The 82nd Annual Conference of the Agricultural Economics Society
Royal Agricultural College
31st March to 2nd April 2008

Optimal agricultural policy and PSE measurement: an assessment and application to Norway

David Blandford
The Pennsylvania State University, University Park, PA, U.S.A.

Rolf Jens Brunstad
The Norwegian School of Economics and Business Administration, Bergen, Norway

Ivar Gaasland
Institute for Research in Economics and Business Administration, Bergen, Norway

Erling Vårdal
University of Bergen, Herman Fossgt. 6, 5007 Bergen, Norway
Email: erling.vardal@econ.uib.no

Abstract:
The producer support estimate (the successor to the producer support equivalent) calculated by the OECD is widely used as an indicator of distortions created by agricultural policies. In this paper we demonstrate that changes in the relative (percentage) PSE are not an accurate indicator of the implications of policy reform for domestic welfare or for trade distortions. We demonstrate that it is important to consider the implications of changes in both the level and the form of support in evaluating the impact of policy reform. Using a model of Norwegian agriculture we show that reforms indicated towards the provision of public goods, while apparently leading to an increase in relative support, are actually superior to existing agricultural policies or to a policy aimed at eliminating subsidized exports both in terms of reducing trade distortions and increasing domestic economic welfare.

Keywords: Agricultural policy, trade distortion, domestic support, producer subsidy estimate (PSE)

JEL-classification: C61, F13, F18, Q17, Q18

1. **Introduction**

The producer support estimate (PSE) is a measure of the monetary transfer to producers from consumers and taxpayers through existing agricultural policies. Its conceptual basis is as a summary of the incidence of government policies through an equivalent subsidy. Originally the acronym PSE stood for producer subsidy equivalent. The theoretical foundation for the PSE was established by Corden (1971); Josling (1973 and 1975) applied the concept to agricultural policies and coined the term producer subsidy equivalent.

Since the mid 1980s the OECD has published data on the PSE for OECD members and for some non member countries. OECD's annual estimates provide the only readily available and consistent source of internationally comparable information on levels of support for agriculture. Cahill and Legg (1989-90) and Legg (2003) provide an overview of the definitions and use of the OECD's support measurements.

The publication of internationally comparable PSE figures has increased transparency on the nature and incidence of agricultural policies in OECD countries. The PSE concept has also contributed to establishing a base for internationally binding commitments on domestic support through the Aggregate Measure of Support (AMS) in the Uruguay Round of trade negotiations of the World Trade Organization (WTO).[1]

Given the prominence of the OECD, and the WTO connection, it is not surprising that PSE estimates have attracted much public attention and received wide media coverage. The summary measure, relative PSE or %PSE (expressed as a percentage of the value of gross farm receipts) is frequently cited in the international debate on agricultural policies, and used as a yardstick of policy "misconduct", i.e., unfair competition with farmers in unsubsidizing countries. The higher a country's relative PSE, the more likely that the country's agricultural policy will be criticised by other countries (e.g., Oxfam, 2005).

Nevertheless, as indicated by Tangermann (2005), the relative PSE is merely a measure of monetary transfers from consumers and taxpayers, and thus an indicator of policy effort in favor of farmers. It was never intended to be an indicator of trade impact or welfare, and high relative PSEs do not necessarily indicate such effects.

Whether a high relative PSE is indicative of policy misconduct cannot be determined from the PSE figure alone, but hinges fundamentally on whether the welfare benefits of policies exceed their costs. This is the thread that we follow in this paper. We examine welfare theory and investigate how a switch in the direction of policies with a better

[1] One principal difference between the AMS and the PSE is that the former uses fixed international reference prices derived from a specific base period, while the latter uses current international reference prices. Furthermore, while AMS excludes green and blue support, PSE includes all budget support given by the government.

theoretical foundation will affect PSE figures. We also explore the relationship between the PSE and trade distortions.

2. Agricultural support, welfare and trade distortions

It is widely accepted that there are externalities and public goods related to agricultural activity. Examples cited are the amenity value of the landscape, food security, and preservation of rural communities and rural lifestyle (see Winters, 1989–1990 and OECD, 2001). The implications for agricultural policy are controversial, in particular, whether the agricultural support can be justified to ensure the production of non-commodity outputs, and what policy instruments are efficient in achieving desired levels of public goods. In the current WTO negotiations, for example, some high-cost countries have used alleged non-commodity outputs (the so-called "multifunctionality" of agriculture) to argue for the maintenance of import protection. Low-cost exporting countries reject such arguments. Their view is supported by studies that demonstrate that efficient policies for multifunctional agriculture do not depend on import protection (e.g., Chang et al., 2005; Peterson et al., 2002).

If we accept that the central role of agricultural policy is to correct for market failure, Pigouvian subsidies equal to marginal benefits should be used whenever agricultural activities, through production or input use, affect the supply of public goods and have positive externalities (Blandford and Boisvert, 2002). However, such subsidies would clearly be counted in the PSE.

Consider the case of no subsidies and no tariffs or no non-tariff trade restrictions, and consequently a PSE equal to zero. With positive externalities this would clearly be suboptimal, as production and/or input use would fall short of optimal levels. Correcting this through Pigouvian subsidies would result in a positive PSE, but that would not indicate policy misconduct. On the contrary, it would be the result of an optimal policy that internalizes externalities. If support were initially provided by means other than Pigouvian subsidies, a switch to an optimal policy might well result in a reduction in the total PSE since prices and, most likely, production would decline. However, the relative PSE might be unchanged or even increase. To investigate this formally we use a simple partial model.

We assume the following production function for agriculture:

$$(1) \qquad Y = L^{\alpha} K^{\beta}, \qquad \alpha + \beta < 1,$$

where Y is agricultural production, L is land, and K is an aggregate of other factors of production, which for simplicity we refer to as capital. The Cobb-Douglas function is chosen mainly for expositional clarity. In Appendix 1 we provide derivations for the more general Constant Elasticity of Substitution (CES) case.

