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ANALYSIS

Measuring farm sustainability and explaining differences in sustainable efficiency

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ABSTRACT

A major objective of European agricultural policy is to have a sustainable and efficient farming sector that is applying environmentally-friendly production methods. Policy makers aim to combine a strong economic performance and a sustainable use of natural resources. Therefore, it is important to measure and to assess farm sustainability. For a large dataset of Flemish dairy farms, a valuation method that is based on the concept of opportunity costs is used to calculate and analyze differences among the sample farms with respect to the creation of “sustainable value”. But more important than measuring the creation of sustainable value is to analyze differences in sustainable efficiency. Therefore, sustainable efficiency measures are calculated and differences in sustainable efficiency are explained. Using panel data, an effect model captures the determinants of sustainable efficiency of the studied farms. The empirical model shows that, in general, larger farms have a higher sustainable efficiency. Also farmer's age and dependency on support payments proved to be determining characteristics for observed differences in sustainable efficiency.

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1. Introduction

One of the major objectives of European agricultural policy is to have a sustainable and efficient farming sector, which uses safe and environmental-friendly production methods and provides quality products that meet consumers' demands. Sustainability is seen as a key element towards a profitable long-term future for farming and rural areas. Policy makers aim to combine strong economic performance with the sustainable use of natural resources in the field of agriculture (Boel, 2005; European Commission, 2004).

An important conclusion of the United Nations Conference on Environment and Development in 1992 is that the major cause of the continued deterioration of the global environment is the unsustainable pattern of consumption and production (United Nations, 1992, pp. 18). While sustainable consumption targets consumers, sustainable production is related to companies or organisations that make products or offer services (Veleva and Ellenbecker, 2001). Despite the difficulty of defining sustainable production and the vagueness of several definitions, there is a clear consensus to move from definition attempts toward developing and using concrete tools for measuring and promoting actual sustainability achievements.

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To meet with the challenges of sustainability, an approach for integrated assessment of companies is required to provide a good guidance for decision-making (Krajnc and Glavic, 2005a). Therefore, it is important to measure and to assess farm sustainability. The aim of this research is to measure the sustainability of dairy farms in terms of 'sustainable value' and 'sustainable efficiency' and to find out why farms differ in sustainable efficiency. The Flemish dairy sector is used as test-case and example to identify farm sustainability. Using a large data set, the sustainable value creation of dairy farms and its evolution during 1995–2001 is analyzed. Further, the robustness of our results is tested by using different benchmarks for calculating sustainable efficiency. The existence of frontrunners and laggards among dairy farms is investigated by testing whether good/bad farm performance is repeated from year to year. Furthermore, possible causes of observed differences are studied using an empirical model. Finally, the link between partial productivity measures, eco-efficiency measures and sustainable efficiency is analyzed.

2. Theoretical framework

Pezzey and Toman (2002, pp. 1) state that: "concern about sustainability is almost as old and enduring as the dismal science itself, though the word itself has come into fashion only in the past decades". Since the publication of *Our Common Future* by the World Commission on Environment and Development (WCED, 1987), the idea of sustainable development came to the forefront of the public debate. This World Commission added its voice to the appeal for new ways of measuring progress that would go beyond economic signals and capture a fuller sense of human and ecological well-being (Hardi and Zdan, 1997). However, sustainability proved to be a remarkably difficult concept to define and to apply in practice. Moreover, relevant 'measurement' of sustainability is fraught with difficulties of principles and practice. Hence, there are, understandably, but nevertheless disappointingly, rather few published empirical studies on this topic (Pezzey and Toman, 2002).

The need for procedures to measure sustainability is increasingly recognized (Tyteca, 1998). Although the concept has different meanings to different people, it is far from meaningless (Farrell and Hart, 1998). Indicators can help to identify, define and communicate about sustainability issues and they can be used to forecast and monitor the results of policy choices (ESDI, s.d.). Good indicators provide key information about a physical, a social or an economic system and they allow analysis of trends and cause-and-effect relationships (Veleva and Ellenbecker, 2001). Moreover, indicators of sustainable development should provide solid bases for decision making at all levels (Becker, 1997; Capello and Nijkamp, 2002). Decision makers need indicators that show the links between social, environmental and economic goals to better understand how to achieve economic growth that is in harmony with the natural systems within which we live and work (Farrell and Hart, 1998).

