontal and a vertical dimension. The horizontal dimension include the spatial division of economic activities, which can be related to place of production, place of residence and place of demand.

For each of the three divisions respectively, 275 municipalities have been used in the present version of LINE. The vertical dimension refers to division of economic actors, which has been divided into social accounting matrix categories including sectors (12 sectors have been used), factors (educational groups have been used), household types (11 types of households have been used), demand components, and commodities (20 commodities have been used)

The real circle is basically a keynesian demand circle, where demand create production, which in turn create demand. A description of how the real circle runs in the present context is given in Hasler et al (2002).

#### ***2.4. The integrated model system: an overview***

The models are linked in a common framework in order to ensure maximum consistency in the results.

##### *The AAGE-ESMERALDA link*

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 in different municipalities.

##### *The AAGE/ESMERALDA – LINE link*

The AAGE/ESMERALDA system provides a set of mutually consistent results concerning a range of macro economic variables (gross output, gross value added, employment, private consumption, exports, imports etc.) at the national level, and a range of agricultural economic variables (gross output, gross value added, employment, input use, land use) at the local level. These results can be used as inputs to the LINE model for subsequent assessment of local economic consequences for production, income, employment etc. in individual municipalities.

In the construction of scenarios for the development in agricultural policies etc., the global general equilibrium model GTAP<sup>5</sup> has been applied. The GTAP model is capable of generating price

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<sup>5</sup> Global Trade Analysis Project – a global database and general equilibrium model with main focus on trade relations between different regions in the world. For more information, see e.g. Frandsen & Jensen (2000) and Hertel (1997)

data, at the world market as well as in Denmark, for given international economic assumption. Such price data are used as input to the other models.

In the modelling of the local economy with LINE, population forecasts from a population model developed by Statistics Denmark has been used.

### **3. The Baseline Scenario, 1995-2010: Scenario assumptions and results**

The future of Danish rural municipalities is expected to be affected by the general economic trends towards more emphasis on service and high-tech manufacturing industries and lower emphasis on primary industries (agriculture, fisheries etc.) and low-tech manufacturing. Despite the decreasing relative importance of agriculture, this sector still contributes significantly to the local economy in a large number of municipalities. Thus, the economy in such agricultural municipalities will be affected by changes in the economic conditions facing the agricultural sector.

The specific construction of the baseline scenario below builds on the general assumption that the future development in broad terms follows current trends. Such trends include

- trends in general macro economic and structural development,
- trends in the development within the agricultural sector, and
- trends in regional distribution of the macro- and agricultural economic development.

These trends are modified to the extent this is necessary, due to e.g. known changes in policies. Such policy changes include the Agenda 2000 reform and the impacts of the Danish Aquatic Environmental Action Plan introduced in 1998.

#### ***3.1. Baseline for the macroeconomic development***

The macro economic baseline describes a 15 year projection for production in individual sectors of the Danish economy – where the projection is conditional on a number of assumptions concerning the general economic growth, already known policy conditions (decided changes in agricultural and environmental policy), national and international market developments as well as ongoing trends in the Danish economy.

The baseline is based on a number of central assumptions, including the development in labour force, productivity and market conditions. A main element in the baseline scenario is the international production and market conditions, including the implementation of the Agenda 2000 reform of the Common Agricultural Policy. The reform implies changes on a number of crops and cattle products, changes in hectare and animal premiums and introduction of some new premiums. Danish Institute of Food Economics has assessed the perspectives for the Danish agricultural sector after Agenda 2000 using the GTAP model and the underlying database<sup>6</sup>. The GTAP projection takes into account the expected developments in population, productivity and income in different regions of the world until 2010.

Especially the price implications for Denmark, in terms of relevant import and export prices, but also the international demand for Danish products are interesting in the current context, as these are some of the major driving forces in the analysis. The GTAP analysis provides these price effects, where account has been taken for reform impacts on world market prices for various internationally traded products.

