Efficient Supply of Cultural Landscape in a CGE Framework

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Abstract— **It is often assumed that the agricultural sector produces public goods or positive externalities that benefit the domestic consumers, in addition to its production of private goods. Efficient agricultural support is consequently directed towards resolving market failures caused by the existence of these public goods or externalities. We illustrate how this can be achieved in a Computable General Equilibrium model for one multifunctional aspect of agricultural production, namely the production of cultural landscape. Using a public good modeling framework as point of departure, we develop supply- and willingness to pay functions for cultural landscape. Governmental agricultural support is adjusted to achieve efficient supply of the public good. As an illustration we apply our framework using a general equilibrium model for Norway. We show that efficient supply of cultural landscape can be achieved even with a tremendous reduction in initial overall support of agricultural production.**

Keywords— **CGE modeling, Multifunctionality, Public Goods.**

I. INTRODUCTION

Several of the industrialized countries support their domestic agricultural sector, both by budget support and by protectionism. Norway can be seen as an example. Norwegian farmers received 65 percent of their income from governmental support in 2006, according to OECD's agricultural report [1]. This support can, from an economic point of view, only be justified if it corrects for a market failure. It is often assumed that the agricultural sector produces public goods or externalities that benefit the domestic consumers, in addition to the sector's production of private agricultural goods. Brunstad, Gaasland and Vårdal [2] describes amenity value of landscape, food security and maintenance of population in remote areas as central public goods supplied by the Norwegian agricultural sector. If domestic agricultural production causes market failures of this sort, governmental support directed towards resolving the market failure will be efficient.

This article focuses on the agricultural sector as a supplier of cultural landscape. Its main contribution is that it provides a framework for modeling supply and demand for cultural landscape in a Computable General Equilibrium (CGE) framework. We assume that land used in the agricultural sector has a dual value, one as input in the agricultural production and one as output of cultural landscape. As a result of that the agricultural sector optimizes its input of land without taking the consumer preferences for cultural landscape into consideration, we expect supply of cultural landscape to become socially inefficient without any governmental interventions. By including a marginal willingness to pay for cultural landscape valuation in the private consumers' utility function we can determine the magnitude of both the consumers' marginal amenity benefits and the agricultural sectors conditional demand for land. Socially optimal supply of cultural landscape production occurs when the sum of the agents' marginal benefits of farmland equals the marginal costs of cultural landscape production. We allow the government to resolve any inefficient supplies of cultural landscape by financing the provision of the public good through subsidizing the use of land in the agricultural sector. When subsidies are directed towards resolving the problem of inefficient supply of cultural landscape it will internalize the benefits. This will lead to an efficient level of agricultural support.

The rest of this article is systematized as follows. In section 2, we discuss supply and demand for cultural landscape in a figure framework. The figure analysis constitutes the foundation of the programming in the article. In section 3, we describe how we can incorporate the supply- and willingness to pay function for cultural landscape in a CGE framework, and how an endogenous subsidy can be used to secure efficient supply of cultural landscape. In section 4, we illustrate the supply and demand for cultural landscape in a CGE model for Norway. This is done to illustrate how the level and direction of agricultural support will change while directing it towards securing efficient supply of cultural landscape. The programming is done using the MPSGE syntax. In section 5 we sum up the discussion in the article.

II. EFFICIENT SUPPLY OF CULTURAL LANDSCAPE

Other attempts to model the multifunctionality of agricultural production is scarce. The nearest related articles in this field deals with applied CGE analysis regarding the reform of Swiss' agricultural policy [3; 4]. This analysis does not discriminate between various public goods produced by the agricultural sector, but describes a link between ecological and non-intensive farming and the production of public goods. Cretegny postulates a joint output CET function for the agricultural sector. The farmers must choose among producing a private good by intensive farming or producing a public good by converting to more non-intensive farming. The farmers receive governmental direct payments decoupled from the level of output, in exchange for producing the public good.

