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Evaluating Economic Policy Instruments for Sustainable Water Management in Europe

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Executive Summary

Definition of the analysed EPI and purpose

Denmark's landscape is dominated by agriculture. When the current Danish pesticide tax was implemented, the overall aim was to reduce pesticide residues in crops, water courses, lakes, ground water, soil and rainwater and thereby to lower the risk of environmental damage and negative health effects. Denmark is one of very few countries with largely untreated tap water. Water catchment for drinking water purposes is based solely on ground water (GEUS, 2010). In contrast, most other countries use surface water as drinking water (Aarhus University, 2011a).

The more precise objective regarding the effect of the pesticide tax, which was implemented in 1996, was a reduction of pesticide consumption of between 5 % and 10 %. When the tax rate was doubled in 1998 the stated objective was to reduce consumption by 8 % to 10 % more. Providing an incentive to reduce pesticide consumption, the tax was expected to contribute to reaching the overall aim for the Danish pesticide policy – reducing agricultural pesticide consumption to a level reflecting a treatment frequency index (TFI) of 1.7. The TFI represents the number of pesticide applications on cultivated areas per calendar year in conventional farming, assuming use of a fixed standard dose. The case study demonstrates the challenges of choosing an optimal tax design in a complex world where, additionally, not all individuals in the target group necessarily react to the incentives as predicted by economic modelling.

Introduction

The Danish pesticide tax was introduced in 1996 and is levied on sales prices. At the time, during the planning process it was concluded that it would be impossible to base the tax on the toxicity due to the complexity of determining toxicity and due to the impossibility of ranking the different types of negative effects (i.e. on groundwater, fish in watercourses, biodiversity in windbreaks etc. etc.) of different pesticides. The tax rate was doubled in 1998 (see Table 1.1). The rate is differentiated according to pesticide category.

Table 1.1 - Danish pesticide tax (% of retail price, exclusive VAT and other taxes)

%	1996	1998
Insecticides	37	54
Fungicides	15	33
Herbicides	15	33
Growth regulators	15	33

The tax is charged to manufacturers and importers who then incorporate it into the product price. All manufacturers/importers are obliged to register with the tax authorities. Taxed products have to be marked with a special label designed by the authorities. This special label indicates the tax category and the maximum price of the product, the argument being that this system precludes the possibility of registering the product at a low price (and a low tax) before selling it at a higher price without a higher tax. Customs and taxation authorities are obliged to control manufacturers and importers. Non-compliance can be sanctioned with fines or imprisonment at a maximum of two years (Ministry of Taxation, 1998).

The focus in the present case study is on the pesticide tax on agriculture. The tax is also applied to other pesticide users such as private home owners and horticulturists. Tax revenue is fully reimbursed to the agricultural sector – primarily by a lowering of the land tax.

Legislative setting and economic background

In Denmark, there is a strong preference for having untreated drinking water. Danish drinking water is normally untreated and if pesticide limits are violated in a well for drinking water, the well will normally be closed instead of treated. The introduction of the pesticide tax in 1996 took place against a background of failure to reach the aims of the pesticide policy with the previous policy measures and a general move towards a green tax reform, shifting the tax burden from income taxes to environmental taxes (Ministry of Taxation, 2001). Thus, an expert committee had paved the way for the tax with a 1992 report proposing a reform that would include, among others, more environmental taxes on water, energy and transportation in order to encourage work and discourage consumption (Ministry of Taxation, 2001: 47).

In connection with the implementation of the EU Water Framework Directive (EC/60/2000) the pesticide tax is slated for redesign. In the future, the tax rate is supposed to reflect the environmental harm of the chemical compounds rather than the sales price of the product. Furthermore, the new centre-left government (October 2011) have announced that an increase in the pesticide tax is planned, following up on similar plans by the former Liberal-Conservative government (Danish Government, 2009, 2010, 2011).

Since the original introduction of the tax, structural developments in Danish agriculture exhibit consistently increasing farm size, which has probably hampered the effect of the pesticide tax, as the evidence indicates that larger Danish farms (above 150 ha) use more pesticides and are less focused on using the smallest amount of pesticides, than smaller farms (Pedersen et al. 2011, 2012).

Brief description of results and impacts of the proposed EPI

A most likely baseline scenario for the development of the TFI, had a pesticide tax not been implemented, would be stability around the 1994 level, the year before the adoption of the tax was known, assuming unchanged policy instruments, crop composition, climate and prices of pesticides and crops. Consequently, the baseline scenario for the development without a pesticide tax would be a stable TFI around 2.5 from 1996 and onward.

The trajectory of the treatment frequency index (TFI) indicates that the tax has had a very small effect, at best. It is conceivable that the developments in grain prices (increases some years) as well as pesticide prices (decreases) have counteracted the effect of the taxes, obscuring an actual effect of the taxes. But while this may hold for 2007 and 2008, which had abnormal price developments, the pattern for the first half of the decade does not appear to support such a conclusion. Neither has the development in the composition of crops substantially changed the need for pesticides. However, poor crop rotations at some farms and appearance of new pests have increased the consumption of pesticides some (Ørum et al., 2008). The isolated effect of the pesticide tax has not been evaluated ex post. Consequently, it is impossible to deem the tax either a success or a failure. However, the Danish pesticide policy instrument mix can be considered a failure since the policy mix has failed to bring pesticide consumption even near a TFI of 1.7, which was predicted ex ante.

The tax has had some distributional effects within the sector; farmers who grow crops with a higher pesticide need and farmers living in regions with lower land values will, on average, experience a poorer net result than other farmers. Furthermore, the price label system connected to the tax is costly for producers and importers of pesticides. Transaction costs were estimated ex ante to be small. Current levels of illegal imports of pesticides are impossible to estimate but every now and then illegal pesticide transports are revealed by the authorities.

There are cross effects with other policies. E.g. 1) the CAP links farm subsidies to compliance with environmental regulation and the CAP's second pillar includes subsidies for pesticide-reduced or pesticide-free crop cultivation. On the other hand, agricultural policy is not yet completely decoupled from production incentives. 2) the Water Framework Directive is one of the causes that the Danish pesticide tax is now slated for redesign 3) the Danish nitrogen regulation causes a lower use of growth regulators in Denmark.

Conclusions and lessons learnt

The precise effects of the pesticide tax are unknown. Due to the relatively inelastic demand for pesticides, environmental effects might be larger for other types of environmental taxes. However, the transaction costs tied to the pesticide tax appear to have been relatively small, which suggests that the tax may still be a relatively cost effective policy instrument, assuming that it has had an effect. Full reimbursement of the revenue, primarily through lower land taxes, made the tax more acceptable to the agricultural sector, but, unsurprisingly, the tax is not popular among the farmers. Redesigning the tax to reflect toxicity might improve the environmental effects as well as the perceived legitimacy of the tax among farmers. Due to the inelastic demand of pesticides relatively high tax levels are probably needed.

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1 Background – Danish pesticide tax

The Danish government presented its first Pesticide Action Plan in 1986. The aim was to protect humans – both pesticide users and the population at large - against health risks of pesticides and to protect the environment. While systematic monitoring of pesticide compounds in surface and groundwater had not yet been established, concerns were mounting that pesticides would seep into the groundwater, the source of Denmark's largely untreated drinking water supply. The plan staked out two parallel tracks for the Danish pesticide policy: 1) A system for review of plant protection chemicals and a requirement that import, sale and usage of any plant protection chemicals are subject to approval by the Environmental Protection Agency 2) Policy measures to reduce the use of pesticides by 50 % before 1997 (using treatment frequency and sale of active ingredients as indicators) (Pedersen et al., 2011, 2012; Bichel Committee, 1998:31).

Danish groundwater has been monitored for pesticides since 1990. Between 1990 and 1995, pesticides were found in about 12 % of the test filters and in 4 % of the filters the concentrations exceeded drinking water limits of 0.1 ⊠g/l (Holten-Andersen et al., 1998). Drinking water monitoring showed similar frequencies (ibid). Both programmes included only eight pesticides.

In 1994 it was assessed that it would be possible to reach the objective of the Pesticide Action Plan regarding a 50 % reduction in sale of active ingredients, given the policy measures in place at the time. However, it was deemed impossible to reach the objective regarding treatment frequency without further political initiatives. Consequently, in 1995 the Danish Parliament decided to implement a pesticide tax to take effect in 1996 (Ministry of Taxation 2004).

1.1 Baseline before the 1996 pesticide tax was implemented

Danish policy objectives regarding pesticide *consumption* are measured by a 'treatment frequency index' (TFI) and by statistics for the sale of active ingredients in the pesticides. Both statistics are based on registered sales. The TFI represents the number of pesticide applications on cultivated areas per calendar year in conventional farming assuming use of a fixed standard dose (Pedersen et al., 2011). While subject to criticism, the TFI was deemed to be the best indicator for the environmental impact of pesticides by a government-appointed committee of experts (Ministry of Taxation 2004). The baseline for the objective of a 50 % reduction was calculated as the average TFI in the years 1981-85 (Environmental Protection Agency, 1998). The 50 % reduction in consumption was later calculated as corresponding to a TFI of 1.7 (corrected for crop composition) (Bichel Committee, 1998), which is still (November, 2011) the policy objective. The development in the Danish treatment frequency index before the introduction of the pesticide tax is depicted in Figure 1.1.

