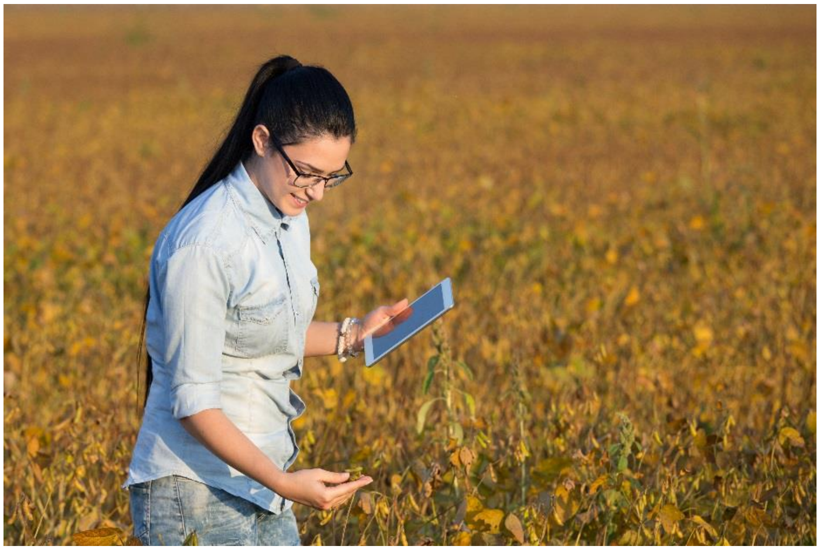
Policy Instruments for Addressing Externality in Agriculture



Paper prepared for CAPI

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1. Introduction

Modern industrial agricultural practices have come under increasing scrutiny because of the externality (or spillover) costs of farming. For example, environmentalists in the EU are hoping to ban glyphosate, because it is considered harmful to animals and humans. Yet, glyphosate is a herbicide used with genetically modified, glyphosate-tolerant crops, such as canola and corn, in zero tillage systems to reduce soil erosion and promote soil carbon storage. Lobbyists have been more successful in banning neonicotinoids, which are a class of insecticides considered harmful to pollinators (Butler 2018), but important for controlling pests. Air and water quality tend to be negatively impacted by farm operations. Nitrogen (N) leaching into groundwater can result in 'blue baby syndrome', while N runoff into surface waters causes eutrophication thereby harming aquatic animals. Carbon dioxide (CO_2) emissions from machinery operations degrade soils, and methane (CH_4) from livestock production, increase the potential for global warming. Other externalities include noise, smell and other nuisances that may be considered harmful.

Clearly, agricultural activities generate many benefits to society, but there are also costs. Although net value added can easily be calculated as the quasi-rent (or producer surplus) attributable to agriculture, there are positive and negative externalities that are neglected or not properly accounted for in determining the overall contribution that agriculture makes to society. Not surprisingly, the focus has been more generally focused on the negative externalities associated with modern agriculture, with a relatively recent study concluding that the hidden food-system externality costs in the United Kingdom exceeded ₤120 billion in 2017 (Fitzpatrick et al. 2017).

Consideration of externalities is important in countries where industrial agriculture and exports dominate. In countries such as The Netherlands, which is the second largest exporter of agricultural commodities by value in the world, the externality costs and benefits need to be balanced against value added to get a sense of whether the agricultural sector provides an overall benefit to society. This is not to suggest that, if the externality costs exceed value added, agriculture should be abandoned entirely in a country. Rather, it might be necessary to cut back somewhat on the intensity of agricultural production to reduce the externality costs, but not abandon industrial agriculture entirely.

My purpose in this paper is to examine critically the issue of externality in agriculture and what can be done about it. In this regard, it is important to remember that something might be identified as a problem but may, in fact, not be a problem – we should not simply assume a problem exists and then try to solve it without knowing whether the problem even exists or not. With this in mind, I begin in the next section by reviewing some studies that have identified the problem of externality, measured its extent, and recommended that action be taken to reduce or perhaps even eliminate externalities in agriculture. From some of these studies, one might draw the conclusion that we should stop 'industrial' farming, including intensive crop and livestock production, and return to a more extensive, 'ecologically-friendly' agriculture – a throwback to earlier days. The objective of this essay is to provide insights into this issue.

In section 3, I discuss policy instruments for addressing externalities. These include regulations, purchases of certain property rights, and a variety of incentives that include subsidies and taxes. Then, in section 4, I consider uncertainty in the identification and measurement of agricultural externality, and its implications. My conclusions follow.

2. Externalities in Agriculture: The Evidence

A number of studies at the turn of the millennium sought to determine the potential costs of the externalities associated with agricultural activities. Several estimates circulating in the ecosystems (but not economics) literature suggest that traditional evaluations relying on market measures largely underestimate the impact of human activities on ecosystems.