We focus on the supply and demand for cultural landscape. The crucial assumption in our model framework is that the amount of land used as input in the agricultural sector is equal to the output of cultural landscape in the economy. A discrepancy between agricultural sector's demand for land and the social optimal supply of cultural landscape may occur in absence of governmental interventions. This is captured by figure 1, where the amount of farm land in agricultural production is set from agricultural sector's cost minimization without subsidies or other distortion implemented. Quantity of farmland is denoted L while the market price in the farm land market is denoted w_L. The supply curve for agricultural land is determined by the marginal costs of using land in agricultural production, denoted *MC*. The marginal cost of farmland is determined by the alternative value of using land for other purposes[1]. The marginal cost of using land in the agricultural sector is increasing and reflects that there is a given endowment of land in the economy, such that an increase of farmland can only take place by bidding land away from other sectors. Notice that the marginal costs of farmland is equivalent to marginal costs of cultural landscape production. This is a result of our dual value assumption.

Figure 1 assumes a situation where the agricultural sector demands the amount L_A of land to the price w_L^0. The social optimal amount of cultural landscape production is the amount L^*. At this level of cultural landscape supply the marginal costs of cultural landscape production equal the sum of marginal benefits of the two agents: agricultural sector's conditional factor demand, CFD_A, and the consumers' marginal willingness to pay for cultural landscape, *MWP*. The inefficient supply of cultural landscape depicted in figure 1 can be resolved by governmental interventions. The goal then becomes aiming the support directly towards correction of the market failure. This is done by subsidizing land used in the agricultural sector. In a situation similar to the one depicted in figure 1, the Norwegian agricultural sector becomes more land intensive as a result of the increase in land support. In figure 2 we apply traditional tax analysis to illustrate correction of the market failure. For simplicity we assume a constant subsidy per unit of agricultural land.The subsidy is adapted such that the agricultural sector uses L^* units of land as input. The level of support is then determined by the distance between the market price, w_L^*, and agricultural sector's willingness to pay for L^* units. As shown by figure 2 and later will be shown formally, this level of support is equal to the consumers' marginal willingness to pay, P_{MWP}, for L^* units of cultural landscape. The Samuelson rule for optimal supply of a public good states that there will be an efficient supply of a public good when the sum of all agents' marginal willingness to pay for the public good equals the marginal costs of providing the good. This condition is consequently satisfied in the farmland market described in figure 2.

Our assumption that the applied amount of farmland is equal to the output of cultural landscape might seem a bit restrictive. But, as the model results in section 4 illustrates, this assumption will give us desirable

