Modeling strategic farmer reactions when introducing a sustainability performance based subsidy system

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Keywords: green growth; CAP; policy design; strategic reaction

Abstract

The paper develops and illustrates a methodology for an adaptive subsidy system based on farms' sustainability improvements. The hypothesis is that such a subsidy system actively encourages the transition towards a more sustainable agriculture, opposite to the EU CAP system currently in use. The main difference with the current system is that the farm subsidy level is now based on the farm's sustainability score relative to other comparable farms. An individual farmer has to make a strategic trade-off between subsidy maximization and profit maximization (before subsidies), under uncertainty. Various strategic reactions of farmers to adaptive subsidizing are modeled in a game-theoretic setting with the help of agent based modeling.

1 Introduction

The objective of the paper is to develop a conceptual framework and methodology for an adaptive subsidy system based on farms' sustainability improvements. The hypothesis is that such a subsidy system actively encourages the transition towards a more sustainable agriculture, opposite to the system currently in use In the EU. The main difference with the current system is that the farm subsidy level is now based on the farm's sustainability score relative to other comparable farms. While the sustainability items (such as greenhouse gas emissions, water use, nitrate leaching etc) and the way the sustainability scores are calculated, are known a priori to the farmers, the strategic behavior of other farmers, i.e. to what extent they will make sustainability efforts, are unknown a priori. An individual farmer therefore has to make a strategic trade-off between subsidy maximization and profit maximization (before subsidies), under uncertainty.

The paper is elaborated as follows. In a first scene setting we critically review the current subsidy system and its impact on sustainability. The second section introduces the paper's conceptual framework in which we elaborate the alternative subsidy system based on relative sustainability performances. In the following section we explain how the sustainable value methodology can be used to calculate the relative sustainability scores. The dynamic agent based model that incorporates the different strategic reactions of farmers to the introduction of the new subsidy system is described in the subsequent section. The empirical case of Belgian dairy farming is used to illustrate the sustainable value methodology and the emergent outcome of the agent based model. In the discussion section we describe the pros and contras of a subsidy system which is based on sustainability performance but simultaneously introduces additional uncertainty for the farmers.

2 The current CAP subsidy system

The Common Agricultural Policy (Treaty of Rome, 1957)'s initial focus rested upon increasing productivity, ensuring stable markets, food security and low consumer food prices. To this end, different mechanisms were put in place, such as import levies and import quotas, internal intervention prices, production related direct subsidies and production quotas. The CAP has been substantially reformed over the years. With the Agenda 2000 reform (COM(97) 2000), the CAP was divided into two pillars, one for production support and one for rural development. The latter pillar accounted for about one fourth of total CAP support. The 2003 reform introduced the Single Farm Payment, which entailed a decoupling of subsidies from particular crops (OECD, 2004). Subsidies are now predominantly coupled to agricultural land. In support, several cross compliance measures are introduced relating to environmental, food safety and animal welfare standards. The effectiveness of this cross compliance is criticized given that many of the measures are already part of good agricultural practices (Breen et al., 2005). The coupling of subsidies with land is also criticized as this resulted into increasing land prices, as land owners internalized the subsidy in the land prices (Femenia et al., 2009). The current CAP system is under revision (COM(2010) 672). Propositions start from a basic payment scheme with a flat rate per hectare, accounting for about 60% of the support, complemented with a green payment scheme, accounting for 30% of support, which focuses on crop diversification, permanent grassland and ecological focus areas.

3 Alternative system based on relative sustainability score

3.1 Recoupling, with different focus

While in the past coupling of subsidies with production created an adverse incentive to overproduce, exemplified by the milk and wine lakes (Jones, 2001), the coupling advocated here follows a different motivation. Given the increasing pressure on our resource base (fossil fuels, rock phosphate etc) and the creation of unwanted externalities (greenhouse gases, nitrate leaching etc) on the one hand (Pretty et al., 2001), and increasing demand projections driven by population dynamics and increasing welfare standards on the other hand, public interest has shifted towards propelling green growth instead of growth. Green growth focuses both on the input and output side of production. Subsidies, as main economic instrument used in the agricultural sector, are one of the means to stimulate private actors in the direction of green growth. The question is then how this subsidy system should look like in order to do so. It is clear that it has to focus both on the 'green' and 'growth' pillar, hence advocating for a recoupling, however with a different focus.