The most notable of these are due to Costanza et al. (1997, 2014).[1] These authors suggest that the economic value of food and fibre from agriculture is low relative to the other ecosystem services that the land can provide. But their estimates are based on limited empirical research; for example, Costanza et al.'s (1997) estimate of the ecosystem values for agriculture for the EU-27 is based on data from only one experimental arable farm in Denmark taken from Porter et al. (2009). As a result, such information is not directly useful for policy purposes. Nonetheless, this has been the approach followed in most studies.

For the UK, Pretty et al. (2000, 2001, 2005) and O'Neill (2007) estimated that the total external costs of agriculture were substantial, constituting some £233 million (£429 million in 2018; US$549 million),[2] or 89% of average net farm income in 1996, but less than three percent of 1996 agricultural value added. They recommended that policy should aim to internalize the external costs by redirecting public support from polluting activities to sustainable practices, using subsidies to encourage 'positive' farm activities that are under-provided in the market place. These should be combined with a mix of advisory and institutional mechanisms, regulatory and legal measures, and economic instruments (e.g., taxes on nitrogen fertilizer) to correct negative externalities.

For the U.S., Tegtmeier and Duffy (2004) estimated the annual external costs of agricultural activities to range from $7.7 to $22.8 billion (after conversion to $2018), or some 5.0 to 15.0 percent of value added. Based on 168.8 million hectares of cropland in the United States, they calculated that the external costs varied from $39.74 to $129.17 per hectare. This suggests that some action might be needed to address agricultural

[1] Costanza et al. (2014) estimate that the Earth's ecosystems have an annual value of $142 trillion, or more than double global GDP. Since these measures are based on people's stated or revealed preferences, the derived value of ecosystem services is clearly too high because it fails to take into account budget constraints. Yet, it is also too low because without any ecosystem services humans would go extinct – the actual value is therefore infinite. The problem is that decisions should not be made on the basis of average (total) measures, but on costs and benefits at the margin. Unfortunately, our analysis suffers from the same criticism because data are lacking on marginal costs and benefits.

[2] Inflation in the UK between 1996 and 2018 was 84%; in this section, some values are also converted to U.S. dollars using exchange rates of 1£=$1.28 and 1€=$1.13.

externalities, with the authors arguing for intervention to reassess and reform agricultural policy. Any reforms and new policies need to be carefully considered because policies that address certain types of externalities may lead to adverse consequences elsewhere in the agricultural sector and may involve high transaction costs that outweigh the benefits of taking action – externality might not be a problem after all.

Similar findings to those of the earlier UK and U.S. studies were also found in a Swiss study by Pillet et al. (2002). Both the UK and U.S. studies focused mainly on agriculture's negative externalities, ignoring potential positive ones. Additionally, they only focused on the supply side (including externalities as an additional cost), ignoring the benefits to consumers.

The study by Fitzpatrick et al. (2017) ignored value added and compared externality costs against gross expenditures on food, likening ₤120 billion ($153.6 billion) in negative spillovers in 2017 with consumer expenditures of ₤120 billion in 2016. Unlike the earlier studies, they include in their calculation of externality costs the adverse impacts of the food system on consumers, with the negative impacts of such things as heart disease, cancer and obesity linked to consumption of food and valued at £44.9 billion. The externality costs of food production, as opposed to only agricultural production, are valued at £16.1 billion annually; these include costs of food poisoning (£1.7 billion) and costs related to the use of organophosphate pesticides (£12.0 billion). Externality costs also included farm support payments (£6.4 billion), loss of biodiversity (£12.8 billion), and degradation of natural capital (£30.9 billion), of which greenhouse gases and emissions of pollutants constitute £12.2 billion ($15.6 billion).

One problem with the Fitzpatrick et al. (2017) study is its erroneous attribution of economic costs and benefits. For example, support payments do not constitute an externality cost as these are an income transfer, and neither a cost or benefit. It is unlikely that support payments incentivize greater production, because most EU support of farmers in now decoupled (see van Kooten 2019). However, even where support remains coupled to production, the associated externality costs calculated by the authors are counted elsewhere – the UK study double counts externality costs. Another problem is the failure to establish a link between the farm-level production of commodities, much of which is exported, and overall consumption of food, much of which is imported.[3]

A final study considered here is a Dutch study by Jongeneel et al. (2016), which sought to provide an economic foundation for the measurement of externality, concluding that studies tend to overestimate the true costs of externality. The Netherlands study employed data from the period 2005 to 2012 – a period during which the EU moved away from support payments that incentivized agricultural output to ones that were decoupled from production; farmers now receive a direct payment that no longer depends on what or how much farmers produce (van Kooten 2019). For this period, the researchers found the annual externality costs to average €1,868 million ($US 2,111 million), while gross annual externality benefits (positive externalities related to provision of habitat for certain birds, mental health benefits of on-farm clinics, etc.) averaged €263 million ($297 million).[4] Given that annual value added in Dutch agriculture has been calculated to be some €10,604 million ($11,983 million), total average annual net benefits from agriculture amount to €8,736 million ($9,872 million). Nonetheless, on an area basis, net externality costs were estimated to average €849/ha ($959/ha) of arable, horticultural and pasture land.