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<sup>6</sup> The analysis has been carried out by FØI for the so-called "Idégruppe" for the Minister of Food, Agriculture and Fisheries in 2000, cf. Frandsen & Jensen (2000)

In the scenario, economic growth<sup>7</sup> is mainly a result of the assumed growth in labour productivity. Capital grows by around 34 per cent – or 2 per cent per year. The growth in real investments follows the development in capital. The productivity growth implies an accumulated growth in GDP at some 37 per cent (2.1 per cent per year). The remuneration of land increases by almost 30 per cent in the baseline (corresponding to an annual growth rate at 1.7 per cent). Interpreting the GDP-deflator as an indicator for the growth in production costs, the growth in money wage corresponds to an accumulated growth in real wage expenses at almost 43 per cent (or 2.4 per cent per year). On the other hand, comparing the money wage with the development in consumer prices leads to an accumulated real wage growth at almost 38 per cent (corresponding to an annual increase at 2.2 per cent). For agriculture, the total increase in output can be accredited to increasing pig production. This is due to generally favourable conditions for export of pig meat, which has been determined in the international analyses. Hence, the baseline projection indicates annual growth rates at around 2 per cent for the most important real macro-economic indicators.

### ***3.2. National and regional agricultural development in the baseline***

The baseline concerning the developments in the agricultural sector is assumed to be affected by an exogenous national projection of the farm structure development, which subsequently is distributed regionally, using the ESMERALDA model. The exogenous projection is based on Strukturudvalget (1998), and it includes figures for the development in the number of farms, grouped according to acreage, as well as figures for the development in the number of cattle and pig farms, grouped according to herd size.

The number of farms is expected to fall from 69000 in 1995 to 41000 in 2010. Of the 41000 farms in 2008, around 17500 are expected to be full time farms. Along with the concentration of agricultural production on fewer farms, there is also an increasing concentration of livestock production on fewer herds. Hence, the projection expects reductions in the numbers of cattle and pig herds at 40-50 per cent during the considered time span, with reductions in the numbers of small and medium-sized herds, and increasing numbers of large herds.

In addition to the expected farm structure development, the market conditions including changes in prices and subsidies have implications for the agricultural baseline projection. The applied assumptions in that area are identical to the ones concerning the macro economic baseline projection, including the impacts of Agenda 2000. Furthermore, assumptions have been made concerning the environmental policy conditions, in order to represent the current environmental regulations. We focus on the livestock density restriction, the requirement for utilisation of nitrogen in animal manure and reduced fertilisation standards for the individual crops. As the farm structure exhibits a significant geographical variation, these conditions have different implications in different parts of the country.

Based on the assumptions a baseline projection has been made using ESMERALDA. The projection provides results for the aggregate distribution of land on various crops, numbers of animals in various livestock categories, as well as a number of economic variables.

Changes in relative crop prices imply changed competitiveness among various crops, and so does the development in farm structure. Hectare premiums to oilseeds decrease significantly as part of the Agenda 2000 reform. This is a major explanation to a significant reduction in rape area from 117000 ha to 56000 ha. Roughage areas exhibit a decrease as a consequence of sustaining existing milk quotas. Taking into account an increasing milk yield per cow, the number of cows decreases

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<sup>7</sup> A range of macroeconomic indicators is retrieved from Jacobsen (2001)

and hence the need for roughage area. The fallow area increases as a consequence of the development in farm structure. Hence, an increasing share of the farms will be subject to set-aside requirements. In aggregate, the cultivated area decreases slightly.

As indicated above, existing milk quotas are assumed to be maintained and continue to be binding, and the average milk yield per cow is assumed to increase, which leaves room for a decreasing number of dairy cows. A decrease in the number of dairy cows and related rearing cattle is observed. The production of slaughtering calves is related to the activity in the dairy cattle sector, and the number of suckling cows is connected to the number of fat calves. Thus, we observe a decrease in the numbers of these cattle categories as well.

In contrast to cattle production, pig production is not subject to quotas (however it should respect livestock density requirements). Thus, a considerable number of farms are able to increase the production of pigs, which increases by about one per cent per annum.

The outlined developments lead to a small increase in aggregate crop output value, despite an 8 per cent decrease in crop price level. One explanation for this is a growth in productivity and hence lower effective input prices. In addition, the transfer of land from roughage production (which is not included in the crop output) to cash crop production accounts for some of the increase in crop production.

