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The Welfare Effects of Greenhouse Gas Emissions in German Pork Production

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Abstract

Greenhouse gas (GHG) emissions are an externality of the pork production process. To respond to climate change concerns and reduce GHG emissions, internalizing this external effect using a market-based economic instrument would be economically efficient. We calculate the welfare effects of GHG emissions using a partial equilibrium model of the German pork market. Sensitivity analysis is used to investigate the impacts of emission prices and emission rates on the welfare effects of reducing GHG emissions. Potential overall welfare gains amount to roughly € 360,000 in the base setting and increase to roughly € 3 million when emission prices are tripled. This sensitivity highlights the need for more dependable estimates of key parameters such as emission prices and emission rates. However, even the largest estimates of these welfare gains are relatively small. By contrast, the distributional effects of internalizing GHG externalities in pork production for producers, consumers and the state are large in all scenarios. The large redistribution effects that follow from even a small pork price increase as a result of internalizing GHG emissions indicate that attempts to tie German pork production into such policies would be highly controversial but may create incentives to invest in technologies which mitigate GHG emissions.

Keywords: Welfare effects, greenhouse gas emissions, pork production, partial equilibrium model

JEL codes: H23, Q18, Q54

1. Introduction – Greenhouse Gas Emissions and Agriculture

In the last couple of years, increasing public as well as scientific attention has been paid to climate change issues. Especially regions with disadvantageous climatic and environmental conditions suffer from increasing weather variability including storms, droughts, floods and other natural hazards caused by climatic alteration. Agricultural production and the rural areas of these unprivileged regions are those suffering most in the current situation and have few resources to adapt to or to reduce the impact of future disasters (Tol, 2011).

A handful of countries and regions contribute a substantial share to global greenhouse gas (GHG) emissions and much more than other regions. On the basis of per capita GHG emissions this becomes obvious in form of higher consumption levels and standards of living. Under ethical and equity aspects this is in particular problematic because most of the victims of climate change are not among the responsible polluters (e.g. Tol, 2011).

This fact indicates the nature of GHG emissions which makes it difficult to find political solutions either on a global or a national scale. Unlike most other environmental problems GHGs influence the entire global climate system independent of the exact location of their emission. Hence, the incentives for the single polluter to reduce emissions can be very low because his GHG abatement costs are generally much higher than his individual marginal damage costs, which are often close to zero. Simultaneously, those who suffer from certain damages due to climate change cannot trace them back to a specific polluter who is responsible for these damages, and from whom compensation could be claimed.

The documented increase in GHG concentrations in the atmosphere has many causes and the gases are released in many activities and sectors, of which agriculture is especially important. According to FAO estimates, agriculture is responsible for about one third of global GHG emissions; about 40 percent of anthropogenic methane (CH₄) emissions are due to wet rice cultivation, and another 25 percent comes from livestock; 80 percent of man-made nitrous-oxide (N₂O) emissions are attributed to agriculture (FAO, 2009). Despite the industrial focus of the country, agriculture releases about 13 percent of overall GHG emissions in Germany (including emissions from agricultural land use and land use change) (Rösemann, 2010). Although 28 percent of these emissions can be assigned to the draining and use of boggy soils, livestock production is responsible for more than 70 percent of overall agricultural GHG emissions (Hirschfeld et al., 2008).

Determining live cycle GHG emissions for agriculture is associated with several unique challenges. Unlike the industrial sector where GHGs mostly consist of CO₂ emissions because they are closely connected to fossil fuel consumption, three different GHGs (CO₂, N₂O and CH₄) play a major role in agriculture. These gases have different degrees of global warming potential and are therefore all translated into CO₂ equivalents. Furthermore, their synthesis is predominantly not connected to energy use, i.e. agricultural GHG sources are diverse and depend on factors such as local climate and soil conditions, production technology and the intensity of external factor input. Due to these characteristics, the estimation of average product-related GHG emissions is challenging in an agricultural context and suspected to be subject to considerable fluctuation. On average, German conventional pork production emits around 3.07 kg CO₂ equivalents/kg carcass weight (Hirschfeld et al., 2008), but this value varies widely across different pork production systems (organic vs. conventional, depending on manure treatment technologies, etc.).