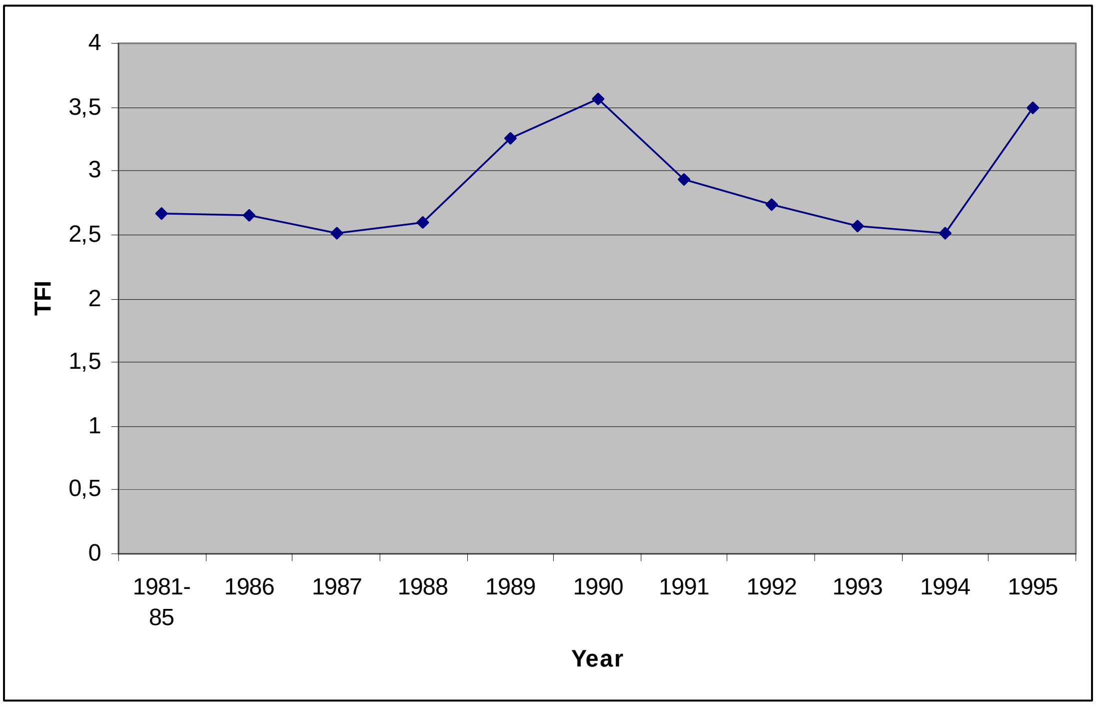

Figure 1.1. Treatment frequency index (TFI) before implementation of the pesticide tax 1996

Note: For 1981-85, the average level of consumption is shown.

TFI was quite stable in the first years following the introduction of the Pesticide Action Plan (1986). In 1989-90 the TFI increased quite dramatically before returning to a level in 1991-94 close to the average of the baseline years (1981-85). In 1995, the year before the implementation of the pesticide tax, the TFI again increased dramatically due to a hoarding in anticipation of the tax (Statistics Denmark, 1997; Ministry of Taxation, 2004).

A most likely baseline scenario for the development of TFI without introduction of a pesticide tax would be stability around the 1994 level, the year before the implementation of the tax were known, assuming unchanged policy instruments, crop composition, climate and prices of pesticides and crops. Consequently, the baseline scenario for the development without introduction of a pesticide tax is a stable TFI around 2.5 from 1996 and onward.

1.2 Key features of the pesticide tax

Prior to 1996 a general pesticide fee (3 % of the wholesale price of pesticides) had been in force but the purpose of this tax was only to recover the administrative costs associated with the approval of pesticides and it had no effect on consumption of pesticides (Ministry of Taxation, 2004; Andersen et al., 2001).

A new pesticide tax was implemented in 1996. The tax was levied on sales and aimed to reduce *consumption* of *approved pesticides*, as per the objective of the Pesticide Action Plan. An ex ante impact assessment showed with 'high uncertainty' that the tax would reduce the consumption of pesticides by 5 % to 10 % assuming a price elasticity of 0.5 – an assumption which was characterised as highly uncertain (Minister of Taxation, 1995; L 44 1997/98).

However, it soon became clear that the Pesticide Action Plan objectives, in particular the objective of a 50 % reduction in the TFI, would not be reached with the tax rates applied at the time. Consequently, the Danish Parliament decided to increase pesticide taxes as of November 1998 (see Table 1.1). On average, the tax increase led to a doubling of the pesticide tax (L 44 1997/98; Ministry of Taxation, 2004). It was estimated that the new tax rates would reduce consumption by 8 % to 10 % from 1998 to 1999 (assuming a price elasticity of 0.75) and that a projected decrease in the price of grain would reduce pesticide consumption by another 10 %. In total, a reduction of 18 % to 20 % was expected from 1998 to 1999, which would lead to a TFI of just below 2.0. The reduced use of pesticides was expected, 'in the short or the long term', to reduce pesticide residues in crops, water courses, lakes, ground water, soil and rainwater and thereby to lower the risk of environmental damage and negative health effects (L 44 1997/98). The tax rates of 1998 are still in force (November, 2011).

Table 1.1 - Danish pesticide tax (% of retail price, exclusive VAT and other taxes)

%	**1996**	**1998**
Insecticides	37	54
Fungicides	15	33
Herbicides	15	33
Growth regulators	15	33

One of the arguments for differentiating the tax among types of pesticides was that the costs per treatment vary quite a lot for different types of pesticides. A differentiation of the tax would therefore approximate a tax-per-treatment principle. A lower tax rate was applied to other types of pesticides, which are typically not used in agriculture as these had less severe environmental effects (L 44 1997/98).

The tax is charged to manufacturers and importers who then incorporate it into the product price. All manufacturers/importers are obliged to register with the tax authorities. Taxed products have to be marked with a special label designed by the authorities. This special label indicates the tax category and the maximum price of the product, the argument being that this system precludes the possibility of registering the product at a low price (and a low tax) before selling it at a higher price without a higher tax. Customs and taxation authorities are obliged to control manufacturers and importers. Breach of the law can be sanctioned with fines or imprisonment at a maximum of two years (Ministry of Taxation, 1998).

The tax also applied to other pesticide users such as private home owners and horticulturists. The focus in the present case study is on the pesticide tax on agriculture.

The tax revenue is fully reimbursed to the agricultural sector primarily through a lowering of the land tax and as well as other types of support (e.g. subsidies for organic agriculture and protection of the water environment) (Ministry of Taxation, 2004). NGO's representing agriculture and the chemical industry were involved in the political processes when the tax were designed (see Section 3.4).

In connection with the implementation of the EU Water Framework Directive (EC/60/2000) the pesticide tax is slated for redesign. In the future, the tax rate is supposed to reflect the environmental harm of the chemical compounds rather than the sales price of the product. Both the former liberal-conservative government and the new centre-left government (October, 2011) have planned an increase in the pesticide tax (Danish Government, 2009, 2010, 2011). The former government planned to increase the revenue from the pesticide tax by EUR million 10 in 2011 and by EUR million 20 in subsequent years and to reimburse the revenue to farmers through further decreases in the land tax (the Danish Government, 2010). It is not yet clear in detail what the new government will do.

The pesticide tax is only one of several policy instruments targeted towards reduced pesticide consumption. The suite of instruments includes more economic instruments (e.g. voluntary agreements with compensation) as well as information measures and regulatory measures. The mix of instruments makes it difficult to isolate the effect of the tax.

Before the tax level was raised in 1998 an expert *Committee to assess the consequences of a total or partial abolition of pesticides* commissioned by the Minister of Environment and Energy (Bichel Committee, 1998) assessed that it would be possible to reach a TFI of 1.7 without any substantial economic burden on farmers or for society as a whole within a period of 5 to 10 years (Bichel Committee, 1998: 142). The objective of a TFI of 1.7 was repeated in the second Pesticide Action Plan adopted in 2000 and in the Pesticide Action Plan for the years 2004-2009 (Pedersen et al., 2012); both plans failed to reach the objective (see Section 3.1). The former Danish liberal-conservative government (2001-2011) planned for the objective to be achieved by the end of 2013 (the Danish Government, 2009). It is unknown whether the new centre-left government, which took office in October 2011, will retain the overall objectives for pesticide reduction.

Several publications hold full or partial ex ante and ex post evaluations of the tax. Examples are: Bichel Committee (1998, 1999), Andersen et al. (2001, meta evaluation including several ex ante assessments), Ørum (1999, 2003, 2007), Ørum et al. (2008), Ministry of Environment (2008), Ministry of Environment et al (2007), Danish Economic Councils (2009, 2010), Pedersen et al. (2011, 2012).

2 Characterisation of the case study area (Denmark)

2.1 Environmental characterisation

Denmark's total geographic area is 43 098 km² (Statistics Denmark, 2011a) and is dominated by agriculture. Table 2.1 illustrates the distribution of land among different uses in Denmark in 1995, the year before the pesticide tax was implemented.

Table 2.1. Land use, Denmark, 1995 (%)

Agriculture	66.3
Forests and 'dry types of nature'	15.6
Built-up areas	9.8
Wetlands	5.2
Lakes and watercourses	1.5
Unclassified	1.6
	100.0

Source: Statistics Denmark, 2011a.

