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Impacts of policies to implement the EU Water Framework Directive on development strategies and income of typical pig farms in an intensively farmed region of Germany

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Impacts of policies to implement the EU Water Framework Directive on development strategies and income of typical pig farms in an intensively farmed region of Germany

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Abstract

Agriculture is to a large extent responsible for missing the objective of the EU Water Framework, a good condition of water bodies in Germany and other parts of Europe. In Germany, in order to reach this target in future, the Fertilization Ordinance will be amended. Economic instruments would be another option to improve water quality. Against this background, the study examines impacts of such policies on farm strategies and income for certain fictitious, but typical farms that can be seen as representative for the most common pig farm types in the Muensterland, an intensively farmed region in Germany. From a number of farm development strategies, a mixed integer linear programming model identifies the best individual strategy for each policy and the resulting investments, production changes and income effects. The model results confirm that water protection policies decrease potential future incomes of typical pig farms. A tightening of the Fertilization Ordinance by reducing the phosphorus balances that must not be exceeded by the farms significantly reduces future income compared to an unchanged Fertilization Ordinance. The same applies to the introduction of levies on nutrient surpluses – along the lines of the Dutch policy. Nevertheless, future development strategies of the farms stay mainly the same in all scenarios with different water protection policies: Farms increase stable capacity in all scenarios. Along with this growth, manure export increases as well as the number of animals per hectare on the farms.

Keywords: Fertilization Ordinance, levies, pig farms, mixed integer linear programming model, manure.

JEL classification: Q 18

1 Introduction

Agriculture is identified to be one of the most important polluters regarding the diffusion of nutrient discharge into German water bodies. Hence, agriculture is to a large extend responsible for missing the objective of the EU Water Framework Directive, a good condition of water bodies, in Germany as well as in North-Rhine-Westphalia (NRW) in 2015 (cp. MUNLV 2009). That is the reason why especially environmental groups advise a stronger restriction of fertilizing with nitrates and phosphorus than it is currently the case in Germany (cp. e.g. SRU 2004).

High regional nutrient balances and nutrient discharge can be observed especially in intensively farmed regions where a high cattle and/or pig density can be found (cp. BMU and BMELV 2012, p. 43, Haas et al. 2005). Such a region is the "Muensterland", which is located in North-Rhine-Westphalia. Such intensively farmed regions can also be found in other countries: The rising specialization and concentration in regions with favorable conditions on the one hand and the abandonment of cropping in non-favorable regions on the other hand is a phenomenon of an agriculture that opens evermore to the worldwide market (cp. e.g. WBA 2005, pp. 30). Therefore we find this development also in countries like France, Spain, Italy and England with their agrarian-intensive regions Brittany, Galicia, Lombardy, and North-West-England (cp. Pau Vall and Vidal 2011).

Against this background, it will get increasingly important to put in place policies that are on the one hand able to reduce environmental problems in such intensively farmed regions but on the other hand have as few costs as possible. Income losses of farms in such regions are an important part of these costs. Thus, the impacts of different possible policies on farm strategies and income have to be analyzed in order to assess different water protection policies.

Germany tries to reduce the pollution of water bodies by farms with the aid of the Fertilization Ordinance ("Duengeverordnung") but also with means of voluntary measures, i.e. Agri-Environmental Measures (AEM). In order to reach the objectives of the EU Water Framework Directive, the Fertilization Ordinance will be amended (cp. Bund-Laender-Arbeitsgruppe zur Evaluierung der Duengeverordnung 2012a). In the Netherlands farms had to pay levies for nutrient surpluses in the past (cp. e.g. Wegener and Theuvsen 2010, p. 17). The combination of all political instruments – that also comprised e.g. production quotas for pig and poultry and individual projects to improve nutrient management at farm level (cp. OECD 2007, pp. 40) - resulted in a strong reduction of nutrient surpluses in the Netherlands (cp. Baumann et al. 2012, p. 58).

From a resource economic point of view, economic instruments like levies are supposed to be more efficient than regulatory law (cp. e.g. SRU 2004, pp. 219; Gawel et al. 2011, S. 235): The idea is that polluters with relatively low abatement costs avoid more pollution whereas polluters with very high abatement costs e.g. prefer to pay a levy and reduce less. A specific abatement attainment can potentially be reached at lower costs compared to regulatory law that demands the same abatement attainment by every polluter, as the Fertilization Ordinance does (cp. Endres 2007, pp. 124).

Pig farms in the region “Muensterland” are particularly concerned by the requirements of the Fertilization Ordinance: In previous years, many of them have increased their stable capacities. They have to consider the existing limitations of manure disposal according to the Fertilization Ordinance in their development strategies. Especially concerning the phosphorus balance, many farms already produce an averaged amount of manure of more than 20 kg P_2O_5 / ha. As the Fertilization Ordinance limits the fertilization with phosphorus to 20 kg P_2O_5/ha, they cannot spread all of their manure to their own fields but have to export manure to other farms. If they invest in further stable capacities, they will have to export more manure or rent more land. According to the fertilizer Ordinance they get the building permission only if they either account for enough “manure land” themselves or if they can show up certificates as proof of contracts with other farms about manure export (§ 42 Abs. 2 S. 1 NBauO[1]) Thus, they have to consider either high manure export costs or very high local rental rates within their investment calculations. Stricter limitations of fertilization would certainly increase these already high costs. Pig farms in the region "Muensterland", which are already highly affected by the Fertilization Ordinance, will certainly be even more concerned by a tightening of this instrument and also by alternative water protection policies.

Against this background, the main research objective of this study is to analyze farm development strategies which certain typical pig farms in the region "Muensterland" put in place under different water protection policy scenarios. This includes consequences on investments, production and farm income. They were derived by a single farm model that was continuously discussed with a panel of experts from farms and extension services (see below) .The three analyzed scenarios are the reference scenario, meaning an unchanged Fertilization Ordinance, and the two alternative scenarios: a tightening of the existing Fertilization Ordinance as well as an introduction of levies on nutrient surpluses.

The following sections describe the methodology that is used in the study: Section 2 introduces the model that is developed to elaborate different water protection policies; section 3 describes the used data and analyzed scenarios. Section 4 shows the model results. Finally, in section 5 the results are discussed and conclusions concerning the impacts of different water protection policies on development and fertilizing strategies and income of pig farms in the region "Muensterland" are drawn. This also allows several conclusions concerning the effectiveness of the different analyzed policy instruments.

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1 Here, we refer only to the Fertilizer Ordinance. In September 2013 a novel of the Federal Building Code ("Baugesetzbuch") which affects big commercial stables with little fodder production, entered into force. We decided to discuss this separately (see section 5.1) in order to contrast it with the impacts of the fertilizer ordinance and levies.

2 The model

Impacts of different political instruments can be analyzed on the sectoral and/or macroeconomic or farm level. Partial or general equilibrium models and regional models allow the analysis of sectoral and regional impacts. But they do not allow studying impacts on single farms or on specific groups of farms, which is one of our main interests. This is possible with models on the farm level. The disadvantage of such models is that they depend on exogenous prices of products and factors that are endogenous in aggregated models (vgl. DEITMER 2006, p.29).

The decision for a specific type of model also depends on the political instrument that should be analyzed. Political instruments that have very farm specific effects can hardly be analyzed by aggregated models, here models on farm level are preferable (cp. BALMANN et al. 1998, p.223). On the one hand, this study analyzes impacts of instruments like the Fertilization Ordinance, which have farm specific effects. On the other hand it focuses on very specific groups of farms (hog finishing farms, piglet breeding farms and pig farms with a closed system in the region “Muensterland”). This is the reason why we use a single farm model.

Apart from the question of aggregation level, it has to be decided how time should be considered in the model. Steverink et al (1994) used a static LP model to investigate the impacts of environmental policies on cattle breeding goals of one dairy farm.

But the static analysis ignores the development of farms over time. Neither does the comparative-static analysis, which compares two static equilibriums (cp. Gabler Wirtschaftslexikon) show how farms develop over time when past decisions influence future development possibilities. This is only possible by dynamic models. Accounting for these path-dependencies is very important whenever investment decisions will impact future periods’ outcome, which surely is the case when pig farms might grow.

Generally, the consideration of time raises the complexity of models enormously. This is the reason, why models that consider the interactions between farms (like partial/general equilibrium or regional models) and therefore already have a high complexity, are mostly comparative-static.

In order to simulate reactions and development strategies of pig farms in greater detail under different politic scenarios and to show their development over a whole period by regarding path dependencies, a dynamic programming single farm model is used in this study (cp. Steffen and Born 1987, pp. 278; Mailitius 1996, p. 179f).

The model uses a mixed integer linear programming approach to integrate binary variables as it would not make sense to model e. g. continuous number of hog places for new stables. The farm is a portfolio of production activities (cp. Hardaker et al. 2004, p.145) which the farm manager optimizes in such a way that the farm income becomes maximal. The dynamic model optimizes farm activities simultaneously over all periods. This results in optimal adoption pathways to changing external variables. It is assumed that the decision maker knows in advance the development of all external variables e.g. prices. As perfect information is assumed, the results have a normative character and show how farm managers should react to changes in external variables in order to maximize their income (cp. Keusch 2001, p. 11).

