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OPTIMAL AGRICULTURAL POLICY AND PSE MEASUREMENT: AN ASSESSMENT AND APPLICATION TO NORWAY

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

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Abstract:
The producer support estimate calculated by the OECD is widely misused as an indicator of distortions created by agricultural policies. In this paper we demonstrate rigorously that a change in the relative (percentage) PSE is not an accurate indicator of the implications of policy reform for domestic welfare or for trade distortions. If there are positive externalities linked to agricultural inputs (e.g., land), we demonstrate that replacing output subsidies by optimal Pigouvian subsidies may result in an increase or a reduction in relative PSE depending on the parameters of the production function. Using the example of Norway we show that an increase in the relative PSE is likely if the focus of agricultural policies shifts from income support to the provision of public goods.

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

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

1. **Introduction**

The producer support estimate (PSE) is a measure of monetary transfers from consumers and taxpayers to producers through agricultural policies. Its conceptual basis is as an equivalent subsidy of the incidence of government policies Corden (1971). Josling (1973 and 1975) applied the concept to agricultural policies and coined the original 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. The OECD's annual estimates provide the only readily available and consistent source of internationally comparable information on government support for agriculture. Cahill and Legg (1989-90) and Legg (2003) provide an overview of 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 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 (total support 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 as being trade distorting (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 actually 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 pursue in this paper. We examine welfare theory and investigate how a switch in the direction of policies that are

[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 WTO green and blue box categories of support, the PSE includes all forms of support provided by the government.

oriented towards correcting for market failure 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 support can be justified to ensure provision of non-commodity outputs, and what policy instruments are efficient in achieving the desired supply of public goods. In the current WTO negotiations, for example, some high-cost importing 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 trade restrictions, and consequently a PSE equal to zero. With positive externalities this would clearly be suboptimal, since 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, the 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) $$Y = L^{\alpha} K^{\beta}, \qquad \alpha + \beta < 1,$$

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. Assuming the small country, small sector case output and factor prices are given. We further assume that there are no 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:

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

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

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

$$(5) \qquad \begin{aligned} L' &= \left[\alpha^{1-\beta}\beta^{\beta}\right]^{\frac{1}{1-\alpha-\beta}} \\ K' &= \left[\alpha^{\alpha}\beta^{1-\alpha}\right]^{\frac{1}{1-\alpha-\beta}} \\ \frac{Y'}{L'} &= \frac{1}{\alpha} \\ \frac{K'}{L'} &= \frac{\beta}{\alpha}. \end{aligned}$$

The welfare optimum is characterized by:

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

$$(6) \qquad \begin{aligned} L^* &= \left[\alpha^{1-\beta}\beta^{\beta}\frac{1}{(1-\gamma)^{1-\beta}}\right]^{\frac{1}{1-\alpha-\beta}} > \mathrm{L'} \\ K^* &= \left[\alpha^{\alpha}\beta^{1-\alpha}\frac{1}{(1-\gamma)^{\alpha}}\right]^{\frac{1}{1-\alpha-\beta}} > \mathrm{K'} \\ \frac{Y^*}{L^*} &= \frac{1-\gamma}{\alpha} < \frac{Y'}{L'} \\ \frac{K^*}{L^*} &= \frac{\beta(1-\gamma)}{\alpha} < \frac{K'}{L'}. \end{aligned}$$

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. As the price of land is normalized to 1, γ is assumed to be less than 1.

We also observe 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:

$$(7) \qquad W_{MAX} \qquad \begin{aligned} PSE^* &= \gamma L^* = \gamma\left[\alpha^{1-\beta}\beta^{\beta}\frac{1}{(1-\gamma)^{1-\beta}}\right]^{\frac{1}{1-\alpha-\beta}} \\ \%PSE^* &= \frac{\gamma L^*}{Y^* + \gamma L^*} = \frac{\alpha\gamma}{1-\gamma+\alpha\gamma} \end{aligned}$$

We now define a measure of trade distortion, *TD*, as the relative difference between production of the agricultural good in the absence of support and with a subsidy. In the case of an optimal subsidy, trade distortion equals:

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

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:

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

In order to compare this to the welfare optimum we set the subsidy rate such that land use is identical under the two regimes, i.e. $\hat{L} = L^*$. It follows from (6) and (9) that:

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

and

[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 trade reversals. In the empirical example used in this paper we employ an index of changes in net imports as a proxy measure for trade distortion.