Indicators can be used (i) individually, (ii) as part of a set, or (iii) in the form of a composite index that combines individual indicator scores into a single number. Such a single aggregated number can be very useful in communicating information on

general sustainability to the public and to decision makers (Farrell and Hart, 1998). Possible disadvantages are that the methods to achieve an aggregation are often subjective (Becker, 1997; Huetting and Reijnders, 2004) and that every index contains hidden assumptions and simplifications (Hanley et al., 1999). Therefore, such combined indicators need to be used judiciously. Farrell and Hart (1998) state that in many cases, indicators to measure sustainability are no more than combined lists of traditional economic, environmental and social indicators with the word 'sustainable' added to the title. Nevertheless, such combination is a first significant step because it recognizes that all three areas (economic, ecological and social) matter: sustainable development is a holistic concept and ideally one should strive to consider all three pillars of sustainability simultaneously. Therefore, it is important that the development of indicators does not stop at this stage (Farrell and Hart, 1998). Economic and ecological analysis need to be combined (Kaufmann and Cleveland, 1995) and one should concentrate on the interaction rather than on just the environment itself (Jollands et al., 2003). The advantage of aggregate indicators is that the information is presented in a format tailored to decision makers (Constanza, 2000; Jollands et al., 2003; Azapagic, 2004). However, we need to be careful and informed about the way of aggregation, the uncertainties, the weights and the data source. Decision makers are too busy to deal with these details and the beauty of the aggregate indicator is the fact that it does the job for them (Constanza, 2000). But, no single indicator can possibly answer all questions and therefore multi-dimensional indicators can be needed (Opschoor, 2000; Veleva and Ellenbecker, 2001).

In recent years, different frameworks and indicator systems have emerged that claim to evaluate sustainability both at firm level and at higher level. Most of the focus in measuring and evaluating progress towards sustainable development has been at the national level (Veleva and Ellenbecker, 2000; Figge and Hahn, 2004a). Well known examples are the ecological footprints (e.g. Wackernagel and Rees, 1995), genuine savings (e.g. Pearce and Atkinson, 1993), the index of sustainable economic welfare (e.g. Daly and Cobb, 1989), and the dashboard of sustainability (e.g. IISD, s.d.).

Sustainability is a global concept and a firm is only a small subsystem that interacts in various ways with surrounding systems. Nevertheless, companies are essential actors in socio-economic life and as such they contribute to the realization of sustainable development (Tyteca, 1998). Corporations are the organisations with the resources, the technology, the global reach, and ultimately, the motivation to achieve sustainability (Hart, 1997). Defining and measuring corporate sustainability is more than just an academic concern. Corporate entities are increasingly under pressure to demonstrate how they contribute to the national sustainability goals outlined by governments (Atkinson, 2000). The concept behind sustainability indicators for business is simple. On the one hand, the aim of these indicators is to answer the question of how one might objectively know whether a company is moving towards or away from sustainability in all three dimensions: environmental, social and economic (Lawrence, 1997). On the other hand, defining the appropriate indicators is not easy (Veleva and Ellenbecker, 2000).

Assessing a company's contribution to sustainability can be measured by subtracting the costs from the benefits

created by that company. For this purpose both internal and external costs and benefits need to be considered. External costs or benefits that arise from production (or consumption) falling on someone other than the producer (or consumer) are called externalities. An example of the assessment of the total external costs for UK agriculture is given by [Pretty et al. \(2000\)](#) and for the agricultural sector of the United States by [Tegtmeier and Duffy \(2004\)](#). If the benefits of a firm exceed the sum of internal and external costs, the firm contributes to sustainability. From a theoretical point of view this way of measuring sustainability provides a very powerful measure of corporate contributions to sustainability because they translate the requirements of the constant capital rule at the macro level into measures at the micro level ([Figge and Hahn, 2004a](#)), but the necessity to express environmental and social damage in monetary terms, severely limits the practicability.

