Incorporating Environmental Impacts into Value Added from Organic and Conventional Farming

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Incorporating environmental impacts into value added from organic and conventional farming[♦]

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Abstract

We aim to improve the policy relevance of the aggregate welfare indicators regarding the economic and environmental features of farming practices. First, an analytical framework for measurement of environmentally adjusted net national product for agricultural sector is provided. Second, shadow pricing of direct disutility of environmental deterioration is illustrated with implications of the Finnish water protection policy measures restricting the use of manure on conventional and organic livestock farms during the period 1994-2002. Our simulated shadow prices per cubic meter manure are quite considerable reflecting the potentially high opportunity costs in terms of value added forgone if the only option to comply with regulation is to cut output. In practice, the organic farms seem to comply well with current regulation, and the environmentally harmful contribution of conventional farms to welfare is relatively small.

Keywords: national income accounting, environmental performance, technology choices

JEL Codes: H23, O47, Q18, Q25

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1. Introduction

Organic farming has become an important option for policies promoting food safety and environmental quality of food production (COM (2004) 415 final). By ruling out the use of synthetic fertilizers and other chemicals organic farming represents an environmentally 'clean' technology which can be viewed as a constrained version of conventional farming in agriculture. Its potential environmental friendliness does not come without a cost. Yields in organic farming are in general significantly lower than under conventional management, even though the yield differences vary between products and to a certain extent between countries. (Lampkin et al. 1999, Offerman and Nieberg 2000, Zanoli and Gambelli 1999)

Depending on the farming strategies adopted also the environmental impacts will change accordingly. It is necessary to evaluate the existing measures of economic performance of conventional and organic farming technologies from a point of view of environment, since conventional economic indicators may be misguided. We aim to improve the policy relevance of the aggregate welfare indicators regarding the economic and environmental features of farming practices.

We provide an analytical framework for measurement of environmentally adjusted net national product for agricultural sector.[1] Agricultural income (value added) forms part of conventional national income accounting. When a Net National Product (NNP) is calculated in practice, the measurement of economic activity is based on market transactions and market prices. At least in principle, the environmental impacts of products can be traced back to the technology used in the production. Different production technologies imply different environmental performance, and this should be reflected in welfare accounting.[2] Productivity measurement faces a similar challenge. What is crucial to notice in decision making it that productivity measurement involves commonly used economic efficiency measures that are based on the prevailing prices. This may be a problem for evaluation of sustainability, since market prices of final products do not capture social costs or benefits such as environmental quality. Our analysis seeks to develop more comprehensive indicators of sustainability in agriculture for policy makers by showing how the conventional indicators of economic performance should be completed.

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[1] For a good overview of the extensive literature on environmental (green) accounting, see Heal and Kriström (2003).

[2] The link between green accounting and efficiency measurement has been elaborated in, e.g., Huhtala (1998, 2003).

In their study on environmental accounting in agriculture, Hrubovcak et al. (2000) have provided a theoretical framework with an empirical illustration to incorporate the environmental impacts of agricultural production into the existing income accounts. Here, we take a step further in our analysis and place a special emphasis on environmental impacts and technology. We introduce organic farming as an alternative technology for comparison purposes. Furthermore, we carry out shadow pricing of direct disutility of environmental deterioration of each technology using farm accounting data. This is a most natural way to proceed as the agricultural value added at the national level is based on output produced at the farm level.

The empirical shadow pricing method we apply here has its origin in Färe et al. (2001, 2002). The purpose is to draw a distinction between good and bad outputs. By exploiting the duality theory, the shadow-pricing model can be derived from the output distance function using the envelope theorem. Since the cost for reducing bad outputs is in terms of forgone revenue from good outputs, each bad output commands its own shadow price at the margin. In other words, social costs of environmentally detrimental outputs can be estimated assuming that abatement is only possible by adjusting agricultural production, or output/value added at the farm level. Given the estimated opportunity cost of production, we have an upper bound for a shadow price of bad produced.

Our data consist of Finnish livestock farms in unbalanced panels, extending over the period 1994-2002. There are 2086 observations for 259 conventional farms and 230 observations for 51 organic farms. The directional output distance function is estimated on input and output variables constituting these panels. In addition to a good output (value added) a bad output (manure) is produced. Inputs include capital, labor, energy, land, and other materials. The point of departure for our empirical shadow pricing is an assumption that the current Finnish regulation reflects the environmental preferences of the society. With certain exceptions, maximally 15 kg phosphorus is allowed to be spread per hectare cultivated land annually. The regulation must be taken into account in application of manure as well. If this policy measure is restrictive, the performance of the farms change as the environment becomes a factor to be taken into account in the economic maximization problem. Moreover, since an undesirable by-product (manure surplus) is produced, its effects on the environment have negative welfare consequences that should be taken into account in policy making. The shadow price implicitly reveals the value that the regulatory authorities put on the last unit manure spread on land causing environmental damages. If the authorities know the environmental preferences of the society and know how and to what extent undesirable output affects the environment, the shadow price is the correct value from a socially optimal point of view.