Data regarding land use in Denmark are imperfect for the last decade but data exist for the development in agricultural areas. By 2006 the agricultural area had declined to 63 % of the Danish area (Statistics Denmark, 2011b).

Organic fields have increased from 0.6 % (1995) of the total agricultural area to 5.2 % (2009) (Statistics Denmark, 2011b+c+d). Conversely, the amount of fallow fields decreased dramatically after 2007, when 6.9 % of the agricultural area lay fallow, to 2.6 % in 2008 and 0.2 % in 2009 before a small increase in 2010 to 0.4 % (Statistics Denmark, 2011c+e). The decrease in fallow fields follows the European Union repeal of a requirement for set asides.

As for crop distribution, grain - primarily wheat and barley - is the most important crop (56 % of the area in 2009). Another 20 % to 30 % of the land is used for production of roughage for livestock. From 1989 to 2009 the share of fields with grain has been relatively stable. On the other hand, there has been a large decrease in pulse and root crops and approximately a corresponding increase in grass and green fodder, which can be explained primarily by a shift from fodder turnips to maize for silage (Statistics Denmark, 2011a: 243-244).

Since the 1960s Danish farms have become more and more specialised. Today, more than 50 % of the farms have neither cattle nor pigs while less than 3 % have both cattle and pigs (compared to 70 % in 1968) (ibid). The size of an average Danish farm has been increasing. In 2009 the average land holding of 63 ha was well above the EU average (ibid). About 20 % of the Danish farms had land holdings of at least 100 ha (ibid).

Pesticides constitute a potential threat to both human health and nature and environment, which is illustrated by the aims in the Danish Pesticide Action Plans (see Section 2). The EU Water Framework Directive (WFD) prescribes a 'good chemical status' in surface waters and, in principle, a no-pollution-at-all standard for groundwater, although in practice, the principle is defined as minimum anthropogenic impact in both surface waters and groundwater (EU Commission, 2011). In the river basin management plans - produced in compliance with the WFD - pollution from pesticides is listed as a pressure on groundwater and drinking water in the river basin management plans (Naturstyrelsen/Danish Nature Agency, 2011).

Denmark is one of very few countries with largely untreated tap water. Water catchment for drinking water purposes is based solely on ground water (GEUS, 2010). In contrast, most other countries use surface water as drinking water (Aarhus University, 2011a).

Danish drinking water supply is based on a decentralised system with 2 622 public waterworks (2006) (GEUS, 2010). While the country's per capita freshwater supply is low compared to other EU member states, the water resource is reasonable given exploitation rates. Hence, Denmark's water exploitation index in 2002 was calculated at .04, well below the .2 mark that indicates scarcity (EUROSTAT – water statistics).

There is a lack of coherent time series regarding Danish pesticide pollution but an increasing number of wells for water have been closed due to pesticide pollution and pesticides have been detected in 37 % of the water intakes (2009) and in watercourses (see Section 3.1). According to the Ministry of Environment (2011b) indications are that the total pesticide load in Denmark is increasing.

A proposal for a Danish indicator for pesticide effects on nature has been developed on behalf of the Danish Environmental Protection Agency but has not been implemented (Kjær et al., 2008). However, the Ministry of Environment has announced (November, 2011) that it will soon introduce a new indicator for the pesticide load (Ministry of the Environment, 2011b).

2.2 Economic characterisation

The Danish population has increased from 5.1 mio. in 1990 to 5.6 mio. in 2011 (Statistics Denmark, 2011a). Population density was 129.4/km^2 in 2011. GDP per capita is depicted in Table 2.2.

Table 2.2. GDP per capita, EUR (2011 prices)

Year	1990	1995	2000	2005	2010
EUR	33 376	36 069	40 544	43 506	43 210

Source: Statistics Denmark, 2011g.

The mid-1990s marked the ending of a long period of high unemployment rates and strapped public finances. Thus, Table 2.3 shows a positive development in key economic indicators such as unemployment rates as well as the national budget and public debt between 1995 and until the onset of the financial crisis in 2008. Since then most indicators show a negative development.

Table 2.3. Development in macroeconomic indicators 1995-2010, %.

Year	1995	2000	2005	2010
Unemployment rate, 4th quarter	6.5	4.2	4.1	7.4
Inflation	2.1	2.9	1.8	2.3
Interest rate (discount)	4.25	4.75	2.25	0.75
Budget deficit/surplus as % of GDP	-2.9	2.3	5.2	-2.7
Public debt as % of GDP	72.6	52.4	37.8	43.6

Source: Statistics Denmark, 2011o+k+p+q.

As for agriculture, some key figures are presented below.

Table 2.4. Gross national product at factor cost, agriculture, million EUR (2011 prices)

Year	1990	1995	2000	2005	2010
Million EUR	6 017	4 901	3 797	3 300	3 512

Source: Statistics Denmark, 2011m

The gross national product at factor cost has been fluctuating in the last decade due to changing pork prices and in 2009 a low milk price (Statistics Denmark, 2011a:246).

Table 2.5. The contribution of agriculture in (%) to Denmark's total gross national product at factor cost

Year	1990	1995	2000	2005	2010
%	4.1	3.0	2.0	1.6	1.7

Source: Statistics Denmark, 2011m+p.

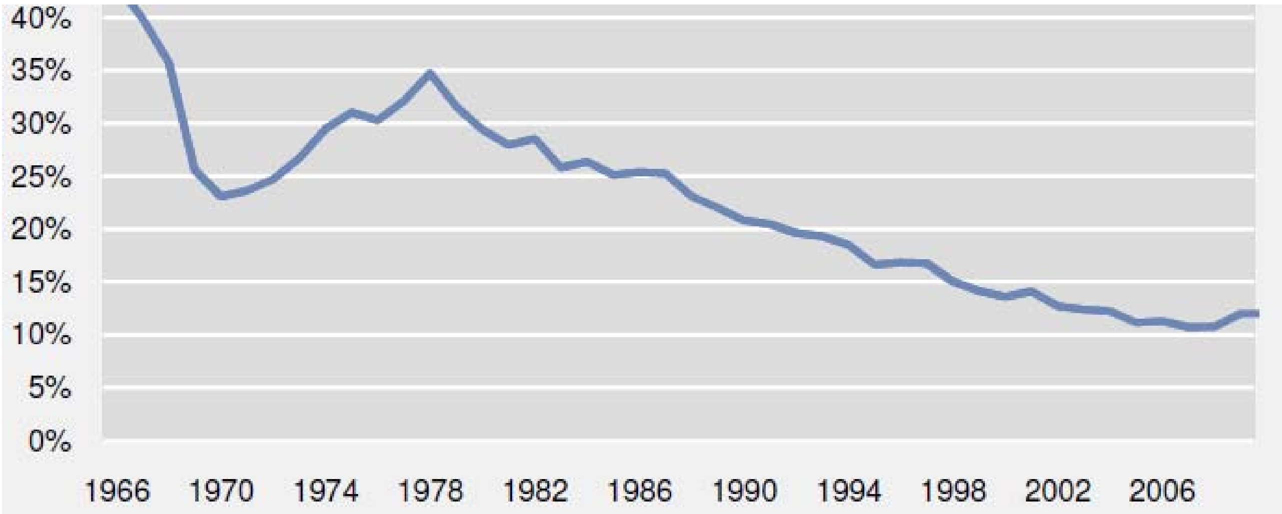

Figure 2.1. The share of agriculture of total Danish exports

Source: Denmark's Radio, 2011.

Table 2.6. Total debt, Danish farms, million EUR (2011 prices)

Year	1990	1995	2000	2005	2009
Million EUR	21 738	21 450	24 490	32 445	41 044

Source: Statistics Denmark, 2011i.

Table 2.7. Grants to Danish agriculture for running expenses, million EUR (2011 prices)

Year	1995	2000	2005	2010
Million EUR	1 041	944	1 108	1 051

Source: Statistics Denmark, 2011j.

Table 2.8. Farmer families operating income before rent, wage and pension, full time farms, average, EUR (2011 prices)

Year	1990	1995	2000	2005	2008
EUR	90 186	112 630	135 038	95 196	85 811

Source: Statistics Denmark, 2011n.

3 Assessment Criteria

3.1 Environmental outcomes

This section outlines the effects of the Danish pesticide tax. The section focuses primarily on the response of the economic agents, i.e. farmers - partly because a limited behavioural response by definition translates into limited changes in pressures and impacts on the water-related ecosystem and partly because studies on the environmental effects of the pesticide tax are lacking. Thus, we will briefly outline the features of the tax, its effect on pesticide consumption and for perspective we include information about modelled effects on water ecosystems.

Measuring the exact effect of the pesticide tax on pesticide consumption is complicated by the fact that the Danish pesticide policy employs a mix of policy instruments. The first Danish Pesticide Action Plan (1986) relied mainly on regulatory and information measures but these were later supplemented with economic instruments such as the pesticide tax and voluntary agri-environmental schemes. The pesticide tax was introduced in 1996 and the tax rates were doubled in 1998 to the levels of 33 % and 54 % depending on the type of pesticide (see Section 1.2). As mentioned, it was expected that the new tax rates in combination with a projected decrease in the price of grain would reduce pesticide consumption to a level of a TFI just below 2.0 in 1999 (see Section 1.2). The development of the Danish TFI is illustrated in Figure 3.1.

