How effective can environmental taxes be in reducing the environmental impact of pig farming systems?

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ABSTRACT

Environmental taxes are a form of incentive regulation available to governments in order to drive reductions in environmental impact. The aims of this study were to: 1) develop a framework that enabled quantification of the potential effect of environmental taxes on pig diet composition and 2) examine the relationship between tax level and its effectiveness in reducing environmental impacts from pig systems. Three taxes were investigated: a carbon tax on the feed ingredients as purchased, and two financial penalties on the field spreading of N and P in manure respectively. Each tax was integrated into a diet-formulation model for pig diets in Eastern and Western Canada and tested at a range of tax levels. The results were then tested in a Life Cycle Assessment model representative of pig farming systems in the two regions, which calculated the potential effect of the diets on the aggregated environmental impacts of each farming system. The environmental impact implications of each environmental tax were quantified using four impact categories: Global Warming Potential, Acidification Potential, Eutrophication Potential and non-renewable resource use. As environmental tax levels increased, trigger points in the tax range caused dietary change which reduced levels of the targeted emission type. In almost all the tax scenarios the largest reductions in the target emission per Canadian Dollar (C$) increase in cost were achieved at the lower end of the tax range tested, as diminishing marginal returns were evident. The taxes on spreading N and P in manure did not significantly reduce levels of any environmental impact category tested in most cases. In many of the scenarios the environmental taxes altered the diet in a way which significantly increased levels of at least one of the environmental impact categories considered. These results showed the potential for taxes which target specific emissions, to increase system-level environmental impacts in livestock production. The study demonstrated how system-level environmental impact models can be used to quantify the potential of environmental taxes set at different rates to reduce overall environmental impact levels in livestock systems.

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1. Introduction

Pigouvian taxes are a form of incentive regulation available to governments in order to drive reductions in environmental impact (referred to in this context as environmental taxes). In comparison to more complex policy instruments, such as cap and trade, environmental taxes are relatively simple and give greater certainty regarding the monetary cost of the polluting emissions (Barthold, 1994). Pigou and other economists have long argued that environmental taxes are effective in forcing companies to internalise external costs related to their activities and ensure consumers are confronted with prices which reflect the full marginal social cost of a product (Hackett, 2011). Environmental taxes have often been used to incentivise environmental impact reduction in the agriculture sector; for example, some countries have introduced taxes on spreading nitrogen and phosphorus, which affect farm-level decision making within livestock production systems (ECOTEC Research and Consulting, 2001; Sjöberg, 2005; Soil Service of Belgium, 2005). More recently due to concerns about climate change, there have been many proposals to introduce carbon consumption taxes as a mechanism to curb the carbon footprint of developed economies (World Bank, 2013).

When taking decisions concerning environmental taxes in order to reduce the environmental impact of livestock production systems, policy makers need to consider the following issues.

Firstly, which type/s of environmental impact is the tax designed to reduce? There are a number of environmental impact issues which are of concern regarding livestock production. While most recent attention has been given to the contribution of the livestock sector to greenhouse...
gas emissions (GHGs), other important environmental impact issues for the sector include the amount of crops grown for animal feed, water use and the contribution of nutrients excreted in animal manure to problems such as eutrophication and acidification (Bouwman et al., 2013; Eshel et al., 2014; Steinfeld et al., 2006). In many cases there may be more than one important environmental issue policy makers are trying to address regarding livestock production; it is therefore important that any taxes levied to reduce one type of environmental impact do not promote behaviour which increases other types of environmental impacts.

Secondly, at which point in the production system should taxes be levied in order to be most effective? This will depend on the environmental issue which is being targeted, as different parts of the production system are most important for different types of impact. Generally, when considering the environmental impact of livestock production (and particularly for non-ruminant systems), the production of feed materials and, the storage and disposal of manure are the most important aspects of the production system for most impact categories (Basset-Mens and Van Der Werf, 2005; Leinonen et al., 2012; Williams et al., 2006). For example, feed production contributes around 65% of Global Warming Potential caused by Canadian pig farming systems, and emissions from housing and manure management causing around 70% of eutrophication cost from Canadian pig farming systems (Mackenzie et al., 2015). Administrative feasibility is also a factor in this decision: a tax must be levied on an aspect of the system which can be measured reliably in order to be practical. Preferably any tax should allow livestock producers to alter production practices to reduce levels of the type of pollution which are targeted by the tax and thus their liability.

Thirdly at what penalty level should any environmental tax be set? Environmental taxes usually aim to reduce behaviour which is harmful to the environment rather than to raise large amounts of extra revenue (Fullerton et al., 2010). In order to be socially acceptable environmental taxes should not unduly penalise domestic industries, thus making them vulnerable to cheap imports which do not have to adhere to the same regulations. In relation to climate change this phenomenon is commonly referred to as “carbon leakage” (European Commission, 2009). As such, environmental taxes should be designed to reduce environmental impact in the most cost-effective manner possible.