The paper is organized as follows. In section 2, we present a simple growth model in which organic nutrient surplus (manure) is a by-product of all agricultural production both in organic and conventional farming. Section 3 shows how shadow prices can be derived using directional output distance functions. In section 4 an empirical application based on a Finnish FADN sample illustrates the implications for measurement of value added (NNP) from the Finnish agricultural sector. Section 5 concludes.

2. National accounting incorporating undesirable output

Our analytical framework is based on national accounting to identify the components of value added generating growth in the agricultural sector. The framework builds upon the result of Weitzman (1976) which proves how net national welfare measurement can be theoretically justified. The well-known result states the valuation principle for an economy maximizing utility subject to capital stock over time. Formally, a first best optimal solution can be derived by setting up a social planner's utility maximization problem over time. Utility is derived from consumption, C, whereas the accumulation of capital over time, $dK/dt = f(K) - C$, is determined by total output, $f(K)$, minus consumption, i.e., net investments, I. As shown by Weitzman, a linear support of the Hamiltonian along the optimal path corresponds to national welfare, or $NNP=C+I$. We use the above accounting rule as a guiding principle to build up an output measurement framework for the agricultural sector. The basic model will be completed with environmental impacts of production.

The agricultural sector produces conventional food products, c, and organic food products, g, such that production of consumption goods in total is $C=c+g$. Capital, K, is a sector specific input. Simultaneously with production of goods, a bad output, $b=\alpha C$, causing environmental degradation is generated. The environmentally negative or bad output we model in the empirical illustration is manure generated in animal production as excessive amounts of manure spoil recreation possibilities due to odors or water pollution impacts. The by-product causing nuisance enters into the economy as an externality through preferences as a separate argument in the utility function and therefore inevitably decreases utility directly. The utility function takes the form $U(C,b)$ with $U_C>0$ and $U_b<0$. In the social planner's optimization problem, the objective function

$$\int_o^{\infty} [U(C,b)] e^{-rt} dt$$

is discounted over time by a constant social interest rate, $r > 0$. The objective is maximized subject to an equation of motion and an initial condition of the capital stock, K

$$\dot{K} = f(K) - C \qquad \text{and} \qquad K(0) = K .$$

We form the current value Hamiltonian for the social planner optimization problem above

(1) $$H = U(C, \alpha C) + \lambda(f(K) - C) .$$

The Hamiltonian is to be maximized subject to C to achieve a socially optimal allocation of resources. We write the first order conditions

(2) $$\partial H / \partial C = U_C - U_b \alpha - \lambda = 0$$

(3) $$\dot{\lambda} = \lambda(r - f_K)$$

(4) $$\dot{K} = f(K) - C \qquad \text{and } K(0) = K .$$

What is crucial for our empirical analysis on measuring the environmental performance of agricultural sector is to determine how to include the environmental impacts in the accounting framework for value added. This can be done with the help of the Hamiltonian and the optimality conditions above. By linearizing the utility function, we have

$$\overline{\mathrm{H}} = U_C \cdot C + U_b \cdot \alpha C + \lambda \dot{K} .$$

Dividing the linearized current value Hamiltonian by the marginal utility of consumption (assuming that U_C is constant), we arrive at a monetary value measure of a green net national product (GNNP) which corresponds to a welfare measure that includes measurable environmental impacts

$$(1') \qquad \overline{GNNP}_b = (1+\frac{U_b}{U_C}\alpha)C + (1+\frac{U_b}{U_C}\alpha)\dot{K} = f(K) + \underbrace{\frac{U_b}{U_C}}_{\tau}\underbrace{\alpha f(K)}_{b}$$

where τ denotes the shadow price of bad output which is valued using the ratio of marginal utilities. Recalling that the conventional NNP is defined as consumption plus investments $NNP = C + \dot{K} = C + f(K) - C = f(K)$, or implicitly assuming that *b=0*, equation (1') suggests that two adjustments should be made for the conventional NNP when *b>0*: (1) The by-product, $b=\alpha f(K)$, should be taken into account in the output possibilities set (and in output frontier being estimated), and (2) the negative contribution of bad output should be shadow-priced by $\tau < 0$ (as $U_b < 0$). The product of these components should be included in measurement of national product.

Our primary intentions are not only to suggest welfare indicators that incorporate environmental features of farming practices, but also to suggest an alternative empirical framework for approximating farms actual contribution to welfare. An interesting question is then how to measure the shadow prices that a society places on undesirable outputs. Here, environmental regulation can prove helpful.

In purpose of alleviating leakage of nutrients to the waters, the Finnish authorities have imposed environmental regulation limiting the application of fertilizers, including organic manure, on the fields. Farms are allowed to use maximally 15 kg phosphorous per hectare land. If this policy is restrictive the farms' performance should change as the bad output becomes a factor to be taken into account in the economic optimization of production. Furthermore, since this also means that the authorities hold the view that the by-product is undesirable its effects on the environment has negative welfare consequences that should be reflected in national accounting. This is illustrated in Figure 1.