A very popular measure to express corporate contributions to sustainability is the measure of eco-efficiency (e.g. [Schmidheiny, 1992](#); [OECD, 1998](#), [WBCSD, 2000](#); [Jollands et al., 2004](#); [Meul et al., 2005](#)). Eco-efficiency can be defined as the ratio of created value per unit of environmental impact. [Figge and Hahn \(2004a\)](#) state that eco-efficiency has three major shortcomings to measure corporate contributions to sustainability. First, eco-efficiency is a relative measure giving no information on effectiveness. Second, advances in environmental performance due to improved eco-efficiency can be over-compensated because better eco-efficiency may lead to growth and thus increased use of environmental resources. This is called the rebound effect ([Mayumi et al., 1998](#); [Herring and Roy, 2002](#)). However, environmental resources which are saved due to improved eco-efficiency might be employed by other companies which are less eco-efficient. Third, eco-efficiency does not take into account all social and environmental impacts simultaneously.

The concept of sustainable development at firm level has been more and more applied in recent years. Well known examples are The Global Reporting Initiative (e.g. [GRI, 2002](#)), ISO 14031 (e.g. [ISO, 1999](#)), and the Eco-efficiency framework of the World Business Council for Sustainable Development (e.g. [WBCSD, 2000](#)). Regardless of the large number of available sustainability indicators for companies, there is no framework to evaluate the sustainability of production systems ([Veleva and Ellenbecker, 2000](#)). [Tyteca \(1998\)](#) showed that the principles of productive efficiency can be used to elaborate sustainability indicators at the firm level. [Callens and Tyteca \(1999\)](#) worked out indicators based on both the concepts of cost-benefit analysis and the principles of productive efficiency. [van Calker et al. \(2006\)](#) used the multi-attribute utility theory to develop an overall sustainability function for Dutch dairy farming systems. Besides data at the attribute level, stakeholders and experts are used for the assessment of subjective and objective attributes respectively. The sustainability function showed to be a suitable method to rank and compare different dairy farming systems ([van Calker et al., 2006](#)). [Krajnc and Glavic \(2005a\)](#) designed a model for obtaining a composite sustainable development index in order to track integrated information on economic, environmental and social performance with time. In other words, they developed an aggregate measure which can be used to compare and rank companies regarding sustainable development. Using the concept of

analytic hierarchy process, the impact of individual indicators on the overall sustainability of a company can be assessed. The analytic hierarchy process is a multi-attribute decision model used to derive weights of indicators by the prioritization of their impact on overall sustainability assessment of the company. In [Krajnc and Glavic \(2005b\)](#), the effectiveness of the proposed model is illustrated with a case study. Possible drawbacks of this model are the selection of indicators and the way in which the weights of indicators are determined ([Krajnc and Glavic, 2005a,b](#)).

[Figge and Hahn \(2004a, 2005\)](#) introduced the concept of sustainable value, a new approach to measure corporate contributions to sustainability, based on the assessment of the value of capital beyond economic capital. They developed a valuation methodology to calculate the cost of sustainable capital and the sustainable value creation of companies. The capital approach and the concept of opportunity costs to determine a company's sustainable value are applied. Using the notion of capital, [Constanza et al. \(1991\)](#) define sustainability as the amount of consumption that can be continued indefinitely without degrading any capital stocks. For this, capital must be considered in the broad sense: inasmuch as the environment contributes to the productive process, it should be considered as a factor of production ([Serafy, 1991](#)). Using the capital concept can help in conceptualizing the measurement of sustainability and can facilitate the dialogue between economists and ecologists ([Harte, 1995](#)). In a broad sense capital consists of (i) natural capital, (ii) physical capital, (iii) human capital and (iv) intellectual capital. Except for natural capital, all other types are considered as human-made capital ([Perman et al., 2003](#)).

The constant capital rule is the key to the capital approach to sustainability. The sustainable value approach relates the efficiency of capital use by companies (micro level) to the efficiency of a benchmark (macro level) ([Figge and Hahn, 2005](#)). A company contributes to more sustainable development whenever it uses every single form of capital more efficiently than other companies. With respect to the micro level the approach shows whether the different forms of capital have been allocated to the most value creating use. On the macro level, the sustainable value approach expresses the excess value created by a company while preserving a constant level of capital use on the macro level. Hence, the approach is based on the notion of strong sustainability ([Figge and Hahn, 2004a, 2005](#)).