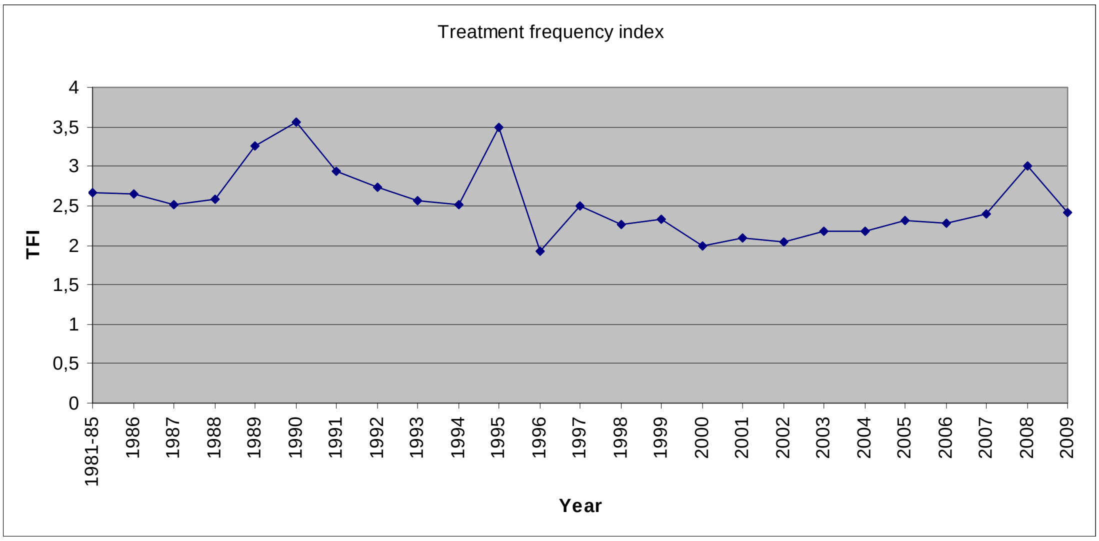

Figure 3.1 – Treatment frequency index (1981-2009)

Note: For 1981-85, the average level of consumption is shown.

In the period before the introduction of the tax (1981-1995) the TFI hovered at around 2.5 (except for 1989, 1990 and 1995). In 1996, when the pesticide tax was first implemented, the TFI dropped to the lowest level (1.9) for the entire period 1981-2009. Part of the explanation for this decrease appears to be that farmers had hoarded pesticides in 1995 in anticipation of the tax (Statistics Denmark, 1997). In 1997-1999 consumption was back at a level around a TFI of 2.5 despite the doubling of tax rates in 1998. Consequently, the expectation of a TFI just below 2.0 was not met in 1999 although grain prices decreased and pesticide prices increased this year. However, by 2000 pesticide consumption dropped to a TFI level of 2.0. But since then the TFI has gradually increased to a level around 2.5 again.

The assessment of the pesticide tax must also take into account changes in the external context that may have counteracted the pesticide tax. While the price on pesticides for most years has remained at the 1996 level, it has been decreasing since 2005 (see Figure 3.2). When the price decreases so does the nominal value of the tax. The grain price has been fluctuating considerably (e.g. it was very high in 2007) (Ørum et al., 2008:103).

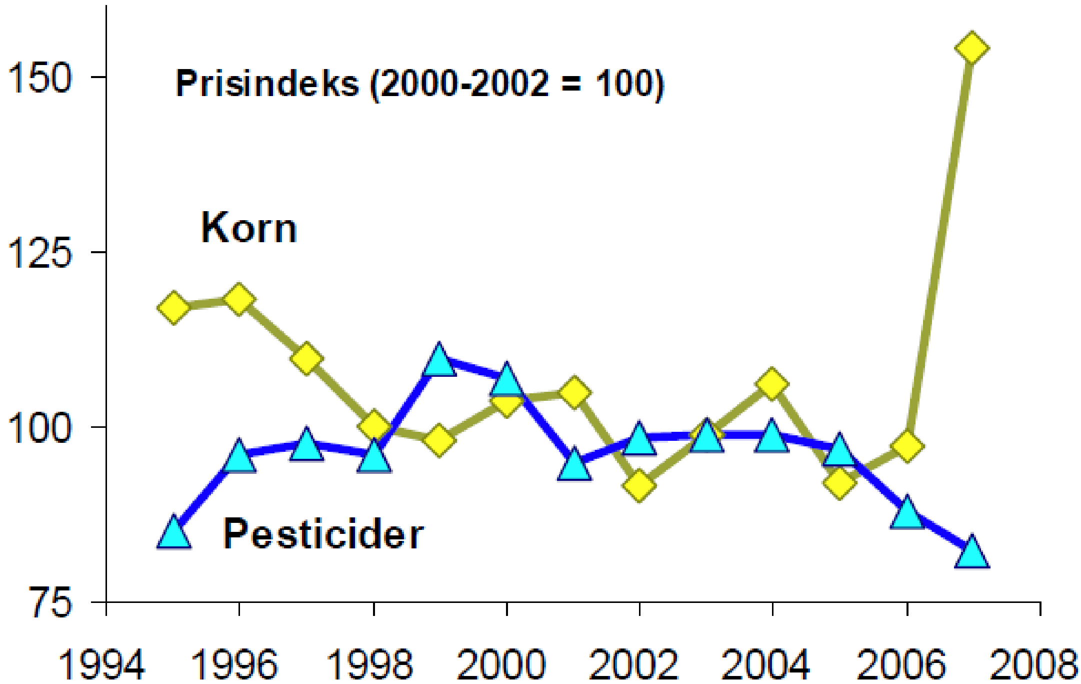

Figure 3.2 – Price index (2000-2002=100) for grain (korn) and pesticides (pesticider)

Source: Ørum et al. (2008: 103).

The Danish composition of crops is important for the TFI too – different crops need different treatment. However, the development in the composition of crops in the years 1996 to 2001 led to a decrease in the actual need for pesticides of 0.08 in the TFI (Ørum et al., 2003). For the period between 2003 and 2007, the development in the composition of crops has not substantially changed the need for pesticides (Ørum et al., 2008: 105). However, the occurrence of new pests in Denmark, in particular more insects, stimulated by unusually mild Danish winters, among others, might have influenced the TFI. Furhtermore, in some years higher grain prices may have stimulated preventive spraying in some crops. Finally, an increase in the amount of winter crops combined with a poor crop rotation at approximately 50 % of the farms with winter crops has increased the need for herbicides (Ørum et al., 2008).

Such changes would alter the economically optimal level of the TFI from the original estimate of 1.7 (Ørum et al., 2008). Thus for 2007, Ørum et al. (2008) calculated the economically optimal TFI level to be 2.08 (before the higher 2007 grain price was realised).

Moreover, their calculations showed that within a TFI interval between 1.7 and 2.0, farmers' economic yield would not vary much, although a lower TFI was economically optimal for the farmers. The implication - emphasised by the authors - was that behavioural changes would not happen automatically but required 'strong(er) incentives', for instance through a pesticide quota system or higher pesticide taxes (Ørum et al., 2003, 2008).

Furthermore, structural developments in Danish agriculture exhibit consistently increasing farm size. The share of farms larger than 75 ha increased from 8 % in 1989 to 25 % in 2009 (Statistics Denmark, 2011a: 243). A 2003 estimation indicated that larger farms (150-200 ha) tend to use 15 % more pesticides than smaller farms (50-80 ha) corrected for crop composition and location (Ørum et al., 2003). Likewise, a survey among farmers showed that farmers with farms larger than 200 ha are more focused on optimising yield than smaller farmers and less on using the smallest amount of pesticides (Pedersen et al., 2011).

With the pesticide consumption currently at about a TFI of 2.5, clearly the Danish mix of pesticide policy instruments has failed to deliver on the objective of reducing pesticide consumption to a level of 1.7 TFI. In a 2010 assessment, the Danish Economic Councils (2010: 158f) concluded that the 1998 tax has failed to give the farmers incentives to reach the 1.7 target - this despite the fact that Danish pesticide tax levels are the highest in the world according to the Danish Competition Authority (Konkurrencestyrelsen, 2006: 253). The explanation for the poor effect of the tax, according to the Danish Economic Councils, is an inelastic demand for pesticides. The implication is that quite high tax levels are necessary for the tax to have the desired effect.

No ex post evaluations have assessed specifically whether the pesticide tax has delivered the expected reductions in the consumption of pesticides, namely a 5 to 10 % reduction (for the 1996 tax) and an additional 8 % to 10 % reduction by 1999 following the rate increases in the 1998 tax (see above). The trajectory of the TFI alone indicates that the tax has only a very small effect. It is conceivable that the developments in grain prices (increases some years) as well as pesticide prices (decreases) have counteracted the taxes, obscuring an actual effect of the taxes. But while this may hold for 2007 and 2008 with abnormal price developments, the pattern for the first half of the decade does not appear to support such a conclusion (see figures 3.1 and 3.2).