Lengers and Britz (2012) developed such a model, called DAIRYDYN, to analyze costs of dairy farms reducing greenhouse gas emissions. The basic structures of DAIRYDYN were transferred to the hog sector and adopted to the problem statement of this research. Beside the required changes in the model in order to account for totally different operation flows in a hog instead of a dairy farm the model is extended by a phosphorus balance, respective restrictions, and the possibility to export manure and to rent land, among others.

The fully informed, risk neutral and rational decision maker schedules the production and investment program at the beginning of the projection period 2012 till 2025 in such a way that the net present value of expected profits is maximal. He has to maintain a positive cash balance, but can also take up credits which have to be paid back at the end of the optimization horizon (cp. Lengers and Britz 2012, p.

122). The optimization horizon ends at the end of the usage lifetime cycle of the stables that are built during the projection period. This allows to model investment decisions which are not influenced by the liquidation of the farm at the end of the optimization period. Between the end of the projection period and the end of the optimization period prices, costs and performance parameters are assumed to be constant.

2.1 *Animal production*

The modeled animal production processes are breeding piglets and fattening hogs. In the typical piglet breeding farm, the piglets are sold when they reach a weight of 25 to 30 kg. The typical combined farm first breeds the piglets and then fattens them (closed system), but it can also decide to sell them. The typical hog finishing farm buys young pigs and fattens them. Typical performance data, labor requirements, manure excretions and costs of the productions processes and also the selling weights were obtained by means of discussions with the experts within the panels.

As sows live longer than one year, decisions on the sow herd in one year have consequences on the sow herd of following years. Sows reaching their maximal age need to be slaughtered. Additional slaughter is possible to reduce the herd size. Young sows can be bought to recruit the herd. Sows give birth to piglets according to the defined performance. In the combined farm the number of raised piglets - and in the hog finishing farm the number of bought young pigs - minus the losses during fattening gives the number of slaughtered hogs.

2.2 *Feeding*

Fodder can either be produced or bought. To guarantee that the pigs get enough minerals and protein, a minimal fraction of soya meal and mineral fodder is defined which can only be bought. These fractions are defined according to fodder ratios used in reality for sows, piglets and hogs considering the different fodder phases (cp. Kirchgeßner et al. 2011, pp. 239; LWK NRW 2010). The fodder quantities per pig result also from the panel discussions.

The model assumes a three-phase feeding. It furthermore assumes a phosphor reduced fodder ratio.

2.3 *Cropping*

As the model focuses on pig production, the plant production is depicted very roughly: modeled farms can only choose to grow grain (barley, wheat, and triticale) and corn which are the typical grown cultures, following the experts. Corn cultivation is restricted to 50% of the crop rotation (cp. LWK NRW 2012c, p. 1). Requirements to labor, machines as well as yields, costs and prices are taken from KTBL (2010). The produced amount of grain and corn is used as fodder. The surplus can be sold.

2.4 *Nutrient balances and fertilization*

Nutrients out of mineral fertilizer and manure contribute to the nutrient balance whereas nutrient removal through harvest as well as manure export reduces phosphorus and nitrogen balances. Nitrate out of manure is reduced by gaseous N-losses. Fertilizing with mineral and organic fertilizer has to fulfill the nutrient requirements of the plants but should not significantly exceed the demand: the Fertilization Ordinance restricts the nutrient surpluses. It allows a nitrogen balance of 60 kg N/ha and phosphorus balance of 20 kg P_2O_5/ ha in average of the farm's hectares and over several years. Furthermore nitrogen out of manure should not exceed 170 kg N/ha/a. Fertilizing with manure or other mineral fertilizer containing N is forbidden from 1th November till end of January on arable land. These restrictions are implemented in the model.

2.5 *Capacity, investments and financing*

In the initial situation the modeled farms have specific equipments of stables and manure reservoirs. This equipment was discussed in advance with the farm consultants within the panels. Investment decisions over different stable types (for sows, piglets and fatteners) in different sizes can be made every second year. Thereby, the number of binary variables is kept at a manageable size (cp. Lengers und Britz 2012, p. 125). The mentioned investments allow farmers to build up new herd capacities or to replace old stables. They can also decide to build up more manure reservoirs or to replace old ones. Stables and manure reservoirs cannot be sold. The value of sellable technical equipment compensates for their demolition costs at the end of their usage lifetime (cp. Lengers und Britz 2012, p. 126).

Investments can be financed from accumulated cash or credits. Credits are distinguished by interest rate and pay-back time. Accumulated cash gives interest (cp. Lengers und Britz 2012, p. 126).

2.6 *Labour, land and manure export*

Beside the family employees that are on hand at the typical farms in the initial situation, they can hire an apprentice and a further external employee. The farms have initial equipments of own and rented hectares. Annually they can decide to rent more or less land. Land is needed for cropping but also to apply manure. If not all manure can be spread to the farm’s land without valuating the restrictions of the Fertilization Ordinance, it has to be exported. Manure export is costly (cp. chapter 3).

3 Data scenarios

In order to analyze the effects of different water protection policies on pig farms, data from “typical” farms are used. Many characteristica of these typical farms were obtained within a panel process, in which per panel two to four consultants as well as a group of eight farm managers of pig keeping farms in the region “Muensterland” took part. The data basis was then complemented with, statistical and engineering-data (cp. LWK NRW 2012, KTBL 2010, LWK NRW 2011 a+b). Compared to the concept of representative or average farms, “typical” farms are also orientated on real farms in a region but they do not depict all details of them.

Advantages of using the concept of typical farms compared to that of average farms are especially that the panel process generates data that can incorporate the newest developments in great detail. Moreover, variables (like e.g. the age of existing stables) can be used that cannot be seen within any statistic (cp. Hemme 2000, pp.19). The panel process allows a plausibility check of the received data so that the modeled farms and farm reactions are very realistic and untypical production processes can be eliminated (cp. Farwick and Krämer 2008, pp. 2). Our panel process is an iterative process and combines the methods that are used by Hemme (2000, pp. 20), Deitmer (2006, pp. 33) and Farwick and Berg (2011, pp. 63) .

The region “Muensterland” can be divided into the two regions “Westmuensterland” and “Muensterland Nord-Ost”. The situation in both regions is slightly different, especially concerning the land market and the pig and animal density, and different extension services give advice to the pig farms. Against this background typical farms were identified for each region. Some farms work in a closed system, in which piglets are raised and then fattened. But most farms specialize either in piglet breeding or in hog finishing. Therefore, three typical farms were described for each of these systems in each of the two regions.

The typical hog finishing farm in “Westmuensterland” is for example representing an important part of the hog finishing farms in a region with a high cattle and pig density as concerns size, husbandry system, labor endowment, fodder, crops and production technology (cp. Deitmer 2006, p. 3). This essay shows exemplarily the results for three of the six typical farms. Thus, table 1 shows the most important figures of the typical hog finishing farm in the region “Westmuensterland” and that of the typical piglet breeding farm and the typical closed system in the region “Muensterland-Nordost”. The size of all farms exceeds the statistical average (cp. it.NRW 2012) as the statistic contains also e.g. part-time farms that are not in the focus of this study.

Table 1: Main characteristic of three typical farms in the region “Muensterland”

Criterion	*Unit*	*Hog finishing farm*	*Piglet breeding farm*	*Closed System*
Stable capacity				
Hog	Places	2300	0	1000
Sow	Places	0	270	120
Remaining use time of the stables including production technology	Years	12	9	9
Agricultural land	ha	80	42,5	60
Arable land	ha	80	42,5	60
Grassland	ha	0	0	0
Proportion of Rented land	%	50	50	67
Rental rate				
Within “new” contracts	€	950	800	800
Within “old” contracts	€	550	400	400
Proportion of specific crops in the crop rotation				
Grain (wheat, barley, triticale, rye)	%	50	60	60
Corn	%	50	40	40
Labor endowment	FTE*	1,5	1,5	1,2
Capacity of external manure reservoirs	m^3	1700	500	800

Source: Own calculation and illustration.

“Muensterland” is the hot spot of pork production within North Rhine-Westphalia (NRW) and one of the two hot spots in Germany: about one quarter of all German pigs are raised in NRW (own calculations according to Statistisches Bundesamt 2012, p. 21). The pig farms in the region “Muensterland” raise 58% of all pigs in NRW. These are 1.2 million piglets, 0.3 million sows and 2.4 million hogs (own calculations according to it.NRW 2011a, p. 16). Thus, the farms identified to be typical for that region represent a high number of pig farms and pigs in NRW and Germany.

One caveat in the use of typical farms as described by the extension officers is that they are very often more successful than the average. Especially farms that are planning to quit the business do not make use of consultation offers. They are therefore not represented by the “typical farms” in this study. Therefore, with our approach we can show how certain farms in the region will react to different policies, but we cannot say anything about changes of e. g. farm structure or the overall number of pigs in the region. We will come back to limitations of the study result in the discussion section.

According to the Common Agricultural Policy (CAP), it was assumed in all scenarios that the proposal of the European Commission (EC), which the EC released in November 2011, will be implemented. In other words from 2013 on, 7 % of the arable land of the pig keeping farms cannot be used for the disposal of manure or the production of grain or corn. Under that condition the farms receive direct payments as a regional uniformed premium minus the modulation. Also the claim of the EC to stick to a trinominal crop rotation is considered (cp. chapter 3). The ban of changing grassland to arable land is not considered separately as the farms only use arable land (cp. table 1).