Producer surplus as defined by the profit function is:

$$\Pi = pY - wL - rK, \tag{2}$$

where p is the price of the agricultural good and w and r are the prices of land and capital respectively. Using the small country, small sector argument we assume that output and factor prices are given. We further assume that there are no tariff or non-tariff trade barriers so that p is the world market price.

Maximizing profit yields the following supply and factor demand functions under the assumption of perfect competition:

$$\begin{aligned} Y &= \left[\alpha^{\alpha}\beta^{\beta}\frac{p^{\alpha+\beta}}{w^{\alpha}r^{\beta}}\right]^{\frac{1}{1\text{-}\alpha\text{-}\beta}}, \\ L &= \left[\alpha^{1-\beta}\beta^{\beta}\frac{p}{w^{1-\beta}r^{\beta}}\right]^{\frac{1}{1\text{-}\alpha\text{-}\beta}}, \\ K &= \left[\alpha^{\alpha}\beta^{1-\alpha}\frac{p}{w^{\alpha}r^{1-\alpha}}\right]^{\frac{1}{1\text{-}\alpha\text{-}\beta}}. \end{aligned} \tag{3}$$

Now let us assume that agricultural land generates a domestic public good in the form of amenity benefits, for which society has a constant marginal willingness to pay. The social optimum can be found by maximizing the following welfare function:

$$W = \Pi + CS + \gamma L, \tag{4}$$

where γ is the constant marginal willingness to pay for landscape amenity. *CS* is consumer surplus, which is constant since the agricultural good can be freely imported or exported at the world market price *p*.

Assuming now that $p = w = r = 1$, we use the competitive, free trade, no subsidy case as a point of reference:

$$\Pi_{MAX} \qquad Y' = \left[\alpha^{\alpha}\beta^{\beta}\right]^{\frac{1}{1-\alpha-\beta}}$$

$$L' = \left[\alpha^{1-\beta}\beta^{\beta}\right]^{\frac{1}{1-\alpha-\beta}}$$

$$(5) \qquad K' = \left[\alpha^{\alpha}\beta^{1-\alpha}\right]^{\frac{1}{1-\alpha-\beta}}$$

$$\frac{Y'}{L'} = \frac{1}{\alpha}$$

$$\frac{K'}{L'} = \frac{\beta}{\alpha}.$$

The welfare optimum is characterized by:

$$W_{MAX} \qquad Y^* = \left[\alpha^{\alpha}\beta^{\beta}\frac{1}{(1-\gamma)^{\alpha}}\right]^{\frac{1}{1-\alpha-\beta}} > Y'$$

$$L^* = \left[\alpha^{1-\beta}\beta^{\beta}\frac{1}{(1-\gamma)^{1-\beta}}\right]^{\frac{1}{1-\alpha-\beta}} > \mathrm{L'}$$

$$(6) \qquad K^* = \left[\alpha^{\alpha}\beta^{1-\alpha}\frac{1}{(1-\gamma)^{\alpha}}\right]^{\frac{1}{1-\alpha-\beta}} > \mathrm{K'}$$

$$\frac{Y^*}{L^*} = \frac{1-\gamma}{\alpha} < \frac{Y'}{L'}$$

$$\frac{K^*}{L^*} = \frac{\beta(1-\gamma)}{\alpha} < \frac{K'}{L'}.$$

Comparing (6) with (4) and (5), we see that the welfare optimum can be achieved in a competitive setting by using a Pigouvian subsidy, $s_L = \gamma$, per unit of land. Remember that we have normalized the price of land to 1. γ is therefore assumed to be less than 1.

We see that the welfare optimum requires higher production of the agricultural good and greater land use, but lower production per unit of land than the no-subsidy case. The welfare optimum also requires greater use of capital, but lower capital intensity than the competitive (no-subsidy) case.

In this model the absolute and relative PSEs are:

$$W_{MAX} \qquad PSE^* = \gamma L^* = \gamma\left[\alpha^{1-\beta}\beta^{\beta}\frac{1}{(1-\gamma)^{1-\beta}}\right]^{\frac{1}{1-\alpha-\beta}}$$

$$(7) \qquad \%PSE^* = \frac{\gamma L^*}{Y^* + \gamma L^*} = \frac{\alpha\gamma}{1-\gamma+\alpha\gamma}$$

We now define a measure of trade distortion, *TD*, as the relative difference between production of the agricultural good under no support and with some kind of subsidy scheme. In the case of an optimal subsidy, trade distortion equals:

(8) $$TD^* = \frac{Y^*}{Y'} - 1 = \left[\frac{1}{1-\gamma}\right]^{\frac{\alpha}{1-\alpha-\beta}} - 1 > 0$$

We see that TD^* is increasing in γ.[2]

Now consider the case where agricultural support is proportional to production and the subsidy rate is s_Y. This gives the following solution:

(9) $s_Y > 0$
$$\begin{aligned}
\hat{Y} &= \left[\alpha^{\alpha}\beta^{\beta}(1+s_Y)^{\alpha+\beta}\right]^{\frac{1}{1-\alpha-\beta}} > Y' \\
\hat{L} &= \left[\alpha^{1-\beta}\beta^{\beta}(1+s_Y)\right]^{\frac{1}{1-\alpha-\beta}} > \mathrm{L}' \\
\hat{K} &= \left[\alpha^{\alpha}\beta^{1-\alpha}(1+s_Y)\right]^{\frac{1}{1-\alpha-\beta}} > \mathrm{K}' \\
\frac{\hat{Y}}{\hat{L}} &= \frac{1}{\alpha(1+s_Y)} < \frac{Y'}{L'} \\
\frac{\hat{K}}{\hat{L}} &= \frac{\beta}{\alpha} = \frac{K'}{L'} > \frac{K^*}{L^*} \\
P\hat{S}E &= s_Y\hat{Y} = s_Y\left[\alpha^{\alpha}\beta^{\beta}(1+s_Y)^{\alpha+\beta}\right]^{\frac{1}{1-\alpha-\beta}} \\
\%P\hat{S}E &= \frac{s_Y\hat{Y}}{(1+s_Y)\hat{Y}} = \frac{s_Y}{(1+s_Y)} \\
T\hat{D} &= (1+s_Y)^{\frac{\alpha+\beta}{1-\alpha-\beta}} - 1.
\end{aligned}$$