The output possibilities set, *P(x)*, includes now both outputs; *C* (good) and *b* (bad). In this particular case, the regulatory authorities pursue an environmental policy that imposes maximal allowed quantity of manure use in production. The restriction in effect is illustrated by the bold vertical line, b', which constitutes the dividing-line between subsets of output bundles where manure is and isn't giving rise to negative external effects. Shadow prices of manure are given by the slopes of the frontier. Given the regulation, the shadow price implicitly reveals that the authorities consider the last unit manure spread on land to cause negative external effects, or environmental damages, at the value of τ'. If the authorities know the environmental preferences of the society and know how and to what extent undesirable output causes damage, they impose an optimal restriction and the shadow price, τ', reveals the correct damage value from a socially optimal point of view.

On the cost side, the value of shadow price of bad output depends on how large a reduction in the undesirable output is wanted with respect to an increase in the desirable output. At point *(C',b')* the shadow price of an additional unit of bad output is $\tau' < 0$, which is the revenue forgone, $-(\tau' \cdot \partial b) = p \cdot \partial C$, $\partial b = 1$ due to the last reduced unit of bad output. This reflects the marginal rate of transformation between bad and good outputs and, as such, can be interpreted as the marginal abatement cost at point *(C',b')*.

If the farm faces a shadow price of manure, $q \leq 0$, lower than the price corresponding to the restriction line, $\tau' < 0$, i.e., at any point on the frontier to the left of the line, e.g., at point A', the manure use is not causing any environmental damages. However, if the farm faces a shadow price at any point on the frontier to the right of the restriction line, e.g., at point B', the manure use in production gives rise to external effects that harm the environment (as indicated by the stringency of regulation limiting the nutrient use). The price of this negative externality is $\tau^B = \tau' - q^B$ and, consequently, the value of the total environmental damages from producing at point B is $\tau^B \cdot (b^B - b')$.[3]

Given the accounting rule in equation (1') and using the shadow price information from the regulation adopted, the expression that approximate farms' *actual* contribution to welfare is

(1'') $GNNP^{ikt} = C^{ikt} + \tau^{ikt} \cdot (b^{ikt} - b'^{ikt})$,

[3] This corresponds to τb in equation (1').

(i) $b'^{ikt} = R \cdot x_4^{ikt}$

(ii) $b^{ikt} - b'^{ikt} = nee^{ikt} \geq 0$

(iii) $\tau^{ikt} = \tau' - q^{ikt} \leq 0$

where x_4 denotes land (hectare) and R the maximally allowed manure use (per hectare). The expression in (i) means that every farm, *k*, of type *i* (organic or conventional) faces a unique manure restriction, b'^{ikt}, in terms of absolute quantities at every point of time, *t*. Furthermore, nee^{ikt} denotes the negative external effects (see Figure 1), and τ' denotes the shadow price of manure corresponding to the restriction. The negative external effects take non-negative values, which means that for the observations where $b^{ikt} < b'^{ikt}$ these effects are set to zero. Furthermore, τ' is set equal to the simulated value of q', i.e., the shadow price that the representative farm faces when satisfying the restriction. The calculated τ' implicitly reveals the value that the regulatory authorities ascribe to the negative external effects on average when imposing the restriction. That is, $\tau^{ikt} = \tau' - q^{ikt}$ is the value of the environmental damages from one more unit of manure that exceeds the maximally allowed quantity of manure use.

As expressed in equation (1''), manure is an inevitable by-product such that to be able to produce the good output, *C*, the farm has to produce some bad output, *b*. If *nee* > 0, this also means that the farm has to produce the additional negative value $\tau \cdot \partial nee(C)$ to produce an additional unit good output. Hence, to compensate for the negative value when calculating GNNP for this particular unit, the social net revenue is $\partial GNNP = (p + \tau \cdot \partial nee(C)) \cdot \partial C$, $p = 1$.[4] The changes in the flow variables, ∂C and $\partial nee(C)$, can be regarded as taking place during a certain year and, therefore, the contribution to the GNNP for that particular year can be calculated.[5]

3. Shadow pricing and directional distance functions

The most recent development in efficiency measurement has extended the analyses to include undesirable, polluting commodities that are outputs from some production process (see, e.g., Färe and Grosskopf 1998). To calculate shadow prices of bad outputs, in our case manure, a shadow-pricing model originating from Färe et al. (2002) is used (see also Färe and Grosskopf 2004, and

[4] If *C* is measured in monetary terms then *p* = 1.

[5] Annual production is assumed to be taking place at the margin.