Simultaneously, a rising global population and changing consumption patterns are increasing demand for animal products such as meat and milk. Since the production of animal products generally consumes much more of energy and nutrients than plant products this increasing demand for meat and dairy products leads to a strongly rising land consumption.

Meat consumption in Germany has fluctuated around 61 kg carcass weight per person over the last 15 years (ZMP, 2008), which is low, compared with other developed countries. In the 1980s, the Germans consumed more than 70 kg per person (ZMP, 2000). Despite a growing awareness of animal welfare patterns and of the complex interrelation of meat consumption and climate change and land use issues, the pork producing sector in Germany has grown constantly over the last decades, leading to agglomeration and intensification of production and a rising export supply. This is widely considered to be a big success.

However, if pork producers and consumers do not take the costs of GHG emissions into account when making production and consumption decisions, the apparent economic success of the expanding pork sector in Germany could be overstated. In this paper we aim to assess the welfare economic consequences of GHG emissions in German pork production. If GHG emissions are considered to be an externality of the pork production process, it would be economically efficient to internalize this external effect by using a market-based economic instrument. We abstract from the practical difficulties of implementing such an instrument, which would be considerable given the large number of GHG sources in pork production and the heterogeneity of pork production systems. To estimate the economic stakes involved, we

assume that an instrument that internalizes the costs of GHG emission in pork production can be devised. The advantage of such an instrument is that it would reduce GHG emissions not only by reducing the quantity of pork produced, but also by generating incentives for technological and organizational improvements.

We study the impact of the assumed internalization of GHG emissions in the German pork sector by estimating price changes and welfare effects using a simple single-market comparative static model. To assess the impact of certain model parameters we conduct a sensitivity analysis. In chapter 2 we present the methodology and data sources, results are depicted in chapter 3. In chapter 4 we discuss the results as well as the methodology and assumptions which are followed by the conclusions and implications in chapter 5.