The per hectare externality costs associated with Dutch agriculture are significantly higher than those found in other countries, perhaps all other countries. This should not be a surprise given the small size of the Netherlands (only 1.89 million ha of farmland) and the fact that it is the second largest exporter of agricultural commodities (and food products) in the world after the U.S. The existing land available to the agricultural sector is likely to be more intensely farmed than in all other countries (with some regional exceptions). Thus, we might take $960/ha as an upper bound on the externality costs of

[3] In 2017, about half of domestic food production was consumed within the UK; UK exports of food and drink amounted to £22.0 billion, but the country had a trade deficit regarding food and drink of £24.2 billion. https://www.gov.uk/government/publications/food-statistics-pocketbook-2017/food-statistics-in-your-pocket-2017-global-and-uk-supply [accessed 19 February 2019].

[4] No attempt is made here to correct values for inflation.

agriculture. However, estimates of externality costs are extremely sensitive to the social cost of carbon used to evaluate CO_2 emission related to agricultural activities and land use.

In the Netherlands, 3.4 megatons (Mt) of CO_2 emissions are estimated to come from peat soils, with another 26.0 Mt of CO_2 and CO_2-equivalent (CH_4 and N_2O emissions converted to CO_2 equivalence from a global warming perspective) originating with agricultural activities, including emissions (or uptake) of CO_2 from changes in soil organic matter. Using a shadow price of carbon of €16/tCO_2 ($20.80/t$CO_2$), the associated estimate of €470.4 million ($531.6 million) amounted to one-quarter of the total externality cost of Dutch agriculture. If a social (marginal) cost of carbon (SCC) of $30.70 (approximately €27) per tCO_2 was used instead, the average externality cost would be €793.8 million, or 36% of revised annual externality costs of €2,191.4 million.

3. Externalities in Agriculture: Policy Instruments for Addressing Externality

Production externalities occur when the agricultural producer making a decision does not recognize the external or spillover effects of that decision. Externalities include agricultural practices that have a negative impact on the environment, reduce the quality of life of others, and/or add costs to other production activities (e.g., fish production in a lake is reduced due to eutrophication from nitrogen and other nutrient runoff that causes too much plant growth). Because these cases involve negative off-farm effects that can injure and accumulate into the future, the sustainability of current agricultural practices is called into question. Conversely, public good externalities arise because markets do not provide the necessary incentives to landowners to supply enough of the public good or amenity that society desires. Thus, government intervention may be required to protect agricultural land and open space, scenic viewscapes, wildlife habitat, wetlands and so on.

So how do we go about addressing externalities in agriculture? What policy instruments are available for reducing the costs of externality? There exists a vast literature concerning how policymakers should address all sorts of externalities related primarily to air and water pollution. In this section, a variety of approaches are discussed; some of the approaches are general to the way economists have thought about externality, but many are unique to agriculture and land use. Policies to address externality range from regulations that require landowners to do something, such as contour ploughing (which involves ploughing across the slope following the contour lines), or that prevents certain activities (e.g., draining wetlands, planting illegal crops). Regulations could also involve land-use zoning, the purchase of certain property or development rights to land, and even education and moral suasion. Finally, many policies involve economic or financial incentives, such as charges, emissions trading and other incentives that lead to a reduction in externalities. We begin by considering economic incentives.[5]

Economic Incentives

Economists tend to focus primarily on regulations and economic incentives. Economic theory leans toward the use of economic incentives, although regulations are more effective in achieving a predetermined target (e.g., see van Kooten 2013, pp.298-302). The issue here concerns prices versus quantities (Pizer 1997; Weitzman 1974). Suppose the authority wishes to reduce fertilizer use in a particular watershed. It could regulate farmers so they use no more than a specified quantity of fertilizer; the objective could be achieved by limiting how much fertilizer each farmer in the watershed can purchase, with farmers potentially able to trade their allocations with other farmers in the watershed. Alternatively, the authority could tax fertilizer so that the quantity purchased by farmers in the watershed equals the desired level.

The tax and regulatory outcomes should be identical – the price (tax) and quantity (limits) are opposite sides of the same coin. However, when abatement costs and/or benefits are uncertain (i.e., the demand for fertilizer is unknown), picking a tax can lead to the ‘wrong’ reduction in fertilizer use, while choosing a quantity can result in a mistake about expected crop yields. Such errors have social costs. If the marginal cost of abating fertilizer

[5] Barichello et al. (1995) discuss agricultural externalities and land use in the context of British Columbia, with particular focus on the Fraser Valley. Some of the ideas presented here are formed by their discussion, although they provide much greater depth and with specific examples.

use is steep (crop yields decline rapidly with reductions in fertilizer application), a tax on fertilizer might be preferred. The tax can be slowly increased, thereby avoiding potentially undesirable costs of reducing fertilizer; if crop yields are not very sensitive to fertilizer reductions, a quantity restriction might be more effective in achieving the desired reduction in fertilizer applications.