Färe et al. 2005).[6] Formally, let $C = (C_1,...,C_M) \in \Re_+^M$ and $b = (b_1,...,b_J) \in \Re_+^J$ be vectors of good and bad outputs, respectively, and let $x = (x_1,..., x_N) \in \Re_+^N$ be a vector of inputs. The technology of reference is the output possibilities set, $P(x)$, which for a given vector of inputs denotes all technically feasible output vectors. This output set is assumed to be convex and compact with $P(0) = \{0,0\}$. Furthermore, inputs and good outputs are assumed to be freely disposable and bad outputs only weakly disposable. Finally, good outputs are assumed to be null-joint with the bad outputs. This means that good outputs cannot be produced without producing bad outputs. The directional output distance function is defined on $P(x)$, as

$$(5) \quad D(x,C,b;g) = \max_{\beta}\{\beta : (C + \beta \cdot g_C, b - \beta \cdot g_b) \in P(x)\}, \qquad g_C \in \Re_+^M, \quad g_b \in \Re_+^J$$

which then inherits its properties from $P(x)$. The solution, β^*, gives the maximum expansion and contraction of good outputs and bad outputs, respectively. The vector $g = (g_C = 1, -g_b = -1)$ specifies the direction in which an output vector, $(C,b) \in P(x)$, is scaled so as to reach the boundary of the output set at $(C + \beta^* \cdot g_C, b - \beta^* \cdot g_b) \in P(x)$, where $\beta^* = D(x,C,b;g)$. This means that the producer becomes more technically efficient when simultaneously increasing good outputs and decreasing bad outputs. The distance function takes the value of zero for technically efficient output vectors on the boundary of $P(x)$, whereas positive values apply to inefficient output vectors below the boundary. The higher the value the more inefficient is the output vector. Finally, the directional output distance function satisfies the translation property

$$(6) \qquad D(x, C + \alpha \cdot g_C, b - \alpha \cdot g_b; g) = D(x,C,b;g) - \alpha$$

where α is a positive scalar.

When deriving the output shadow-pricing model the duality between the distance function and the revenue function is exploited. Let $p = (p_1,..., p_M) \in \Re_+^M$ and $q = (q_1,..., q_J) \in \Re_-^J$ represent absolute

[6] Marklund (2003) provides an application of this model to the Swedish pulp industry, together with a thorough overview of the development of the estimations of bad output shadow prices. See also Marklund and Samakovlis (2003) and Marklund (2004).

prices of good and bad outputs, respectively. Then the relative shadow prices of bad outputs, in terms of the *m:th* good output, can be calculated from

$$(7) \qquad \frac{q_j}{p_m} = \left(\frac{\partial D(x,C,b;g)}{\partial b_j} \Big/ \frac{\partial D(x,C,b;g)}{\partial C_m} \right), \qquad j = 1,\ldots,J$$

which is the marginal rate of transformation between the $j:th$ bad output and the $m:th$ good output, MRT_{jm}, where $\partial D(\cdot)/\partial C_m < 0$ and $\partial D(\cdot)/\partial b_j \geq 0$. The shadow price is then measured in terms of decreased production of C_m, which has to be met when reducing b_j marginally.

4. Estimation and results

Following, e.g., Färe et al. (2005) the directional output distance function is parameterised by using a quadratic flexible functional form and estimated using an econometric, COLS estimating, procedure.[7] This means that the distance function is first estimated by OLS and then 'corrected' by adding the largest residual to the intercept. The corrected distance function, *CD(.)*, takes non-negative values and for farm type *i* (organic or conventional) and farm *k* in time period *t*, it can be written as

(8)

$$\begin{aligned} CD^{ikt}(x^{ikt}, C^{ikt}, b^{ikt}; g) = \{ & (\alpha_0 + \max(\varepsilon^{OLS})) + \sum_{n=1}^{N} \alpha_n x_n^{ikt} + \sum_{m=1}^{M} \beta_m (C_m^{ikt} + b_J^{ikt}) + \sum_{j=1}^{J-1} \gamma_j (b_j^{ikt} - b_J^{ikt}) \\ & + \frac{1}{2} \sum_{n=1}^{N} \sum_{n'=1}^{N} \alpha_{nn'} x_n^{ikt} x_{n'}^{ikt} + \sum_{n=1}^{N} \sum_{m=1}^{M} \delta_{nm} x_n^{ikt} (C_m^{ikt} + b_J^{ikt}) + \sum_{n=1}^{N} \sum_{j=1}^{J-1} \eta_{nj} x_n^{ikt} (b_j^{ikt} - b_J^{ikt}) \\ & + \frac{1}{2} \sum_{m=1}^{M} \sum_{m'=1}^{M} \beta_{mm'} (C_m^{ikt} + b_J^{ikt})(C_{m'}^{ikt} + b_J^{ikt}) + \sum_{m=1}^{M} \sum_{j=1}^{J-1} \mu_{mj} (C_m^{ikt} + b_J^{ikt})(b_j^{ikt} - b_J^{ikt}) \\ & + \frac{1}{2} \sum_{j=1}^{J-1} \sum_{j'=1}^{J-1} \gamma_{jj'} (b_j^{ikt} - b_J^{ikt})(b_{j'}^{ikt} - b_J^{ikt}) \\ & + \rho_i + \kappa_k + \varphi_t \}^{OLS} + b_J^{ikt} \end{aligned}$$

where κ_k and φ_t are parameters representing farm and time specific effects, respectively, and ρ_i is a parameter that represents farm type effects. This is the expression to differentiate when calculating shadow prices of outputs, in accordance with equation (7). The functional form in (8) satisfies non-