3.2 Sustainable Value as measure for green growth

The proposition in this paper is to base the firm subsidy level on the firm's contribution towards green growth. Given the fixed total amount of subsidies for agricultural support, a subsidy distribution mechanism across firms is necessary. This distribution can be based on the firm's relative contribution to green growth compared to other, similar firms. In order to operationalize this proposition, a transparent measure for green growth need to be developed upon which the subsidy distribution can be based. The Sustainable Value (SV) method, first developed by Figge and Hahn (2004) and further adapted by Kuosmanen and Kuosmanen (2009) and Mondelaers et al. (2010), offers an interesting starting point for a firm level green growth measure.

The SV method offers two new perspectives with respect to conventional burden-oriented approaches. First, the method applies a value-oriented approach, which assesses and aggregates resource use and environmental impacts according to their effect on value creation rather than according to their actual burden (Figge and Hahn, 2004). Second, by integrating principles from financial economics, SV assesses resource use from the viewpoint of the investor or resource supplier (a private investor or the government), rather than from the perspective of the resource user (the firm), or casualty of resource use (the environment). This perspective is closer to a perspective of common resource governance, which can be seen in most agricultural policies (e.g. allocation of subsidies, land management, quota, etc.).

Understanding resource use is fundamental to clarifying the link between firms' production decisions and the sustainability of these decisions. For sustainability assessment, the set of traditional economic resources must be extended to the various forms of capital in the production system. These are natural capital (land, CO_2, water, …), manufactured capital (buildings, machinery, ...), human capital (labor units, skills and knowledge), and social capital (social bonds, networks,…). The SV method uses this categorization of resources into various forms of capital to assess where different resources should be invested for maximum value creation. As the SV method includes social and natural capital, market prices are often not available or are ill-defined. This problem is overcome by using the opportunity cost as guiding principle. As in financial markets, the opportunity costs of a resource's use by a particular firm are found by comparing the value created by that firm with the (weighted) average value created with the same resource at the aggregate level. This, depending on the investor's viewpoint, might be the market, the industry or the economy as a whole. Firms with a positive SV have higher than average resource use productivity and hence contribute to overall SV creation. Firms with a negative SV reduce the overall SV creation. As the method indicates which firms create more value than the average with the resources under consideration, the outcome of the method can be used to support resource providers in their aim for more SV creation.

The SV-calculus to make the method operational is explained in Mondelaers et al. (2010). How to incorporate the reference market is expressed in formula 1. Depending on the investor's preference, all kinds of investment combinations with a firm *i*'s resource set can be made in the market. The part of a firm *i*'s resources x_i invested in a firm *k* depends on the weighting vector $w_k = (w_{k1}, \ldots, w_{kR})$, attributed to firm *k* by the investor. Weights are resource specific, w_{kj} thereby reflects firm *k*'s weight for resource *j* in the overall benchmark. The market as benchmark consists of *n* individual firms *k*, each with their own specific transformation function g_k. The market-based opportunity cost thus becomes:

$$G(x_i) = \sum_{k=1}^{n} \left[g_k(x_k + w_k x_i) - g_k(x_k) \right] \quad (1)$$

with *G(.)* = market based opportunity costs; *n* = number of firms in the market; w_k = vector of weights of firm *k* in the benchmark; $g_k(x)$ = firm *k*'s transformation function; x_i = the amount of resources consumed by firm *i*; $g_k(x_k)$ = the return firm *k* already realizes with its own resources x_k

The term between brackets indicates the additional return created by firm *k* with a share w_k of firm *i*'s resources. It thus reflects the additional return that an investor could obtain by investing a share w_k of firm *i*'s resources in firm *k*. By summing over all firms in the market the total additional return created by the market with firm *i*'s set of resources is obtained. By comparing this with firm *i*'s initial return, the sustainable value of firm *i* is obtained. This leads to following general representation of the SV-formula, which allows to calculate the firms' SV-score as single index for their relative contribution towards green growth:

$$SV_i = z_i - \sum_{k=1}^{n} \left[g_k(x_k + w_k x_i) - g_k(x_k) \right] \quad (2)$$