1. The immidiate alternative use for Norwegian farmland is forestry.

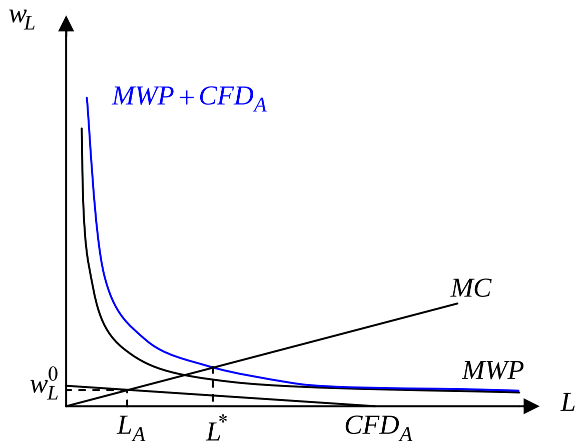

Fig. 1 Inefficient Supply

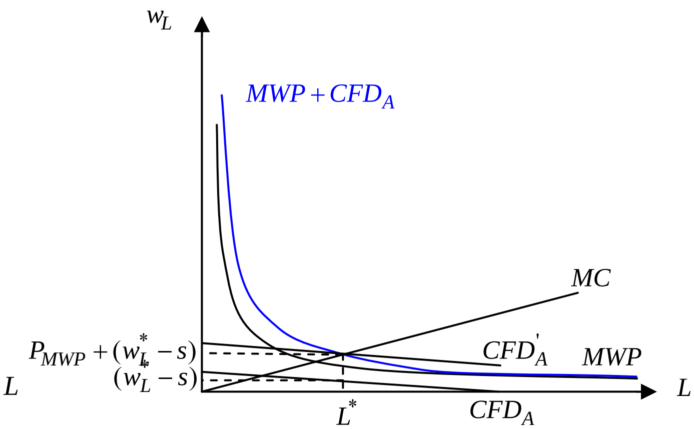

Fig. 2 Efficient supply

model features. If total domestic agricultural production decreases due to increased competition from abroad, the agricultural sector becomes more land intensive as the government will increase the land subsidy to maintain an efficient supply of cultural landscape. The agricultural sector then transforms from a food production orientated industry towards cultural landscape production as primary occupation. We will not face a corner solution where agricultural sector produces solidly with land input. This cannot be the case as there is need for other inputs for cultivating the farmland and create the amenity benefits for the consumers. Our model framework allows that the social optimal amount of farmland is determined. The type of farming, i.e. agriculture's input mix, is determined from agricultural sector's cost minimization.

III. SUPPLY AND DEMAND FOR CULTURAL LANDSCAPE

In the previous section we illustrated supply and demand in the market for cultural landscape, and described further how an inefficient allocation in the market can be counteracted by use of land subsidies. We will in this section describe how the analysis can be transferred to a CGE model framework. Our public good supply framework is rooted in a model layout formulated by Markusen and Rutherford [5] and further described in Rutherford [6]. Our framework differs from Markusen- and Rutherford's layout in three significant ways.

Rutherford [6] includes a sector "GP," a Leontief technology[2] which converts private goods inputs into a public good, in his model. It is assumed that the private goods inputs are perfectly mobile between the public good sector and the other sectors, which produce private goods. In our model, the production of the public good is similar to the input of land in agricultural sector. We assume that no other inputs directly contribute to the production of the public good.

Next we look at the consumers' valuations of the public good. Rutherford [6] introduces personalized markets for the public good. Each of the consumers is endowed with the total output of the public good in the economy. This means that each of the consumers is supplied with the total production of the public good, which is what we will expect from the characteristics of a public good. The consumer income encompasses then both private and public endowments. By setting a consumer's valuation of public good demand equal to his or her endowment, the consumer's budget constraint will be unaffected. The consumers' marginal willingness to pay for the public good is

2. Note that a MPSGE model is built by using constant elasticity of substitution (CES) production- and utitity functions. The Leontief production function is a special case of the CES function.

accordingly expressed through the commodity prices in the personalized markets. Rutherford's model set the marginal willingness to pay to an arbitrary number. We are interested in linking the consumers' marginal willingness to pay for the amenity benefits of the cultural landscape production to previous studies. By using a price-adjustment instrument[3] we allow the marginal willingness to pay for cultural landscape to be determined by a utility function postulated by Lopez, Shah and Altobello [7].

Finally we look at efficient provision of the public good. In Rutherford's [6] framework it is assumed that the government uses tax income to purchase the public good in order to finance an efficient supply of this commodity. In our framework this implicates that the government is bidding land away from the agricultural sector, which cannot be the fact. To gain realism to our model layout we allow the government to finance the provision of the public good through subsidizing the use of land in the agricultural sector.