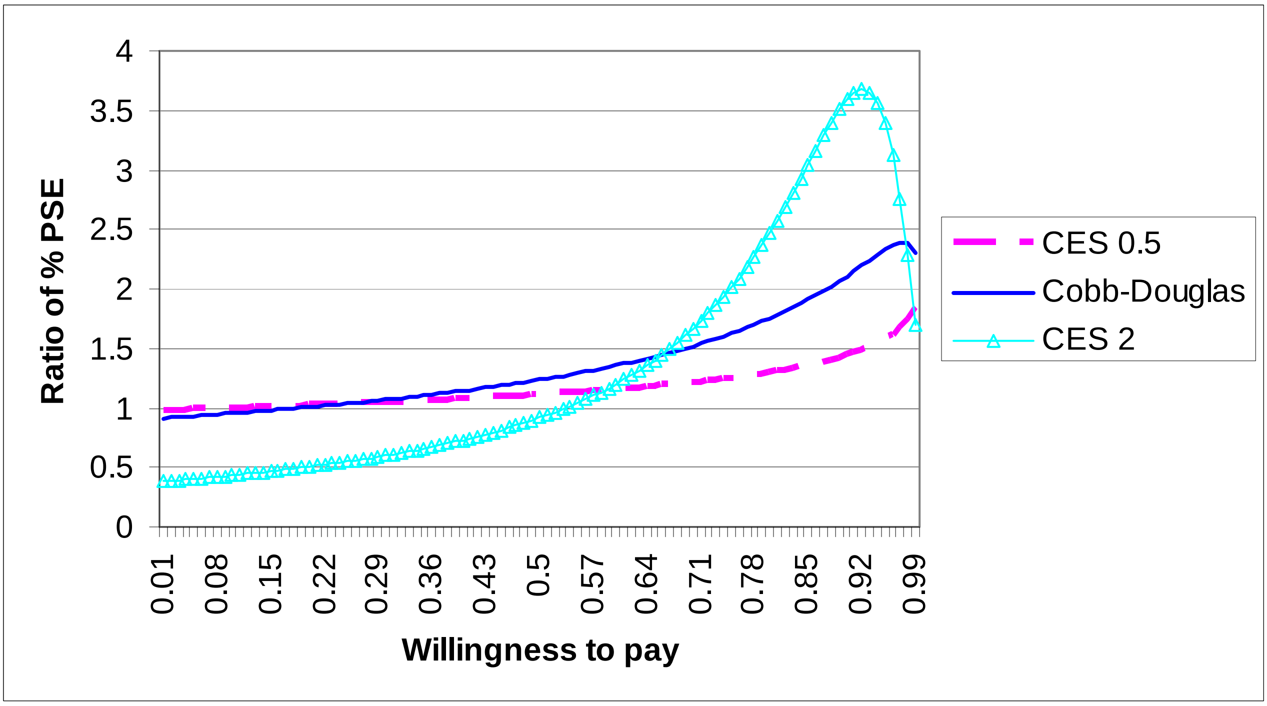
(11) $$P\hat{S}E - PSE^* = s_Y \hat{Y} - \gamma L^* = \left[\frac{s_Y}{\alpha(1+s_Y)} - \gamma\right] L^* = \left[\frac{1-(1-\gamma)^{1-\beta}}{\alpha} - \gamma\right] L^* > 0\,.$$