The TFI became the objective defining Danish pesticide policy because TFI was considered the best indicator for the environmental load at the time and because a reduction to 1.7 was assessed as achievable without substantial operational economic and socio-economic costs (Ministry of Environment and Energy et al., 2000: 4). When the TFI was introduced as a measure for consumption of pesticides in 1986 it was concluded that it is 'extremely difficult' to determine an environmentally reasonable level for the use of pesticides and therefore consumption of pesticides should be reduced 'as much as possible' – and a level of 1.7 was considered economically possible (Bichel Committee, 1998: 31). The objective remains a key benchmark for current Danish pesticide policies.

Danish TFI is low compared to TFI in other countries. A 2006/2007 comparison with TFI in three other countries in Northern Europe with large agricultural production shows (Table 3.1) very large differences.

Table 3.1. Treatment frequency index (TFI) and yield in wheat (2006/2007)

	UK (2006)	France (2006)	Germany (2007)	Denmark (2007)
TFI in wheat	6.74	4.1	5.8*	2.62
Wheat yield, tonnes per ha.	8.0	6.9	7.3	7.3

Source: Jørgensen and Jensen 2011.
Note: *Snail pesticides not included.

Jørgensen and Jensen (2011) explain the differences by five factors: 1) Varying pests, 2) Climatic differences, 3) Varying focus on gross/net yield, 4) Differences in political action plans, 5) Varying advisory services and variation in the independency of the advisory services. Furthermore, the Danish nitrogen regulation is having an effect on pesticide consumption by e.g. causing less use of growth regulators than in the other three countries (Jørgensen and Jensen, 2011).

Additionally, pesticide use can be measured by 'active ingredients'. In 2001 Danish farmers used 1.07 kg active ingredients from pesticides per ha. EU-15 average was 2.92 kg (Konkurrencestyrelsen, 2006). However, 'use of active ingredients' is not considered a very precise environmental indicator.

The pesticide tax and other policy instruments such as the advisory service constitute delivery mechanisms for a Danish TFI of 1.7. However, what environmental effects a

TFI of 1.7 would deliver, if reached, is quite unclear. According to the latest pesticide action plan, which covers the period 2004-2009, the pesticide policy is built on an effective approval system of pesticides and a minimization of the use of pesticides to a level compatible with 'profitable cultivation'. These measures are supposed to ensure continued supplies of pure ground water and pure food. The pesticide plan also mentions that pesticides have a negative effect on flora and fauna but effects are neither spelled out nor quantified (Ministry of Environment and Ministry of Food, 2003).

An assessment concerning the value of using the TFI as a policy indicator concluded that TFI 'is not a precise indicator for environmental effects' (Kjær et al., 2007). TFI can only be considered an indicator for effects *within* the field (and even here it is not very precise) while it does not address effects on flora and fauna in biotopes adjoining the fields (Kjær et al., 2007: 24). The Economic Councils (2010: 158) concludes that the TFI-indicator is not reliable as an indicator of environmental effects but should be considered an indicator of consumption only. The council points out that the negative effects on nature from pesticide use in the period 2000 to 2006/2007 have been 'unchanged to decreasing' while the TFI has been increasing. Consequently, the Danish Government is (November, 2011) planning to introduce a new indicator based on the toxicity of the different pesticides. The first studies using the new indicator suggest that not only the TFI has increased, so has the new and more precise indicator for environmental effects (Ministry of the Environment, 2011b).

As for effects on the aquatic environment, an increasing number of wells for water have been closed although registrations are inadequate as to the causes of these closings. It is estimated that about 5 % of wells for water used for drinking water contain pesticides in amounts that exceed legal limits (Danva, 2011).

In 2009 the surveillance programme found pesticides in 37 % of the water intakes. In about a third of these the quality limit values were violated (GEUS, 2010:68). It is not possible to establish a time series for the development due to differences in measurement methods. For the whole period 1990 to 2009 pesticides have been detected in 50 % of the intakes; 18.9 % of the intakes have experienced a violation of the quality limits in the period.

Measurements of pesticides in watercourses document occurrence of many different pesticides in Danish watercourses. A 2006 test with 60 samples in five watercourses found 22 different pesticides. Most common were AMPA, BAM and glyphosate, which all appeared in at least 70 % of the samples. However, no quality limits were exceeded in any of the samples (Aarhus University, 2011b).

A recent study modelling behavioural and environmental effects of a tradable pesticide quota, incorporating a price increase on pesticides of about 80 %, concluded that such a quota would reduce the pesticide pressure on the water resource by 25 % on average across the country - but this does not translate directly into a comparable reduction in impact on water ecosystems (Nielsen et al., 2011). But a report under the Danish Pesticide Leaching Programme concluded simply that pesticide monitoring has demonstrated the risk of leaching of a number of pesticides to the water ecosystem when these substances are applied in the maximum dosages allowed (Rosenbom et al., 2010; table 17 and 19, quoted in Nielsen et al., 2011).

3.2 Economic Assessment Criteria

The political decision to introduce a Danish pesticide tax and designing it as described in Section 1 was influenced by an interdepartmental committee led by the Ministry of Finance. The committee issued a report on the effects of green taxes on businesses (Andersen et al., 2001: 87), which estimated (based on calculations in Rude, 1992) that a pesticide tax rate of about one-third of the price of pesticides would have a noticeable effect on the environmental impact of pesticides. It was further described how negative economic effects on agriculture could be reduced by reimbursing the revenue – for instance by lowering property taxes.

Apparently, the pesticide tax was not compared with other policy alternatives and a cost-benefit-analysis was not carried out. A 1999 expert committee (Bichel Committee, 1999: 86ff) gave up on a comprehensive valuation exercise citing a lack of data on health risks and effects on the environment.

Furthermore, the rationale behind introducing a pesticide tax seems to have been driven by a) the comprehensive Danish green tax reforms of the 1990s aimed at gaining a double dividend by taxing environmental externalities and using the revenue to lower income taxes, in particular (Ministry of Taxation, 2001: 47) and b) the fact that there were problems in reaching one of the policy goals of the Danish Pesticide Plan (TFI of 1.7) through information and advisory services.

There is no specific assessment of the cost effectiveness of the pesticide tax. However, a government analysis of policy instruments to fulfil the aims of the Danish pesticide policy concludes that in general ad valorem taxes (such as the Danish pesticide tax) are cost effective policy instruments for reduction of the use of pesticides (Ministry of Environment et al., 2007: 17). Transaction costs of the pesticide tax were assessed ex ante to be quite small (see Section 3.6).

Needless to say, farmers are the main target of the tax and are therefore to some extent burdened by the tax. However, Before the tax level was raised in 1998 an expert committee commissioned by the Minister of Environment and Energy (Bichel Committee, 1998) assessed that it would be possible to reach a TFI of 1.7 within a period of 5 to 10 years without any substantial economic burden on farmers or for society as a whole (Bichel Committee, 1998: 142).

The pesticide tax revenue is fully reimbursed to the sector but there is some redistribution among different types of farms (see Section 3.3). Manufacturers and producers carry a burden too, as they are required to mark taxed products with a special label designed by the authorities indicating the tax category and the maximum price of the product; this system is considered relatively costly by the Danish authorities (see Section 3.3). Private home owners pay the tax too but their pesticide consumption is rather limited compared to agricultural use. Private home owners are not subject to reimbursement; revenue from private home owners is reimbursed to the agricultural sector (Interview Ministry of Taxation, 2011). Until 2003 the revenue was reimbursed to agriculture primarily through a lowering of the land tax by 0.43 %. A smaller part of the revenue was redistributed for various purposes within the agricultural sector. These were determined by the Ministry of Food following negotiations with the agricultural organisations. According to a 1997 agreement between the government and supporting parties part of the revenue was also used to support organic farming and improvement of the water environment (Ministry of Taxation, 2004). In 2003 the reimbursement system was changed and it was decided to reimburse a fixed percentage (83 %) of the revenue to a lowering of the land tax. The remaining 17 % are reimbursed to different activities in the agricultural sector through the Ministry of Food and the Ministry of Environment. Between 2001 and 2008 total revenue has varied between EUR million 53 and 66 (Dansk Landbrug, 2007 (2011 prices)).

There are no precise calculations or analyses as to how or whether the pesticide tax has reduced risks to human health and/or the environment. However, one of the main stakeholders, the Danish Water and Wastewater Association, estimate effects of the tax to be small and point to the inelastic demand for pesticides as the cause (see also Section 1). This NGO suggests that more targeted instruments – e.g. pesticide bans in water catchments – would be more cost-effective measures. However, several instruments will be needed because normally targeted instruments will not address all types of negative effects (biodiversity, health etc.). For instance, a ban on pesticides in water catchments will have a beneficial impact on groundwater but will not improve biodiversity significantly (Interview, Danish Water and Wastewater Association, 2011).

Another more targeted command-and-control-instrument is a ban on spraying in marginal zones extending up to 10 metres from lakes and watercourses to be implemented in Denmark from 2012. This is expected to affect biodiversity positively. The positive effects on the environment might be larger compared to other policy instruments but so would control and monitoring costs.

As described in Section 3.5, about one third of Danish farmers can be considered less responsive to economic policy instruments than the main share of farmers, as the former are more focused on optimizing yield than on prices on pesticides and crops (see Pedersen et al., 2011, 2012). Therefore, a pesticide tax does not give these farmers as strong an incentive to change behaviour as the farmers who are more focused on optimizing economic yield. The more economically oriented farmers should be responsive to taxes but, needless to say, responsiveness depends on the tax level and there are indications that the current tax levels, although comparatively high, are too low to prompt significant changes in farmer behaviour. The differences in responses to economic incentives do not appear to reflect underlying structural factors as the two groups of farmers are alike with regard to structural variables such as farm size and distribution across plant, cattle and pig production (Pedersen et al., 2012).