Given that CO_2 and other GHG emissions, principally methane and nitrogen oxides (N_xO), account for the single largest cost component of externalities associated with agricultural activities, a carbon tax would seem to be the most logical economic instrument to apply to agricultural activities. A carbon tax is easy to implement when it is applied to emissions from fuel use, the production of inputs, such as fertilizer and other chemicals, and a few other activities. However, it is much more difficult to implement when we consider emissions from livestock, soil degradation, fertilizer applications, and so on. For some of these activities, we could simply tax inputs according to the CO_2 and equivalent emissions they release as a result of their use. The main obstacle is the political fallout from attempting to tax farm inputs; politicians are unlikely to implement taxes on farmers.

To avoid taxing farmers and to avoid the costs and difficulties of monitoring land and other input uses, other policies have been implemented. These might be considered of a regulatory nature, but they are more nuanced as they combine regulation with incentives. In theory, regulations or standards are inefficient compared to taxes or charges for achieving environmental objectives, but from a practical standpoint, the informational requirements for determining appropriate charges may be more onerous than what is required under the more nuanced regulatory approach. For example, the information required to reduce the externality costs of soil erosion, even within a single watershed, are too onerous to enable the authority to set a universal charge. In these circumstances, the case for some sort of regulatory approach to be employed is a strong one, which is why it has extensively been used in the agricultural sector.

Cross Compliance

Cross compliance is one of the simplest means for reducing some of the externalities associated with agricultural production. Because it forces farmers to comply with environmental standards to be eligible for farm subsidies, cross compliance is deemed a red-ticket policy. It describes practices that agricultural producers must implement in order to be eligible for government support payments – cross compliance essentially offsets externalities that are associated with the agricultural output that the payments incentivize. In the U.S., for example, farmers at various times were required to set-aside some of their cropland, with farmers often entering set-aside land in the Conservation Reserve Program (discussed further below).

In the European Union, producers are compensated for providing public goods in the form of environmentally-friendly farming practices – a so-called *greening component* that is added to the single farm payment that farmers receive. The program might therefore be considered a green-ticket policy as it incentivizes more of the desired public good. The greening component imposes a set-aside requirement referred to as the Ecological Focus Area. However, the new environmental requirements are costly for farmers as the set asides lead to a minimum 5% reduction in subsidy payments that are worth more than $200,000 annually to some individual farms (van Kooten 2019, p.231).

Purchase of Development Rights and Land-use Restrictions

Zoning is one of the primary regulatory tools used to enforce a desired geographical distribution of permitted land uses. Zoning must be beneficial to society or else it would not have been undertaken; thus, it has to result in a social surplus which the land-use plan, or blueprint, then distributes among landowners. Zoning basically assigns development rights and distributes the surplus associated with the land-use plan in an arbitrary manner. This assignment has three major impacts on agriculture. First, it does not fairly distribute the surplus associated with the development as there are definite winners and losers, with the latter generally not compensated by the former. Second, it invites speculation and encourages rent seeking to gain variances to the zoning ordinance – to the blueprint. Third, planning is not a dynamic process capable of reflecting the changing demographics of a growing farm community and the nearby urban developments. As a result, zoning and the tax regime associated with it suffer from lethargy, a lack of coordination between levels of government, and the failure to consider private non-commercial use of land. But the major objection to zoning is that it creates inequities, with a farmer's ability to earn income affected by the zoning ordinance.

British Columbia's Agricultural Land Reserve (ALR) and similar legislation (e.g., greenbelts) in other jurisdictions prevent development of land for commercial, industrial and residential uses. The ALR is an extreme example of zoning. The ALR does not usually impact landowners far from urban areas, but it does have adverse economic and income distributional consequences near urban areas. The original ALR legislation led to windfalls by some landowners, but wipeouts for others (van Kooten 1993). In the longer term, it led to the 'impermanence syndrome' whereby farmland becomes fragmented, agricultural service providers disappear, farmers are unable to achieve economies of scale, farmers increasingly need to deal with vandalism and nuisance complaints, and urban residents lobby against intensification of farm operations (e.g., opposing feed lots, greenhouses, etc.) because they are really interested in maintaining open space rather than farmland.[6]

An alternative to zoning is for government to purchase certain property rights. One means is for the authority to purchase land and subsequently sell it back to the original owner minus certain rights that contribute to land degradation. It is also possible that only some part of the land is sold or leased to an agricultural producer. The problems with the purchase of property rights are its expense and, perhaps, the inability to subdivide a farm property because of other extant zoning regulations.

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[6] The argument that the ALR is meant to protect society's ability to produce food in the future is nonsense. Food security is not a problem as the Netherlands has shown. The Dutch farm their land so intensively that it is the world's second largest exporter of food despite a land base that pales in comparison to land available in BC.