An 11 per cent decrease in the value of livestock production at the national level is also a result of the baseline projection. Of this decrease, a major part stems from price reductions (20-35 per cent price decrease on cattle products and around 25 per cent price decreases on pig and poultry products), which are to some extent offset by a 17 per cent increase in the quantity produced, especially in the pig sector.

Total gross yield comprises yields from crop and livestock production, but also included economic yields from subsidies, e.g. hectare and cattle premiums. At the national level, this gross yield figure is projected to decrease by 8 per cent, which is less than the weighted average of the crop and livestock yield reductions, because some of the price reductions are compensated by increasing hectare and animal premiums in the Agenda 2000 reform.

The aggregate projected changes in the agricultural sector in the baseline as outlined above are not equally distributed across regions. The regional distribution of the development in production, distinguishing crop and livestock production, and total gross yield (including subsidies and other agricultural revenues) by county is also provided by the projection.

There appears to be differences in the crop production effects across counties. Thus, municipalities in some parts of Jutland and Bornholm exhibit decreases in crop production value, whereas crop output value from municipalities in the remaining regions increases.

There is also some regional diversity in the changes in livestock output value. A crucial determinant for the changes is the initial farm and production structure. In regions dominated by crop production (West Zealand and Storstrøm), the trend towards further specialisation in crop production continues, whereas in cattle-dominated regions, the output value in cattle production goes down due to the quota restrictions and price reductions. The sign of the output value effect on pig production depends on the balance between price decreases and quantity increases.

Total agricultural gross yield includes gross yields from crop and livestock production but also agricultural subsidies. As livestock production constitutes a major share of total gross yield in most regions, the regional pattern for total gross yield in broad terms follows that of livestock



production. Thus, cattle-dominated regions face the largest decrease in total agricultural gross yield, whereas less cattle-intensive regions face more moderate changes.

The impacts of changes in the economic conditions for agricultural production on agricultural gross profits and employment are also calculated. At the national level, agricultural profits are projected to decrease by 7 per cent in the projection period (or 0.5 per cent per annum), whereas the employment in primary agriculture decreases by 41 per cent (3.5 per cent per annum). The results show that in counties with large emphasis on especially cattle production, the total gross profit can be expected to go down, whereas in counties dominated by crop production, gross profits will increase due to increased productivity, which also leads to lower agricultural employment. A major driving force behind this productivity increase is the farm structure development.

It is possible to calculate results for other municipality groupings than regional groupings (counties). In Hasler et al (2002), results for groupings representing various concepts of rurality are presented. Comparing results from such municipality groups with the national average provides an opportunity to evaluate the relative impacts on agriculture in the considered municipality type.

### **3.3. Baseline for the regional economies**

Based on the above assumptions in AAGE and ESMERALDA concerning developments in prices and further market conditions, including environmental regulations, a baseline projection has been made using LINE. Output from AAGE and ESMERALDA has been used as exogenous variables in LINE as explained above.

The assessments of the regional economic effects are divided into gross output, gross domestic product GDP (at factor cost) and disposable income. While development in GDP and gross output reflects the regionally distributed effects on *place of production*, the effects on disposable income reflects the consequences for households distributed on *place of residence*.

The assumptions behind the baseline scenario are that demand for commodities reflects an increasing income level and increasing demand for a variety of products. Demand for food and for low manufactured commodities are expected to go down relatively, whereas demand for highly manufactured and "high tech" commodities and advanced services are expected to increase. Because production structure in rural areas is directed towards low manufactured commodities growth in production is expected to be lower compared to national average, whereas urban areas and especially the metropolitan area are expected to be markedly beyond average.

It is apparent from results, that the differences between counties and regions are remarkable, e.g. are the vulnerable municipalities (one of the municipality groupings used in Hasler et al (2002)) expected to have growth rates in GDP at 19% compared to the national average on 31 %. Also municipalities with a high share of production in agricultural sector ("agricultural municipalities") are expected to have relatively low growth rates on approximately 24%. Both GDP and gross output refers to the effects divided on place of production, and the differences in effects can partly be explained by the distribution of the agricultural effects.