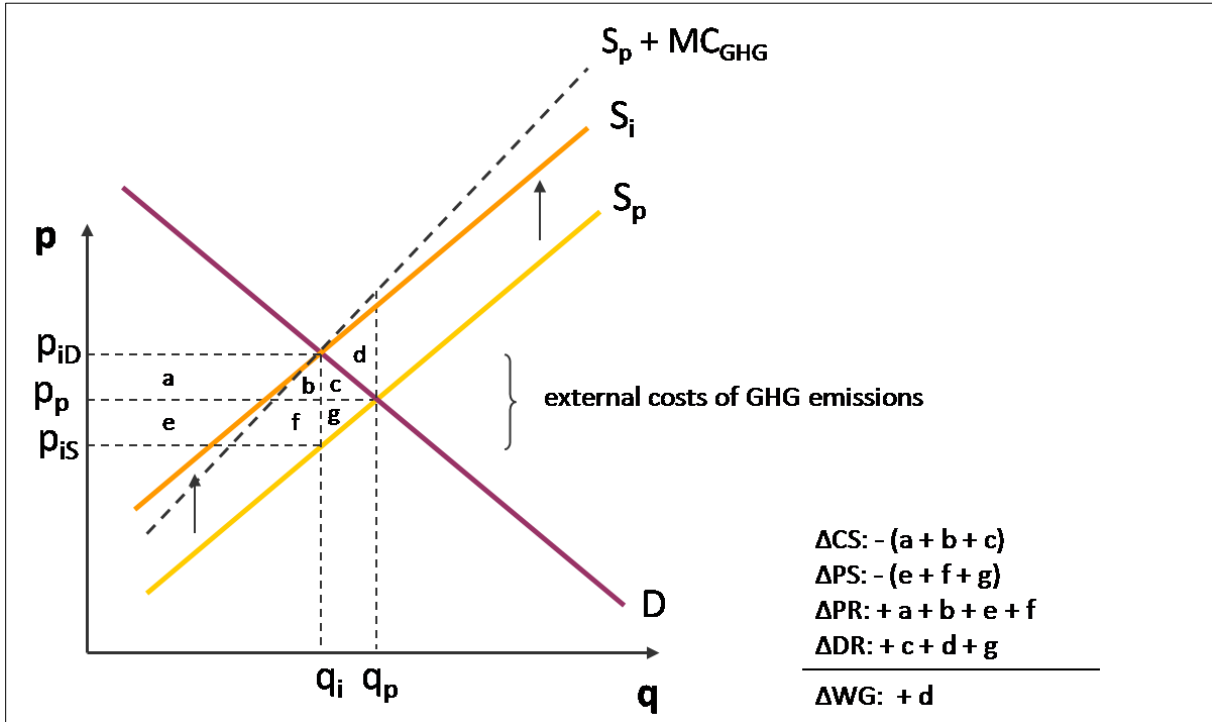
2. Methodology and Data Sources

We use a partial equilibrium model to simulate the welfare effects of internalizing the externality ‘GHG emissions in German pork production’. The model includes isoelastic demand and supply curves, price and quantity data for pork in Germany are used to calibrate the curves. Figure 1 shows the model design schematically. In the initial situation, p_P and q_P represent price and quantity, respectively, only private costs are considered here. To internalize the externality the supply curve is shifted up by the amount of the GHG emissions’ costs ($S_i - S_p$), leading to a new market equilibrium (q_i ; p_{iD} and p_{iS} for consumer and producer price, respectively). The difference between p_{iD} and p_{iS} represents the external costs of GHG emissions, i.e. the tax rate or the certificate price, depending on which of these two market-based economic instruments was chosen. The shift and the new equilibrium enables us to calculate the welfare effects, that is changes in consumer and producer surplus (CS and PS), public revenue (PR), the reduction of damages due to the internalization of GHG costs (DR – damage reduction) and the overall welfare gain (WG).

Elasticities are taken from the literature and public sources. Because meat consumption in Germany has not changed much in the last 15 years, we use an own price elasticity of demand for pork in Germany (-0.83) from Thiele (2008) which is derived from a cross-sectional dataset of 2003. Supply elasticities for pork are not available, neither in literature nor in elasticity data bases of e.g. the United States Department of Agriculture (USDA) or the Food and Agricultural Policy Research Institute (FAPRI). On enquiry we got the elasticity used in the European Simulation Model (ESIM) which uses the same value (2.18) for all EU-15 countries (Banse, 01.06.2010). Price data is taken from the data appendix of the German Journal of

Agricultural Economics, which provides adjusted monthly data for many agricultural products. We used the average consumer price for pork in Germany for 2009 (4.69 €/kg carcass weight). Quantity data for pork in Germany are derived by multiplying the per capita consumption of pork per year by the population (3,235,000 t). The external costs of GHG emissions are calculated by multiplying the emission rate (3.07 kg CO₂ equivalents/kg carcass weight) (Hirschfeld et al., 2008) by the price for CO₂ emission certificates (13.60 €/t CO₂ equivalents) on the exchange in Leipzig, Germany. For the emission price we used the average price of January to May 2010. The emission rate covers all life cycle GHG emissions of pork production up to the farm gate including those due to the production of external inputs such as feed and fertilizers.

Figure 1: The welfare effects of internalized GHG emissions in German pork production (schematic)



(Source: own illustration)

By construction we assume that the supply curve (S_p) covers all other external costs except the damages caused by climate change or that there are no other external costs, respectively. Also, we assume constant marginal damage costs, i.e. $S_p + MC_{GHG}$ curve matches S_i .