Another approach is to employ easements or restrictive covenants, which can ensure that a particular land use remains in effect indefinitely and that development rights are not repurchased at some future date – this then prevents the irreversible loss of important conservation land. Thus, the purpose of a restrictive covenant is to bind current and future landowners to specific land uses. A restrictive covenant might simply restrict certain crop practices or other uses of a field; certain agricultural practices, crop choices and crop rotations could be elements of a restricted covenant. Conversely, an easement on land restricts what can be done with a specific portion of a field; for example, an easement might prevent ploughing within 10 meters of a wetland area to protect waterfowl habitat. Easements and covenants ensure that the landowner is compensated for the restriction on use thereby providing the landowner with funds to set against losses from implementing the environmentally-friendly changes. Easements and restrictive covenants also bring stability to the land base and discourage speculation, with land values better reflecting social values and the capacity of the farmland while resulting in a more viable agriculture.

Payments for Ecological Services and Contracting

An alternative to zoning and purchase of development rights is for government to enter into long-term agreements with farmers to restrict land use in environmentally sensitive areas or to idle specified parcels of land. The best example is the U.S. Conservation Reserve Program (mentioned above), where landowners bid to idle pre-identified highly-erosive parcels of land for a period of upwards of ten years. Implementation of the North American Waterfowl Management Plan of 1986 saw Saskatchewan farmers enter into five- and ten-year license agreements that paid them annually to protect a wetland area and equivalent area of cropland for waterfowl habitat, and lease agreements of ten years that paid farmers to plant dense nesting cover and predatory fences to protect breeding waterfowl (see van Kooten 1993; van Kooten and Schmitz 1992). Similar types of arrangements continue in one form or another, along with legislation that prevents, or at least slows, the conversion of marginal wetlands and grasslands into cropland. In some cases, farmers can purchase wetlands or grasslands from a wetland or grassland reserve created for the purpose of ‘no net loss' of wetlands/grasslands.

Payments for environmental (ecological) services (PES) also rely on contracts to ensure that services are protected over time. For example, contracts are used to create carbon offset credits, often without government involvement. Carbon aggregators enter into contracts with landowners to plant trees and keep land in forests for perhaps 25 years or more. The aggregated carbon credits are then certified by a recognized certifier who sells them on the mandatory or voluntary carbon market. Since these are private contracts that occur most often in developing countries, the door is open for corruption as contracts require governance structures, such as rule of law, that are lacking in many countries. A major problem is that, once landowners are paid to plant trees, they have no incentive to retain the land in forest; monitoring is less than ideal and annual payments may not always be significant to prevent reconversion to crops (see van Kooten 2017, 2018). Designing proper incentives in these situations is a challenge that still needs to be resolved.

Best Management Practices

It is difficult to track carbon fluxes in soils, the farms which contribute most to eutrophication in a watershed, and sources of other externalities. How does the policymaker calculate the carbon fluxes related to agricultural land use, or determine how to tax non-source nutrient runoff? A practical alternative to a tax or subsidy is to provide incentives for farmers to adopt best management practices (BMPs). Depending on the sector, a BMP is defined in terms of what an agricultural producer should do to reduce soil degradation (e.g., zero tillage, crop rotations), to minimize methane emissions (e.g., as related to manure handling), and how and when to apply chemicals optimally, and so on. BMPs address externalities indirectly; for example, one of the stated goals of the BMPs is carbon sequestration, primarily in soils. Rather than attempting to reduce fertilizer applications via a tax or cap-and-trade program, or using a combination of taxes and subsidies to incentivize carbon sequestration with its inherent monitoring problems, a BMP simply improves such outcomes compared to existing practices.

Many BMPs are already part of Canada's Farm Stewardship Program, which falls under the Canadian Agricultural Partnership (CAP) framework and provides subsidies to farmers who adopt BMPs in their sector. Since programs are agreed upon by the two levels of government (federal and provincial), funding for BMPs differ from one province to the next (see van Kooten 2019). Under the Farm Stewardship Program, a permanent tame forage BMP covers 50% of establishment and certified seed costs up to a maximum of $10,000, while a permanent native forage BMP covers 90% of establishment and certified seed costs up to $10,000.

In Manitoba, the government will cover between 25% (most usual) to at most 50% of the cost of adopting the practice. The programs that are eligible are: (1) establishment of cover crops (reduce erosion); (2) pasture improvements; (3) increased frequency of perennials within annual crop rotations; and (4) planting of perennials on sensitive lands. None of these programs pay directly for carbon uptake, but for adoption of the BMP. Overall payments are limited to $10,000 per year per farm. In addition, farmers can get some funding for activities that reduce CO_2 and other GHG emissions but they have to write up a plan under carbon management; this program requires farmers to detail the emissions savings before they are eligible for any funding.