In all scenarios the forecasts of FAPRI-ISU (2011) concerning the developments of prices of pork, piglets and fodder were assumed. These are trends that are projected for the whole world market. As pork is a worldwide traded commodity, it makes sense to take such worldwide price trends. The price for piglets follows the pork price in the long run. Therefore for piglet prices the same trends as for pork prices were put into the model. For the development of fodder prices, the prognosis for the wheat price, which can be seen as leading price for grain, is used. This is also a price that is built at the world market. This is the reason why the prognosis by FAPRI-ISU (2011) for worldwide trends are also a reasonable assumption for the development of fodder prices. We assume that farmers are also orienting their expectations at these forecasts.

The forecasts assume a strong increase in pork prices and a much lesser increase in fodder prices.

The assumed developments of performance and further cost parameters base partly on the forecasts of the experts. Additional assumptions concerning e.g. private expenditure are a result of the analysis of the results of bookkeeping pig farms (cp. LWK NRW 2012) and of KTBL (cp. KTBL 2010). For these variables it is more reasonable to take these "local" data. For example, the development of performance parameters can better be projected by analyzing past trends in bookkeeping data or by the discussion of projections with local experts than by taking worldwide trends. The same is true for prices that are built at local markets like rental rates for land and export costs for manure. The first is a result of developments on the local land market. The last is the outcome of demand and supply at the so called "nutrient stock" ("Naehrstoffboerse") in North Rhine-Westphalia.

The discussions within the panels furthermore allow us to account for feedback mechanisms. These mechanisms take place on the one hand at the land market and on the other hand on the market for manure exports ("Nährstoffbörse"). They cannot be captured within the single farm models used in our analysis, but are, of course, very important for farm developments. This is the reason why the developments on these two local markets were discussed in great detail and for every scenario with the local experts. Within these discussions past trends resulting from analyses of bookkeeping results and other statistical information (cp. e.g. LWK NRW 2012) were taken into account as well. Furthermore structural circumstances were discussed intensively. Moreover, the discussions were taken up again after having the results of the model calculations. If the experts judged that certain strategy that came out of the model would change the assumed prices for land and manure exports, the relevant external parameters were changed in the model and the calculations were repeated. By this iterative panel process, the resulted trends on the land market and on the market for manure exports could be captured in the model.

We do not have to account for any feedbacks to the prices for pork, piglets and fodder. As it was already mentioned, these prices are built at the worldwide market. It can be assumed that the influence of the developments of the farms in the region “Muensterland” on worldwide prices will be too small to make any difference and therefore can be disregarded.

The reference scenario (=scenario 1) assumes the continuation and full implementation of the Fertilization Ordinance as it is at the moment, mainly related to the following contents (cp. BGBl 2007):

- “The amount of livestock manure applied in any year to agriculturally used land on a holding, together with that deposited to land by livestock, must not exceed 170 kg of nitrogen per hectare.” (BMU 2012, p. 44)
- Application of fertilizers to arable land is prohibited from 1th of November till 31th of January (cp. BMU 2012, p. 43).
- The N area balance, calculated as the average input/output per hectare of the three preceding years, must not exceed 60 kg/ha.
- The P_2O_5 area balance, calculated as the average input/output per hectare of the six preceding years, must not exceed 20 kg / ha per year (cp. BMU 2012, p. 44).

Already in the reference scenario it is assumed that the costs which have to be paid for the manure export (per cubic meter manure exported to other farms) increase yearly. The discussions within the panel process showed that the amount of manure that is exported from farms in this regions to farms in other regions increased heavily in the past. The experts assume that this will be continuing in the future. If the overall amount to be exported out of this region will increase, also the cost per cubic meter of exported manure will increase. This is due to the following relation: The higher the amount of manure that has to be exported to other farms, the harder it is to find a farm within the region that still has capacity to absorb “foreign” manure. As the so called “Verordnung über das Inverkehrbringen und Befördern von Wirtschaftsdünger“ - that was put in place at the 21.07.2010 - forces the farms to report the amounts of manure export, the compliance to the Fertilization

Ordinance is surveyed also on farms that import manure. To find farms that can absorb foreign manure and still show compliance to the Fertilization Ordinance, the distribution radius has to raise with increasing export amounts. Therefore the transport distances as well as transport costs rise. The yearly cost increase, projected within the panel process, is 30 Cent per cubic meter manure in the region “Muensterland Nord-Ost” and 60 Cent for hog finishing farms in the region “Westmuensterland”, starting with 7 € per cubic meter in both regions at the beginning of 2012. The reason for the higher increase in “Westmuensterland” is that already today the animal density is higher there than in the region “Muensterland Nordost”. Therefore the regional phosphorus balance is very high in “Westmuensterland”. For example the county “Borken” has the highest regional phosphorus balance in whole North Rhine-Westphalia (cp. Jacobs 2011, LAURENZ 2006, p. 5., DMK 2012). Furthermore the region directly borders to the Netherlands, from where a lot of manure is coming in the region, which probably won`t change in the future.

Scenario 2 assumes a tightening of the Fertilization Ordinance. One central demand of the German Advisory Council concerning Fertilizing (Wissenschaftlicher Beirat fuer Duengungsfragen 2009, 2011) and other environmental associations and scientific councils (cp. among others SRU 2004, p. 218; Wissenschaftlicher Beirat Bodenschutz des BMELV 2000, p. 66) was the reduction of phosphorus balances on soils that are already saturated with phosphorus. In the same line, the working group which the German Federal Ministry of Food, Agriculture and Consumer Protection constructed to work out proposals for an amendment of the Fertilization Ordinance, advises to reduce the maximum phosphorus balance to zero on such soils (cp. Bund-Länder-Arbeitsgruppe zur Evaluierung der Duengeverordnung 2012). That would affect most soils in the region “Muensterland” (cp. e.g. Haas et al. 2005).

Therefore, in the alternate scenario (=scenario 2) it is assumed that the P_2O_5-balance must not exceed 0 kg/ha/year per farm. This also means a strong reduction in the N balance, as most nitrate fertilizer in pig keeping farms is manure with a given relation of P_2O_5 and N.

The rest of the standards of the Fertilization Ordinance are the same in scenario 2 as in scenario 1.

As a consequence of the reduction in the phosphorus balance in scenario 2, it is assumed that the amount of manure exports out of the region increases compared to the reference scenario. The panel experts assume that this would also lead to a stronger increase in the cost of manure export. As a consequence in scenario 2 the yearly increase is not 30 but 75 Cent per cubic meter manure in the region "Muensterland Nordost". In the region "Westmuensterland" the yearly increase is assumed to be 1 Euro instead of 75 Cent per cubic meter manure for hog finishing farms.

In contrast, it is assumed that the rental rates increase in the same way as they do in the reference scenario: according to the experts, pig farms will export more manure instead of renting more land if they have to keep this new lower limit.

The third scenario (scenario 3) models the introduction of levies for nutrient surpluses, as it was done within the so called MINAS (MINerals Accounting System) in the Netherlands between 1998 and 2005: the levy amounted to 2.30 € per kg N-surplus and 9.10 € per kg P_2O_5-surplus (cp. Wegener and Theuvsen 2010, p. 17). The OECD criticized that within the MINAS high levy-free surpluses were possible. Only if the surpluses lay above these borders, the farms had to pay levies. The OECD judged that without those levy-free surpluses the instrument would have worked much better (cp. OECD 2007, p. 49; and also SRU 2008, p. 470). That is why the scenario 3 introduces levies for each kilogram of surplus.

The impacts of levies for nutrient surpluses are analyzed by creating three different scenario variations: scenario 3a models the introduction of such levies (the same rate as in the Dutch case) that subsist parallel to the already existing limitations of the Fertilization Ordinance. Among others, the limitation of the allowed nutrient surpluses stays the same as in the reference scenario. The farms can decide to produce surpluses until they reach the limits of the Fertilization Ordinance, but have to pay levies for these surpluses. Or, in the other extreme, they reduce their surpluses and consequently their payments to zero. The second strategy would certainly lead to higher manure export costs or higher costs for renting land.

If all farms in the region "Muensterland" had to pay levies for nutrient surpluses, the incentive to export manure would increase in the same way as in scenario 2. That is why the scenario models the same increase in costs as in scenario 2.

The second variation of scenario 3 models the introduction of levies that replace the limits of N and P_2O_5 surpluses in the Fertilization Ordinance, but it keeps the regulation of manure application (170 kg N/ha).

Farmers' response to these levies will impact manure export costs. If for most farms it is worthwhile to pay the levies instead of increasing the manure export (assuming constant land endowment) the export costs per cubic meter manure in the region would stay the same as in the reference scenario. This is what scenario 3b models.

But it could also be the case that many farms in the region decide to export more manure compared to the reference scenario. In that case the increase in costs per cubic meter manure will be higher than in the reference scenario. This is why scenario 3c assumes the same development of manure costs per cubic meter than in scenario 2.