[7] Regarding the COLS estimator, see, e.g., Greene (1993). The particular approach adopted is used in Lovell et al. (1994), where, e.g., a Shephard output distance function is estimated. The COLS procedure applied on the directional output distance function is in more detail described in Marklund and Samakovlis (2003).

negativity, symmetry, $\alpha_{nn'} = \alpha_{n'n}$, $n \neq n'$, $\beta_{mm'} = \beta_{m'm}$, $m \neq m'$, and $\gamma_{jj'} = \gamma_{j'j}$, $j \neq j'$, and the translation property in equation (5).

In our estimations C_1 denotes the sum of organic good output, g, and conventional good output, c. Manure is denoted b_1, and x_1 denotes capital, x_2 labor, x_3 energy, x_4 land, and x_5 other materials. As in Färe et al. (2005), before estimating the expression in (8), the data are normalized by dividing each output and each input by its mean value, $(\overline{C}, \overline{b})$ and $\overline{x}$, respectively. This means that when estimating the distance function one unit of each variable equals its mean value.

The original farm level data come from Finnish bookkeeping farms that participated in the Farm Accountancy Data Network (FADN) during 1994-2002. The selected conventional and organic animal farm data samples consist of farms that have a share of livestock return of total return that is at least 60 percent. They are considered to be livestock (milk and beef) specialized farms. Furthermore, farms for which there only is one single observation are excluded. This result in unbalanced panels, extending over the period 1994-2002 and consisting of 2086 observations for 259 conventional farms and 230 observations for 51 organic farms. Descriptive statistics are given in Table 1.

Results

The directional output distance function is estimated on mean normalized data, using a COLS procedure. The particular procedure used imposes the function properties of translation, symmetry, and non-negativity. Further tests reveal that the estimated function satisfies null-jointness for 1257 out of 2316 observations (60 percent), and monotonicity in good and bad outputs for all observations. The parameters of the estimated distance function are provided in Table 2.[8]

To be able to measure welfare in accordance with equation (1'') the shadow prices reflecting the stringency of regulation τ's for each farm type ("average" compound, τ', organic, τ'^{org}, and conventional, τ'^{con}, i.e., representative by technology) are first calculated for given b' and C'. In practice, τ's are calculated at mean of inputs, $\overline{x}$, assuming technical efficiency, i.e., $CD(\overline{x}, C', b'; g) = 0$. The values for b' are derived from regulation according to which Finnish farms are allowed to use maximally 15 kg phosphorous per hectare land; this corresponds to the use of maximally 20 m^3 manure per hectare, i.e., R = 20 in equation (1'').[9] The representative compound animal farm uses $\bar{x}_4$ = 38.86 hectare land in production (see Table 1) and, hence, the maximally allowed use of manure is b' = 20*38.86 = 777 m^3. By simulation, using the estimated distance function, it is established that 777 m^3 manure corresponds to C' = 412,610 FIM. Given these output quantities, and mean quantities of inputs, $\bar{x}$, the representative compound farm faces a shadow price amounting to q' = -675.45 FIM (roughly € 115), which corresponds to τ' as shown in Figure 1. Similar simulations have been carried out for calculating shadow prices reflecting the stringency of regulation for representative organic and conventional farms. The simulated maximally allowed use of manure and corresponding shadow price for a representative organic and conventional farm are b'^{org} = 20*47.40 = 948 m^3, τ'^{org} = -610.24 and b'^{con} = 20*37.91 = 758 m^3 , τ'^{con} = -683.20, respectively.

The shadow prices imposed by regulation can be compared with the shadow prices estimated for the representative farms in sample as reported in Table 4. To certain extent the shadow prices reflect the farming technologies adopted. Given their larger acreage, the organic farms are less constrained by the manure restriction than the conventional farms on average. In general, the simulated shadow prices within the range of € 100 – 115 per cubic meter manure are quite considerable and reflect the opportunity cost of value added forgone if the only abatement option is to cut output.