In order to compare this to the welfare optimum we set the subsidy rate such that $\hat{L} = L^*$. It then follows from (6) and (9) that:

(10) $$(1+s_Y) = (1-\gamma)^{\beta-1} \quad , \quad s_Y = (1-\gamma)^{\beta-1} - 1 \quad \text{and} \quad \frac{s_Y}{(1+s_Y)} = 1-(1-\gamma)^{1-\beta},$$

(11) $$P\hat{S}E - PSE^* = s_Y\hat{Y} - \gamma L^* = \left[\frac{s_Y}{\alpha(1+s_Y)} - \gamma\right]L^* = \left[\frac{1-(1-\gamma)^{1-\beta}}{\alpha} - \gamma\right]L^* > 0.$$

[2] While theoretically sound, an exact measure of trade distortion may be difficult to calculate in practice given that both consumption and production may change and that there can be reversals in net trade. In the empirical example used in the paper we employ an index of changes in production as a proxy measure for trade distortion.

As this difference in absolute PSE is increasing in γ it must always be positive. The difference in percentage PSE is given by:

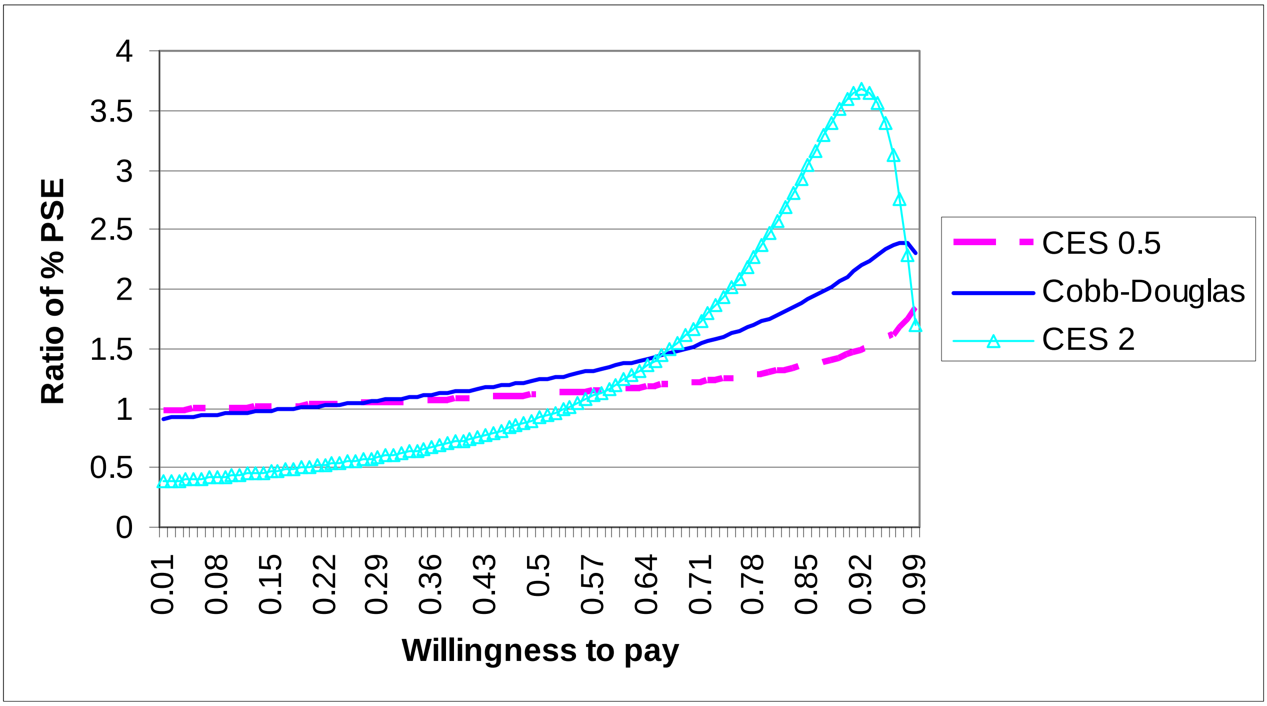
(12) $$\%P\hat{S}E - \%PSE^* = 1-(1-\gamma)^{1-\beta} - \frac{\alpha\gamma}{1-\gamma(1-\alpha)}.$$

From (12) we see that the size of the relative PSE in the product subsidy case compared to the land subsidy case is indeterminate. The sign depends on the willingness to pay (γ), the scale elasticity ($\alpha+\beta$), the distribution parameter, that is the relative values of α and β, and, in the more general CES case, on the elasticity of substitution. This is illustrated in Figure 1. For a distribution parameter equal to 0.1 and a scale elasticity of 0.99, that is α=0.099 and β=0.891, we have computed:

(13) $$\frac{\%PSE^*}{\%P\hat{S}E}$$

for various values of the willingness to pay (γ) – given on the horizontal axis. For the Cobb-Douglas case we see that for low γ the ratio of the %PSE (on the vertical axis) is lower for

Figure 1: Relative %PSE for area subsidies compared to product subsidies



area support than production support. For γ in excess of 0.2 the opposite is the case. In addition we graph the results for a low elasticity of substitution of 0.5, and a high elasticity of substitution of 2. The two curves are based on the CES derivations in the appendix. Again we see that the ratio of the %PSE is lowest for area support when γ is low. And we see that variation in %PSE is highest in the high elasticity case. To explain these results further, write (13) as:

$$\frac{\%PSE^*}{\%P\hat{S}E} = \frac{\left(\hat{Y}/s_Y\hat{Y}\right)+1}{\left(Y^*/\gamma L^*\right)+1}$$

If we go from area support to price support, production as well as total PSE will increase $\left(\gamma L^* < s_Y\hat{Y}\right)$. Consequently, if the percentage increase in production is larger than the percentage increase in total PSE, (%PSE*/$\%P\hat{S}E$) will increase and visa versa. And this is what happens in the right hand side of Figure 1. The willingness to pay γ is here high compared to production cost. This calls for high levels of support. In the case of area support it is possible to restrict the production by substituting towards the targeted input. If we choose production subsidies instead, production will increase markedly by the help of a substantial increase in capital. The higher elasticity of substitution, the shaper is this tendency. In the left hand side of the diagram, i.e. for lower γs, the percentage increase in production is less than the percentage increase in total PSE. Naturally, the use of capital increases if we choose production instead of area subsidies. But the switch to more capital is less dramatic compared to the high γ case.