4. Potential Pitfalls

There remains a great deal of uncertainty around the monetary values used in association with externalities. For example, the data used by Jongeneel et al. (2016) come principally from a consulting company, NIBE. Experts in Sustainability. On their website, they provide costs associated with 17 types of externality, including, for example, the marginal costs of CO_2 emissions and noise pollution. As noted on their website (http://www.nibe.info/nl/faq), "these costs represent what society should be prepared to pay for reducing the environmental impact [of the externality] to a sustainable level" (translated from original). Three examples of marginal externality costs include the following:

- Global warming potential: €50/tCO_2 ($56.50/t$CO_2$)
- Ozone layer depletion: €30/kg CFC-11 or equivalent ($33.90/kg CFC)
- Eutrophication: €9/kg phosphate ($10.17/kg PO4-3)

These values come from three sources: NIBE, CE (a Delft consulting company) and TNO (Netherlands Organization for applied research that is independent of government, university or any private sector firm). These values are as much a result of political as well as economic considerations. For example, the value of global warming potential was increased from €16/tCO_2 in 2015 to €50/tCO_2 in early 2019. Some values are based on surveys, others on benefit transfer methods and others as shadow prices from mathematical programming models. True values are quite uncertain, and this uncertainty can have a large effect on outcomes as illustrated earlier.

Consider again the marginal social cost of carbon (SCC), because CO_2 accounts for the single most important component of measured externality costs in agriculture. The government of British Columbia currently collects a carbon tax of $C35/t$CO_2$ ($26.25/t$CO_2$) that is expected to increase in increments of $C5 annually and reach $C50/t$CO_2$ ($37.50/t$CO_2$) by 2021, almost identical to the SCC for that year calculated by the Nobel Laureate William Nordhaus using his 2016 version of the Dynamic Integrated Climate and Economics (DICE) model (see Nordhaus 2013). With such values of the SCC, GHG emissions constitute half or more of the total externality costs of agricultural activities in the Netherlands and elsewhere.

What marginal cost should be used, Robert Pindyck (2013, 2017) finds integrated assessment models (IAMs) such as DICE to be too ad hoc, with outcomes highly sensitive to assumed parameter values. Nicholas Lewis (2018) finds that the parameterization of the carbon-climate component of the DICE model, in particular, is faulty. Not surprisingly, the same is true of the climate models themselves (see Lewis and Curry 2015, 2018; Hourdin et al. 2017; Millar et al. 2017). Despite such criticism, IAMs offer one of the only ways that economists can provide policy advice that is informed by the findings of the climate models and the Shared Socioeconomic Pathways (SSPs), or storylines, that are used to determine future CO_2 emissions (Riahi et al. 2017).

This does not mean that the problem of uncertainty is resolved. Rather, integrated assessment modelling should make one more sensitive to the uncertainty. The limits of the parameters need to be better explored. We provide an example using the DICE model. As noted, the SCC used by Jongeneel et al. (2016) was \$18/tCO_2, while the NIBE changed its value to \$56.50/tCO_2 several years later. What is the appropriate value? The IPCC (2013) indicates that the equilibrium climate sensitivity (ECS) parameter – the rise in temperature under a double-CO_2 atmosphere compared to pre-industrial times – lies between 1.5^{o}C and 4.5^{o}C, with best estimate of 3^{o}C; Nordhaus employs an ECS of 3.1^{o}C in DICE. Recent research finds that the ECS might be as low as 0.5^{o}C (Lewis and Curry 2018; Scafetta et al. 2017), although an ECS of 1.0^{o}C is often assumed to be the minimal value. Although the ECS is only one of many parameters in the DICE model that affect the SCC, a perspective on possible range of values that SCC can take is provided in Figure 1. In the baseline scenario, the SCC is determined to be \$44/tCO_2 (\$2015) in 2025, but it falls to \$24/tCO_2 if the ECS parameter is 2.0^{o}C and to less than \$8/tCO_2 if it is 1.0^{o}C. This alone has severe implications for measures of the externalities attributable to the agricultural sector.

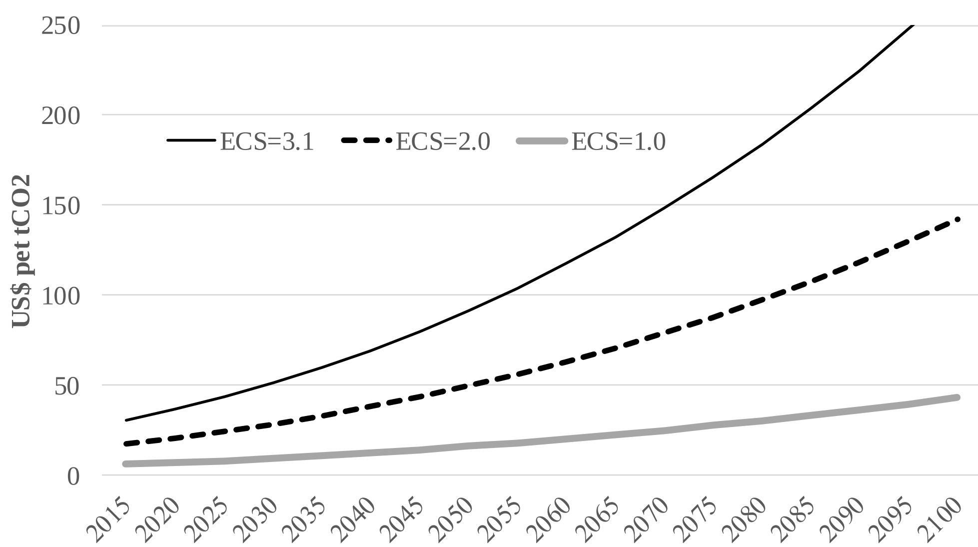

Figure 1: The Effect of the Equilibrium Climate Sensitivity on the Social Cost of Carbon
Source: Author's calculation using DICEvR2016 Model