In a second step, we conduct a sensitivity analysis. The model's parameters, e.g. elasticities, are varied by realistic amounts, also based on literature and public sources. The results (available from the authors) are found to be robust to reasonable variations in parameter values.

Table 1: Selected characteristics of all applied scenarios

| Scenario | Base | A | B | C | D | E | F | G |
|--|---|--|--|--|---|--|--|--|
| Production system | Conventional | | | | Organic | | | |
| What is varied | | Emission price | | Emission rate | | | | |
| | Average ¹ | | | Best practice ¹ | Allocation of manure emissions ² | Base organic/Average ¹ | Best practice ¹ | Manure emission factor ¹ |
| Selected characteristics (compared to base scenario) | Slatted floor, 1,000 pigs per farm, Two-phase dry feeding system; Emission price: € 13.60 / t CO ₂ -equivalents | Maximum price of the period January 2008 – May 2010 (€ 28.75 / t CO ₂ -equivalents) | Hypothetical price of € 40.00 / t CO ₂ -equivalents | Better fattening performance and feed conversion rate, different feed ration, multiphase liquid feeding system | Allocation of manure emissions solely to pig production; (also: lower daily gain, lower final weight, lower killing out percentage) | 50 pigs per farm (=no specialization), housing on deep litter, different feed ration (e.g. abdication of soy), longer fattening period due to lower feed conversion rates and daily gain | 400 pigs per farm, 2-zones barn, multiphase liquid feeding system, better fattening performance (compared to base organic) | Higher emission factor for deep litter compared to base organic → manure emission factor is a very unstable and highly fluctuating parameter |

¹ = Hirschfeld et al. (2008); ² = Williams et al. (2006)

We then focus on sensitivity to the parameters that determine the external costs of GHG emissions – the assumed costs of the GHG emissions of pork production and the emission rate. Emission costs are varied based on changing certificate prices, and emission rates are varied to reflect differences due to organic and conventional production systems, different allocation of manure emissions and best practice farming.

Altogether, the base scenario and seven different scenarios for the sensitivity analysis are calculated. A description of these scenarios and the main differences between them are provided in Table 1.

3. Results

In the base simulation run with current model parameters, external costs of pork production in Germany amount to 4 ct/kg carcass weight. This leads to a consumer price increase for pork of 3 ct/kg or 0.64%, while the total quantity produced falls by 17,190 t or 0.53%. The welfare gain amounts to roughly € 360,000 for the German economy and the reduction of damages due to GHG emissions is valued at € 760,000. Consumer surplus, producer surplus and government revenue changes by around € -97.5, -37 and +134 million, respectively.

We next explore the sensitivity of the results to key model parameters. We calculate changes for seven scenarios that differ from the base scenario either due to the assumed emission price (scenarios A and B) or the emission rate (scenarios C to G).

In scenario A and B we increase the emission price to € 28.75 and 40.00 /t CO₂ equivalents, respectively. These hypothetical prices are roughly double and triple the base price of € 13.60 /t CO₂ equivalents. The results are presented in

Table 2. In scenario A (B) external costs increase by 9 ct/kg carcass weight (12 ct/kg), consumer price by 6 ct/kg (9 ct/kg) and the quantity produced falls by about 36,000 t (50,000 t). The welfare gain from internalizing this cost increases to roughly € 1.6 million (€ 3 million). The reduction of damages due to the correction of the externality increases by almost the same factor. The changes in consumer and producer surplus and government revenue more than double (almost triple) compared with the base scenario.