From a place of residence point of view, the results are somewhat different. The effects on disposable income are more homogeneous within the regions than the effects on gross output and GDP. This can be explained as the result of the redistribution of economic growth, which takes place through the commuting system, where income earned in high growth municipalities are transferred to the surrounding residential municipalities.

However, the differences in growth are also notable from a place of residence point of view. Thus, the negative results for the rural areas regarding place of residence are not of the same relative magnitude as the differences from a place of production point of view.

#### **4. An environmental regulation scenario - uniform reduction in the livestock density requirement**

One of the main challenges for the environmental regulation of Danish agriculture is the non-point character of the emissions, the different environmental capacities in the regions because of heterogeneous natural conditions, as well as heterogeneity amongst farmers. Significant differences in the production, resources, and natural conditions of the individual farms form this heterogeneity, which influences the effectiveness and the costs of environmental regulation. The variations in natural conditions are important for the variation in environmental effectiveness and include, amongst other factors, differences in soil types. Focusing on livestock density requirements as an instrument to reducing nitrogen pollution, the environmental policy scenario models the effects of tightening the existing requirements to livestock density. As such regulation is more relevant for a future than a historic scenario, the analysis of the regulation is based upon the above baseline scenario.

##### ***4.1. Modelling the environmental policy scenario***

The scenario comprises computations of the distribution effects between regions by the application of both ESMERALDA and LINE and the linking of these models. The environmental policy scenario in this study involves modelling the sector and regional economic effects of a uniform reduction in the number of livestock units per hectare at the farm level, where livestock units are defined according to standard nitrogen contents in animal manure. Specifically, the maximum livestock density is assumed reduced by 23 per cent<sup>8</sup>.

As ESMERALDA builds on a large number of representative farms, it is possible to model the impacts of this regulation on different farm types, including farms with a high initial livestock density and farms with lower livestock densities. Hence, the average reduction in livestock density due to the regulation is presumed to be lower than the imposed 23 per cent.

##### ***4.2. Regional livestock density effects***

Regional effects of the regulation on livestock density are shown in table 1. The tightened livestock requirements emerging from the environmental policy sub-scenario lead to an average livestock density of 1.0 livestock units per hectare at the national level – corresponding to the aggregate level in 1995 – the base year. As the requirement is only binding on farms with livestock density on the limit or higher, the average reduction is lower than the 23 per cent mentioned above.

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<sup>8</sup> This seemingly awkward percentage stems from a comparative analysis between a geographically differentiated regulation with 15 per cent reduction on clay soil and 25 per cent reduction on sandy soil. As the major part of Danish livestock dense farms are located on clay soil, the effect of this regulation on aggregate livestock density corresponds to that of a uniform reduction of 23 per cent. (See Hasler et al., 2002)

Table 1. Regional livestock density (livestock units per hectare)

	1995 LU/ha	Projected baseline,		Livestock regulation	
		2010 LU/ha	2010 LU/ha	LU/ha	per cent change
Capital region	0.4	0.34	0.33	<b>0.0</b>	
West Zealand	0.6	0.43	0.42	<b>-3.9</b>	
Storstrøm	0.4	0.38	0.36	<b>-3.5</b>	
Bornholm	1.0	1.08	1.05	<b>-3.3</b>	
Funen	0.9	1.03	0.97	<b>-3.1</b>	
South Jutland	1.1	1.17	1.08	<b>-5.4</b>	
Ribe	1.1	1.24	1.19	<b>-7.6</b>	
Vejle	1.1	0.95	0.89	<b>-4.4</b>	
Ringkøbing	1.2	1.15	1.08	<b>-6.8</b>	
Århus	0.9	0.93	0.88	<b>-6.1</b>	
Viborg	1.3	1.41	1.31	<b>-9.3</b>	
North Jutland	1.1	1.26	1.20	<b>-6.8</b>	
Whole country	1.0	1.06	1.00	<b>-6.0</b>	

Notes: All livestock densities adjusted to reflect 1995 figures from DS (Statistics Denmark)