A. *Supply*

In the CGE model applied for the modeling in section 4 the private consumers have endowments of land which they rent to the production sectors. Their total endowment, denoted M, constitutes the supply of land in the economy. Land is assumed to be perfectly mobile between the production sectors. Land used as input in the agricultural sector is denoted M_A, while land used as input in the rest of the economy is denoted M_O. Land used as input in the agricultural sector constitutes the total supply of cultural landscape in the economy. To model this relationship we include an agricultural land sector and a cultural landscape commodity in our CGE model. The agricultural land sector produces the cultural landscape commodity, denoted L, by using land input. The CES production function for cultural landscape is defined in equation 1.

$$L = \left[a_1 M_A^{\rho}\right]^{1/\rho} \quad \text{where} \quad M_A = M - M_O \qquad [1]$$

3. See Rutherford [6] for a description of possible uses of Auxiliary variables.

It is easy to show that the input of M_A will be equal to the output of L, when the parameter a_1 is equal to one. The cultural landscape commodity is treated as an intermediate commodity and is used as input in agricultural production. The expanded model is calibrated such that the agricultural sector applies total output of cultural landscape as input in benchmark. The relationship between the output of cultural landscape in the agricultural land sector and the input of cultural landscape in agricultural sector is conditioned by the market clearance condition, underlying the MPSGE modeling structure.[4] Assuming the simplest case where agriculture applies land and another input, K, in its production, we write the clearance in the cultural landscape market as equation 2. Following the figure framework the market price in the farmland market is denoted w_L, while price of the other input is denoted w_K. Constants in the CES production function are denoted b_1 and b_2 and the level of agricultural sector's output is denoted A. The model is calibrated with an endogenous ad valorem subsidy, s, on agriculture's input of farmland.

$$\frac{\partial \Pi_{AL}(p)}{\partial p_L} \geq \left[\frac{w_L(1-s)}{b_1}\right]^{r-1} \left[\left(\frac{w_L(1-s)}{b_1}\right)^r + \left(\frac{w_K}{b_2}\right)^r\right]^{\frac{1-r}{r}} A \qquad [2]$$

where $r = \dfrac{\rho}{\rho - 1}$

Solving the first order condition for profit maximization in the agricultural land sector we find that any value of M_A is a profit-maximizing choice. This implies that the agricultural sector's conditional demand for farmland determines the total supply of cultural landscape in the economy. Equation 2 shows that an increase in the price of farmland or a decrease

4. An Arrow-Debreu model can be solved as a complimentary problem by using three equilibrium conditions. The marked clearance condition states that there cannot be excess demand in any commodity market. Rutherford [6] writes this condition as:

$$\sum_j y_j \frac{\partial \Pi_j(p)}{\partial p_i} + \sum_h \omega_{ih} \geq \sum_h d_{ih}(p, M_h)$$

The first sum, by Shephard's lemma, is the net supply of good i by the production sectors. The second sum is the consumers aggregated initial endownment of good i. These two sums represent aggregated supply of good i. The right hand side represents aggregated demand for good i.

in overall agricultural production will cause a decrease in agriculture's demand for land, ceteris paribus. This may cause an inefficient supply of cultural landscape, which can be counteracted by the farmland subsidy. We refer to the figure analysis in section 2.

B. *Demand*

Having described the supply for cultural landscape we now turn to the determinants of demand for cultural landscape. Following Rutherford [6] we introduce personalized markets for the public good, endowing each consumer with the total output of cultural landscape from the agricultural land sector by using a quantity adjustment instrument, i.e. an endogenous endowment. Notice that our framework differs from Rutherford's model in that we apply only one representative consumer for modeling the demand in the economy. The representative consumer's income, denoted I, encompasses now both incomes from primary factors rented to the production sectors and the consumer value of the public good. The amount of cultural landscape in the economy is determined by L from equation 1. Let w be a vector of factor prices net of tax and E be a vector of endowments of f primary factors. Then the representative consumer's income can be written as equation 3.

$$I = \sum_f w_f E_f + P_{MWP} L \quad \text{where} \quad f = 1,\ldots,F \qquad [3]$$