5. Conclusions

An increasing number of studies have sought to measure the externality costs of agricultural production. Some studies have included the adverse effects of food consumption (obesity, cancer, food waste, etc.) in their attempt to find the 'true' societal costs of agriculture, but this only muddles the message by attributing the social costs of undesirable personal decisions to farmers. When studies examine solely the externality costs that might appropriately be laid at the feet of agricultural producers, the costs are much less although perhaps higher in some cases than society might wish. In a worst case scenario of a country with a highly-industrialized, intensive agricultural sector, the Netherlands, externalities account for perhaps 18% of the total surplus that the sector provides to the national economy. This percentage will rise somewhat if a higher social cost of carbon is employed, and fall accordingly if a lower cost is assumed.

Estimates of externality costs in agriculture are highly sensitive to the assumed shadow damages caused by 'pollutants' such as phosphates, methane, nitrogen and N_xO, and CO_2, and the extent to which their emissions can be attributed to agricultural activities. Since there is a great deal of uncertainty regarding the shadow damages associated with these 'pollutants' and the value of any other nonmarket (negative or positive) externalities, decision makers should avoid a rush to enact policies to correct externalities. Simply noting that there is a problem may not be sufficient to warrant action to deal with it. Perhaps the Canadian approach of incentivizing farmers to apply best management practices is most reasonable.

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References

Barichello, R.R., R.M. Porter and G.C. van Kooten, 1995. Institutions, Economic Incentives and Sustainable Rural Land Use in British Columbia. Chapter 2 in *Managing Natural Resources in British Columbia. Markets, Regulations, and Sustainable Development* (pp.7-53) edited by A. Scott, J. Robinson and D. Cohen. Vancouver: UBC Press.

Butler, D., 2018. Scientists hail European ban on Bee-harming pesticides, *Nature News* April 27. doi: 10.1038/d41586-018-04987-4. At https://www.nature.com/articles/d41586-018-04987-4 [accessed 14 February 2019].

Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton and M. van den Belt, 1997. The Value of the World's Ecosystem Services and Natural Capital, *Nature* 387: 253–61.

Costanza, R., R. de Groot, P. Sutton, S. van der Ploeg, S.J. Anderson, I. Kubiszewski, S. Farber and R.K. Turner, 2014. Changes in the Global Value of Ecosystem Services, *Global Environmental Change* 26: 152-158.

Fitzpatrick, I., R. Young, M. Perry and E. Rose, 2017. *The Hidden Cost of UK Food*. November. Bristol, UK: Sustainable Food Trust. 80pp. https://sustainablefoodtrust.org/articles/hidden-cost-uk-food/ [accessed 14 February 2019].

Hourdin, F., T. Mauritsen, A. Gettelman, J. Golaz, V. Balaji, Q. Duan, D. Folini, D. Ji, D. Klocke, Y. Qian, F. Rauser, C. Rio, L. Tomassini, M. Watanabe and D. Williamson, 2017. The Art and Science of Climate Model Tuning, *Bulletin of the American Meteorological Society* March: 589-602. doi:10.1175/BAMS-D-15-00135.1.

IPCC, 2013. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. 1535pp. Cambridge, UK: Cambridge University Press.

Jongeneel, R., N. Polman and G.C. van Kooten, 2016. *How Important are Agricultural Externalities? A Framework for Analysis and Application to Dutch Agriculture*. REPA Working Paper 2016-04. Resource Economics and Policy Analysis, Department of Economics, University of Victoria, Victoria, Canada. http://web.uvic.ca/~repa/publications.htm

Lewis, N., 2018. Abnormal climate response of the DICE IAM – a trillion dollar error? April 22. At https://www.nicholaslewis.org/tag/climate-sensitivity/ [accessed 20 February 2019].

Lewis, N. and J.A. Curry, 2015. The Implications for Climate Sensitivity of AR5 Forcing and Heat Uptake Estimates, *Climate Dynamics* 45: 1009-1023.

Lewis, N. and J.A. Curry, 2018. The Impact of Recent Forcing and Ocean Heat Uptake Data on Estimates of Climate Sensitivity, *Journal of Climate* 31(August): 6051-6071.