Next, the price of the negative externality, $\tau^{ikt} = \tau' - q^{ikt}$, is calculated for each farm. The result shows that there are 910 observations for which $\tau' < q^{ikt}$, i.e., for which shadow prices are calculated on the technological frontier to the right of the restriction line in Figure 1. As can be seen from Table 3 (upper part), generally, one unit external effects (additionally one m^3 manure overuse) , $\partial(b^{ikt} - b'^{ikt})$, caused by organic farms commands a social cost of nearly 50 percent higher than the social cost of one unit external effects caused by conventional farms when excluding those farms with $\tau^{ikt} = 0$. However, the outcome is reversed when those farms with zero social costs are included in the calculation (Table 3 lower part). An obvious reason for this disparity should be that

[8] Additionally, to check for possible multicollinearity problems the condition number (see, e.g., Greene (2000)) of the data matrix is calculated, revealing the test statistic value of 235. This is quite good considering that a flexible functional form is representing farm technology.
[9] Depending on the livestock category, the phosphorus (P) content of one cubic meter manure is approximately 1 kg. However, only 75 percent of the potential P content of manure is "bio-available" according to regulation.

the organic farm in general uses manure more extensively in production than does the conventional farm due to its larger acreage (see Table 1), but if organic farms violate the manure restriction they do it more seriously than the conventional farms do.

Having derived the necessary components of GNNP (τ' and b'^{ikt}), the contribution to welfare from representative Finnish farms (by farm type) is approximated according to equation (1''). The NNP results are provided in Table 5. On average, the contribution from the Finnish animal farms amounted to FIM 348,990 during 1994-2002, having accounted for the value of the total environmental damages amounting to FIM 390. Furthermore, during the same period, organic farms contributed less to welfare than did the conventional farms, specifically FIM 302,440 compared to FIM 354,050. The organic contribution is 85 percent of the contribution from conventional farms. However, from Table 5, it may also be inferred that conventional farms, by overuse of manure, cause environmental damages at a value that is on average FIM 510 (€ 85) per farm.

It seems that Finnish animal farms generally use phosphorus by complying with environmental regulation. A majority of the farms apply less manure than is maximally allowed by policy. However, we have data on potential manure amount only and the use of synthetic phosphorus by conventional farms is not accounted at all. It may be alarming that potential manure use already makes some of the conventional farms exceed the restriction. For these farms, contracts for exchanging manure with farms having excess land area for spreading manure might be attractive. Interestingly, farms that are willing to apply manure produced outside their own farm are paid a subsidy of € 65 per hectare. This makes about € 3.25 (or FIM 20) per cubic meter manure which is perhaps surprisingly close to our estimate on the social costs reported in Table 3. In this sense, our analysis gives justification for the subsidy level chosen by the Finnish policy makers as it corresponds well to our estimate on the value of damage calculated by opportunity costs.

5. Conclusions

Our theoretical framework for national accounting takes into account environmental impacts of alternative production technologies in agriculture. A formalized optimization problem helps to keep track of direct and indirect environmental effects. We illustrated our analytical findings by considering water protection policy measures in the Finnish agriculture. In purpose of alleviating leakage of phosphorus and nitrogen to the waters, the authorities have imposed restrictions that limit the use of organic manure as a fertilizer. If this policy measure is effective, the performance of the farms change as the environment becomes a factor to be taken into account in the economic maximization problem. Furthermore, since an undesirable by-product is produced, its effects on the environment have negative welfare consequences that should be reflected in national accounting. The shadow price implicitly reveals the value that the regulatory authorities put on the last unit manure spread on land causing environmental damages. If the authorities know the environmental preferences of the society and know how and to what extent undesirable output affects the environment, the shadow price is the correct value from a socially optimal point of view.

Our simulated shadow prices per cubic meter manure are quite considerable reflecting the high opportunity costs in terms of value added forgone if the only option to comply with regulation is to cut output. In practice, the organic farms seem to comply well with current regulation, and the environmentally harmful contribution of conventional farms to welfare is relatively small. However, we had data on potential amounts of manure produced on farms only and the use of synthetic phosphorus by conventional farms was not accounted at all. It may be alarming that potential manure use already makes some of the conventional farms exceed the restriction. Finally, it is interesting from a policy point of view that our estimate on the value of damage per cubic meter manure based on opportunity costs is very close to the level of subsidy applied in manure exchange contracts of Finnish the agri-environmental schemes implemented by the government.