The marginal valuation of the cultural landscape commodity, denoted P_{MWP}, is the market price in the personalized commodity market. The market clearance condition for this market states that the consumer's Marshallian demand for cultural landscape, the optimal demand for given prices and level of income, cannot exceed supply of the cultural landscape commodity. The market price in the personalized commodity market is set without any distortion in Rutherford's [6] framework. We want a more restricted price setting in our model, since the market price, P_{MWP}, represents the consumer's marginal willingness to pay for cultural landscape. This is done by allowing the market price to be endogenously determined from a willingness to pay function, described in section C. The price setting is controlled by a price adjustment instrument that works through imposing an endogenous tax on the consumer's purchase of cultural landscape. This will cause the buyer price of cultural landscape to become $(1+t)P_{MWP}$ where t is the ad valorem rate of the tax. Assume for simplicity two private goods: agricultural commodity, A, and other commodity, O, with corresponding prices denoted P_A and Po, respectively. This is similar to the structure of the CGE model applied in section 4. Net supply of cultural landscape is represented by equation 1. The market clearance condition for the CES demand function can then be written as equation 4. Equation 4 shows that an increase in t will decrease the demand for L, ceteris paribus. The clearance condition will than cause market price P_{MWP} to decrease to maintain market clearance. This mechanism allows the market price in the personalized commodity market to adapt according to the marginal willingness to pay function.

$$L = \frac{\left[(1+t)P_{MWP}\right]^{r-1} I}{\left[(1+t)P_{MWP}\right]^{r} + \left[P_O\right]^{r} + \left[P_A\right]^{r}} \qquad [4]$$

$$\text{where} \quad r = \frac{\rho}{\rho - 1}$$

C. *Calibrating the amenity benefit function*

In this paragraph we show how an amenity benefit function, postulated by Lopez, Shah and Altobello [7], can be incorporated in our model. The calibration and application of the function is based on Brunstad, Gaasland and Vårdal [8]. The function will be the determinant of marginal willingness to pay in the personalized commodity market. In lack of more relevant data, the function will be calibrated by using results from a contingent valuation study from Sweden [9]. This will of course create some controversy regarding the results, but we apply this data more as an illustration. For a more thorough discussion of the controversy of applying the Swedish study for valuing Norwegian cultural landscape, see Brunstad, Gaasland and Vårdal [8].

Lopez, Shah and Altobello [7] postulate the amenity benefits of agricultural land as a function of the Cobb Douglas form. The amenity benefits are determined by amount of land used in agricultural production, population and income per capita. Population is denoted P while income per capita is denoted Y. We know from equation 1 that amount of land used as input in the agricultural sector is similar to output of cultural landscape, denoted L.

$$WTP = BL^{\varepsilon_1} P^{\varepsilon_2} Y^{\varepsilon_3} \quad [5]$$

B is a constant and the exponents describe elasticities. Lopez, Shah and Altobello [7] arrived at the estimates $\varepsilon_1 = 0.172$, $\varepsilon_2 = 0.796$ and $\varepsilon_3 = 3.877$. The estimate for income elasticity indicates that cultural landscape is a luxury good, while the elasticity for population indicates that the amenity benefits are strongly dependent on the size of the population. Cultural landscape is then close to being a pure public good. The elasticity ε_1 implies that marginal willingness to pay for cultural landscape is strongly decreasing in input of land in the agricultural sector. By taking the derivative of equation 5 and including the income- and population parameter in the constant, we find the marginal willingness to pay function for cultural landscape. This function is similar to the non-linear function MWP depicted in figure 1 and 2. To make notation consistent with the previous section, we denote marginal willingness to pay as P_{MWP}.

$$P_{MWP} = \varepsilon_1 \bar{B} L^{\varepsilon_1 - 1} \quad \text{where} \quad \bar{B} = BP^{\varepsilon_2} Y^{\varepsilon_3} \quad [6]$$