Millar, R.J., J.S. Fuglestvedt, P. Friedlingstein, J. Rogelj, M.J. Grubb, H.D. Matthews, R.B Skeie, P.M. Forster, D.J. Frame and M.R. Allen, 2017. Emission Budgets and Pathways Consistent with Limiting Warming to 1.5°C, *Nature Geoscience* 10: 741-747. http://dx.doi.org/10.1038/ngeo3031

Nordhaus, W.D., 2013. Integrated Economic and Climate Modeling. Chapter 16 in *Handbook of Computable General Equilibrium Modeling, Volume 1A, 1st Edition* (pp.1069-1131) edited by P. Dixon and D. Jorgenson. Dordrecht, NL: Elsevier. (DICE model found at https://sites.google.com/site/williamdnordhaus/dice-rice)

O'Neill, D., 2007. *The Total External Environmental Costs and Benefits of Agriculture in the UK*. 24 April 2007. 33pp. London, UK: Environment Agency. http://webarchive.nationalarchives.gov.uk/20140328084622/http://www.environment-agency.gov.uk/static/documents/Research/costs_benefitapr07_1749472.pdf [accessed 19 February 2019].

Pillet, G., N. Zingg and D. Maradan, 2002. Appraising Externalities of Swiss Agriculture. A Comprehensive View. Bern: Swiss Federal Office of Agriculture. https://www.academia.edu/19974676/appraising_externalities_of_the_swiss_agriculture_a_comprehensive_view_ [accessed 19 February 2019].

Pindyck, R.S., 2013. Climate Change Policy. What do the Models Tell Us? *Journal of Economic Literature* 51(3): 860-872.

Pindyck, R.S., 2017. The Use and Misuse of Models for Climate Policy, *Review of Environmental Economics and Policy* 11(1): 100-114. Doi:10.1093/reep/rew012.

Pizer, W.A., 1997. *Prices vs. Quantities Revisited: The Case of Climate Change*. Discussion Paper 98-02. October. 52pp. Washington, DC: Resources for the Future.

Porter, J., R. Constanza, H. Sandhu, L. Sigsgaard and S. Wratten, 2009. The Value of Producing Food, Energy, and Ecosystem Services within an Agro-ecosystem, *AMBIO: A Journal on the Human Environment* 38(4): 186-193.

Pretty, J., C. Brett, D. Gee, R. Hine, C.F. Mason, J.I.L. Morison, H. Raven, M. Rayment and G. van der Bijl, 2000. An Assessment of the Total External Costs of UK Agriculture, *Agricultural Systems* 65(2): 113-136.

Pretty, J., C. Brett, D. Gee, R. Hine, C.F. Mason, J.I.L. Morison, H. Raven, M. Rayment, G. van der Bijl and T. Dobbs, 2001. Policy Challenges and Priorities for Internalizing the Externalities of Modern Agriculture, *Journal of Environmental Management* 44(2): 263-283.

Pretty, J.N., A.S. Ball, T. Lang and J.I.L. Morison, 2005. Farm Costs and Food Miles: An Assessment of the Full Cost of the UK Weekly Food Basket, *Food Policy* 30(1): 1-20.

Riahi, K., D.P. van Vuuren, and 43 others, 2017. The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview, *Global Environmental Change* 42: 153-168.

Scafetta, N., A. Mirandola and A. Bianchini, 2017. Natural Climate Variability, Part 2: Interpretation of the Post 2000 Temperature Standstill, *International Journal of Heat and Technology* 35(Special Issue 1, September): S18-S26.

Tegtmeier, E.M. and M.D. Duffy, 2004. External Costs of Agricultural Production in the United States, *International Journal of Agricultural Sustainability* 2(1): 1-20.

van Kooten, G.C., 1993. Preservation of Waterfowl Habitat in Western Canada: Is the North American Waterfowl Management Plan a Success? *Natural Resources Journal* 33(Summer): 759-75.

van Kooten, G.C., 2013. *Climate Change, Climate Science and Economics: Prospects for an Alternative Energy Future*. Dordrecht, NL: Springer. (466pp.)

van Kooten, G.C. 2017. Forest Carbon Offsets and Carbon Emissions Trading: Problems of Contracting, *Forest Policy and Economics* 75: 83-88.

van Kooten, G.C., 2018. The Challenge of Mitigating Climate Change through Forestry Activities: What are the Rules of the Game? *Ecological Economics* 146(April): 35-43.

van Kooten, G.C., 2019. *Applied Economics, Trade and Agricultural Policy*. Toronto, ON: University of Toronto Press. 372pp. Under consideration. Available at: http://web.uvic.ca/~kooten/Agriculture/ProjectEvaluation.pdf

van Kooten, G.C. and A. Schmitz, 1992. Preserving Waterfowl Habitat on the Canadian Prairies: Economic Incentives vs. Moral Suasion, *American J of Agricultural Economics* 74(February): 79-89.

Weitzman, M. L., 1974. Prices vs Quantities, *Review of Economic Studies* 41(128), 477-491.