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

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

which may be greater or less than one, depending on the willingness to pay (γ), the scale elasticity (α+β), the distribution parameter, $\alpha/(\alpha+\beta)$, and, in the more general CES case, on the elasticity of substitution. In Figure 1, (12) is computed for a distribution parameter equal to 0.1 and a scale elasticity of 0.99, that is α= 0.099 and β=0.891. For the Cobb-Douglas case we see that for low values of γ the %PSE is lower for area support than for production support.[3]

Figure 1: Relative %PSE for optimal area subsidies compared to product subsidies yielding the same land input



[3] As γ approaches zero, the ratio of percentage PSE in (12) approaches $\alpha/(1-\beta)$, which is less than 1. This is seen by using L'Hospital's rule. Therefore, for low γs, $\%PSE^* < \%P\hat{S}E$. For large γs, $\%PSE^* > \%P\hat{S}E$, because of the two following observations: (i) when γ=1 we see from (12) that the ratio of percentage PSE is 1. (ii) For γ=1, the slope of the ratio of percentage PSE is negative. Therefore, for γ's close to 1 $\%PSE^* > \%P\hat{S}E$.

For γ in excess in excess of 0.2 the opposite applies. 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 Appendix 1. Again we see that the ratio of the %PSE in (12) is lowest when γ is low. And we see that variation in %PSE is highest in the high elasticity case. To explain these results further, it is useful to keep in mind the definition of %PSE:

$$\%\text{PSE} = \frac{\text{Subsidies}}{\text{Production} + \text{Subsidies}} = \frac{\dfrac{\text{Subsidies}}{\text{Production}}}{1 + \dfrac{\text{Subsidies}}{\text{Production}}}$$

If we change from production support to area support, both production and subsidies will decrease. From the definition above, we see that the %PSE (and the ratio $\frac{\%PSE^*}{\%P\hat{S}E}$) will increase if subsidies per unit of production increase (and vice versa). This is what happens in the right hand side of Figure 1: Here the willingness to pay γ is high, which demands a high level of land use, L^*, compared to a pure market solution. When L^* is ensured through production subsidies, use of capital, *K*, as well as production, *Y*, will be high. Consequently, the welfare gain from using area subsidies is related to the potential for lower levels of *K* and *Y*. This potential increases with the elasticity of substitution, σ. The change in subsidy per unit of production is affected by two opposing forces: substitution of *K* for *L* entails costs that raise the unit subsidy, but reduced production tends to decrease the unit subsidy because of decreasing returns to scale. In the right hand side of Figure 1, higher unit cost due to substitution dominates over the scale effect, so the %PSE increases, even if the welfare gain is positive. For low levels of L^*, as is the case in the left hand side of the figure, only minor substitution is required, and the cost is therefore low. Here, the %PSE decreases when land subsidies are introduced.

Figure 1 and Appendix 3 show the sensitivity of the PSE-ratio with respect to parameter values. First, we see that the PSE-ratio declines with the value of the scale elasticity. For scale elasticities below 0.6, the PSE-ratio is mostly below 1. The cost gain from lower production (when using an area subsidy) decreases with the scale elasticity, and tends to be dominated by the costs of substitution.

The PSE ratio also decreases with the cost share of *L*. When this is low, the transition from production support to a land subsidy implies a strong decline in the price of *L* relative to *K*, which promotes substitution, and thereby elevates the costs of substitution in the PSE-ratio. Finally, the substitution parameter matters. For high levels of γ (i.e., high levels of L^*), the PSE-ratio increases with the substitution parameter while the opposite applies for low levels of γ. Here, the substitution costs are decisive. In the first case, where substantial substitution takes place, these costs are quite high, while they are low in the latter case, where only minor substitution is called for.

This 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 when the willingness to pay for public goods is high, and when: 1) the inputs that enhance the public good have a low cost share in agriculture (which gives a potential for substantial substitution), 2) technology allows substitution towards these inputs (at the expense of others such as capital and pesticides), and 3) diseconomiies of scale are low (so that the cost increase from reducing production is moderate).

For the trade distortion we have that:

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

since $\alpha+\beta>0$. Trade distortion will always decline when going from production to area subsidies.