3.3 Distributional Effects and Social Equity

The agricultural sector is the main sector affected by the Danish pesticide tax. Horticulture and home owners are affected by the taxes too but the present case study is focused on pesticide taxes paid by farmers. Other stakeholders, e.g. water users, nature conservationists etc. might be affected positively due to changes in pesticide use triggered by the pesticide tax. However, as described (see Section 3.1), pesticide use is not decreasing in Denmark although it cannot be ruled out that the tax might have prevented an increase in pesticide use to an even higher level.

The Danish Water and Wastewater Association assess effects of the tax to be small due to the inelastic demand for pesticides (Interview Danish Water and Wastewater Association, 2011). The Danish Society for Nature Conservation finds that pesticide taxation is a good instrument but that the pesticide tax level has been too low to deliver the necessary effects (e.g. the Danish Society for Nature Conservation, 2008). Consequently, these stakeholders find that the tax has offered rather insignificant positive effects for water users, nature conservationists etc.

In general, the tax does not directly affect farmers' education, leisure activities or social connections while the full tax revenue from the farmers plus the revenue from private home owners is reimbursed to the farmers through a lowering of the land tax (see Section 3.2). Needless to say, individual farmers might have a net benefit/loss due to the tax design. An average farm of 165 ha farm spends between EUR 15 000 and 22 000 per year on pesticides (Konkurrencestyrelsen, 2006 (2011 prices)).

Farmers, who have reduced their use of pesticides due to the tax, might hypothetically have experienced positive health effects. The current use of pesticides in Denmark was assessed by a committee not to constitute a large threat to farmer health and epidemiological analyses have detected no long-term health effects in farmers exposed through their occupation to pesticide levels resembling current Danish use of pesticides (Bichel Committee, 1998). However, 25 % of the Danish farmers perceive that their health risk of spraying pesticides is large or very large (Pedersen et al., 2011, 2012). On the other hand it is a smaller share of the farmers who find that the risk to the environment is large or very large (ibid).

The pesticide tax has some distributional effects within the agricultural sector. Distributional effects were analysed before the implementation of the pesticide tax in 1996. It was noted that excise duties normally are passed on to the consumers/users through higher prices. However, the market for pesticides is characterised by being a market where producers and importers normally have a monopoly on their particular pesticide brand – sometimes there is no substitution option to other pesticides. Consequently, prices are often independent of the marginal costs, development costs and costs of approval of the pesticide. On the contrary, prices are decided based on the products use value for the farmers. While a pesticide tax does not increase the use value of the pesticide for the farmer, producers and suppliers will probably have to carry part of the tax burden (Minister of Taxation, 1995). As mentioned (see above), the revenue from the tax was fully reimbursed – primarily through lower land taxes.

Manufacturers and producers have to mark taxed products with a special label designed by the authorities indicating the tax category and the maximum price of the product. Customs and taxation authorities are obliged to control manufacturers and importers. A 2006 analysis concluded that the pesticide tax, due to this system, was among the ten most costly regulations within the jurisdiction of the Ministry of Taxation, measured by the burden induced on the businesses. The average burden of this system is estimated to be EUR 3 000 per year per manufacturer/producer. The system is criticized for being too costly and inflexible. Furthermore, it reduces competition because the maximum price of the product has to appear on the label (Konkurrencestyrelsen, 2006: 254).

Ex ante analysis also indicated that distributional effects would vary among different types of farms and in different Danish regions given the tax level and the reimbursement system. Thus, agriculture in Sealand, Eastern Jutland and Viborg County on average stood to get a better net result than farmers in Western-, Northern- and Southern Jutland. Furthermore, farmers in Bornholm County would, on average, end up with a relatively poor net result – primarily because of low land values (and consequently a lower reimbursement of land tax) and farmers in Storstrøm County would get a poor net result due to the high production of sugar beets in that county. Sugar beet production includes a relatively intensive amount of pesticides. Finally, the smallest farms would get the most positive net result as they tended to have the highest land values and the lowest consumption of pesticides.

Many farmers hold the opinion that the pesticide tax represents just another burden, which reduces their income. In studies farmers express the view that the pesticide tax has no behavioural effect because farmers of today use no unnecessary pesticides and further reductions will reduce their yield (Pedersen et al., 2011). 68 % of Danish farmers find that there is a large or very large risk of reduced yield if their use of pesticides is reduced (ibid). A feeling of injustice is quite widespread among the Danish farmers, although agricultural organisations were heavily involved in the policy process (see Section 3.4). Yet farmers say that their arguments against pesticide taxes (and other types of regulation) are not taken into account (Focus Group Interviews, 2008; Pedersen et al., 2011, 2012). For instance, they claim that Danish pesticide taxes force them to compete on unequal terms in the world market. Danish TFI and 'use of active ingredients' is low compared to other EU countries (see Section 3.1).

3.4 Institutions

In Denmark there is a strong norm for having untreated drinking water. Danish drinking water is normally untreated and if pesticide limits are violated in a well for drinking water the well will normally be closed instead of treated. According to one of the major stakeholders – the Danish Water and Wastewater Association - pure groundwater is a gift for the Danes. Pure groundwater has evolved due to biological circumstances making it possible to use only groundwater (and not surface water) for drinking water, combined with a climate with moderate temperatures. This stakeholder finds that it is more cost effective to prevent pollution in groundwater than to clean polluted water, where e.g. the energy costs can be quite high (Interview Danish Water and Wastewater Association, 2011). According to an expert involved in the 1995 political processes around the pesticide tax this norm was reflected in the viewpoints of the politicians involved; pollution of drinking water was not acceptable, while there was less focus on the negative effects of pesticides on biodiversity (Interview, Ministry of Taxation, 2011). In 1997 an expert committee was established to e.g. assess the effects of a total ban on pesticides in Denmark, among others. In this work, the economic costs of a total ban were estimated to be quite substantial – for instance GNP would decrease by 0,8 % (Bichel Committee, 1999).

Furthermore, the introduction of the pesticide tax in 1996 took place against a general move towards a green tax reform shifting the tax burden from income taxes to environmental taxes, among others, in order to encourage work and discourage consumption (Ministry of Taxation, 2001). Thus, an expert committee had paved the way with a report in 1992 proposing a reform that would include more environmental taxes on water, energy and transportation, among others (Ministry of Taxation, 2001: 47).

Despite this trend, the introduction of the pesticide tax did not take place in an entirely supportive institutional setting. Proponents of the tax, the Social Democrat-led government and the leftist opposition argued with reference to the polluter-pays-principle (Ritzaus Bureau, 30.11.1995). Agriculture opposed the tax arguing that it would weaken the competitive position of Danish agriculture while the center-right opposition parties argued that they were against allowing polluters to pay for their actions rather than to ban dangerous pesticides (Ritzaus Bureau, 1.12.1994). In the end the government also relied on the EU who strongly espoused the polluter pays principle (Ritzaus Bureau, 30.11.95).

An important aspect of the institutional setting is the tradition of including agricultural interest organizations in agricultural policy making. Thus, Daugbjerg and Pedersen (2004) argue that the Danish agricultural policy network resembles a close-knit policy community consisting of producer interest organizations and the Ministry of Agriculture who share an interest in maintaining the competitive position of Danish agriculture in international trades. In such, a policy community producer interests enjoy a privileged position.

Daugbjerg and Pedersen (2004) show how this privileged position of farmers affected the designs of the pesticide tax both in 1995 and 1998. The government established a commission of high-level civil servants to produce a proposal for a pesticide tax but with the mandate that the tax had to be construed so as to not diminish the international competitiveness of agriculture and so that revenues were reimbursed to agriculture (ibid: 234). Thus, for the 1994 tax scheme farmers were able to keep the tax revenues within the sector in the form of reduced land taxes, i.e. a non-earmarked reimbursement - the preferred solution by farmers (ibid: 225). When designing the tax the agricultural sector preferred the chosen ad valorem tax, among others, because this type of tax would generate a substantial revenue from private home owners (who were subject to the pesticide tax too) that would go to the agricultural sector (Interview, Ministry of Taxation, 2011).

In 1998 tax rates were increased and the reimbursement was earmarked for organic farming and monitoring of pesticide pollution, changing the redistribution of funds within the sector (Daugbjerg and Pedersen, 2004: 225). Yet, in negotiations over the state budget later that year a cap was placed on land taxes re-establishing a principle of non-earmarked reimbursements. Part of the revenue remains earmarked for research, marketing and other purposes.

The pesticide tax was introduced as an add-on or as part of a mix of policies regulating agricultural production and pesticide consumption. Thus, it did not change existing institutions directly related to pesticide policy but it did change the land taxes, as these were lowered in order to allow for a pesticide tax. Moreover, the pesticide tax led to the establishment of a new institution. In order to administer the earmarked funds an independent fund was set up, which is led by a board in which agricultural interests have the majority while consumer and labour interest organizations are also included. Conventional and organic farmers jointly suggest board members to the minister. The fund decides how the part of the revenue, which is not reimbursed through the lower land tax, is used within the agricultural sector (Promilleafgiftsfonden, 2011).