The previous discussion shows that it is possible that a switch from a suboptimal (production subsidy) to an optimal (input subsidy) policy may well lead to an increase in the relative PSE rather than a decrease. This is more likely the more closely external effects from agriculture are tied to some, but not all, inputs rather than to production and the lower the elasticity of substitution among inputs. Simulations of such policy changes using a model for the Norwegian agricultural sector, discussed below, seem to indicate that this is a realistic possibility.

For the trade distortion we have that:

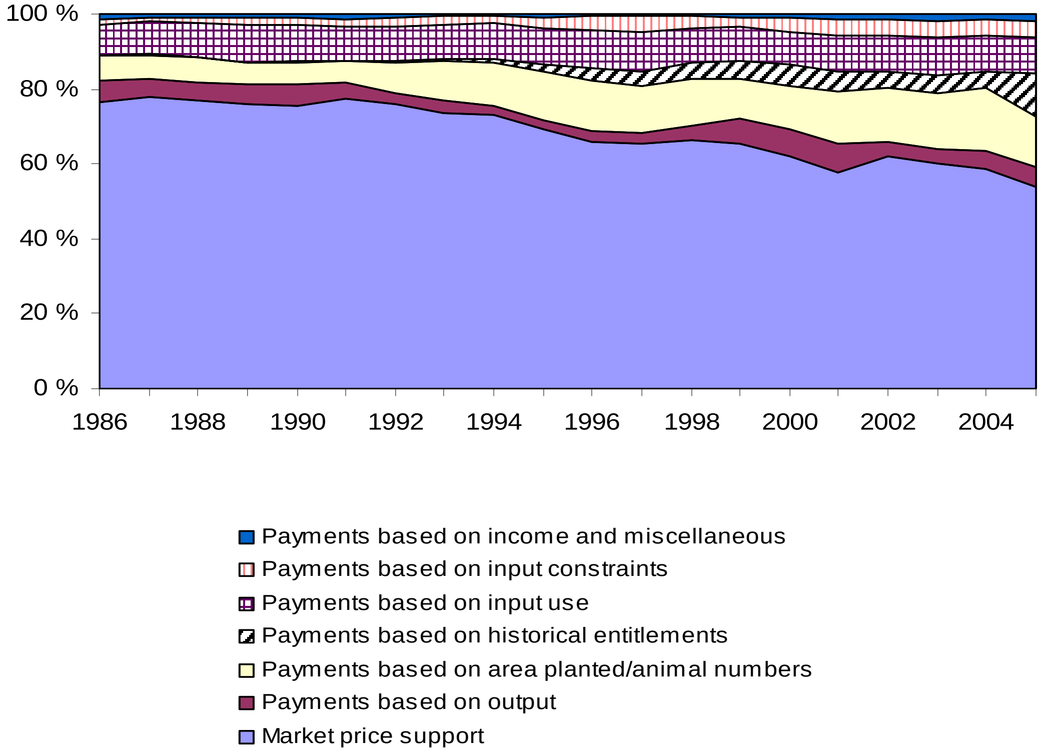
$$\begin{aligned}(14)\quad \widehat{TD} - TD^* &= (1+s_Y)^{\frac{\alpha+\beta}{1-\alpha-\beta}} - \left[\frac{1}{1-\gamma}\right]^{\frac{\alpha}{1\text{-}\alpha\text{-}\beta}} = \left[\frac{1}{1-\gamma}\right]^{\frac{(1-\beta)(\alpha+\beta)}{1\text{-}\alpha\text{-}\beta}} - \left[\frac{1}{1-\gamma}\right]^{\frac{\alpha}{1\text{-}\alpha\text{-}\beta}} \\ &= \left[\frac{1}{1-\gamma}\right]^{\frac{\alpha+\beta(1-\alpha-\beta)}{1\text{-}\alpha\text{-}\beta}} - \left[\frac{1}{1-\gamma}\right]^{\frac{\alpha}{1\text{-}\alpha\text{-}\beta}} \quad > 0\end{aligned}$$

since $\alpha + \beta > 0$.

Tangermann (2005) argues that even if the overall PSE figures cannot be interpreted as an indicator of policy misconduct, the OECD breakdown of the PSE into various categories provides additional information for assessing existing policies and the impact of reform. Of the total PSE for the OECD area in 2005 more than three quarters was in the form of market price support (that is associated with border protection), payments based on production, and payments based on input use (Figure 2). Another fifth was based on area planted, animal numbers, or historical entitlements. Based on such data Tangermann concludes: “for the OECD area overall, less than 5% of the PSE is currently in a form that may potentially be targeted to specific public goods.” (Tangermann 2005, p. 11).

While we agree that a breakdown of the PSE figures into sub categories can help in assessing policy reforms, we have problems with the sweeping conclusion above. The sub categories of support seem naturally to fall in three groups: that varying directly with production, like market price support and payments based on output, that indirectly related to production, like support based on area planted, animal numbers and input use, and that completely decoupled from production. Tangermann seems to assert that Pigouvian subsidies may only be included in the third group.

Figure 2. Composition of Producer Support Estimate for the OECD (% share)



Source: OECD PSE/CSE database (2005).

3. Model example

To illustrate the points advanced in the previous section, we provide empirical examples of how a change in policy from production support to subsidies targeted on public goods, affects indicators like relative PSE, economic welfare and trade distortions.

Norway is particularly well suited as an example in this respect. Relative PSE was 66 % in 2004-06, a figure only matched by Iceland and Switzerland. Norway's agricultural policy is often criticised for being trade distorting and far from optimal (e.g., Lamy, 2007), with more than half of the support directly tied to production levels. The Norwegian agriculture is positioned in the right hand side of Figure 1; i.e. production costs are high (uncompetitive agriculture) compared to the willingness to pay for agricultural public goods.