If the model results show that in scenario 3b the farms increase their manure exports, export costs per cubic meter manure cannot stay constant and scenario 3c is more realistic. In this way we account for feedbacks on farmers' decisions on export costs.

Production quotas are a further instrument to reduce phosphorus balances. For example in the Netherlands, production quotas should regulate the regional occurrence of phosphorus out of animal production. Therefore Garbert (2013) investigated the impacts of such quotas on development and fertilizer strategies of typical pig farms in the region Muensterland by using average Dutch quota prices in 2010. But as the only way to implement quotas in our single farm model is by assumptions on quota prices, there is, in principle, no difference between quota and prices. This is the reason why in this article we concentrate on the effects of levies.

4 Results

Table 2 shows important results of the model computations for three typical farm types and all scenarios.

The hog finishing farm adapts its production program to the changes concerning production costs in all scenarios that assume higher export costs per cubic meter manure (Sc 2, 3a and 3c). There the increase in production capacity takes place later than in scenario 1 and 3b. Overall fattening places increase from 2300 places in the initial situation to at the end 6900 in scenario 1 and 3b and 6800 places in the other scenarios. This also demands more manpower. The piglet breeding farm has the same production program in all scenarios. The sow places increase from 270 in 2011 to 420 from the year 2016 on. The farm which produces in a more or less closed system also has the same production program in all scenarios. The combined farm increases the fattening places from 1200 to 2500 and the sow places from 120 to 300 places. After this investment in the year 2020, the farm starts to sell between 30 and 120 piglets per year. Besides their family employees all farms have to hire extra employees (cp. table 2).

In spite of the relatively strong increase in the number of animals in all farms, no farm raises the number of hectares in the same way. The number of animals per hectare increases. As a result the manure export rises as well per animal as overall in all farms over the time. Considering the very high rental prices the manure export seems to be the better alternative. However, an increase in manure export also raises the costs out of manure disposal per animal, but this does not greatly influence the development strategies. This model result was discussed with the experts and considered plausible.

Table 2: Main characteristics of the development strategies of the typical hog finishing farm

	Sc1	*Sc 3b*	*Sc2*	*Sc 3a*	*Sc 3c*
Fattening Places	2300 → 4300 (2015) → 6900 (2020)		2300 → 4300 (2015) → 5800 (2020) → 6800 (2025)		
Land (in ha)	80, till 2020: 58		80, till 2020: 70		
Labour (in FTE)	1,5 → 2 (2015) → 3 (2020)		1,5 → 2 (2015) → 2,5 (2020) → 3 (2025)		
Average P_2O_2 balance (kg/ha)	20	0	0	0 2025:20	0 2025: up to 87

Source: Own calculation and illustration.

Table 3: Main characteristics of the development strategies of the typical piglet breeding farm

	Sc1	*All other scenarios*
Sow Places	270 → 420 (2016)	
Land (in ha)	42 – 50	
Labour (in FTE)	1,5 → 2,5 (2016)	
Average P_2O_2 balance (kg/ha)	20	0

Source: Own calculation and illustration.

Table 4: Main characteristics of the development strategies of the typical "closed system"

	Sc1	*All other scenarios*
Sow Places	120 → 300 (2020)	
Fattening Places	1200 → 2500 (2020)	
Land (in ha)	60 – 63	62 – 75
Labour (in FTE)	1,3 → 2,8 (2020)	
Average P_2O_2 balance (kg/ha)	20	0

Source: Own calculation and illustration.

Table 2 also shows an important result concerning the relevance of scenario 3b: it can be observed, that all farms prefer to reduce their phosphorus balances to zero and avoid any levy. This is achieved – as the model results show – by increasing the manure export. Therefore, scenario 3b (unchanged export costs) is not a valid scenario and will not be considered anymore.

Figures 1 to 3 show that the costs of manure disposal increase in all farms after the investments in stable inventory: In each figure the uppermost graph depicts the farm`s income ignoring costs of manure disposal as well as fertilizer value of manure in the reference scenario. The graph directly below (in each figure) displays the income in the reference scenario if these positions are considered.

Due to the assumed increase in the price spread between pork/piglets and fodder income rises over time in all farms. This effect is enhanced by the increasing number of pigs per farm.

In the first years of the projection period, the typical farms cannot realize positive operating incomes, even in the reference scenario. This means that own production factors like family employees, own land and capital are not fully paid. For example, family employees do not earn the market-based wage of 15 € per working hour. Nevertheless, the typical farms do not give up production, but even increase production capacity, as we assume full-informed decision-takers, who know that e.g. price trends are positive and the investments will pay off.

If all costs of manure are considered, this reduces operating income per pig of the hog finishing farm in 2025 by about 5 € in scenario 1. Based on the higher animal density at the farm and an extreme increase in the number of pigs on the one hand and the increase in manure export costs per cubic meter of manure on the other hand these costs increase extremely from about 6 500 € in 2012 to about 100 000 € per year in 2025 (cp. figure 1).

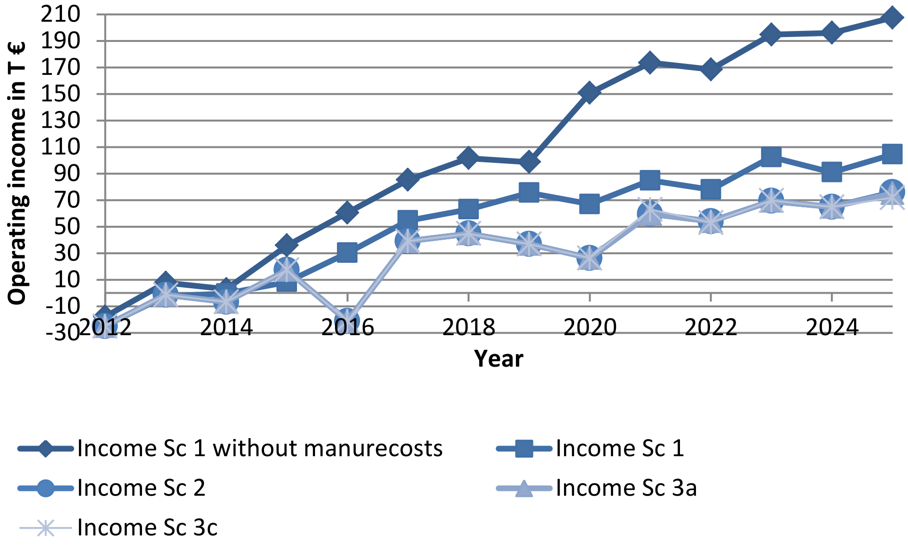
The income in each year depends not only on the prices but also heavily on the amount of manure exported in each year. In all scenarios except the reference scenario, the amount of manure exported sometimes changes between two years, for example between the year 2015 and 2016 (and 2024 and 2025 in the scenario 3c, cp. figure 1). But the resulting change in operating income should not be over-interpreted: In the model, it is implemented that all reservoirs have to be depleted at least to 80% once a year in spring. Such fluctuation can only be reached by filling up all manure reservoirs until the end of one year, which means that in the year before or the following year the reservoirs would have to be depleted not only once but two or three times. In reality such strategies usually do not exist. Therefore, in reality, the amounts will not vary that much between the years.

Taking manure costs into consideration the operating income of the hog finishing farm declines significantly in all scenarios that assume higher export costs per cubic meter manure than in the reference scenario. Due to these higher export costs, it is worthwhile for the farm to rent more land in order to avoid more exports compared to the reference scenario (cp. table 2).

Despite of these higher and over time rising costs, the farm decides most of the time to avoid any levies by producing zero nutrient surpluses in scenario 3a and 3c. Therefore farm incomes equal that in scenario 2. The levies seem to be higher than the relative export costs per kg phosphate in the manure. Only in the last year of the projection period the situation changes in the scenarios: due to the extreme rise in export costs per cubic meter manure, it is worthwhile for the farm to avoid as much manure exports as possible and to pay levies instead. This results in a very high P_2O_5-surplus in scenario 3c and a surplus of 20 kg/ha in scenario 3a, which is the maximum value that is supposed to be allowed in this scenario (cp. table 2).

In scenario 2, 3a and 3c, resulting from a tighter regulation or respective levies farms income is reduced by something between 25 000 and 30 000 € per year after the first investment.

Figure 1: Development of operating income from fattening hogs in the typical hog finishing farm

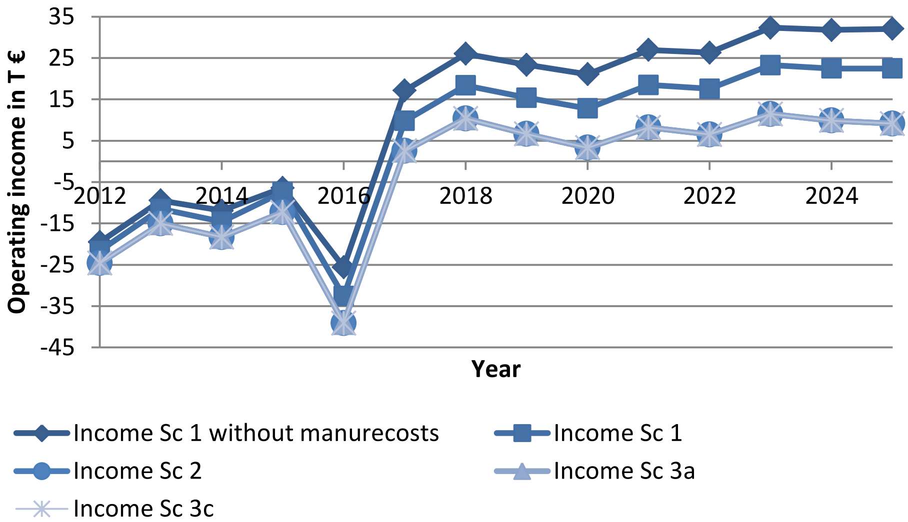


Source: Own illustration.