3.3 Calculation of SV-based subsidy in year t+1

The above section explains how to calculate the individual firm SV-scores, which, due to their relative nature, allow to compare firms' relative contribution towards green growth. The question is now how to distribute the total amount of subsidies across the different firms based on these relative scores. While firms with a positive SV-score contribute to green growth, those with negative SV-scores destroy green growth. A penalty and reward system is against the spirit of a subsidy system, and probably politically difficult to sell. The most plausible strategy is therefore to allocate no subsidies to the worst performing firm and to increase the subsidy share based on the SV-scores. This can be operationalized as follows. The lowest SV-score is set to zero and the absolute value of this lowest SV-score is added to the remainder of SV-scores. Adding all SV-scores and dividing the total amount of subsidies by this total SV-score gives the amount of subsidies per SV-unit. Multiplying by the firm's amount of SV gives its total amount of subsidies.

$$SV_{i,new}^{t} = SV_{i}^{t} + SV_{lowest}^{t} \quad (3)$$

$$s^{t+1} = \frac{S_{tot}^{t+1}}{\sum_{i=1}^{n} SV_{i,new}^{t}} \ with \ \sum_{i=1}^{n} SV_{i,new}^{t} = n \cdot SV_{lowest}^{t} \quad (4)$$

with s^{t+1} = euro subsidy per SV-unit; S_{tot}^{t+1} = total amount of subsidies in year t+1

$$s_{i}^{t+1} = s^{t+1} \cdot SV_{i,new}^{t} \quad (5)$$

with s_{i}^{t+1} = amount of subsidies for firm i in year t+1

The consequence of this operationalization is that the subsidy per SV-unit is function of the lowest SV-score, as indicated in formula 5.

4 Strategic farmer behavior

While the current subsidy system is calculated largely irrespective of the farm's contribution to growth or sustainability, the proposed alternative subsidy system incorporates both. The public incentive is that this will trigger farmers to adopt practices that both stimulate creation of added value and reduction of environmental burden. Main possible farmer strategies are:

1. to improve the efficiency;
2. to remain status quo;
3. to opt out.

Figure 1 is illustrative for input related strategies. Strategy 1 aligns with the policy incentive. Different forms of efficiency improvement can be identified. Increasing the technical input efficiency of the targeted inputs might reduce the input use (strategy 1a, figure 1), while changing the input mix might trigger a better cost efficiency (strategy 1b, figure 1). A combination of both leads to economic efficiency improvement (strategy 1c, figure 1). Changing the output mix might reduce the production of unwanted outputs, hence improving allocative output efficiency, while increasing the technical output efficiency increases the output for a given set of inputs. In case of strategy 2, no input and output changes, only the amount of subsidies will change, as the base for subsidy calculation changes. Strategy 3 occurs when the subsidies are an essential part of the farmer's income, combined with difficulties to convert the farm in the desired policy direction, e.g. due to path dependency.

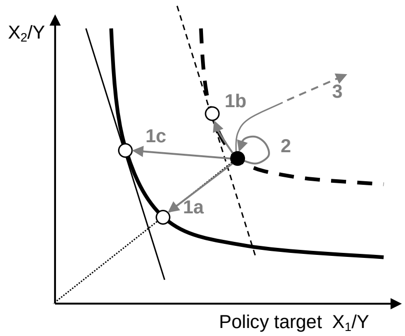

Figure 1. Possible input related farmer strategies due to the policy shift. The dotted isoquant shows the farmer's current position, the full isoquant the technological frontier. Straight lines show the price mix between inputs X_1 and X_2. Strategy 1 improves input technical efficiency, strategy 1b input allocative efficiency, strategy 1c combines both. Strategy 2 is to remain status quo, while strategy 3 is to opt out