The model

Our analysis is based on a price-endogenous model of Norwegian agriculture. The model includes the most important commodities produced by the Norwegian agricultural sector, in all 13 final and 8 intermediate product aggregates. Of the final products, 11 are related to animal products while 3 are related to crops. Inputs needed to produce agricultural products are land, labor (family and hired), capital (machinery and buildings), concentrated feed, and an aggregate of other goods. The model distinguishes between tilled land and grazing on arable land and pastures.

Domestic supply is represented by about 400 "model farms". Each model farm is characterized by Leontief technology, i.e. with fixed input and output coefficients. Although, inputs can not substitute for each other at the farm level, there are substitution possibilities at the sector level. For example, beef can be produced with different technologies (model farms), both extensive and intensive production systems, and in combination with milk. Thus, in line with the general Leontief model in which each good may have more than one activity that can produce it, the isoquant for each product is piecewise linear. Also, production can take place on small farms or larger more productive farms. Consequently, there is an element of economies of scale in the model.

The country is divided into nine regions, each with limited supply of different grades of land. This introduces an element of diseconomies of scale because, *ceteris paribus*, production will first take place in the best regions. Domestic demand for final products is represented by linear demand functions. Economic surplus (consumer's surplus plus producer's surplus) of the agricultural sector is maximized, subject to demand and supply relationships, policy instruments and imposed restrictions. The solution to the model is found as the prices and quantities that give equilibrium in each market. A broader description of the model is offered in Appendix A.

Assumptions and results

In the analysis, we assume that the only argument for public intervention in agriculture is to secure sufficient levels of agricultural public goods, such as cultural landscape and food security. In this respect, two different policy approaches are considered: 1) a policy exclusively targeted to the provision of agricultural public goods through the payment of input-based subsidies (primarily on land), and 2) production support until approximately the same levels of public goods are provided. Obviously, of these two alternatives the first represents an efficient policy.

As a basis for comparison, Column 1 in Table 1 presents the model's representation of the existing policy in the base year (1998). In spite of climatic disadvantages, production was high and imports were low. Norway is self-sufficient in most of the products listed. For dairy products there is a surplus and the equivalent of roughly 12% of domestic milk production is disposed of through subsidized exports of cheese. The Arctic climate does not permit sufficient production of high-quality grain for bread-making, so roughly half of the wheat used domestically is imported.

As may be seen, the present policy is costly. The total PSE is NOK 15 billions (roughly EUR 1.9 billlion at current exchange rates) which equals 60 % of the value of production at the farm level. Divided by employment and land area support is NOK 250,000 (EUR 31,000) per full-time equivalent worker (FTE) and NOK 17,000 (EUR 2,125) per hectare. A break-down of the PSE into various categories, shows that about 50 % of the support is in the form of market price support, generated by import tariffs in the interval 171-429 % and export subsidies. The rest of the support is through payments based on output (15 %), area planted or animal numbers (12 %) and input use (25 %).

The final row in Table 1 contains an index of distortion, TDI. This index is defined as the weighted sum of the relative divergence between imports under free trade and the simulation in question:[3]

$$TDI=\sum_j \alpha_j \frac{\overline{M}_j - M_j}{\overline{M}_j}, \quad where \quad \alpha_j = \frac{p_j \overline{M}_j}{\sum_{jj} p_{jj} \overline{M}_{jj}} \quad \forall\ j, jj = 1..m$$

As weight (α), we use the import value share of each product j in a free trade solution, where p_j is the world market price and $\overline{M}_j$ is the free trade import volume. $\overline{M}_j$ is found from a model simulation assuming free import and no support. M_j is the import in the counterfactual simulation. With this definition, the magnitude of trade distortion increase with the index, and $0 \leqslant TDI \leqslant 1$. In the simulation of the current policy, we can see that TDI is close to 1. Only the present import of wheat, with a free trade import value share of 3,8 %, pulls TDI slightly below 1.

Most of the support is currently attached to the production of private goods. Even the support that is linked to land, animals or other inputs is only targeted to the provision of public goods to a minor degree, e.g., through requirements for landscape preservation or restrictions on agricultural production practices. Therefore, the present policy is weakly targeted to sources of market failure.

Table 1: PSE, welfare and trade distortion

[3] In section 2 we used the relative divergence from production in free trade. Since we hardly get production in free trade, we have changed the measure.

		Provision of public goods	
	Current policies	Efficient policy	Production support
Production (mill. kg.)			
Milk	1,672	710	1,236
Beef and veal	82	29	60
Pig meat	100	0	73
Sheep meat	23	30	17
Poultry meat	28	0	20
Eggs	44	10	32
Wheat	211	150	154
Coarse grains	1,021	339	746
Potatoes	298	312	291
Land use (mill. hectares)	0.85	0.54	0.54
Employment (1000 person-years)	60	18	28
PSE (billion NOK)	15	6	9
Market price support	7	0	0
Output support	2	0	9
Input support	6	6	0
PSE (percentage)	60 %	65 %	54 %
Economic welfare (billion NOK)	14	24	21
Index of trade distortion	0,99	0,34	0,67

The implications of a policy exclusively aimed at the provision of public goods are illustrated in Column 2 of Table 1, following an approach by Brunstad *et al.* (1999, 2005). In this case, the amenity value of the agricultural landscape is taken into account by incorporating information on willingness to pay, as inferred from contingent valuation studies, in the objective function of the model. On the basis of these studies, the amenity value is higher for grazing and pasture than for tilled land, and the marginal willingness to pay diminishes with increased agricultural activity.

As the results show, when public good provision is the policy aim, agricultural production and employment fall substantially, but a large proportion of land remains in production (64 % of the base level solution). A switch towards land-intensive production techniques takes place, represented by extensive sheep meat production. The total PSE falls to roughly 40 % of the current level, and economic welfare, defined as the sum of producers' and consumers' surplus deducted for subsidies, increases by NOK 10 billion.