The question is whether the relatively strong accommodation of agricultural interests in the design of the pesticide tax can explain its poor effect. On the one hand, agriculture was not able to avert pesticide taxes as farmers in most other European countries were. On the other hand, the economic incentive was somewhat weakened by the reimbursement via land taxes, which relaxed the economic constraints of the farmers. Moreover, as shown in later analyses (Ørum et al, 2003, 2008), the tax rates were not high enough given the rather inelastic demand for pesticides, as well as other contextual factors such as grain prices that pushed the demand for pesticides.

3.5 Policy Implementability

The Danish pesticide tax was a national tax and therefore not a flexible instrument in the sense that the tax could be adapted to local particularities. However, the tax is flexible in the sense that farmers can determine whether to pay the tax or to reduce their pesticide consumption.

As for the policy process (as outlined in Section 3.4) agricultural interests enjoyed a privileged position in the policy community while environmental and other groups at the time worked more at the periphery of the policy areas (Daugbjerg and Pedersen, 2004; Interview, Ministry of Taxation, 2011; Interview, Danish Water and Wastewater Association, 2011). Needless to say, agricultural organisations and farmers were against the introduction of the tax and were fighting it in the media, among others. However, the policy design, particularly the reimbursement through land taxes and the establishment of a new institution administering the revenue, reflected the wishes of agriculture (see Section 3.4) and eased the implementation (Interview, Ministry of Taxation, 2011). It is not clear that agriculture directly influenced tax rates, but given the premise of the policy decision that the tax could not impair the international competitiveness, it is conceivable that agricultural interests were considered when tax rates were set. During the 1994/95 discussions of the tax design in the Tax Board of the Danish Parliament a total of six NGO's approached the board in oral and/or written form: Three of them represented agricultural organisations, one represented fruit growers, one represented the agrichemical trade and the last represented the textile industry (Minister of Taxation, 1995). In addition to agricultural interests various committees of either experts or civil servants (Dithmer Commission) participated in policy preparation but within the framework specified by the government and apparently anticipating agricultural interests.

Ministries did cooperate in the preparatory commissions, e.g. a cross-ministry committee of civil servants prepared an assessment of green taxes, including the pesticide tax (Daugbjerg and Pedersen, 2004). The case study has identified no budgetary constraints on the ministries at that stage of the political process. After the tax was put into force, transaction costs connected to the tax have been quite modest (see Section 3.6). Consequently, it is fair to assume that budgetary constraints and the regulatory burden on ministries regarding implementation have been modest, as well.

When the tax was designed there were many meetings between the Ministry of Taxation, the Ministry of Environment and the Ministry of Agriculture (Interview, Ministry of Taxation, 2011). The Ministry of Taxation preferred a tax based on the toxicity of pesticides but according to the Environmental Protection Agency (EPA) it was impossible to establish such a tax because it was impossible to rank the different types of negative effects of pesticides (on groundwater, fish in watercourses, biodiversity in windbreaks etc. etc.) (Interview, Ministry of Taxation, 2011). The assessment from one of the experts of the Ministry of Taxation involved in the process at the time is that the EPA did not dare to rank the negative effects because this would implicitly indicate that some offices (groundwater, biodiversity etc.) in the EPA were more important than others (Interview, Ministry of Taxation, 2011). The Ministry of Agriculture preferred an ad-valorem-tax to a per-unit-tax because such a tax would confer a smaller share of the tax burden on farmers and a larger share on produceres/importers while the full revenue was reimbursed to the agricultural sector - thereby making a net benefit for the sector. Furthermore, agriculture would also collect the revenue paid by private home owners (Interview, Ministry of Taxation, 2011). This model was finally chosen.

All sector policies affecting the prices of crops and pesticides can reinforce/reduce the expected effects of the pesticide tax. A prime example is the EU Common Agricultural Policy (CAP), which previously revolved around product support rather than producer support providing incentives for larger production and potentially reducing the effect of the pesticide tax. An example of CAP affecting pesticide consumption is the dramatic decrease in fallow fields in recent years following the European Union repeal of a requirement for set asides (see Section 2.1). Another example is the trend towards moving of measures from the single payment scheme to rural development. Other policies, e.g. the EU energy policy (e.g. by affecting biofuels) as well as EU's nature and environment policies and a range of other Danish and EU policies can reinforce/reduce the expected effects of the pesticide tax (see Table 3.2 for some examples).

Table 3.2. Examples of barriers and synergies with other policies

EPI Objective: Reduce pesticide residues in the environment (crops, soil, water)		
Other policies	*Objectives*	*Barriers and synergies*
EU pesticide policies -Framework directive on sustainable use of pesticides.	To protect human health and the environment from possible risks associated with the use of pesticides.	+++ In so far as the pesticide tax is effective it is fully congruent with the EU pesticide policy.
EU Common Agricultural Policy.	Stimulate agricultural production.	+ The first pillar links agricultural support to compliance with environmental and other regulation, incl. pesticide regulation. The second pillar includes subsidies for pesticide-reduced or free crop cultivation. But agricultural policy is not yet completely decoupled from production incentives.
EU Water Framework Directive.	Protection and improvement of water quality.	++ Article 16 of the directive sets limits on concentration on surface waters of a list of priority substances and other pollutants, including pesticides. In connection with the implementation of the EU Water Framework Directive the pesticide tax is slated for redesign.
EU Conservation Polices. Habitats directive. Bird directive.	Protection of natural habitats and biological species.	+ Establishes special conservation areas where pesticide use may be restricted.
Energy Policy. Renewables directive. Biofuels transport.	Promotion of use of renewable sources in energy production, incl. mandatory national targets. Promoting use of biofuels in transport.	-(-) Support for energy crops offers incentives for intensive production of such crops, including use of pesticides. It is not yet clear how large a share of renewable and fuel sources would derive from agricultural crops, which will determine the degree to which energy policies contradict pesticide policies.

An important barrier for the policy implementability of the pesticide tax seems to be that contrary to what is normally assumed in economic modelling not all farmers are profit maximisers. A recent Danish study based on a survey with 1 164 farmer respondents systematically analysed the most important economic and non-economic barriers in the decision patterns of Danish farmers regarding plant protection (Pedersen et al., 2011, 2012; Christensen et al., 2011). One of the main findings of the study, which applies cluster analysis, is that approximately one third of the Danish farmers attach greater weight to obtaining physical yield than to prices on pesticides and crops when they make decisions. These farmers primarily optimise *physical* yield. On the other hand, around half of the farmers focus more on prices. They optimise *economic* yield. In other words, only about half of the farmers respond to price incentives in the manner assumed in ex ante analyses of pesticide taxes. The analysis indicates that farmers who are more focused on optimising physical yield (and less on prices) are less responsive to increases in pesticide taxes and other types of economic instruments than the farmers in the price-oriented cluster. As pointed out above, these differences do not appear to reflect underlying structural characteristics, as the farmers in the two groupings are alike with regard to structural variables such as farm size and distribution across plant, cattle and pig production (Pedersen et al., 2011, 2012; Christensen et al., 2011; Nielsen, 2009).

A 2007 inter-ministerial report found that a TFI of 1.7 might be reached by raising the tax levels from the current 33 % and 54 % to 90 % (fungicides) to 460 % (insecticides). One problem with tax increases of this magnitude is the risk of illegal importing of pesticides from neighbour countries (Ministry of Environment et al., 2007). Current levels of illegal imports are impossible to estimate but every now and then illegal pesticide transports are revealed by the authorities (Ministry of Environment, 2011a). In December 2011, the Danish Ministry of Environment revealed the most severe example of illegal import of pesticides to date. An importer of pesticides was reported to the police for illegal import and resale of 45 tonnes of pesticides from Germany in the period 2006 to 2009. A second company and 44 farmers and horticulturists were reported to the police in the same case too (Ministry of Environment, 2011c).

Another feature of the tax design that may reduce its effect is the fact that it is levied on the sales price of pesticides while environmental effects conceivably would be greater if the tax was based either on the TFI (Bichel Committee, 1998) or on the environmental impact of the compounds or specific products. These possibilities were considered when the tax was designed in 1995 but, as mentioned above, it was concluded that it would be too difficult to design the tax base on these elements (Minister of Taxation, 1995; Interview, Ministry of Taxation, 2011). More recently it has again been suggested to redesign the tax based on environmental effects (see e.g. Kjær et al. 2007; 2008). In fact, farmers criticise the lack of evidence that would justify in terms of environmental effects the policy objective of a pesticide consumption matching a TFI of 1.7 (Focus Group interviews, 2008; Pedersen et al., 2011). In November 2011, the Danish Minister of Environment announced that a new tax and a new method for measuring pesticide consumption/load will be presented within a few months (Ministry of the Environment, 2011b).

3.6 Transaction Costs

No specific definition of transaction costs has been identified in the available literature for the case study.

Many meetings were held between different ministries and organisations before the pesticide tax was finally designed in 1995 (see Section 3.5). Meetings were fewer when the tax was doubled in 1998 because now the arguments of the different actors were known (Interview, Ministry of Taxation, 2011).