Percentage deviation from baseline in bold-face

Comparing the environmental policy sub-scenario with the baseline shows that the tightened restriction in the livestock density requirement result in an average decrease in livestock density of about 6 per cent. The largest differences (decreases) from the baseline to the environmental policy sub-scenario are found in Jutland (4.4 - 9.3 per cent) and the smallest differences (decreases) are found in Zealand and Bornholm (0 - 3.9 per cent) with Funen in an intermediary position. This merely reflects the regional distribution of livestock production in Denmark. Although the average livestock density at the national level in the regulated 2010 scenario corresponds to that in 1995 at the national level, this is not the case at the regional (or even the local) level. Livestock densities increase in some counties and decrease in others, compared with 1995. For example, the resulting livestock density will be lower than the 1995-level in Vejle and Ringkøbing counties, but higher in e.g. North Jutland and Ribe counties.

Taking the reductions in livestock density as a simple indicator of the environmental impact of the regulation, the largest relative environmental impact is observed in the most livestock dense western regions (the counties of Viborg, Ribe, Ringkøbing and North Jutland). These regions are also dominated by sandy soils. The lowest environmental impact is seen in the eastern regions, especially in the Capital region.

### ***4.3. Agricultural Gross Factor Income and Employment***

Consequences of the livestock density requirement for agricultural incomes and employment are shown in table 2.

Table 2. Regional agricultural gross factor income and employment effects of livestock density regulation

	Agricultural gross factor income				Farm employment			
	1995	Projected baseline	Livestock regulation	per cent change	1995	Projected baseline	Livestock regulation	per cent change
Capital region	828	1066	1057	<b>-0.8</b>	2640	1246	1240	<b>-0,5</b>
West Zealand	1638	1894	1879	<b>-0.8</b>	4876	2302	2288	<b>-0,6</b>
Storstrøm	2034	2639	2589	<b>-1.9</b>	5211	2214	2187	<b>-1.2</b>
Bornholm	333	268	260	<b>-2.9</b>	922	715	686	<b>-4.1</b>
Funen	2249	2216	2112	<b>-4.7</b>	6631	4069	3699	<b>-9.1</b>
South Jutland	2712	2427	2346	<b>-3.3</b>	8295	5426	5079	<b>-6.4</b>
Ribe	1696	1467	1424	<b>-2.9</b>	5979	3911	3778	<b>-3.4</b>
Vejle	1750	1513	1466	<b>-3.1</b>	5562	3038	2910	<b>-4.2</b>
Ringkøbing	2951	2374	2289	<b>-3.6</b>	9436	5536	5364	<b>-3.1</b>
Århus	2268	2084	1993	<b>-4.4</b>	7214	4239	4057	<b>-4.3</b>
Viborg	2272	1622	1578	<b>-2.7</b>	8253	4786	4600	<b>-3.9</b>
North Jutland	3344	3160	3075	<b>-2.7</b>	10940	7820	7585	<b>-3.0</b>
Whole country	24074	22270	21646	<b>-2.8</b>	75960	44564	43227	<b>-3.0</b>

Percentage deviations from baseline in bold-face

The reduction in the livestock density requirements as stipulated above leads to a relative reduction in total national agricultural production of 3 percent compared to the baseline projection. This is almost exclusively due to a reduction of 7.3 - 7.4 per cent in the value of livestock production relative to the baseline. As there is substantial regional variation in the impacts on livestock density, there is naturally also some regional variation in the economic impacts. The effects on agricultural Gross Factor Income compared to the baseline in the different regions vary from a reduction by some 0.8 per cent to a reduction by 4.7 per cent, resulting in a national average reduction of 2.8 per cent. As might be expected, the most significant reductions are observed in the livestock dense regions in Jutland.

The impacts of the environmental regulation on farm employment also differ between regions, in general following the same pattern as the effects on livestock density and Gross Factor Income. At the national level, a 3.6 reduction in farm employment is observed. Uniformly, the Eastern counties are very little affected by the imposition of more strict livestock requirements, whereas the significant effects on agricultural Gross Factor Income and employment of stricter environmental policy regulation are found in Jutland.