3. Model example

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

Norway is particularly well suited as an example in this respect. The relative PSE was 65% in 2005, a figure only matched by Iceland, OECD (2007). Norway's agricultural policy is often criticised for being trade distorting and far from optimal (e.g., Lamy, 2007), with more than half of support directly tied to production. Norwegian agriculture is positioned in the right hand side of Figure 1; i.e. production costs are high (uncompetitive agriculture) compared to willingness to pay for agricultural public goods in the country.

The model

We use a price-endogenous model of Norwegian agriculture that includes the most important commodities, in all 13 final and 8 intermediate product aggregates. Of the final products, 11 are related to animal production while 3 are related to crops. Inputs used 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 pasture.

Domestic supply is represented by roughly 400 "model farms". Each of these is characterized by Leontief technology, i.e. with fixed input and output coefficients. Although, inputs cannot substitute for each other at the farm level, substitution is possible at the sector level. For example, beef can be produced using different technologies, through extensive and intensive production systems, and in combination with milk. Thus, in line with the general Leontief model in which each good may be produced by more than one activity, the isoquant for each product is piecewise linear. Also, production can take place on small farms or larger and more productive farms. Consequently, economies of scale are reflected in the model.

Norway is divided into nine regions in the model, 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 most productive regions. Domestic demand for final products is represented by linear demand functions. Economic surplus (consumer plus producer surplus) is maximized, subject to demand and supply relationships, policy instruments and imposed restrictions. The solution to the model is found though prices and quantities that give equilibrium in each market. A more detailed description is given in Appendix 2.

Assumptions and results

In our analysis, we assume that the only rationale for public intervention in agriculture is to secure the supply of sufficient levels of agricultural public goods, such as landscape amenity. 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 that provides approximately the same supply of public goods. 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 a typical base year (1998). In spite of climatic disadvantages, production was high and imports were low. Norway was self-sufficient in most of the products listed. For dairy products there was a surplus and the equivalent of roughly 12% of domestic milk production was 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 observed, the current policy is costly. The total PSE is NOK 15.2 billions (roughly EUR 1.9 billion at current exchange rates) which equals 64 % of the value of production at the farm level. With respect tp employment and land area support is NOK 250,000 (EUR 31,000) per full-time equivalent worker 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 range of 171 to 429 % and export subsidies. The remainder of the support is provided 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 trade distortion, *TDI*. This index is defined as the weighted sum of the relative divergence between net imports under free trade and the simulation in question:[4]

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

As weights (α), we use the net import value share of each product *j* in the free trade solution, where p_j is the world market price and $\overline{M}_j$ is the free trade net import volume. $\overline{M}_j$ is determined from a simulation with unrestricted imports and no support. M_j is the net import in the counterfactual simulation. With this definition, the magnitude of trade distortion increases with the value of the index.[5] In the simulation of the current policy, we can see that *TDI* is slightly above 1. Compared to a pure self-sufficiency solution ($TDI = 1$), imports of wheat, with a free trade import value share of 3.8 %, pulls the *TDI* slightly downwards, while subsidised exports of cheese work in the opposite direction.

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 limited 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.

[4] In section 2 we used the relative divergence from production in free trade. Since we estimate that there would be very little agricultural production in Norway under free trade, we have modified the measure.

[5] If we consider a country with an internationally uncompetitive agriculture such as Norway, net imports will be positive in the free import case ($\overline{M}_j > 0$ for $\forall\ j$). If net imports are reduced in the counterfactual ($M_j \leqslant \overline{M}_j$ for

Table 1: PSE, welfare and trade distortion

	Current policies	Provision of public goods: Efficient policy	Provision of public goods: 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)	59.7	17.7	27.8
PSE (billion NOK)	15.2	6.0	9.5
Market price support	6.7	0	0
Output support	2.0	0	9.5
Input support	6.6	6.0	0
PSE (percentage)	64 %	71 %	64 %
Economic welfare (billion NOK)	14.5	24.4	21.2
Value of landscape (billion NOK)	22.3	20.6	20.6
Index of trade distortion	1.002	0.36	0.71