Drake's [9] contingent valuation study is compounded of one main survey with 1089 persons interviewed in all parts of Sweden, and two smaller follow-up surveys with 152 and 49 participants in Uppsala county. The participants were asked how much they were willing to pay in income taxes per year, to avoid half of the total Swedish agricultural area becoming cultivated by spruce. Total willingness to pay for maintaining half of the total agricultural land added up to 3.365 billion SEK/year. We apply this value as a reference for calibrating the marginal willingness to pay function from equation 6. Assuming that total Norwegian agricultural land adds up to L^* in figure 2, the area under the MWP curve between L^* and $L^*/2$ must add up to 3.365 billion. This allows us to find the unknown constant $\bar{B}$ from equation 6.

$$\bar{B} L^{*\varepsilon_1} - \bar{B}\left(L^* / 2\right)^{\varepsilon_1} = 3.365_{billion} \quad [7]$$

Having determined the constant $\bar{B}$, our next task is to implement the marginal willingness to pay function in our CGE model. We exploit the market clearance condition from equation 4: By using the price adjustment instrument described in section B we allow the market price in the personalized commodity market to be determined by the marginal willingness to pay function from equation 6. Notice that the willingness to pay function represents national willingness to pay for cultural landscape. This is the reason for using only one representative consumer in our model framework, not including government.

Using the endogenous tax method offers a simple way of implementing the willingness to pay function in the CGE framework. A word of caution should be added. Imposing a tax in the personalized commodity market will lead to an inefficient adjustment, as the tax will create a discrepancy between the user price and the market price in the commodity market[5].

D. *Optimal subsidy rule*

We will now describe the government's role in supporting an efficient supply of cultural landscape. We have altered Rutherford's [6] efficiency condition to suit our model framework. In Rutherford's framework the government secures an efficient supply of the public good by using their tax revenue to purchase an efficient amount of the public good. A more suitable assumption is that the government subsidizes the use of land in the agricultural sector, as showed by equation 2. The subsidy rate, s, is endogenously set to satisfy the Samuelson condition: The sum of the marginal benefits of farmland equal the marginal costs of cultural landscape production. We have shown that two agents benefit from the production of the agricultural land sector, namely the

5. We are currently working on establishing ways of calibrating the marginal willingness to pay function without use of the price adjustment instrument.

agricultural sector and the representative consumer. Optimal supply must reflect the valuation of the two agents. This leads to the optimal allocation depicted in figure 2. The aim of the government's policy is consequently to maintain equality in equation 8: The sum of the consumer- and agriculture's marginal willingness to pay is set equal to the market price for farmland, i.e. the marginal costs of cultural landscape production. The market price for farmland subtracted by the subsidy must reflect agriculture's willingness to pay for the given amount of land, as shown by figure 2.

$$\left[P_{MWP} + \left(w_L - s\right)\right] = w_L \qquad [8]$$

By some algebraic manipulation on equation 8 the optimal subsidy rule can be written as $s = P_{MWP}$. This shows that the support of agricultural production must be efficient in the model, and that it will internalize the benefits of the private consumers.

IV. MODELLING EFFICIENT SUPPLY OF CULTURAL LANDSCAPE

We intend to apply our model framework in a recently updated CGE model for Norway. This modelling is not complete. As a preliminary illustration we report the results from NORJORD, which is an aggregated static small open economy model. A description of the model can be found in Rødseth [10], though it has been slightly revised since this publication. The benchmark reflects Norway's national accounts in 1996, but the model simplifies the economy to a large extent. Agricultural production is singled out in an aggregated production sector while the rest of the domestic production is represented by a pooled sector. Norwegian agriculture is a heavily subsidized industry. Its support can in broad terms be labelled as governmental- and market price support, but the overall composition of the support is complex [2], e.g. the production is protected to a large degree by import quotas with tariffs on certain products while producers receive both production dependent- and production neutral governmental subsidies. NORJORD simplifies this complex support regime: The budget support is given solely as exogenous price support while protectionism is modelled through a single exogenous tariff on all imports of agricultural goods. It is assumed an initial budget support that constitutes 45 percent of domestic agricultural production while initial tariff is set equal to 400 percent, implying no import of agricultural goods initially. This is done to focus on domestic produced goods for which import is restricted. These simplifications will lead to debatable results. Even so, the preliminary results give a good indication on how our cultural landscape framework can be applied for policy modelling.