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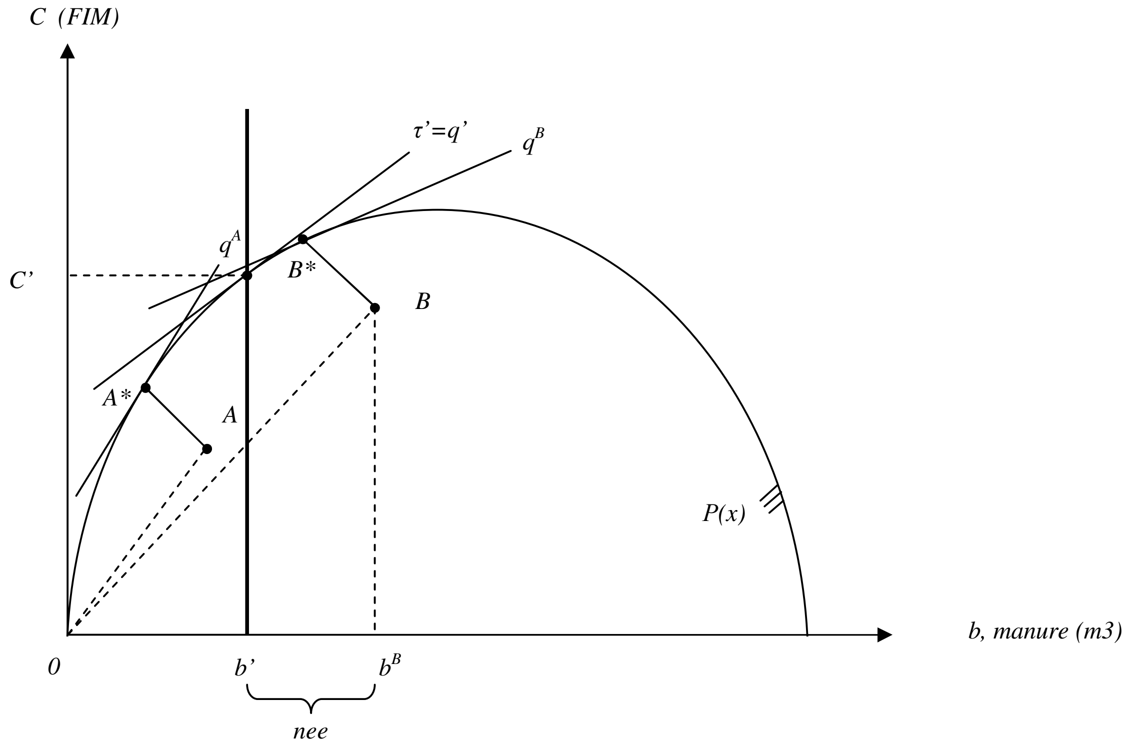

Figure 1. Production frontier, P(x), for good output, C, and bad output, b, when inputs, x, used and shadow prices, q', q^A, q^B. Environmental regulation limiting the amount of bad produced is denoted by b'.

Table 1. Descriptive statistics for variables in the output distance function, representing animal farm technology; mean and standard deviations (in parentheses).

Compound animal farms								
Year	**Number of obs**	**Variables**						
		C_1	b_1	x_1	X_2	x_3	x_4	x_5
94-02	2316	349.38 (175.61)	678.61 (327.30)	487.98 (385.39)	4894.20 (1550.55)	27.84 (15.44)	38.86 (21.42)	192.50 (119.04)
Min		1.51	103.50	7.99	988.00	4.33	8.52	21.42
Max		1418.05	2672.00	2938.44	11921.00	163.64	178.41	1025.86

Conventional animal farms								
Year	**Number of obs**	**Variables**						
		c	b_1	x_1	x_2	x_3	x_4	x_5
94-02	2086	354.56 (170.36)	675.51 (313.01)	482.72 (383.92)	4936.22 (1534.25)	27.74 (15.36)	37.91 (19.51)	192.90 (114.73)
Min		3.83	103.50	7.99	9.88	4.33	8.52	31.80
Max		1173.48	2052.00	2938.44	11921.00	163.64	135.44	1025.86

Organic animal farms								
Year	**Number of obs**	**Variables**						
		g	b_1	x_1	x_2	x_3	x_4	x_5
94-02	230	302.44 (212.23)	706.64 (435.87)	535.70 (396.18)	4513.10 (1646.36)	28.73 (16.10)	47.40 (32.99)	188.83 (152.96)
Min		1.51	172.00	49.95	1159.00	5.74	12.30	21.42
Max		1418.05	2672.00	1622.71	10855.00	98.58	178.41	1016.71

$C_1 = c + g$ = outputs, except direct payments, 1000 FIM (2000 constant prices)

b_1 = manure, m^3

x_1 = capital, machinery and buildings, 1000 FIM (2000 constant prices)

x_2 = labour, hours

x_3 = energy, fuel and electricity, 1000 FIM (2000 constant prices)

x_4 = land, arable area, hectare

x_5 = other material , 1000 FIM (2000 constant prices)

Table 2. Parameter estimates of the mean normalized output distance function, representing animal farm technology. [10]