In the piglet breeding farm manure export costs are also higher than the fertilizer value of manure. Considering these costs - in the years before the investment - the operating income per sow reduces in the reference scenario about 8 €. After investing into higher stable capacity until the end of the projection period this difference increases up to 23 € per sow. The accumulated costs for the farm can be observed in figure 2. It can also be seen that production factors are not fully rewarded before 2017. Costs for buying young sows to increase herd capacities in 2016 reduce the income. Again tighter regulation reduces the income in scenario 2 by about 3000 € to 5000 € in the years before the investment. Afterwards this reduction is about 7000 € up to 13 000 € (cp. figure 2). Per sow the income loss amounts to 16 to 32 € per year after investment. This income loss is due to higher export costs per cubic meter manure and to higher amounts of exported manure in that scenario compared to the reference scenario. The farm rents the same number of hectares in scenario 2 than in the scenario 1 (cp. table 2). Therefore it has to export more manure in order to keep the stricter phosphorus limit.

The levies are high enough to avoid every phosphorus surplus in the concerned scenarios. This means that the same amounts of manure with equal costs are exported in scenarios 3a and 3c as in scenario 2. Thus, the development of income and also the income losses compared to the reference scenario are the same in all three scenarios.

Figure 2: Development of operating income from breeding piglets in the typical piglet breeding farm



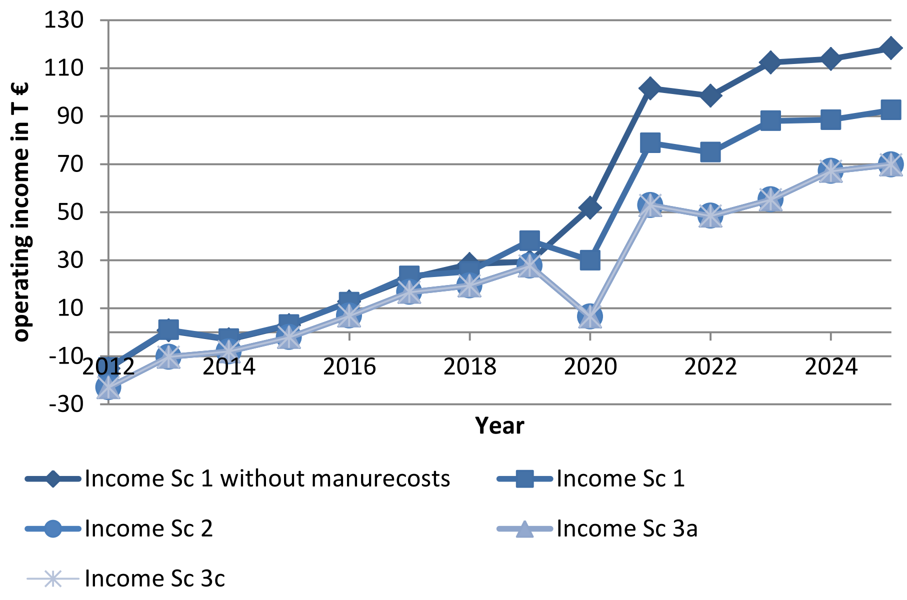
Source: Own illustration.

The development of income of the combined farm in the different scenarios can be observed in figure 3. The increase in stable capacity, which also requires buying more young sows in that year, leads to a reduction in the income in 2020 in all scenarios.

In the combined farm manure export costs and fertilizer value of manure converge in the reference scenario in the years before the investment. Afterwards the income is reduced by the costs of manure disposal. This reduction amounts to 22 000 € up to 28 000 €. In the years before the investment the income in scenario 2 is about 5000 € lower compared to scenario 1 and subsequently about 22 000 up to 28 000

€. The levies are high enough to avoid any phosphorus surplus. Therefore, the income is the same in scenario 2, 3a and 3c (cp. figure 3).

Figure 3: Development of operating income from raising up hogs in the typical farm with a "closed system"



Source: Own illustration.

5 Discussion and conclusion

This chapter discusses the general development strategies that the farms opt for under different water protection policy scenarios together with the impacts on their income. Further on, the farms' fertilizing strategies are examined in order to give hints for the effectiveness of the different policy instruments.

5.1 *Development strategies*

The model results show that typical pig farms in the agrarian-intensive region "Muensterland" will continue to considerably extend their herd capacities in the future. A stricter water protection policy only slightly changes the investment strategy of the typical hog fattening farm. The farmer invests later than in the reference scenario. The sow breeding farms as well as the combined farm do not change their strategies. But the incomes of all typical farms decrease significantly when they have do reduce the amount of manure to spread on their land.

Especially the income losses for the hog finishing farm are very high. It could be shown that all farms do not noticeable rent more land when increasing their herds. This result is due to the huge rental rates in the region. Hence the amount of exported manure increases very much. These exports at the same time mean more transports within and out of the region “Muensterland” and an increase in greenhouse gas emissions out of transports. Furthermore, the increase in traffic in the rural area means a higher burden of traffic noise for the local residents. According to our model result none of the policies considered will reduce the total amount of use of Nitrates and Phosphorous deposited by our typical farms, but only their distribution. Though the export of manure may to some extent reduce mineral fertilizer, due to the high transport costs it is very probable that in the regions bordering to the Muensterland the surplus limits will be reached as well.

A discussion of model results with the experts of the panels resulted in the assessment of these results to be realistic in the future. The strategy of growth as well as the huge growth steps which the typical farms take - according to the model results - seems to be realistic for the future.

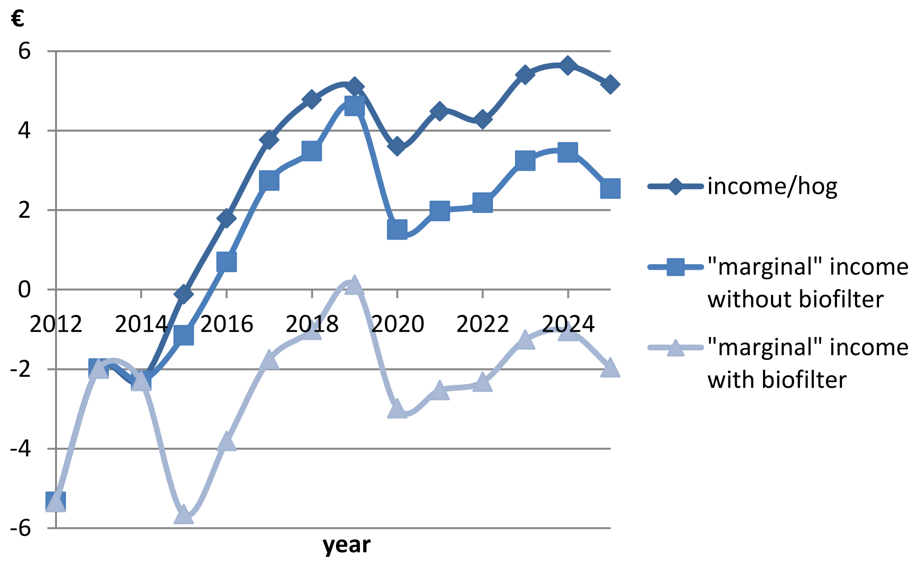
However, considering other political and societal circumstances a typical hog finishing farm at the very least will probably not realize its growth strategy at only one location: according to the model results, a typical hog finishing farm will increase its stable capacity up to 6900 or 6800 stable places. This is done by building up huge new stables, some of which have 2000 or more places. The amendment of the Federal Building Code (“Baugesetzbuch”) in Germany give rise to the impression that commercial hog stables with 2000 and more places cannot prospectively be constructed in the so called “undesignated outlying area”, as this would require an appropriate project-based binding land-use plan. This would mean that stables will have to be smaller to get the permission to be built.

Furthermore, it seems to be realistic that new large stables will have to be constructed with exhaust air filter (biofilter) if they will be constructed directly next to other stables. North Rhine-Westphalia implements the Federal Control of Pollution Act (Bundesimmissionsschutzgesetz) by requiring that new stables that fall under the Federal Control of Pollution Act only get a construction permit if they have an exhaust air filter. For a hog finishing farm this also implies that a filter has to be implemented in the newly built stable if the number of stable places at one location increases to over 2000 by constructing the new stable (cp. MUNLV 2013). There are also political thoughts in other German Federal States like Niedersachsen or Schleswig-Holstein, which have the intention to demand biofilters for new large stables. Hence the typical hog finishing farm probably has to recalculate its investment plans considering the costs of the biofilter.