#### ***4.4. Regional economic of the livestock density regulation***

As demonstrated above, the environmental regulation has economic impacts on the farming sector. As a consequence, this will affect the regional and local economies directly, because farm income and employment is affected. Furthermore, the regulation has impacts on the regional economy through the derived effects on other sectors. As mentioned above the modelled restriction on livestock production is considered to be minor for the overall economy with only limited impacts on other economic sectors. However, one exception is the impact on processing industries related to agriculture, i.e. the slaughtering and dairy sectors. As milk production is assumed restricted by the milk quota in the baseline as well as the environmental regulation scenario, the regulation is not assumed to have any impact on the dairy sector. On the other hand, reduced livestock production has an impact on the activity in slaughtering, especially pig slaughtering, but also to some extent cattle slaughtering. In the results concerning regional economy below, these effects are taken into

account along with the direct effects on the farming sector, using the LINE model. The effects in terms of changes in gross output, GDP and disposable income are shown in table 3.

Table 3. Regional economic consequences of a uniform tightening of livestock density requirement.

per cent deviation from baseline	Gross output	GDP	Disposable income
Capital region	-0,09	-0,08	-0,03
West Zealand	-0,48	-0,22	-0,04
Storstrøm	-0,02	0,09	0,03
Bornholm	-0,63	-0,50	-0,14
Funen	-0,52	-0,36	-0,10
South Jutland	-1,31	-1,08	-0,29
Ribe	-0,97	-0,52	-0,13
Vejle	-0,74	-0,50	-0,14
Ringkøbing	-1,09	-0,76	-0,23
Århus	-0,63	-0,44	-0,11
Viborg	-1,19	-0,83	-0,25
North Jutland	-0,89	-0,55	-0,14
Whole country	-0,50	-0,33	-0,10

Almost all changes are negative, but relatively small, ranging between 0 and 1.4 per cent. Not surprisingly, agricultural regions (especially those with emphasis on livestock production) are most negatively influenced by the uniform restrictions on livestock density, regarding all three indicators (gross output, GDP and disposable income). From a place of residence point of view, i.e. disposable income, the regions are more modestly influenced. Still, however, agricultural areas are affected the most. Thus, negative effects on gross output are most significant in Jutland, whereas regions in the eastern part of the country are almost not influenced by the change in livestock density requirements. Again, this can of course be explained by low numbers of livestock units in these municipalities.

## 5. Concluding comments

This paper has demonstrated a combined model framework for analysing the effects of various changes in e.g. agricultural and environmental policies in a projection setting. The model framework combines three individual economic models and applies specifically designed linkage procedures in order to ensure maximum possible consistency in the model results. The specificities of the individual models and the linkages provides a useful opportunity of combining analyses of e.g. farm-level oriented environmental regulation with macro-economic analyses of overall economic mechanisms and trends, as well as the interrelations between agriculture and other industries at the regional and local levels.

Using the established model framework, a scenario for regulating the livestock density at the farm level has been considered. The analyses show that the regulation will have the largest impacts on agricultural production, profits and employment in regions dominated by sandy soils, i.e. western parts of Denmark, which are also the regions with highest emphasis on livestock production in the agricultural sector. This has major implications for agricultural profits and employment in these regions, but also derived effects on employment and incomes in agriculture-related industries. Looking at the overall economic impacts, the impacts on rural regions is around double of the national average (national GDP, according to workplace, decreases by some 0.33 per cent), as agricul-

ture has a relatively large emphasis in these regions – in municipalities, where agriculture plays a major role, the economic impact is around 2.5 times the national average. Disposable income (according to place of residence) is also affected relatively strong in rural municipalities, compared with the national average, presumably due to a relatively low extent of commuting related to agricultural production.

The results demonstrate some of the potential dilemmas, which may occur between rural development and environmental concerns, especially when the environmental concerns are related to agricultural activity. For example, the regions affected the most by the analysed environmental regulation are also the regions relatively dependent on agriculture. Although the municipalities in these regions are not the poorest regions in Denmark, they still have a general income level below the national average. From a partial perspective, the considered environmental policy regulation will make the economic catch-up in these regions more difficult.

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