In this simulation, support is exclusively tied to factors related to the public goods (land, labor and livestock). No market price support or deficiency payments are used. Because of technological interlinkages, production and trade are affected, but to a far lesser extent than under current policies. As a result, the TDI declines substantially (from 0.99 to 0.34), indicating that imports have surged.

In spite of lower support, higher welfare and less trade distortions, the relative PSE increases from 60 % to 65 %. This confirms that the relative PSE is not a good indicator of how welfare or trade is affected by the change in policy.

Column 3 of Table 1 shows what happens to the indicators when an inferior policy, i.e. production subsidies, is used to achieve the same level of public goods. In this simulation the current production levels (Column 1) are scaled down proportionally until land use and the value of the cultural landscape is equal to the levels of the efficient solution (Column 2). There are no import tariffs, but opposed to the efficient solution, the support is now tied directly to production.

Compared to the efficient solution, land use is the same, but production and the levels of labour and other input factors have increased. Consequently, both support and trade distortions are higher (TDI = 0.67), and welfare is lower. However, in line with the discussion in Section 2, the relative PSE is below previous levels. With reference to Figure 1, the ratio of the relative PSE under efficient policy and production subsidies, respectively, is 1.2. This suggests a moderate elasticity of substitution and a position in the right hand side of the figure, which applies for a high cost agricultural sector.

4. **Conclusions**

In this paper we have demonstrated that changes in the relative (percentage) PSE are not an accurate indicator of the implications of policy reform for domestic welfare or for trade distortions. It is important to consider the implications of changes in both the level and the form of subsidies in evaluating the impact of policy reform. The example of Norway shows that reforms oriented towards the provision of agricultural public goods, while apparently leading to an increase in relative support, are actually superior in terms of reducing trade distortions and increasing domestic economic welfare.

Appendix 1

The following equations are numbered as in the main text. The CES production function is:

(1')
$$Y = \left(\alpha L^{\rho} + (1-\alpha)K^{\rho}\right)^{\lambda/\rho} \qquad \lambda < 1,\ \rho \le 1,$$

λ is the scale parameter assumed to be less than one, i.e. decreasing returns to scale and ρ is connected to the elasticity of substitution, σ, through:

$$\sigma = \frac{1}{1-\rho}.$$

It is useful to consider the following special cases:

(i) $\rho = 1$: linear production function

(ii) $\rho = 0$: Cobb Douglas, i. e., as in the main text

(iii) $\rho = -\infty$: Leontief production function.

The profit function is:

(2')
$$\Pi = pY - wL - rK,$$

and the supply and factor demand functions:

$$Y = (p\lambda)^{\lambda/1-\lambda}\left[\alpha^{1/1-\rho} w^{\rho/\rho-1} + (1-\alpha)^{1/1-\rho} r^{\rho/\rho-1}\right]^{(1-\rho)\lambda/(1-\lambda)\rho}$$

(3')
$$L = (p\lambda)^{1/1-\lambda}\left(\frac{\alpha}{w}\right)^{1/1-\rho}\left[\alpha^{1/1-\rho} w^{\rho/\rho-1} + (1-\alpha)^{1/1-\rho} r^{\rho/\rho-1}\right]^{(\lambda-\rho)/\rho(1-\lambda)}$$

$$K = (p\lambda)^{1/1-\lambda}\left(\frac{1-\alpha}{r}\right)^{1/1-\rho}\left[\alpha^{1/1-\rho} w^{\rho/\rho-1} + (1-\alpha)^{1/1-\rho} r^{\rho/\rho-1}\right]^{(\lambda-\rho)/\rho(1-\lambda)}.$$

If output and factor prices equal 1:

$$L' = (\lambda)^{1/1-\lambda}\alpha^{1/1-\rho}\left[\alpha^{1/1-\rho} + (1-\alpha)^{1/1-\rho}\right]^{(\lambda-\rho)/\rho(1-\lambda)}$$

$$K' = (\lambda)^{1/1-\lambda}(1-\alpha)^{1/1-\rho}\left[\alpha^{1/1-\rho} + (1-\alpha)^{1/1-\rho}\right]^{(\lambda-\rho)/\rho(1-\lambda)}$$

(5')
$$Y' = (\lambda)^{\lambda/1-\lambda}\left[\alpha^{1/1-\rho} + (1-\alpha)^{1/1-\rho}\right]^{(1-\rho)\lambda/(1-\lambda)\rho}$$

$$\frac{Y'}{L'} = \frac{1}{\lambda}\left(\frac{1}{\alpha}\right)^{1/1-\rho}\left[\alpha^{1/1-\rho} + (1-\alpha)^{1/1-\rho}\right]$$

$$\frac{K'}{L'} = \left(\frac{1-\alpha}{\alpha}\right)^{1/1-\rho}.$$

We refer to (5') as the perfectly competitive solution.

With a constant willingness to pay for landscape amenities, define as γ per unit of land, *L,* the welfare optimum yields:

$$Y^* = (\lambda)^{\lambda/1-\lambda}\left[\alpha^{1/1-\rho}(1-\gamma)^{\rho/\rho-1} + (1-\alpha)^{1/1-\rho}\right]^{(1-\rho)\lambda/(1-\lambda)\rho} > Y'$$

(6’) $$K^* = (\lambda)^{1/1-\lambda}(1-\alpha)^{1/1-\rho}\left[\alpha^{1/1-\rho}(1-\gamma)^{\rho/\rho-1} + (1-\alpha)^{1/1-\rho}\right]^{(\lambda-\rho)/\rho(1-\lambda)}$$

$$L^* = (\lambda)^{1/1-\lambda}\left(\frac{\alpha}{1-\gamma}\right)^{1/1-\rho}\left[\alpha^{1/1-\rho}(1-\gamma)^{\rho/\rho-1} + (1-\alpha)^{1/1-\rho}\right]^{(\lambda-\rho)/\rho(1-\lambda)} > L'$$

$$\frac{Y^*}{L^*} = \frac{1}{\lambda}\left(\frac{1-\gamma}{\alpha}\right)^{1/1-\rho}\left[\alpha^{1/1-\rho}(1-\gamma)^{\rho/\rho-1} + (1-\alpha)^{1/1-\rho}\right] < \frac{Y'}{L'}$$

$$\frac{K^*}{L^*} = \left(\frac{(1-\gamma)(1-\alpha)}{\alpha}\right)^{1/1-\rho} < \frac{K'}{L'}.$$

By comparing (6’) and (5’) we see that welfare optimum requires greater production of the agricultural good, greater land use, but lower production per land unit than the perfectly competitive case. If $\lambda > \rho$, the welfare optimum requires greater use of capital. but capital intensity is always lower than the perfectly competitive case.