5 Comparison of emergent value and sustainability outcome between current and adapted subsidy system

5.1 ABM-Approach

The objective is to show the mechanisms at work, and not to provide representative empirical statistics. First we consider the total profit generation and resource consumption given the current subsidy system. Then we illustrate the shift in subsidies due to the policy change towards Sustainable Value based subsidies. This coincides with all farmers adopting the 'status quo' strategy. Subsequently we show changes in sustainable value, subsidy share and firm profit when a single farmer adopts the efficiency improvement strategy. Finally we show the changes when all farmers adopt the efficiency improvement strategy. This very basic ABM-approach allows us to illustrate some of the main effects to be expected from the policy reform, as it covers the two strategies (to do nothing or to all react with full efficiency improvement) which limit the spectrum of possible strategies. More advanced ABM-models, incorporating co-evolutionary genetic algoritms, allow for more in depth exploration of the strategic farmer behavior and the interactions between farmers. Validation can then be obtained by following a participatory approach. This goes beyond the current scope of this paper. To calculate inefficiencies and possible improvements therein, we make use of the technique of nonparametric data envelopment analysis (DEA, Lee et al, 2002). DEA is used to calculate technical and allocative inefficiencies. Inverse DEA is used to calculate changes in outputs when resources are allocated from the particular firm to the benchmark, to obtain the opportunity costs necessary for the SV-analysis, and to calculate changes in resource use when the particular firm adopts an efficiency improvement strategy, as a reaction to the subsidy change.

5.2 Description of empirical case

As an example of a possible application in practice, the modified SV method including production functions (Mondelaers et al., 2010) is applied to a sample of 271 Belgian dairy farms in 2004, derived from the EU FADN data (provided by European Commission, DG AGRI).

It is supposed that policy makers want to target the following variables impacting on natural capital: fresh water use, greenhouse gas emission, nitrogen excretion and land use. In order to calculate the farms' SV-scores, only these variables are reallocated across the firms to construct the benchmark (see section 2). This reallocation is based on the farms' share in the total use of the considered variable. The selection of these environmental variables covers some of the more important ecosystem sustainability issues. Fresh water is becoming one of the scarce resources of the future. Agriculture is moreover one of the main sectors contributing to global warming, with a prominent role for dairy farming, due to methane emissions from enteric fermentation and manure deposition. Nitrate pollution of aquifers is a major environmental issue, and the maximum allowable amount of nitrogen from livestock is set at 170 kg manure N/ha in the EU. Finally, land scarcity is important as agriculture is competing with nature and other land uses. The selected social capital form is labour. Manufactured capital forms are depreciated farm capital, which consists of buildings and machinery, and concentrate use. Both social and manufactured capital forms are not subject to policy reform.

5.3 Results

Switching from hectare based to SV-based subsidies

Figure 2 below shows the sample farms' SV-scores (dotted line), the subsidy distribution based on the current policy regime (grey line) and the distribution when SV is used as base for subsidy calculation. On average, farm subsidies change with 45%, amounting to ± €1600 for an average subsidy of €3570. For small (large) farms with high (low) SV-scores, the changes are more extreme. Figure 2 also shows that the difference in subsidy amounts between farms reduces (standard deviation reduces from €1713 to €1157). This is due to the fact that the SV does not take into account differences in farm size, as the benchmark value for a particular farm is calculated based on the same amount of resources as used by the particular farm.

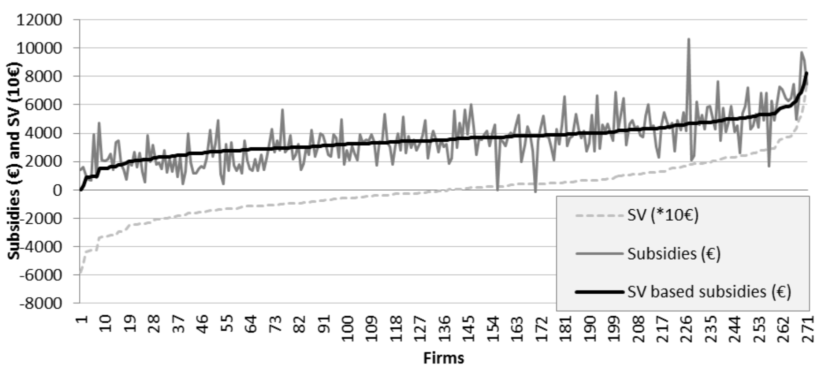

Figure 2. SV-score (in 10€) of Belgian dairy farms in 2004 and change in farm dairy subsidies when SV is used as calculation base for redistribution of subsidies

The average farm profit after payment of labour for our sample farms amounts to €16221 (st. dev. of €41987). With subsidies on average accounting for 22% of this profit, changes therein might mean the difference between making loss or profit for farms.