Different types of taxation models were considered and discussed in the committee preparing the tax – in particular between experts from the Ministry of Agriculture, the Ministry of Environment and the Ministry of Taxation. In particular a tax based on toxicity, preferred by the Ministry of Taxation, was discussed as an alternative to the chosen ad valorem tax but this type of tax was found impossible to design by the Environmental Protection Agency (see Section 3.5). Effects of the proposed tax were calculated ex ante (with high uncertainty) (see Section 3.1 and 3.3).

When the tax was introduced some transaction costs were assessed. Considerations on transaction costs affect the design of the tax. Basing the tax on sales prices the Ministry of Taxation expected to minimize inspection costs and administrative costs, as the number of companies dealing with production and import of pesticides was considerably lower than the number of companies in retail (a tax on the wholesale price was considered too) (Minister of Taxation, 1995). It was estimated that non-recurrent expenses to the labelling system, information and computers would be EUR million 0.4 (2011 prices). Running expenses were estimated at an amount of EUR million 0.2 (2011 prices) for printing and mailing the price labels. The running expenses were paid by the registered companies through payment for the price labels. This system is considered one of the ten most burdensome regulations for the companies within the jurisdiction of the Ministry of Taxation (see Section 3.3). Running expenses might be a bit underestimated. In 2006, one of the two largest chemicals and feed companies (two companies control a very large share of the Danish market) estimated the labelling costs for this company to be between EUR million 0.2 and 0.3 per year (0.3 % of the company's turnover on pesticides (Landbrugsavisen, 2006)).

Orders for price labels are placed with the tax authorities who deliver labels within two weeks. When the products are labelled, producers and importers are welcome to lower the price when selling the products to retail but they still have to pay the tax based on a higher product price (on the label) – as it is very complicated to get the label changed. It is not permitted to increase the price of the product once it is labelled while this would give an incentive to avoid taxation by registering the product at a low price (and low taxation) and then raise the price after labelling. Chemicals and feed companies complain that the system implies that they have to negotiate prices with producers and importers six months before the season starts when they have to affix a revenue label to the products. One company informs that it has to put labels on 300 000 products every season (Konkurrencestyrelsen, 2006). For instance, when world market prices decrease the companies have to put new labels on the products (Interview, chemicals and feed company, 2011).

Although the labelling system imposes some transaction costs on the companies there is no evidence of an impact on the functioning of the pesticide tax.

Customs and taxation authorities are obliged to control pesticide manufacturers and importers. From 2009, cooperation on control with illegal imports of pesticides has been intensified between the Environmental Protection Agency, the tax authorities and the Ministry of Food by establishing a task force on pesticides control (Ministry of Environment, 2011c). From 2009 to 2011, the Environmental Protection has used 0.5 man years per year at the task force, while the tax authorities have used between 0.75 and 1.25 man years per year on the task force and price label administration (e-mail, tax authorities, December 2011; e-mail Environmental Protection Agency, December 2011) (the figure for the Ministry of Food has not been obtained. Figures before 2009 are unknown). In December 2011, the task force revealed the most severe example of illegal import of pesticides to date (see Section 3.5).

Additionally, there are costs to the running expenses for the fund administering the earmarked funds (see Section 3.4). The size of these costs is unknown.

3.7 Uncertainty

The objective of the pesticide tax was clearly specified when implemented (1996-tax: a 5 % to 10 % reduction of pesticide use, 1998-doubling: an additional 8 % to 10 % reduction of pesticide use). However, the effect was estimated ex ante with high uncertainty, among others, due to high uncertainties regarding the price elasticities (0.5 was assumed in 1996; 0.75 was assumed in 1998). Today, measuring the impact ex post is also characterised by high uncertainty; the main problem being that several policy instruments are at play and the fact that pesticide use is affected by a number of other variables (climate, grain prices, farmer motivation, poor crop rotation etc. etc.) with varying degree of complexity, which makes it difficult to decompose their individual contributions to developments in pesticide use. Moreower, knowledge gaps regarding the causal links between land use, pesticide use and effects on environment and nature also entails some uncertainty as to the exact environmental effects of the tax. However, we do know with certainty that the Danish policy mix in pesticide regulation has failed to deliver a TFI of 1.7 in 2009, which was the goal according to the latest pesticide plan. It is quite uncertain though, what environmental effects a TFI of 1.7 would provide.

Regarding economic costs there is a lack of cost benefit/cost effectiveness analyses. However, it is certain that the tax generates substantial revenues, that the revenue is fully reimbursed to the sector (primarily through reduced land tax) and that the tax design and reimbursement method have some distributional effects among the farmers. It is furthermore likely that the transaction costs are relatively low[1].

4 Conclusions

4.1 Lessons learned

The Danish pesticide tax was implemented in 1996 and the tax rate doubled in 1998. Danish pesticide consumption measured by the treatment frequency index (TFI) for the last five year period (2005-2009) has been at approximately the same level as before the tax was adopted (2.5 in 1994), which equals the baseline scenario (without introduction of the tax). No ex post evaluations have assessed specifically whether the 1996 pesticide tax has delivered the predicted 5 % to 10 % reduction in pesticide consumption or whether the doubling of the tax rate in 1998 has delivered an additional 8 % to 10 % reduction, as also predicted. The trajectory of the treatment frequency index (TFI) alone indicates that the tax has only a very small effect, at best. It is conceivable that the developments in grain prices (increases some years) as well as pesticide prices (decreases) have counteracted the taxes, obscuring an actual effect of the taxes. But while this may hold for 2007 and 2008 with abnormal price developments, the pattern for the first half of the decade does not appear to support such a conclusion. Neither has the development in the composition of crops substantially changed the need for pesticides. However, poor crop rotation at some farms and the appearance of new pests have increased the consumption of pesticides some (Ørum et al., 2008). No ex post evaluations of the isolated effect of the pesticide tax has been performed. Consequently, it is impossible to deem the tax either a success or a failure. However, the Danish pesticide policy instrument mix in total can be considered a failure as the policy mix has severely failed to deliver a TFI of 1.7, which was expected ex ante.

It is estimated that about 5 % of Danish wells for drinking water contain pesticides in amounts that exceed legal limits (Danva, 2011). In Denmark, there is a strong norm for having untreated drinking water.

As for cost effectiveness of the pesticide tax no precise assessment has been undertaken. However, a government analysis of policy instruments to fulfil the aims

[1] For the pedigree matrix on uncertainty, see Annex 2.

of the Danish pesticide policy concludes that in general, ad valorem taxes (such as the Danish pesticide tax) are cost-effective policy instruments for reduction of the use of pesticides (Ministry of Environment et al., 2007: 17). Transaction costs of the pesticide tax were assessed ex ante to be quite small.

About one third of Danish farmers can be considered to be less responsive to economic policy instruments than the main share of farmers, as the former are more focused on optimizing yield than on prices on pesticides and crops (see Pedersen et al., 2011, 2012). Therefore, a pesticide tax does not give these farmers as strong an incentive to change behaviour as the farmers who are more focused on optimizing economic yield.

The agricultural sector is the main sector affected by the pesticide tax. However, the full revenue is reimbursed to the sector – primarily through lower land taxes. This reimbursement model was the result of intense exchange/negotiations between agricultural organisations and three ministries, when the tax was designed.

The tax has some distributional effects within the sector. For instance, farmers who grow crops with a higher pesticide need and farmers living in regions with lower land values will, on average, experience a poorer net result than other farmers. Importers and producers of pesticides find the price label system connected to the tax to be costly, a perception which was supported by a 2006 analysis concluding that the price label system is among the ten most costly regulations within the jurisdiction of the Ministry of Taxation.

The current use of pesticides in Denmark was assessed by a committee not to constitute a large threat to farmer health, but 25 % of the Danish farmers perceive that their health risk of spraying pesticides is large or very large (Pedersen et al., 2011, 2012). A smaller share of the farmers finds that the risk to the environment is large or very large (ibid). Many farmers hold the opinion that the tax is unfair and represents just another burden reducing their income.

There is room for improvement for the design of the pesticide tax. The Danish government is currently planning to redesign the tax by changing it from an ad valorem tax to a tax based on toxicity, which means the tax will target environmental effects more directly. However, this redesign is a comprehensive task because different pesticides cause many different types of environmental effects. Due to the inelastic demand of pesticides tax levels should probably be relatively high.

4.2 Enabling / Disabling Factors

In conclusion, the precise effects of the pesticide tax are unknown. Due to the relatively inelastic demand of pesticides environmental effects might be larger for other types of environmental taxes. However, the transaction costs associated with the pesticide tax have apparently been relatively small, which implies that the tax may be a relatively cost effective policy instrument - assuming it is changing pesticide use. Full reimbursement of the revenue, primarily through lower land taxes, made the tax more acceptable to the agricultural sector but, unsurprisingly, the tax is not popular among the farmers. Redesigning the tax to reflect toxicity might improve its environmental effects and make the tax more acceptable to farmers.

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6 Data Sources

See Section 5.

Conversion of DKK to EUR:

OANDA – Historical Exchange Rates: http://www.oanda.com/currency/historical-rates/

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Annex I: Acknowledgements

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Annex II: Pedigree matrix regarding uncertainty (section 3.7)

Table Annex 2.1 Pedigree matrix for performance of pesticide tax with respect to targets

	Environmental outcomes	Economic costs	Distributional effects
Target	Reduce consumption of pesticides	At low costs	Without unintended negative distributional effects
Proxy	2	4	3
Empirical	3	3	3
Method	3	3	3