The producer subsidy equivalent is given by:

$$PSE^* = \gamma L^* = \gamma(\lambda)^{1/1-\lambda}\left(\frac{\alpha}{1-\gamma}\right)^{1/1-\rho}\left[\alpha^{1/1-\rho}(1-\gamma)^{\rho/\rho-1} + (1-\alpha)^{1/1-\rho}\right]^{(\lambda-\rho)/\rho(1-\lambda)}$$

(7’)

$$\%PSE^* = \frac{\gamma L^*}{Y^*} = \gamma\lambda\left(\frac{\alpha}{1-\gamma}\right)^{1/1-\rho}\left[\alpha^{1/1-\rho}(1-\gamma)^{\rho/\rho-1} + (1-\alpha)^{1/1-\rho}\right]^{-1}.$$

This implies that %PSE is increasing in γ.

Our measure of trade distortion is:

(8’) $$TD^* = \frac{Y^*}{Y'} - 1 = \left[\frac{\alpha^{1/1-\rho}(1-\gamma)^{\rho/\rho-1} + (1-\alpha)^{1/1-\rho}}{\alpha^{1/1-\rho} + (1-\alpha)^{1/1-\rho}}\right]^{(1-\rho)\lambda/(1-\lambda)\rho} - 1.$$

Hence, an increasing γ implies an increasing *TD**.

Subsidizing output instead of land yields:

$$\hat{L} = ((1+s_Y)\lambda)^{1/1-\lambda}(\alpha)^{1/1-\rho}\left[\alpha^{1/1-\rho} + (1-\alpha)^{1/1-\rho}\right]^{(\lambda-\rho)/\rho(1-\lambda)} > L'$$

$$\hat{K} = ((1+s_Y)\lambda)^{1/1-\lambda}(1-\alpha)^{1/1-\rho}\left[\alpha^{1/1-\rho} + (1-\alpha)^{1/1-\rho}\right]^{(\lambda-\rho)/\rho(1-\lambda)} > K'$$

(9’) $$\hat{Y} = ((1+s_Y)\lambda)^{\lambda/1-\lambda}\left[\alpha^{1/1-\rho} + (1-\alpha)^{1/1-\rho}\right]^{(1-\rho)\lambda/(1-\lambda)\rho} > Y'$$

$$\frac{\hat{Y}}{\hat{L}} = \frac{1}{(1+s_Y)\lambda}\left[\alpha^{1/1-\rho} + (1-\alpha)^{1/1-\rho}\right] < \frac{Y'}{L'}$$

$$\frac{\hat{K}}{\hat{L}} = \left(\frac{1-\alpha}{\alpha}\right)^{1/_{1-\rho}} = \frac{K'}{L'}$$

where s_Y is the rate of output subsidy. In this case the PSE is:

$$P\hat{S}E = s_Y\hat{Y} = s_Y\left((1+s_Y)\lambda\right)^{\lambda/_{1-\lambda}}\left[\alpha^{1/_{1-\rho}} + (1-\alpha)^{1/_{1-\rho}}\right]^{(1-\rho)\lambda/_{(1-\lambda)\rho}}$$

and

$$\%P\hat{S}E = \frac{s_Y\hat{Y}}{(1+s_Y)\hat{Y}} = \frac{s_Y}{1+s_Y}.$$

We see that $\%P\hat{S}E$ is increasing in s_Y. The trade distortion is:

$$T\hat{D} = \frac{\hat{Y}}{Y'} - 1 = (1+s_Y)^{\lambda/_{1-\lambda}},$$

and $T\hat{D}$ is also increasing in s_Y.

A comparison between the two cases, assuming

$$\hat{L} = L^*,$$

yields:

$$\left(\frac{1}{1-\gamma}\right)^{1/1-\rho} = (1+s_Y)^{1/1-\lambda}\left[\frac{\alpha^{1/_{1-\rho}} + (1-\alpha)^{1/_{1-\rho}}}{\alpha^{1/_{1-\rho}}(1-\gamma)^{\rho/_{\rho-1}} + (1-\alpha)^{1/_{1-\rho}}}\right]^{\frac{(\lambda-\rho)}{(1-\lambda)\rho}}.$$

It now follows that s_Y must be set such that:

$$(10')\qquad s_Y = \left(\frac{1}{1-\gamma}\right)^{(1-\lambda)/_{(1-\rho)}}\left[\frac{\alpha^{1/_{1-\rho}}(1-\gamma)^{\rho/_{\rho-1}} + (1-\alpha)^{1/_{1-\rho}}}{\alpha^{1/_{1-\rho}} + (1-\alpha)^{1/_{1-\rho}}}\right]^{(1-\lambda)(\lambda-\rho)/_{(1-\lambda)\rho}} - 1$$

and

(11)

$$P\hat{S}E - PSE^* = s_Y\hat{Y} - \gamma L^* =$$

$$s_Y\left((1+s_Y)\lambda\right)^{\lambda/_{1-\lambda}}\left[\alpha^{1/_{1-\rho}} + (1-\alpha)^{1/_{1-\rho}}\right]^{(1-\rho)\lambda/_{(1-\lambda)\rho}} - \gamma(\lambda)^{1/_{1-\lambda}}\left(\frac{\alpha}{1-\gamma}\right)^{1/_{1-\rho}}\left[\alpha^{1/_{1-\rho}}(1-\gamma)^{\rho/_{\rho-1}} + (1-\alpha)^{1/_{1-\rho}}\right]^{(\lambda-\rho)/_{\rho(1-\lambda)}}$$

and furthermore that:

$$\%P\hat{S}E - \%PSE^* = \frac{s_Y}{1+s_Y} - \gamma\lambda\left(\frac{\alpha}{1-\gamma}\right)^{1/_{1-\rho}}\left[\alpha^{1/_{1-\rho}}(1-\gamma)^{\rho/_{\rho-1}} + (1-\alpha)^{1/_{1-\rho}}\right]^{-1},$$

where s_Y is given by (10').