In scenarios C and D we vary the emission rate of pork production for conventional and in scenarios E, F and G for organic agriculture. Scenario C represents a best practice type farm (i.e. a farm with an optimized production system with regard to economic structure and GHG emissions) and scenario D represents a pork production system in which the emissions of manure are allocated differently compared to the base scenario. The results are also presented in Table 2. Compared to the base scenario, the emission rate for the best practice (scenario C) farm is 9% lower; this can be transferred directly to consumer and producer surplus as well as government revenue, which decrease by 9% as well. External cost and consumer price increase do not change compared with the base scenario, but the quantity reduction is slightly smaller. Welfare gains and damage reduction are roughly 17% lower than in the base scenario. If the emission rate is roughly doubled (scenario D), the results are very similar to scenario A (in which the emission price is doubled). External costs increase by 9 ct/kg carcass weight, consumer price by 6 ct/kg and the quantity produced falls by about 35,000 t. The welfare effects of scenario D are in the same range as those of scenario A.

Table 2: Sensitivity analysis: results of the base scenario and the scenarios A to G

| Scenario | Base | A | B | C | D | E | F | G |
|--------------------------------------|--------|----------------|--------|----------------------------|-------------------------|--------------|-----------------------|------------------------------|
| What is varied | | Emission price | | Emission rate | | | | |
| Production system | | Conventional | | Conventional | | Organic | | |
| | | | | Best practice conventional | Allocation conventional | Base organic | Best practice organic | High emission factor organic |
| Change with respect to base scenario | Base | +111 % | +194 % | -9 % | +107 % | -33 % | -45 % | + 47 % |
| external costs €/kg CW | 0.04 | 0.09 | 0.12 | 0.04 | 0.09 | 0.03 | 0.02 | 0.06 |
| ΔP €/kg CW | 0.03 | 0.06 | 0.09 | 0.03 | 0.06 | 0.02 | 0.02 | 0.04 |
| ΔQ t | 17.190 | 36.054 | 49.874 | 15.632 | 35.289 | 11.617 | 9.549 | 25.114 |
| ΔCS € '000.000 | 97.44 | 205.11 | 284.48 | 88.59 | 200.73 | 65.79 | 54.05 | 142.58 |
| ΔPS € '000.000 | 36.94 | 77.37 | 106.92 | 33.59 | 75.73 | 24.97 | 20.53 | 53.93 |
| ΔGR € '000.000 | 134.02 | 280.90 | 388.36 | 121.89 | 274.94 | 90.60 | 74.47 | 195.74 |
| ΔDR € '000.000 | 0.72 | 3.17 | 6.10 | 0.59 | 3.04 | 0.33 | 0.22 | 1.53 |
| ΔWG € '000.000 | 0.36 | 1.59 | 3.06 | 0.30 | 1.52 | 0.16 | 0.11 | 0.77 |

CW = carcass weight; Δ = change; P = price; Q = quantity; CS = consumer surplus; PS = producer surplus; GR = government revenue; DR = damage reduction; WG = welfare gain

Scenarios E, F and G represent organic farms. Scenario E depicts an average pork producing organic farm; scenario F – as in the conventional setting scenario C – a best practice case; and scenario G refers to the high uncertainty of GHG emissions in organic or solid manure management systems by assuming a higher emission factor for emissions from deep litter. Since the emission rate is lower in organic systems (in scenarios E and F) compared with conventional systems (base scenario), the effects of internalization are somewhat smaller. External costs are 3 and 2 ct/kg carcass weight, respectively, and the consumer price increases by 2 ct/kg in both cases. Consumer surplus, producer surplus and government revenue amount to € 66 (54), € 25 (21), and € 91 (74) million in scenario E (F), respectively. Due to a higher emission rate in scenario G, external costs amount to 6 ct/kg carcass weight, the consumer price increases by 4 ct/kg and the quantity produced falls by roughly 25,000 t.

4. Discussion

The discussion is divided into two parts. First we discuss the methodology and assumptions employed above, and second we focus on the interpretation of the results.