Differences due to strategic behavior

The new subsidy calculation method has the objective to stimulate farmers to produce more value with less pressure on natural capital. It rewards those who do so with higher subsidies and vice versa. When this objective and the calculation procedure are clearly communicated to the farmers, the farmers can (or cannot, depending on their managerial ability and farm structure) change their farm management accordingly. Farmers who want to react on the policy change can focus on producing more value with their natural capital forms, consuming less natural capital forms for the same value creation or make a combination of both strategies.

Table 1 below summarizes the changes when farm 1 in our sample would improve its management in year 2 by removing its current inefficient employment of the targeted natural capital forms. The farm's radial output efficiency is 1.28, indicating that output could increase by 28% given its current set of natural capital forms. To do so, the farmer should adopt the management of its best mirror farm in the sample. This 28% improvement is however, for different reasons, unrealistic: regional and climatological conditions might differ, path dependency might hinder the farm to improve beyond a certain threshold, managerial capabilities differ between farmers and so on. On the other hand, the technique of DEA does not account for potential progress due to changes in technology beyond those currently known in the market place. An interesting conclusion from table 1 is furthermore that the strategy of efficiency improvement triggered by the efficiency oriented subsidy system pays off twice, once by the increased value creation and once by the resulting increased subsidies. Comparing the farms' SV-scores in year zero and year t, we can see that farm 1 moves from position 126 in the sample to position 5 due to its efficiency improvement.

Table 1. Changes in SV, subsidy, profit and natural capital use when farm 1 in the sample improves its input efficiency

	SV change*	Subsidy change	Profit change	Change in natural capital form**			
				Water use	N-discharge	CO_2-emission	Land use
Farm 1	+43975€	+2699€	+46786€	-447 m³	-30kg/ha	-126 ton	-12 ha

* based on output efficiency improvement ** when input efficiency improvement is considered

Farm 1's efficiency improvement and hence its SV-based subsidy increase also impacts on the remainder of the farms, as their subsidy decreases due to the better performance of farm 1. Their strategic reaction might be either to accept the subsidy decrease or to make a counter move by also improving the efficiency of their natural capital use. Given the economic treadmill (Cochrane, 1958), farmers who do not react will see their share in total subsidies gradually decrease over the years. Figure 3 below shows the difference in SV when the first quarter of the sample (68 farms) improve their input efficiency for the targeted natural capital forms. Accordingly, all farms' share in total subsidies will change due to the efficiency change of the considered group. This group on average saves 15% of water use, 8% of CO_2-emission, 9% of N-excretion per hectare and 11% land. For the total group of farms this means a saving ranging between 2 and 3% for the considered capital forms.

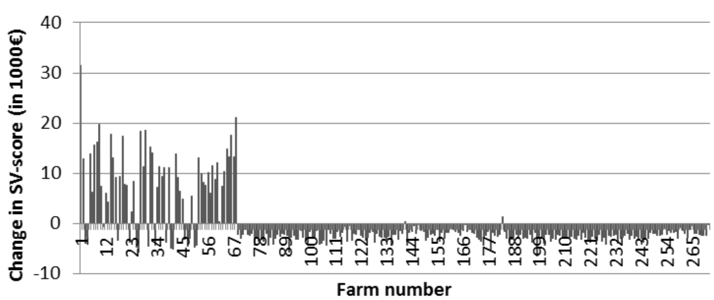

Figure 3. Change in SV-score due to efficiency improvement of first quarter of farms in

6 Discussion

Several issues can be raised concerning the proposed subsidy policy reform and the resulting strategic behavior. First we consider several consequences of the new subsidy system, then we discuss the strategic reactions of the farmers and some market effects.

It is likely that the new subsidy system creates a further schism in the sector, as those who are performing well are rewarded while those who are struggling, are further punished by a decreasing subsidy share. Agriculture becomes more efficient, but likely there will also be more restructuring. Given that the SV-scores are calculated prior to subsidy distribution, the amplification effect is however somewhat tempered.

Linked to this is a potential erosion of diversity given that the new policy system's underlying rationale is efficiency improvement. When the majority of farms convert to the more efficient technology, the sector's adaptive capacity (and hence resilience) decreases. As Goerner et al. (2009) argue, there is a viable window of combinations between resilience and efficiency, but overinvesting in resilience or efficiency leads to unviable outcomes. Given that farmers consider a timespan of multiple years to design their preferred strategy for income stabilization and maximization, they automatically make a trade-off between resilience and efficiency.