The implications of a policy exclusively aimed at the provision of public goods are illustrated in Column 2 of Table 1, following the 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 demonstrate, when public good provision is the policy aim, agricultural production and employment fall substantially, but a large proportion of land remains in

$\forall j$),$TDI \geqslant 0$. With no exports ($M_j \geqslant 0$ for $\forall j$), $0 \leqslant TDI \leqslant 1$. If self sufficiency is pursued ($M_j = 0$ for all j), then $TDI = 1$. Finally, it is possible that $TDI > 1$ if export subsidies result in $M_j < 0$ for one or more j.

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 producer and consumer surplus net of 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 1.002 to 0.36), indicating that imports increase substantially. In spite of lower support, higher welfare and a reduction in trade distortions, the relative PSE increases from 64 % to 71 %.

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

Land use is the same as under the efficient solution but production and the use of labor and other inputs are larger. Consequently, both support and trade distortions are higher (*TDI* = 0.71), and welfare is lower. However, in line with the discussion in Section 2, the relative PSE is below the efficient policy level. With reference to Figure 1, the ratio of the relative PSE under efficient policy and production subsidies, respectively, is 1.1. This suggests that with a relatively high willingness to pay for amenity values, land has a low cost share in agriculture but can replace other factors of production, and, finally, close to constant return to scale.

4. **Conclusions**

A substantial share of current agricultural support in OECD countries is provided through market price support and production subsidies.[6] This policy orientation may need to change if efforts to liberalize international trade through the WTO are successful. There may be pressure to shift away from income support and protection to so-called green support related to provision of public goods and environmental services.

There is a need for appropriate indicators to measure the success of such a policy reform. The relative (percentage) PSE is the most commonly used yardstick of distortions created by agricultural policy. In this paper we demonstrate rigorously that changes in the

[6] According to the OECD PSE/CSE database (2005), approximately three quarters of total PSE was in the form of market price support (border protection) and payments based on production. Tangermann (2005, p.

relative PSE are not an accurate indicator of the implications of policy reform either for domestic welfare or for trade distortions. If there are positive externalities linked to some but not all agricultural inputs (e.g. land), we demonstrate that replacing a regime of output subsidies by optimal Pigouvian subsidies may result in either rise or a reduction in relative PSE depending on the parameters of the production function. As we demonstrate in this paper, using Norway as an example, a rising relative PSE may well be the likely outcome of policy reform in high cost countries.

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11) claims that: "for the OECD area overall, less than 5% of the PSE is currently in a form that may potentially

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.

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be targeted to specific public goods."

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 unit of land 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 the %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 the $\%P\hat{S}E$ 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')
$$s_Y = \left(\frac{1}{1-\gamma}\right)^{(1-\lambda)/(1-\rho)}\left[\frac{\alpha^{1/1-\rho}(1-\gamma)^{\rho/\rho-1} + (1-\alpha)^{1/1-\rho}}{\alpha^{1/1-\rho} + (1-\alpha)^{1/1-\rho}}\right]^{(1-\lambda)(\lambda-\rho)/(1-\lambda)\rho} - 1$$

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

We use 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 should be interpreted as a long run model.

The model covers the most important products in 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 treated as given.

Total supply is the sum of 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. Processing is partly modeled as pure cost mark-ups (meat, eggs and fruit), and partly through 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). Cross price effects are included for meat products, but only own price effects 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, each with 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 or 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:

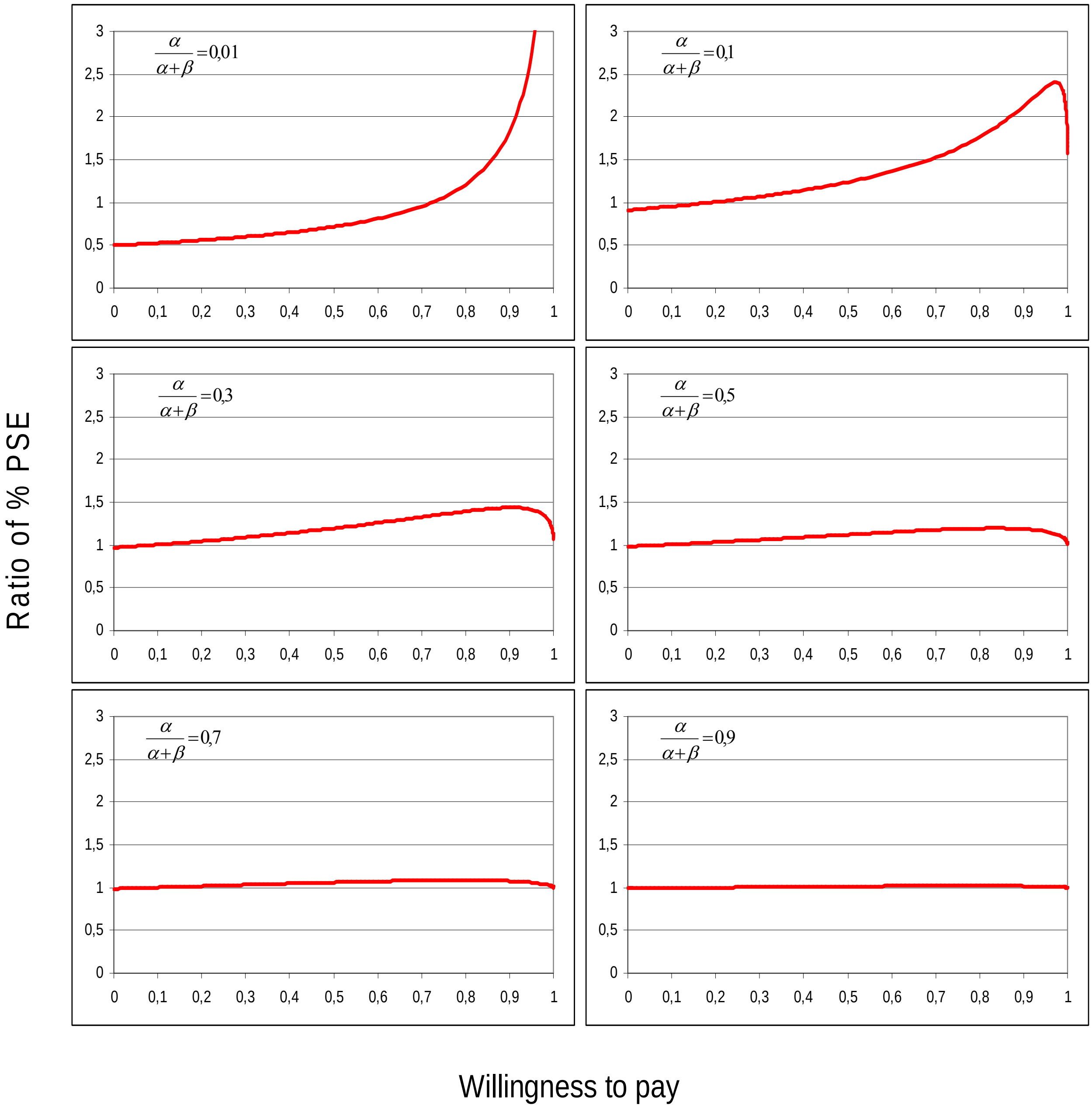
(1) Scarcity restrictions: upper limits for the endowment of land, for each grade of land in each region.

(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.