Methodology and Assumptions

The setting of our study and the model is based on an assumed introduction of a climate protection policy for the pork producing sector in Germany. This policy is implemented by using a market-based economic instrument such as a tax on GHG emissions or the required purchase of emission certificates for every emitted unit of GHG. This setting implicitly assumes that the German pork market is protected from imports by means of a GHG-tariff on pork or some similar measure. In the absence of such an import barrier, foreign pork producers could export their pork products to Germany and, all other things being equal, undercut German suppliers, which would lead to rising imports, decreasing production in Germany and less climate protection.

We used the price for CO₂ emission certificates on the exchange in Leipzig, Germany, as a proxy for the external cost of GHG emissions. This implies that the Leipzig certificate price roughly reflects the true costs of GHG emissions. However, the certificate price only reflects the scarcity on the market for emission certificates, which is directly influenced by the amount of available certificates, which is determined politically. Hence, it does not reflect the true costs (or even the marginal damage costs) of GHG emissions. Pricing the costs of one unit of

GHG emissions and the damages it causes is difficult because economic benefits of emitting GHGs are generated locally, while the damage costs are allocated globally and differ according to the exact location. While the Leipzig price probably does not reflect the true costs of GHG emissions, they are available and reflect the current politically acceptable approach to price GHG emissions in Europe. Our sensitivity analysis (scenarios A and B) shows that varying this price has a large impact on the estimated welfare effects.

Furthermore, some studies suggest that there may be threshold effects in GHG damages by which important subsystems of the climate system suddenly switch, e.g. melting permafrost soils in Siberia or the Gulf Stream. Consequently, the impact of a certain unit of emitted GHGs depends on the amount already released and currently being released by others. In economic terms: marginal damage costs of GHG emissions are not constant. Nevertheless, we assume constant marginal damage costs. This is due to the assumption that the production quantity changes induced by internalization are so small compared with entire market that the marginal damage costs will be constant within this range.

A restrictive assumption of the model is that the supply curve covers all other external costs with the exception of the damages caused by climate change. This does not reflect reality because pork production and consumption has implication, for example in the areas of health and the environment. The German Society for Nutrition (Deutsche Gesellschaft für Ernährung – DGE) recommends not to eat more than 300 – 600 g meat per day (DGE, 2009), which is 15 – 30 kg per year. With 60 kg per year the Germans double this recommended limit. This can cause health problems for the individual person as well as burden the public health system. In addition, some environmental problems such as ground water contamination due to manure have been traced to intensive pork production in Germany. Some might even argue that the treatment of pigs in intensive production systems is inhumane and therefore generates additional external costs.

The demand for pork in our model only varies with own price and not the prices of other products, in particular substitutes such beef and poultry meat. This can be seen as a major limitation of our model. However, incorporating cross-price effects would presumably strengthen our results, because pork would become relatively more expensive compared to other meats if it were the only meat subjected to a climate tax. Consumers would therefore not only reduce their consumption because of own price effects but would also switch to other meats which would become relatively cheaper. On the other hand, it is unlikely that policy makers would subject only pork production to a climate tax. Based on the calculated emission rates in

Hirschfeld (2008), we expect that beef would generally lose and poultry would generally gain from the application of a comprehensive climate protection policy in agriculture, while the impact on pork is not as easy to predict.

Results

The estimated welfare gains (€ 360.000 in the base scenario and between € 110.000 and € 3 million in the remaining scenarios) are very small relative to the size of the pork sector. This also holds for the reduction of damages that is achieved. Nonetheless, as might be expected given the approximately quadratic nature of welfare effects, our results confirm that the impact of varying emission prices and emission rates is non-linear. Tripling (doubling) the emission price (scenarios B and A), leads to increases of a factor 8.5 (4.4) in welfare gain and damage reduction. Doubling the emission rate in scenario D more than quadruples the welfare gain and damage reduction. This highlights again the importance of these two factors in any attempts to integrate agriculture into climate change policy.