It is furthermore known that increased efficiency might result into a rebound effect (Mayumi et al., 1998, Herring and Roy, 2002), as it becomes more interesting (profitable) to employ more resources given the better efficiency. The consequence of a farm's overemployment is however a reduction in its efficiency and hence a reduction in its SV-score in the subsequent time period.

The subsidy system elaborated in the paper only considers a single sector. The SV-method however allows to consider and compare multiple sectors, which might be desirable from a policy perspective. Sector-specific capital forms can be reallocated intra sector while sector unspecific capital forms can be redistributed across different sectors to calculate the SV-scores.

The proposed subsidy reform calculates subsidies irrespective of farm size, as the farm's natural capital forms are reallocated to the benchmark in order to calculate the farm's SV-score. When a large farm attains a positive SV-score, its contribution towards sustainability might be higher in absolute terms compared to a smaller farm. On the contrary, calculating relative sustainability scores allows to maintain a certain variation in scale between farms, interesting from a resilience point of view.

The green pillar of the new CAP reforms, accounting for 30% of the budget, targets vulnerable areas, biodiversity and crop diversification. The majority of subsidies (60%) however remains hectare-based. The modifications proposed in this paper can therefore be applied to the remainder 60% of the EU farm subsidy budget.

With respect to strategic farmer behavior, we first of all have to remark that the proposed simulation not fully captures the potential of agent based model, especially with respect to agents' strategic reactions and interactions. With respect to strategic reactions, the 'opt out' has not been considered, as well as potential market effects of the adoption of the 'efficiency improvement' strategy or the 'opt out' strategy. Although in this paper market prices (f.e. for greenhouse gas emission permits or for manure disposal and processing) are assumed exogenously determined, these might change due to the policy reform. It is furthermore difficult to forecast the actual level of efficiency change due to the policy reform. Farm and farmer specific characteristics impact heavily on the efficiency improvement potential. Other, more advanced, agent based model and simulation techniques (such as genetic algorithms and alike) might allow to better reflect potential interactions and reactions taking into account the farm specific environment. These promising alleys go beyond the scope of this current paper.

The proposed system introduces additional uncertainty for the farmers in a period of already increasing uncertainty. Given that their share in total subsidies is not only dependent on their own performance but relative to the others, farmers can never up front predict what their actual subsidy share will be. This might hamper investment and other strategic decisions. Information uncertainty can be reduced when a system is put in place that informs farmers on their actual position in the group and that forecasts changes in this position (and the resulting subsidy share) due to certain management decisions.

7 Conclusion

The current CAP subsidy system can be criticized given subsidies based on a flat rate per hectare. This results in increased land prices while greening of agriculture is hardly stimulated. In the paper we develop a methodology for an adaptive subsidy system based on farms' sustainability improvements. The hypothesis is that such a subsidy system actively encourages the transition towards a more sustainable agriculture, opposite to the system currently in use. The main difference with the current system is that the farm subsidy level is now based on the farm's sustainability score relative to other comparable farms. While the sustainability items and the way the sustainability scores are calculated, are known a priori to the farmers, the strategic behavior of other farmers, i.e. to what extent they will make sustainability efforts, are unknown a priori. An individual farmer therefore has to make a strategic trade-off between subsidy maximization and profit maximization (before subsidies), under uncertainty. Various strategic reactions of farmers to adaptive subsidizing are modeled in a game-theoretic setting with the help of agent based modeling. We can conclude from the empirical application that farmers reacting on the subsidy reform with an improvement of their input or output efficiency, gain twice, as both their share in total subsidies increases as well as their profit before subsidies. This is also beneficial for the society as the subsidy now results into the reduction of externalities and more efficient resource use. Farmers not reacting on the policy change see their share in subsidies drop back, as well as their competitive position compared to their colleagues. In the discussion section we raise a number of concerns, amongst which the danger for rebound effects, the possible erosion of the sector's resilience due to the focus on efficiency steering the farmers towards a single, superior technology and the increased uncertainty for the farmer introduced by this system.

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