Experts assume that a biofilter increases production costs between 4 to 5 € per hog stable place at least. As the extra income per hog in a new stable of the modeled hog finishing farm in the reference scenario is - according to the model results - already lower than these costs, such costs would lead to a situation in which a new stable gives no extra income for the modeled farm overall. This can be seen in figure 4 for the typical hog finishing farm in the region Muensterland Nord-Ost. The uppermost graph gives the average operating income per hog across all pigs of the farm, whereas the lower graphs ("marginal" income with and without biofilter") show the operating income per pig in each "newest" stable. The lowest graph involves the costs of a biofilter.

Therefore, a profit-maximizing farmer would not construct a further stable under these conditions. He would for instance try to avoid these costs by building smaller stables. Furthermore, these stable should not be allowed to be built at the already existing farm location but have to be constructed as own farm locations, which means a splitting of the whole farm into two or more businesses (one business per new stable). Another probable strategy could be renting stables of colleagues that have quit the business. Over all, it is probably that in the future pig fattening farms will develop on several locations. Nevertheless it has to be considered that there surely will be further technical progress. Thereby the costs of biofilters could decrease in the future.

Figure 4: Profitability of new stables for the typical hog finishing farm in the region Muensterland Nord-Ost with and without a biofilter



Source: Own illustration.

The typical piglets breeding farm increases the number of sow stable places up to 420. Stables of such magnitude are not concerned by the described political instances. Thus the development strategies of hog finishing farms first of all will be affected by ambient air control policies and possible changes in the Federal Building Code.

Furthermore the expert interviews within the panels have shown that there is an increasing resistance by the local residents against large stables. This could foster strategies of farms to develop at different locations by for example renting stables of retiring colleagues instead of still increasing the number of stable places at one location.

To put it in a nutshell, ambient air policies as well as societal instances could affect development strategies of pig farms in the future, whereas, according to our model assumptions a stricter water protection policy, whether it uses statutory requirements on nutrient balances or levies based on these balances, will first of all decrease the income without changing the development strategies.

However, it has to be considered that the assumed price developments in the model are very positive from the pig farms' point of view. FAPRI-ISU (2011) predicts a much stronger increase of the pork and piglet prices in comparison to the ones of grain or fodder. Hence, the reference incomes per pig of the typical farms increase considerably in the future. In a situation where pork and piglet prices do not increase as much as it is assumed in the model calculations, the cost burdens of additional manure export could be too high for farms and let them reduce the stable capacity or quit the business. As a result, development strategies could be strongly affected by water protection policies in such a scenario. Particularly regarding the high proportion of debt capital in large farms the risks for farms rise due to high costs for manure disposal. Furthermore in such a scenario the growth steps would already be smaller in the reference scenario.

These model results represent only strategies of the typical farms. As it was already mentioned (cp. chapter 2), these are those farms that can be identified to be more successful than the average and have therefore a higher probability to continue production and even increase production in future than other farms in the region.

In the past, the structural change has been very strong in the pig production sector: the number of hog finishing farms decreased whereas the number of hogs increased. The number of piglet producing farms also decreased, but the number of sows stagnated (cp. IT.NRW 2011a, p. 9, IT.NRW 2012a, IT.NRW 2008). Against this background, for the near future the panel experts expect a continuing strong structural change in the sector. That is, while there is agreement that the more competitive farms that were modeled in this study will not be influenced much in their development strategies, this may not be the case for the less competitive farms.

Notwithstanding a possible decline in the number of less competitive farms the experts stayed with their assumption of increasing manure export costs that are the base for our model calculations. Reasons for this are:

- the pressure coming from the Netherlands will continue in future,
- controls of keeping the maximum nutrient balances will become sharper,
- nitrates out of digestates from biogas production will count for the 170 kg N- constraint per hectare,
- rental rates and generally the struggle for rented land will rise as consequence of the reform in building law.

5.2 *Fertilizing strategies in the different scenarios*

The model results show that in scenario 2 not only the P_2O_5 -surpluses are reduced to zero as it would be required by law, but also the N-surpluses diminish to zero. This happens because the amount of manure that is allowed to put on the fields in order to not exceed the limit of zero P_2O_5-surpluses is not enough to feed the N-demand of the planted crops. The model assumes strictly rational deciders. For such a decider it is not reasonable to buy and put more mineral N-fertilizer on his fields than the crops exactly need. This leads to zero N surpluses. In reality other N-fertilizing strategies might exist. For example the farmers might give higher amounts of N in order to give enough N in any case. Furthermore, it is in reality very hard to determine the exact N-demand of the planted crops.

Moreover, the model results illustrate that in most cases a levy on nutrient surpluses, which amounts to 9.10 €/kg P_2O_5-surplus and 2.30 €/kg N-surplus (as was the case in the Netherlands), leads to the same nutrient surpluses as a regulatory instrument that forces the farms to have zero P_2O_5-surpluses. Per kg surplus P_2O_5 and N the manure export costs seem to be lower than the assumed levies.

The model results also reveal the huge disadvantage of levies compared to regulatory instruments: the farms cannot always be forced to prevent high nutrient surpluses. At the end of the projection period the hog finishing farm in the region "Westmuensterland" faces such high export costs per cubic meter manure in scenario 3a and 3c that it is worthwhile for it to reduce its manure exports, fertilize its own fields with more manure and pay the levies. In the last year the farm's surplus in scenario 3c is extremely high. Assuming further increases in export costs per cubic meter manure, the situation would be the same in all years following on the projection period.

The manure export, which is a key possibility for pig farms to reduce their own phosphorus balance, exhibits - at a specific point in time - the same costs per cubic meter manure - and therefore per kilogram phosphate – for all amounts of manure at the farm. It does not matter if the farm exports an amount of manure that fills one truck or several trucks, the costs per cubic meter do not change. The reason for this is, that most amounts of manure in a region like "Muensterland" are "traded" over a nutrient stock market ("Naehrstoffbörse"). If a farmer decides to export manure, he has to accept the costs that exist at the nutrient stock market at that moment. Starting from a specific minimum amount of exported manure, it does not really matter how much manure he exports. The costs per cubic meter manure depend mostly on the regional amount of manure to be exported to other farms as well as on the locations of farms that are willing to absorb these manure amounts. The higher the amount of manure to be exported from one region, the higher the probability that only farms that are far away still have absorption capacity and are willing to absorb "foreign" manure. The transport distances rise and with them the costs per cubic meter manure.

From a resource economic point of view this means that for a single farm the marginal abatement costs of 1 kg nutrient surplus – which can be used as an estimate of water pollution - do not increase together with the avoided amount of pollution. In contrast, the marginal abatement costs of this measure are - at a specific point in time - roughly the same for all avoided units. This also means that if the marginal abatement costs of this measure get higher than the levy per unit nutrient surplus, the whole abatement measure gets unprofitable and suddenly high amounts of manure stay within the observed farm.

Such tipping points could be very dangerous for the water bodies. If it is cheaper for a farm to pay the levy per kg nutrient surplus instead of avoiding this surplus, this applies to the last but also to the first evitable kg surplus. Therefore a profit-maximizing farmer would apply all his manure on his own fields up to the allowed 170 kg N per hectare. As the model results confirm for the hog-finishing farm, this could lead to very high surpluses. Obviously, in our model there are no mitigation possibilities available which would prevent these “tipping points”. We discussed these results with the experts who confirmed the model results.

Thus, the impacts of levies on nutrient surpluses in pig farms, which have to export high amounts of manure out of their farms in order to reduce their nutrient balances, highly depend on the development of export costs per cubic meter manure. These costs are the result of the interaction of regional demand and the supply of manure. On the one hand they can even fluctuate highly during the years (and not only between). On the other hand they also vary between the different locations of the single farms. Therefore it is very difficult to capture the actual value. The past showed us that the costs can even rise to unexpected values: the expert interviews within this study revealed that in some regions of „Muensterland“ the costs doubled in the last 3 to 5 years. As is well known the reliability of levies to reach a certain environmental target is one of their main weaknesses (Endres 2007 pp.144). This can also be seen here. If the levies are to lead to cost-efficient abatement and the target level is not very much lower than the actual value they cannot prevent that on some farms or in some regions pollution increases. This could only be increased if the levies are set higher than necessary to reach the target, which would put an extra burden on society. This is a severe drawback of levies compared to regulations. If levies accompany regulations they may still help in increasing the implementation of these regulations and to generate money for mitigating measures, but cannot lead to efficient abatement anymore.

5.3 *Adoption of new technologies*

With the increase of manure depositing costs new technologies that may reduce nutrient surpluses will gain in importance. There are mainly two strategies that might be interesting here and that we did not take into account in our model: separation techniques and increased fodder efficiency.

5.3.1 Separation techniques

Against the background of high manure export costs and very high rental rates for land in the region „Muensterland", technologies get more interesting, which decrease transport costs of at least the phosphorus part of manure out of pig production. Nevertheless, we did not take up this technology option, as such technologies do not seem to be profitable in the near future.