On the other hand, the distribution effects of internalizing GHG emission in German pork production are politically and economically relevant. Such a policy would lead to significant increases in government revenue (€ 134 million in the base scenario and between € 74.5 and 388 million in the other scenarios). € 134 million represents around 9% of the expenditures of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety in 2009 and 13% of its revenues (Bundesfinanzministerium, 2010).

The consumer surplus add up to around € 97.5 million in the base scenario and varies between € 54 and 284 million in the other scenarios. The average consumer surplus reduction per capita amounts to an essentially negligible € 1.19 per year (€ 0.66 – 3.48 depending on the scenario).

However, for the much smaller number of pork producing enterprises the reductions in producer surplus are not negligible. On average, producer surplus decreases by around € 543 per pig farmer and year¹. Depending on the scenario and based on some standard assumptions for pork production in Germany (a slaughtering weight of 94 kg, an output of 2.8 fattened pigs per barn capacity and year, and an average gross margin per pig of € 14.58 in 2009 (AMI, 2010), we calculate a reduction in gross margin per pig of € 2.82 or roughly 19% in the base scenario. This would certainly be noticed by pork producers.

¹ for around 68,000 pig keepers in Germany in 2009 (AMI, 2009)

Hence, independent of the exact price surcharge, the costs per farm are considerably large and thus politically relevant, highly controversial and may lead to investments into organizational or technical activities to reduce GHG emissions.

5. Conclusions and Implications

We have studied the impact of internalizing the external costs of GHG emissions from pork production in Germany. To do so we have employed a simple single-market comparative static model to estimate the welfare effects of the internalization. The main results are that the impact of internalizing GHG emissions from German pork production leads to potential overall welfare gains of roughly € 360,000 in the base setting. When emission prices are tripled welfare gains increase to roughly € 3 million. This sensitivity highlights that the results depend strongly on the assumed GHG prices and the assumed emission rates and depicts the need for more dependable estimates of these key parameters.

Regardless of the assumptions made, overall welfare and damage reduction effects are relatively small in all scenarios that we simulate. Hence, one might question whether it is at all worth the effort of internalizing GHG emissions from pork production – the resulting marginal economic advantages for the overall economy would likely be swamped by the administrative costs of implementing and enforcing such a policy. With this in mind, we do not expect that welfare gains could become an important motivation for justifying the introduction of a climate protection policy in the German pork sector. In distribution terms, however, large impacts on government revenue and gross margins in pork productions are calculated.

The model we have used is simple. Future research will have to look into multi-product linkages and improving our estimates of emission rates and emission prices. We have also abstracted from the entire crucial question of mechanism design – how to apply a GHG tax or emissions trading system to pork production in a manner that leads to the desired reductions in GHG emissions, that generates incentives for the development and implementation of new technologies that reduce GHG emissions, all without generating such high administrative costs as to outweigh the benefits of the policy. Nonetheless, this analysis showed that the costs per farm are considerably large which – given an appropriate realization and implementation – would create incentives to adapt to the new situation by investing in and developing of GHG mitigating technologies.

Additionally, the CO₂ price taken from the Leipzig exchange probably does not even partly reflect the true marginal costs of GHG emissions on the climate. Furthermore, other external

costs of pork consumption (e.g. health and environmental effects) are also not accounted for in our analysis. Hence, further work is required to refine the estimates that we have generated. The issue of unequal distributed impacts of climate change and how to deal with them will have to be debated and decided upon by the political process. Because agriculture contributes a substantial part of overall GHG emissions, policy makers will have to decide whether the sector should be included in GHG mitigation or. If yes – which can be expected following the EU-commission’s proposal of November 2010 for the CAP beyond 2013 – it will be necessary to meet the challenge of the sector-specific organizational and technical difficulties, and think about instruments and potential implications. That is why we wanted to glimpse in and attempted a first step. Clearly, only a market-based economic instrument is suitable to generate incentives for technological and organizational innovations which are necessary to reduce GHG emissions in addition to a pure quantity reduction.

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