NORJORD is calibrated such that the amount of cultural landscape is determined by agricultural sector's profit maximization initially, i.e. the endogenous land subsidy, *s*, is set equal to zero initially. This allow for comparing the social efficient supply of cultural landscape with supply resulting from no governmental interventions directed towards agriculture's input of farmland. We calculate three counterfactual scenarios. The first scenario illustrates the alteration in domestic production of agricultural goods when initial exogenous support is unaltered but we also allow for efficient land subsidy. The second and third scenario assumes that the exogenous support is removed, and describes the scenarios of no governmental support and of efficient support, respectively. The model results are reported in table 1. When implementing the optimal subsidy rule we now encounter a situation similar to the illustration in figure 2. This will imply a positive subsidizing of land input in the agricultural sector. The increase in land support will lead to a relatively more land intensive agricultural production. We see that supply of cultural landscape by far exceeds initial supply of cultural landscape in scenarios representing efficient supply of cultural landscape. This is expected as the consumers' marginal willingness to pay exceeds agricultural sector's marginal valuation of farmland initially. Agricultural sector's valuation is set by Harberger normalization while the consumer's initial marginal willingness to pay is set equal to 3.14.

In the counterfactual experiments where the overall exogenous agricultural support is removed Norwegian agricultural sector experiences a downscaling because of increased competition from abroad. The central scenario is when the exogenous support is removed but we allow for efficient land subsidy. In this scenario the sector becomes more land intensive than in other scenarios, even though the sector's output has decreased significantly. We interpret this as that the sector transforms from a food-production oriented role to a cultural landscape-oriented role, due to the use of efficient land subsidy. This scenario shows that the goal of maintaining efficient supply of cultural landscape can be achieved at a much less level of support than the initial level.

TABLE 1 Model results in NORJORD (Values in million NOK)

	BENCHMARK		NO EXOGENOUS SUPPORT	
AGRICULTURE	*s = 0*	$s = P_{MWP}$	*s = 0*	$s = P_{MWP}$
Domestic	21687.0	21703.3	7248.1	7568.1
Import	.	.	14206.2	13868.8
DOMESTIC INPUT$_A$				
Land	181.4 (0.58%)	724.7 (2.27%)	57.0 (0.53%)	722.5 (6.08%)
Labor	7944.0 (25.23%)	7935.3 (24.81%)	2455.3 (22.75%)	2563.7 (21.57%)
Capital	10656.6 (33.85%)	10644.9 (33.28%)	3304.2 (30.61%)	3450.0 (29.02%)
Other	12701.0 (40.34%)	12685.7 (39.65%)	4978.2 (46.12%)	5151.1 (43.33%)
SUPPORT				
Efficient land support	.	722.5	.	722.5
Budget support	9796	9803.2	.	.
Boarder measure	.	.	.	.

Percentages shows share of total input mix.

V. CONCLUSIONS

In this paper we have presented a framework for calibrating supply- and willingness to pay functions for cultural landscape in a CGE model. To illustrate the method, the Norwegian agricultural sector is used as a case study. We find that the market failure caused by agricultural sector's cultural landscape production can be resolved with a much less overall support than the present level of support of Norwegian agriculture. This follows from that the support is directed towards securing an efficient supply of cultural landscape. Efficient support will transform the agricultural sector's primary focus towards production of cultural landscape rather than production of private goods. Our discussion leaves out other multifunctional aspects of agricultural production, such that a higher overall support than indicated by table 1 can be justified by public good arguments. Even so, the present level of support seems to be overshooting the goal of correcting for such market failures.

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