Coefficient	**Variable**	**Estimate (t-value)**
α_0	Corrected intercept	0.36
α_1	x_1	0.04 (2.14)
α_2	x_2	-0.12 (-2.35)
α_3	x_3	-0.05 (-2.25)
α_4	x_4	-0.01 (-0.47)
α_5	x_5	0.10 (3.73)
β_1	y_1	-0.45 (-20.47)
$\gamma_1=\beta_1+1$	b_1	0.55
α_{11}	x_1x_1	0.01 (0.90)
α_{12}	x_1x_2	-0.08 (-4.37)
α_{13}	x_1x_3	-0.003 (-0.26)
α_{14}	x_1x_4	0.02 (1.54)
α_{15}	x_1x_5	-0.05 (-5.64)
δ_{11}	x_1y_1	0.02 (2.59)
$\eta_{11}=\delta_{11}$	x_1b_1	0.02
α_{22}	x_2x_2	0.12 (2.19)
α_{23}	x_2x_3	0.002 (0.08)
α_{24}	x_2x_4	0.01 (0.45)
α_{25}	x_2x_5	-0.07 (-3.16)
δ_{21}	x_2y_1	0.06 (3.22)
$\eta_{21}=\delta_{21}$	x_2b_1	0.06
α_{33}	x_3x_3	0.02 (2.76)
α_{34}	x_3x_4	-0.02 (-1.54)
α_{35}	x_3x_5	-0.01 (-0.75)
δ_{31}	x_3y_1	0.02 (2.08)
$\eta_{31}=\delta_{31}$	x_3b_1	0.02
α_{44}	x_4x_4	0.06 (3.00)
α_{45}	x_4x_5	0.04 (2.65)
δ_{41}	x_4y_1	-0.07 (-5.16)
$\eta_{41}=\delta_{41}$	x_4b_1	-0.07
α_{55}	x_5x_5	-0.03 (-1.41)
δ_{51}	x_5y_1	0.03 (2.20)
$\eta_{51}=\delta_{51}$	x_5b_1	0.03
β_{11}	y_1y_1	-0.02 (-1.56)
$\mu_{11}=\beta_{11}$	y_1b_1	-0.02
$\gamma_{11}=\beta_{11}$	b_1b_1	-0.02
ρ_2	*conventional farm*	0.06 (3.13)

[10] The parameter estimates of the farm and time specific effects are left out.

Table 3. Descriptive statistics for the price of negative external effects caused by the animal farming sector; mean and standard deviations (in parentheses).

Year	**Compound animal farm (N=910)**	**Organic animal farm (N=53)**	**Conventional animal farm (N=867)**
	$\tau^{ikt} < 0$	$\tau^{ikt} < 0$	$\tau^{ikt} < 0$
1994-2002	-51.36 (45.97)	-72.60 (97.04)	-49.87 (41.62)
Min	-268.72	-203.51	-257.45
Max	-0.08	-0.82	-0.03
τ'	τ'=-675.45	τ'^{org} = -610.24	τ'^{con} = -683.20

*The 1406 observations for which $\tau^{ikt} = 0$ are excluded when generating these statistics

Year	**Compound animal farm (N=2316)**	**Organic animal farm (N=230)**	**Conventional animal farm (N=2086)**
	$\tau^{ikt} \leq 0$	$\tau^{ikt} \leq 0$	$\tau^{ikt} \leq 0$
1994-2002	-20.18 (38.20)	-16.73 (40.96)	-20.73 (36.38)
Min	-268.72	-203.51	-267.45
Max	0.00	0.00	0.00
τ'	τ'=-675.45	τ'^{org} = -610.24	τ'^{con} = -683.20

Table 4. Descriptive statistics for technical efficiency and shadow prices of manure in animal farm production during 1994-2002 (2000 constant prices); averages and standard deviations (in parentheses).

Year	**Compound animal farm (N=2316)**	
	q^{ikt}	$CD^{ikt}(.)$
1994-2002	-701.44 (86.77)	0.46605 (0.07391)
Min	-1164.60	0.00
Max	-406.73	1.01727

Year	**Organic animal farm (N=230)**	
	q^{ikt}	$CD^{ikt}(.)$
1994-2002	-661.45 (96.58)	0.46605 (0.08174)
Min	-1022.57	0.09191
Max	-406.73	0.87327

Year	**Conventional animal farm (N=2086)**	
	q^{ikt}	$CD^{ikt}(.)$
1994-2002	-705.84 (84.50)	0.46605 (0.07302)
Min	-1164.60	0.00
Max	-415.75	1.01727

Table 5. The contribution of agriculture to welfare from animal farms, 1000 FIM at 2000 constant prices; average and standard deviation (in parentheses).

Year	*Compound animal farm (N=2316)*		*Organic animal farm (N=230)*		*Conventional animal farm (N=2086)*	
	$GNNP^{ikt}$	$\tau^{ikt} * nee^{ikt}$	$GNNP^{org,ikt}$	$\tau^{org,ikt} * nee^{org,ikt}$	$GNNP^{con,ikt}$	$\tau^{con,ikt} * nee^{con,ikt}$
94-02	348.99 (175.43)	-0.39 (2.85)	302.44 (212.23)	0.00 (0.01)	354.05 (170.12)	-0.51 (3.30)
Min	1.51	-74.77	1.51	-0.19	3.83	-78.88
Max	1418.05	0.00	1418.05	0.00	1173.48	0.00
τ'	τ'=-675.45		τ'^{org} = -610.24		τ'^{con} = -683.20	