LAURENZ (2012) calculates that it is more worthwhile for an exemplary hog finishing farm in the region Muensterland to export the thick sink phase of manure than to separate manure and export the thick phase for a low cost separation technique. More expensive techniques also have higher separation rates and could therefore reduce transport costs per kg phosphor. But KOWALEWSKY (2011) estimates the costs of techniques with very high separations rates to be actually around 10 € per ton of solid phase. Therefore, according to the above-mentioned study these techniques will also not be worthwhile for the exemplary farm. Of course technical progress may reduce these costs, but a reliable estimate of the future development of costs seems to be impossible at the moment. LAURENZ (2012) assumes that even in the future with a further technical progress of the better techniques of separations, the relative easy technique with centrifuges will still be the one that is most worthwhile of all separation techniques. But for these simple techniques he does not assume further technical progress (cp. Laurenz 2012). Thus, also in the future the export of the sink phase of manure will be more worthwhile than the separation.

Separation could get interesting in combination with biogas producing farms in typical arable farming regions where nutrients out of digested residues can reasonable be used. But this would require on the one hand over-regional concepts that do not exist at the moment. On the other hand, many arable farms would have to produce biogas, which is not very likely according to past experiences (cp. LWK NRW 2013). This is the reason why separation techniques are not implemented in the model. A further reason is, that reliable cost prognoses are not possible (see above).

5.3.2 Increasing fodder efficiency

Strategies to increase fodder efficiency will be very important in future to reduce the nutrient amount to be exported out of pig farms. The model already assumes a phosphor-reduced fodder ratio. Nevertheless, further optimization strategies remain and could be implemented in the model, e.g.:

- differentiate in even more feeding phases
- exacter calculation of the nutrient needs and the optimal date of slaughter
- better monitoring
- assertion of pigs in different performance groups
- targeted application of amino acids
- further breeding progress.

A good overview over possibilities to further increase fodder efficiency can be found e.g. in LWK NRW 2012c. Some of these measures demand investments. E.g. the multi-phase feeding may require investments in further fodder silos. Or the purchasing of an acid fodder may increase fodder hygiene.

To implement these strategies could be a valuable development of the model.

5.4 *Conclusion*

This study showed that water protection policies decrease potential future incomes of typical pig farms in an intensively farmed region in Germany, but did not greatly influence future development strategies of these farms. Analyses of further scenarios demonstrated that the introduction of levies on nutrient surpluses – along the lines of the Dutch policy – reduces incomes mainly in the same way as a tightening of the ordinance.

Assuming the existence of levies on nutrient surpluses at the rate levied in the Netherlands the model results shows that the typical farms will voluntarily minimize these surpluses in most cases. But extremely high manure export costs may result in high fertilization with manure for individual farms. Thus, the model results demonstrate that levies on nutrient surpluses are not able to prevent over-fertilization in all cases. To prevent every over-fertilization, very high levies would be necessary. This means that the instrument of levies would lose cost-efficiency compared to regulatory law.

Furthermore, the model results show that in all scenarios the manure exports from typical farms increase. These exports at the same time mean more transports within and out of the region “Muensterland” and an increase in greenhouse gas emissions stemming from transports. One possibility to avoid a further increase in emissions out of such transports could be to limit further growth in animal density, which means in the number of animals per hectare in that region. This is what the newest novel of the Federal Building Code does: It restricts new huge commercial stables (e.g. stables with more than 2000 fattening stables places). Commercial stables are stables for which the farmer does not own or has rented enough land to produce more than half of the fodder for the animals within this stable. Generally, this means that he owns or has rented insufficient land to put the produced manure onto it. More commercial stables in one region therefore mean a higher animal density. The novel of the Federal Building Act, which restricts the growth of commercial stables, could therefore probably reduce a further increase in emissions out of manure transports in future. Against the background of our model results, this may well be a necessary, albeit perhaps insufficient strategy (see our discussion in section 5.1) if the increase of animals in these highly intensive farming regions with high manure surpluses is to be reduced. According to our model, neither a change in the fertilizer directive nor levies on nutrient surplus could obtain this result.

The effects of politics to implement the EU Water Framework Directive on pig farms in the region “Muensterland” could also apply to other agrarian-intensive regions as for instance Brittany, Galicia, Lombardy or North-West-England. These politics also could considerably affect incomes of pig farms in these regions. Furthermore, other than the modeled changes in water policy, ambient air control policies as well as societal developments and changing price spreads between pigs and fodder could affect pig farms in agrarian-intensive regions substantially and could lead them to increase fodder efficiency in a way that have not yet been modeled in this study. It could be worthwhile to examine these effects in further studies.

References

BALMANN, A.; LOTZE, H.; NOLEPPA, S. (1998): Agrarsektormodellierung auf der Basis 'typischer Be-triebe' - Teil 1: Eine Modellkonzeption für die neuen Bundesländer, *Agrarwirtschaft 47*, Heft 5, pp. 222 - S. 230.

Baumann, R. A.; Hooijboer, A. E. J.; Vrijhoef, A.; Fraters, B.; Kotte, M.; Daatselaar, C. H. G.; Olsthoorn, C. S. M.; Bosma, J. N. (2012): Agricultural practice and water quality in the Netherlands in the period 1992-2010, Ed.: Ministry of Health, Welfare and Sport.

BGBl (Bundesgesetzblatt 2007): DueV (Duengeverordnung, Fertilization Ordinance): Verordnung ueber die Anwendung von Duengemitteln, Bodenhilfsstoffen, Kultursubstraten und Pflanzenhilfsmitteln nach den Grundsätzen der guten fachlichen Praxis beim Duengen, in der Fassung der Bekanntmachung vom 27. Februar 2007 (BGBl. I S. 221), die zuletzt durch Artikel 18 des Gesetzes vom 31. Juli 2009 (BGBl. I S. 2585) geändert worden ist.

BMU (Bundesministerium fuer Umwelt, Naturschutz und Reaktorsicherheit), BMELV (Bundesministerium fuer Ernährung, Landwirtschaft und Verbraucherschutz) (2012): Nitrates Report 2012. Joint report by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and the Federal Ministry of Food, Agriculture and Consumer Protection, Bonn.

Bund-Länder-Arbeitsgruppe zur Evaluierung der Duengeverordnung (2012a): Press release „Nährstoffueberschuesse abbauen: Bund-Länder-Arbeitsgruppe erarbeitet Duengungs-Empfehlungen. Vorschläge zur Weiterentwicklung der Duengeverordnung vorgelegt“ vom 17. Dezember 2012.

Bund-Länder-Arbeitsgruppe zur Evaluierung der Duengeverordnung (2012b): Evaluierung der Duengeverordnung – Ergebnisse und Optionen zur Weiterentwicklung. Abschlussbericht, Bericht im Auftrag des Bundesministeriums fuer Ernährung, Landwirtschaft und Verbraucherschutz, Braunschweig, November 2012.

DAHLHOFF, A.; MATTHIAS, J. (2011): Was darf der Bau kosten?, in: *Landwirtschaftliches Wochenblatt Westfalen-Lippe*, 29/2011, S. 25-27.

Deitmer, J. (2006): Entwicklungsperspektiven rindviehhaltender Betriebe in NRW, Dissertation at the agricultural facultry of the Rheinische Friedrich-Wilhelms-Universität zu Bonn, Bonn.

DMK (DEUTSCHES MAISKOMITEE E.V., 2012): Karte zur Schweineviehdichte und zur Gesamtviehdichte auf Kreisebene, available under: http://www.maiskomitee.de/web/public/Fakten.aspx/Statistik/Deutschland/Maisanbau__Viehbesatz, last call date: 20/12/12.

Endres, A.(2007): Umweltökonomie: eine Einfuehrung, 3. Ed., Stuttgart.

FAPRI-ISU (2011): Agricultural Outlook, Data tables, available under: http://www.fapri.iastate.edu/outlook/2011/, last call date: 11/18/2012.

Farwick, J.; berg, E. (2011): Aufrechterhaltung einer flächendeckenden Landbewirtschaftung in Nordrhein-Westfalen bei zunehmender Entkopplung, Landwirtschaftliche Fakultät der Universi-tät Bonn, Schriftenreihe des Lehr- und Forschungsschwerpunktes USL, No. 165.

Farwick, J.; Krämer, J. (2008): Auswirkungen möglicher Agrarpolitik-Szenarien auf landwirtschaftliche Betriebe in Nordrhein-Westfalen: Eine Simulation anhand typischer Betriebe, 48. Jahrestagung der GEWISOLA *„Risiken in der Agrar- und Ernährungswirtschaft und ihre Bewältigung“*, 24.-26. September 2008, Bonn.

Garbert, J. (2013): Ökonomische Auswirkungen von Politiken zur Umsetzung der Wasserrahmenrichtlinie auf die Schweinehaltung im Münsterland, Dissertation at the agricultural facultry of the Rheinische Friedrich-Wilhelms-Universität zu Bonn, Bonn.

Gawel, E.; Köck, W.; Kern, K.; Möckel, S.; Fälsch, M.; Völkner, T.; Holländer, R. (2011): Weiterentwicklung von Abwasserabgabe und Wasserentnahmeentgelten zu einer umfassenden Wassernutzungsabgabe, final report (draft)in behalf of UBA, funding code (UFOPLAN) 370926201.