In cases where environmental taxes are implemented on livestock systems, they can influence decision making within the sector, including the formulation of animal diets. Quantitative modelling provides a suitable means to evaluate the implications of adopting different diets in livestock systems for environmental impacts. Life Cycle Assessment (LCA) is a generally accepted method to evaluate holistically the environmental impact during the entire life cycle of a product or system (Guinée et al., 2002). Recently, researchers have used LCA modelling to integrate environmental impact considerations into diet-formulation models, in order to formulate diets which restrict or minimise the environmental impact during the entire life cycle of a product or system (Moe et al., 2014; Nguyen et al., 2012). A previous study showed that while attempting to reduce the environmental impact of a pig farming system through diet-formulation, when diets were optimised to minimise a single environmental impact category, large increases in other types of environmental impact may be caused (Mackenzie et al., 2016a). Therefore it could be expected that there would be trade-offs with policies aimed at reducing one type of impact increasing other types of environmental impact caused by the farming system.

Here we develop a diet-formulation tool designed for pig farming systems in Canada, combined with an LCA model of these systems as an exemplar to investigate the potential implications of environmental taxes on diet-formulation and the environmental impact of livestock systems.

The aims of this study were threefold:

1) to develop a framework that enabled quantification of the potential effects of environmental taxes on pig diet composition;
2) to quantify the implications of dietary alterations caused by environmental taxes for the environmental impacts of the production system using multiple environmental impact categories, and
3) to examine the relationship between the level of tax and its effectiveness in reducing environmental impacts through modelling each tax scenario at incremental levels of financial penalty.

Three taxes were each tested in a novel diet-formulation model which was capable of formulating diets for environmental impact objectives (Mackenzie et al., 2016a): a carbon tax on the ingredients as purchased for feed and two financial penalties on the spreading (per kg) of N and P in manure respectively. In each case diets were formulated in two scenarios for Eastern and Western Canada respectively. Pig diets in Eastern Canada are typically based on maize similar to USA pig diets (Thoma et al., 2011), whereas pig diets in Western Canada use wheat and barley as the main cereal component (Patience et al., 1995), as would be common for European pig diets. Testing the tax scenarios in two regions allowed any spatial differences in policy implications for environmental impacts and cost to be quantified. It was hypothesised that the diet-formulation model would respond to these taxes and alter the diets to meet their respective objectives; namely reducing the carbon footprint of the diet and reducing N and P excretion.

2. Materials and methods

2.1. The system considered

Modern pig farming systems can be considered to have 3 distinct production phases; 1) gestation and farrowing – where piglets are produced by breeding sows, 2) the nursery or weaning phase when pigs are separated from their mother and 3) the grower/finisher phase where pigs are fattened from around 30 kg to slaughter weight (PorkCheckoff, 2009). Fig. 1 shows the major components of this system when considered in an LCA model; from the production of feed ingredients to animals shipped for slaughter at the farm gate. Benchmark data from 2012 on Canadian pig farms showed that 78% of feed was consumed per pig produced during the grower/finisher phase with at least 75% of the environmental impacts caused by the grower/finisher phase for multiple environmental impact categories (Mackenzie et al., 2015). This study therefore, concentrated on the potential effect of environmental taxes on diets formulated for the grower/finisher phase of production only. The breeding and nursery production stages were treated as independent to the grower/finisher phase in this study and remained constant for all comparisons made.

2.2. Diet-formulation

A linear programming algorithm for diet-formulation was used to formulate grower/finisher diets for each taxation scenario; the diet-formulation rules used are described in detail in Mackenzie et al. (2015). In this study all diets were formulated to minimise feed cost per kg live weight gain (least-cost) for the grower/finisher phase in each tax scenario. Explanation on the nutritional rules used to formulate the diets can be found in Appendix 1.

There were 5 broad groups of ingredients used in the diet-formulation model; 1) whole cereals such as wheat and maize, 2) protein meals such as soymeal and canola meal, 3) co-products of other production processes, such as wheat shorts from flour milling and corn dried distillers grains with solubles, 4) specialist ingredients such as crystalline amino acids or minerals and 5) fats such as vegetable oil blends or rendered animal fat. Upper limits were placed on the inclusion of individual ingredients in the diets, so that issues of palatability or variability in specific ingredients did not adversely affect feed intake or animal growth (Mackenzie et al., 2016b). Further explanation of the rules used on ingredient limits can also be found in Appendix 1. Average ingredient prices and availability in Ontario and Manitoba for 2015 were provided by TrouwAgResearch, derived from Statistics Canada data.
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