Appendix 2

The model is a partial equilibrium model of the Norwegian agricultural sector. For given input costs and demand functions, market clearing prices and quantities are computed. Prices of goods produced outside the agricultural sector or abroad are taken as given. As the model assumes full mobility of labor and capital, it must be interpreted as a long run model.

The model covers the most important products produced by the Norwegian agricultural sector, in all 14 final and 9 intermediate products. Most products in the model are aggregates. Primary inputs are: land (four different grades), labor (family members and hired), capital (machinery, buildings, and livestock) and other inputs (fertilizers, fuel, seeds, etc.). The prices of inputs are determined outside the model and treated as given.

Supply in the model is domestic production and imports. Domestic production takes place on approximately 400 different "model farms". The farms are modeled with fixed input and output coefficients, based on data from extensive farm surveys carried out by the Norwegian Agricultural Economics Research Institute, a research body connected to the Norwegian Ministry of Agriculture. Imports take place at given world market prices inclusive of tariffs and transport costs. Domestic and foreign products are assumed to be perfect substitutes. The country is divided into nine production regions, each with limited supply of the different grades of land. This regional division allows for variation in climatic and topographic conditions and makes it possible to specify regional goals and policy instruments. The products from the model farms go through processing plants before they are offered on the market. The processing plants are partly modeled as pure cost mark-ups (meat, eggs and fruit), and partly as production processes of the same type as the model farms (milk and grains).

The domestic demand for final products is represented by linear demand functions. These demand functions are based on existing studies of demand elasticities, and are linearized to pass through the observed price and quantity combination in the base year (1998). Between the meat products there are cross price effects, but only own price effects are assumed for other products. The demand for intermediate products is derived from the demand for the final products for which they are inputs. Exports take place at given world market prices.

Domestic demand for final products is divided among 5 separate demand regions, which have their own demand functions. Each demand region consists of one or several production regions. If products are transported from one region to another, transport costs are incurred. For imports and exports transport costs are incurred from the port of entry and to the port of shipment, respectively. In principle restrictions can be placed on all variables in the model. The restrictions that we include can be divided into two groups:

(1) Scarcity restrictions: upper limits for the endowment of land, for each grade of land in each region.

(2) Political restrictions: lower limits for land use and employment in each region, for groups of regions (central regions and remote areas), or for the country as a whole; maximum or minimum quantities for domestic production, imports or exports; maximum prices.

In the model, economic surplus (consumers' plus producers' surplus) of the agricultural sector is maximized. This maximization is performed subject to demand and supply relationships and the imposed restrictions. Which restrictions are included depends upon what kind of simulation that is attempted. The solution to the model is found as the prices and quantities that give equilibrium in each market. No restrictions can be violated, and no model farm or processing plant that is active, runs at a loss.

References

Blandford, D., and Boisvert, R.N. (2002). Multifunctional agriculture and domestic/international policy choice. *Estey Centre Journal of International Law and Trade Policy* 3: 106-118.

Brunstad, R., Gaasland, I. and Vårdal, E. (1995): A Model for the Agricultural Sector in Norway. Working Paper No. 25/95. Foundation for Research in Economics and Business Administration. Bergen.

Brunstad, R.J., Gaasland, I. and Vårdal, E. (1999). Agricultural Production and the Optimal Level of Landscape Preservation. *Land Economics* 75: 538-546.

Brunstad, R.J., Gaasland, I. and Vårdal, E. (2005). Multifunctionality of agriculture: an inquiry into the complementarity between landscape preservation and food security. *European Review of Agricultural Economics* 32: 469–488.

Cahill, C., and W. Legg (1989-90). Estimation of agricultural assistance using producer and consumer subsidy equivalents: theory and practice. *OECD Economic Studies,* No. 13. Paris: OECD.

Chang, H.-H., Boisvert, R.N. and Blandford, D. (2005). Achieving Environmental Objectives Under Reduced Domestic Agricultural Support and Trade Liberalization: An Empirical Application to Taiwan. *Agricultural and Resource Economics Review* 34:1-16.

Corden, W.M. (1971), *The Theory of Protection*. London: Oxford University Press.

Josling, T.E. (1973), *Agricultural Protection: Domestic Policy and International Trade.* Rome: FAO.

Josling, T.E. (1975), *Agricultural Protection and Stabilisation Policies: A Framework of Measurement in the Context of Agricultural Adjustment.* Rome: FAO.

Lamy, P. (2007). The sails of the Viking Longships in the storm of globalization. Speech given at the annual conference of the Nowegian Confederation of Industries., Oslo. http://www.wto.org/english/news_e/sppl_e/sppl52_e.htm

Legg, W. (2003), Agricultural subsidies: measurement and use in policy evaluation. Presidential Address. *Journal of Agricultural Economics* 54 (2): 175-200.

Oxfam (2005). *A Round for Free: How Rich Countries are Getting a Free Ride for Agricultural Subsidies at the WTO*. Briefing Paper 76, Washignton, DC.

Peterson, J.M., Boisvert, R.N. and de Gorter, H. (2002). Environmental policies for a multifunctional agricultural sector in open economies. *European Review of Agricultural Economics* 29: 423–443.

Tangermann, S. (2005) Is the Concept of the Producer Support Estimate in Need of Revision? *OECD Food, Agriculture and Fisheries Working Paper* No. 1, OECD Publishing

Winters, L.A. (1989–1990). The so-called ‘non-economic’ objectives of agricultural support. *OECD Economic Studies* 13. Paris: Organisation for Economic Cooperation and Development, 237–266.