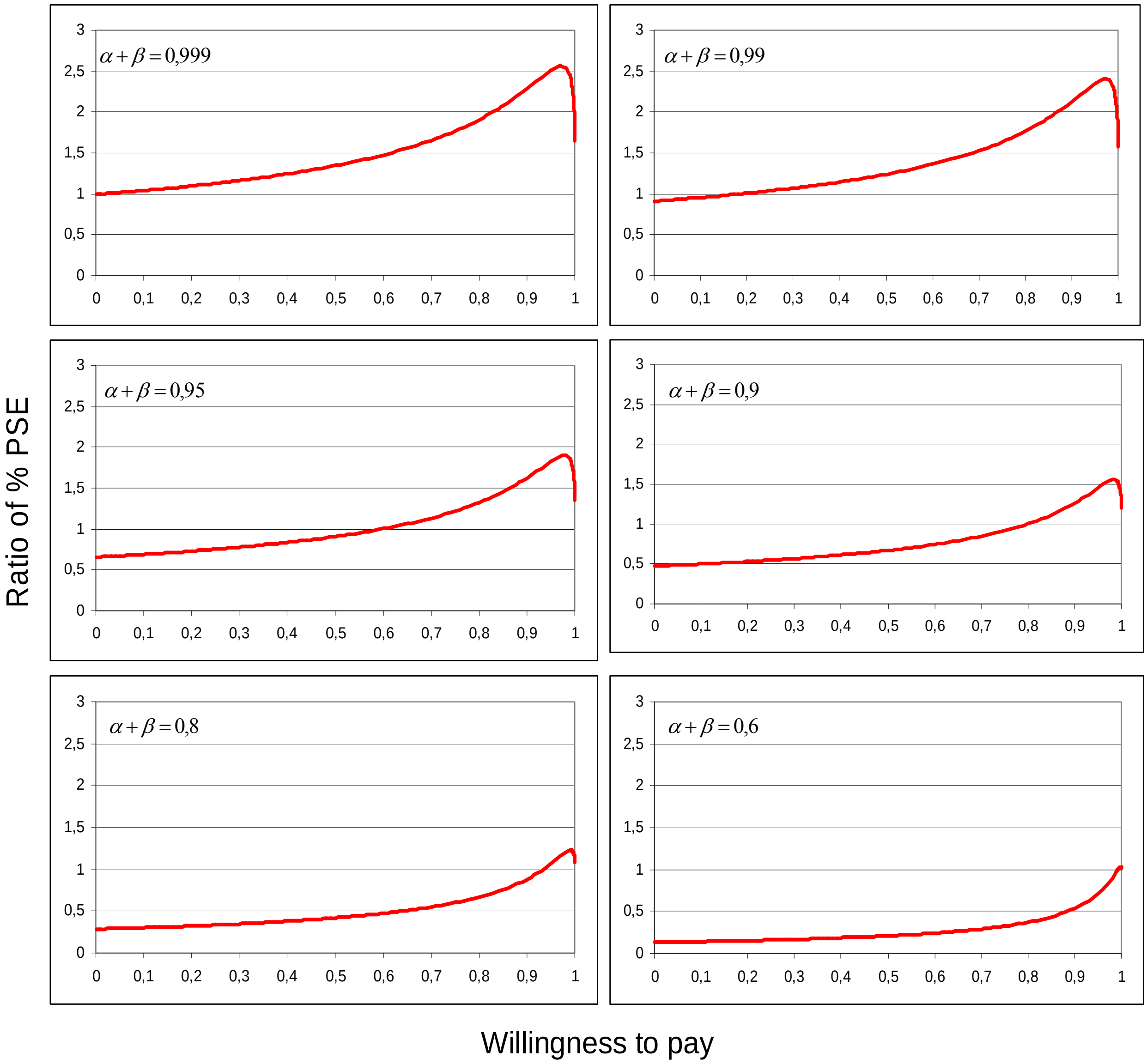
In the model, economic surplus (consumer plus producer surplus) is maximized. This maximization is performed subject to demand and supply relationships and the imposed restrictions. Which restrictions are included depends upon what kind of simulation is performed. The solution to the model is found through 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.

Appendix 1: Sensitivity analysis

Variable distribution parameter. Scale elasticity 0,99



Variable scale elasticity. Distribution parameter 0,1.



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