Haas, G.; Bach, M.; Zerger, C. (2005): Landwirtschaftsbuertige Stickstoff- und Phosphor-Bilanzsalden. Nährstoffbilanzsalden der Landkreise Nordrhein-Westfalens, in: *LÖBF-Mitteilungen*, 2/05, p. 45-49.

Hardaker, J.B.; Huirne, R.B.M.; Anderson, J.R.; Lien, G. (2004): Coping with Risk in Agriculture, 2. ed., Wallingford.

Hemme, T. (2000): Ein Konzept zur international vergleichenden Analyse von Politik- und Technikfolgen in der Landwirtschaf, Landbauforschung Völkenrode, Sonderheft 215, FAL, Braunschweig, also Dissertation at the University of Göttingen.

It.NRW (Information und Technik Nordrhein-Westfalen, Geschäftsbereich Statistik, 2008): Viehhaltungen und Viehbestände in Nordrhein-Westfalen am 3. März 2007 nach Bestandsgrößenklassen, Kennziffer CIII – 4j./07, Duesseldorf.

It.NRW (Information und Technik Nordrhein-Westfalen, Geschäftsbereich Statistik, 2011): Viehhaltungen und Viehbestände in Nordrhein-Westfalen am 1. März 2010. Ergebnisse der Landwirtschaftszählung, Kennziffer C III – unreg./10, Duesseldorf.

It.NRW (Information und Technik Nordrhein-Westfalen, Geschäftsbereich Statistik, 2012): Viehhaltungen und Viehbestände in Nordrhein-Westfalen am 1. März 2010 nach Bestandsgrößenklassen, Kennziffer CIII – unreg./10, Duesseldorf.

Jacobs (2011, Landwirtschaftskammer NRW, department 31): Answer to an email request.

Keusch, A. (2001): Modellierung ressourcenökonomischer Fragestellungen am Beispiel der Erosion im Gebiert des Baldeggersees, Dissertation at the Eidgenössischen Technischen Hochschule Zuerich, Zuerich.

Kirchgeßner, M; Roth, F. X., Schwarz, F. J.; Stangl, G. I. (2011): Tierernährung. Leitfaden fuer Studium, Beratung und Praxis, 13. ed., Frankfurt a. M..

KOWALEWSKY, H. H. (Landwirtschaftskammer Niedersachsen, Fachbereich Energie, Bauen, Technik, 2011): Separierte Gülle als dezentraler Input für Biogasanlagen, Vortrag im Landwirtschafts-zentrum Haus Düsse.

KTBL (Kuratorium fuer Technik und Bauwesen in der Landwirtschaft e. V., 2010): KTBL-Datensammlung. Betriebsplanung Landwirtschaft 2010/11. Daten fuer die Betriebsplanung in der Landwirtschaft, 22. ed., Darmstadt.

Laurenz, L. (2012): personal colloquy, March 2012.

Lengers, B.; Britz, W. (2012): The choice of emission indicators in environmental policy design: an analysis of GHG abatement in different dairy farms based on a bio-economic model approach, *Review of Agricultural and Environmental Studies*, Iss. 93 (2), p. 117-144.

LWK NRW(Landwirtschaftskammer NRW, 2010): Rechenmeister fuer die Schweinefuetterung, Neuauflage 2010, Muenster-Hiltrup.

LWK NRW(LANDWIRTSCHAFTSKAMMER NRW, 2011a): Betriebszweigauswertung Schweinemast in Nordrhein-Westfalen Wj. 2010/2011, Referat Unternehmens- und Arbeitnehmerberatung.

LWK NRW(LANDWIRTSCHAFTSKAMMER NRW, 2011b): Betriebszweigauswertung Ferkelerzeugung in Nordrhein-Westfalen Wj. 2010/2011, Referat Unternehmens- und Arbeitnehmerberatung.

LWK NRW(Landwirtschaftskammer NRW, 2012a): Unternehmensergebnisse buchfuehrender Betriebe in Nordrhein-Westfalen 2010/2011, Muenster.

LWK NRW(Landwirtschaftskammer NRW, 2012b): Fruchtfolge, available under: http://www.landwirtschaftskammer.de/landwirtschaft/ackerbau/fruchtfolge/index.htm, last call date: 10/31/2012.

LWK NRW (LANDWIRTSCHAFTSKAMMER NRW, 2012C): Wie halte ich meine Futterkosten im Griff? Baulehrschau – Sondertag Schweinehaltung am

05.01.2012 ab 10.00 Uhr auf Haus Düsse, Vor-träge von AVERBERG, U.; LEUER, S.; WALGERN, B., available under: http://www.landwirtschaftskammer.de/duesse/lehrschau/sondertage/2012-01-05.htm, last call date: 30/12/2012.

LWK NRW (LANDWIRTSCHAFTSKAMMER NORDRHEIN-WESTFALEN, REFERAT 24 – ENERGIE, BAUEN, TECHNIK -, 2013): Biogas in Nordrhein-Westfalen. Auswertung der Biogasanlagen-Betreiberdatenbank der Landwirtschaftskammer NRW, Stand 20.05.2013, available under: http://www.landwirtschaftskammer.de/landwirtschaft/technik/biogas/veroeffentlichungen/biogas-in-nrw.htm, last call date: 24/11/2013.

Mailitius, O.W. (1996): Die Entwicklung landwirtschaftlicher Betriebe im Talgebiet der Schweiz, Dissertation Zuerich.

Matthias, J. (2011, Landwirtschaftskammer NRW): Biogaskleinanlagen bis 75 kW: Neue Rahmenbedingungen verändern Wirtschaftlichkeit, Vortrag im Rahmen der Fachveranstaltung: „Was bringt das neue EEG 2012? – Rahmenbedingungen für die Landwirtschaft“ am 01.12.2012 im Landwirtschaftszentrum Haus Düsse.

MUNLV (Ministerium fuer Umwelt und Naturschutz, Landwirtschaft und Verbraucherschutz des Landes Nordrehin-Westfalen, 2009): Bewirtschaftungsplan fuer die nordrhein-westfälischen Anteile von Rhein, Weser, Ems und Maas 2010-2015, Duesseldorf.

MUNLV (Ministerium fuer Umwelt und Naturschutz, Landwirtschaft und Verbraucherschutz des Landes Nordrehin-Westfalen, 2013): Immissionsschutzrechtliche Anforderungen an Tierhaltungsanlagen, 19. Februar 2013, Duesseldorf.

OECD (Ed.) (2007): Instrument Mixes Addressing Non-point Sources of Water Pollution, Paris, 14 th February 2007.

Pau Vall, M.; Vidal, C. (Eurostat) (2011): Stickstoff in der Landwirtschaft, verfuegbar unter:

http://ec.europa.eu/agriculture/envir/report/de/nitro_de/report.htm, last call date: 29/12/2011.

SRU (Sachverständigenrat fuer Umweltfragen, 2004): Umweltgutachten 2004. Umweltpolitische Handlungsfähigkeit sichern, Baden-Baden.

SRU(Sachverständigenrat fuer Umweltfragen, 2008): Umweltgutachten 2008. Umweltschutz im Zeichen des Klimawandels, Berlin.

Statistisches Bundesamt (2012): Land- und Forstwirtschaft, Fischerei. Viehbestand und tierische Erzeugung 2011, Fachserie 3, Reihe 4, Wiesbaden.

Steffen, G. und D. Born (1987): Betriebs- und Unternehmensfuehrung in der Landwirtschaft. Ulmer, Stuttgart.

Stevering, M. H. A.; Groen, A. F.; Berentsen, P. B. M. (1994): The influence of environmelntal policies for dairy farms on dairy cattle breeding goals, *Livestock Production Science*, Iss. 40 (1994), p. 251-261.

WBA (Wissenschaftlichen Beirat Agrarpolitik, nachhaltige Landbewirtschaftung und Entwicklung ländlicher Räume beim Bundesministerium fuer Verbraucherschutz, Ernährung und Landwirtschaft) (2005): Zukunft der Nutztierhaltung, Gutachten, Muenster.

Wegener, J.; Theuvsen, L. (2010): Handlungsempfehlungen zur Minderung von stickstoffbedingten Treibhausgasemissionen in der Landwirtschaft, Studie im Auftrag des WWF Deutschland, Ber-lin.

Wissenschaftlicher Beirat Bodenschutz beim BMU (2000): Wege zum vorsorgenden Bodenschutz. Fachliche Grundlagen und konzeptionelle Schritte fuer eine erweiterte Boden-Vorsorge, Bundesdrucksache 14/2834.

Wissenschaftlicher Beirat fuer Duengungsfragen beim BMELV (2011): Nachhaltiger Umgang mit der begrenzten Ressource Phosphor durch Recycling und Erhöhung der Phosphoreffizienz der Duengung, Standpunkt verabschiedet am 22.02.2011, available under:

http://www.bmelv.de/SharedDocs/Downloads/Ministerium/Beiraete/Duengungsfragen/Phosphor.pdf?__blob=publicationFile, last call date: 12/12/2012.

Wissenschaftlicher Beirat fuer Duengungsfragen beim BMELV(2009): Standpunkt des Wissenschaftlichen Beirates fuer Duengungsfragen zur Minderung der Stickstoffueberschuesse in der Landwirtschaft durch Verbesserung der Stickstoff-Effizienz der Duengung, Darmstadt.