Sustainable value is a monetary measure of sustainability. An important advantage of monetary measures is that it gives decision makers environmental information in a format they are familiar with and that readily enables comparison with other types of information ([Farrell and Hart, 1998](#); [Atkinson et al., 1999](#)).

Most approaches to assess sustainability performance are burden orientated; they assess the costs or potential harm of resource use, while the sustainable value approach is value orientated. In fact, burden-orientated approaches focus on the level of environmental impacts caused by an economic activity compared to another set of environmental impacts (how resources should be substituted by each other), while value-oriented impact assessment analysis how much value have been created with this set of environmental impacts as compared with the use of these resources by other companies (where resources should be optimally allocated). [Figge and](#)

Hahn (2004b) state that value- and burden-oriented impact assessments are necessarily complementary and both need to be considered to arrive at an optimal allocation of resources.

On the other hand, the approach does not indicate whether the overall capital use is sustainable, but only how much a company contributes to a more sustainable use of capital. Another drawback is that the usability of the methodology is limited by the available data on corporate capital use and the opportunity cost of the different forms of capital (Figge and Hahn, 2005). Inevitably, indicators are often selected considering the availability of reliable data.

However, we decided to use the sustainable value approach in this research to measure farm sustainability, mainly because an important advantage of the approach is that it integrates different forms of economic, social and environmental capital. In fact, the sustainable value approach can, contrary to other methods, be seen as a fully integrated value oriented assessment tool which can give useful and good guidance for decision making.

3. Methodology

3.1. Methodology to measure sustainability

Benchmarking is a necessary tool to evaluate corporate policies and performance (Krut and Munis, 1998). Adhering to a paradigm of strong sustainability, we consider that a firm contributes to more sustainable development whenever it uses every single form of capital more efficiently than other companies. In practice there is no such super-company, therefore it must be determined if the higher efficiency of the use of one form of capital can compensate for the lower efficiency of the use of another form of capital (Figge and Hahn, 2005). When assessing different capital forms, an aggregation problem is encountered. To solve this problem, a conversion of all environmental impacts into equivalents of one of the impacts may be considered. However, Figge and Hahn (2004a, 2005) use the concept of opportunity cost to circumvent this problem. The opportunity cost of a capital form is the cost of an opportunity foregone (and the benefits that could be received from that opportunity), or the most valuable foregone alternative. Hence, one can consider the opportunity costs of all forms of capital. The opportunity cost (or capital cost) can be calculated as:

$$\text{opportunity cost} = \frac{\text{value added}_{\text{benchmark}}}{\text{capital}_{\text{benchmark}}} \quad (1)$$

A firm creates value when it uses capital more efficiently than the (bench)mark. Hence, we can calculate the value spread by subtracting the opportunity cost (determined by the benchmark) from the efficiency of capital use in company *i*. The value spread reflects the super-efficiency of the use of a form of capital (Figge and Hahn, 2005):

$$\text{value spread}_i = \frac{\text{value added}_i}{\text{capital}_i} - \frac{\text{value added}_{\text{benchmark}}}{\text{capital}_{\text{benchmark}}} \quad (2)$$

The value contribution is calculated by multiplying the value spread of a certain capital form of a company with the

amount of used capital by that company. The sustainable value created by company *i* can be calculated by adding up the value contributions for every form of capital *s* ($s \in [1;n]$ if *n* forms of capital are considered).

$$\text{sustainable value}_i = \frac{1}{n} \sum_{s=1}^n (\text{value spread}_i^s * \text{capital}_i^s) \quad (3)$$

To correct the overestimation of the value created, we divide by the number of capital forms *n* to calculate the sustainable value. Dividing by *n* does not serve to weigh the different forms of capital but only to avoid double counting of value creation (Figge and Hahn, 2005). Efficiency can be expressed by relating the value created to the cost of capital. Figge and Hahn (2005) calculate sustainability efficiency as:

$$\text{sustainable efficiency}_i = \frac{\text{value added}_i}{\text{value added}_i - \text{sustainable value}_i} \quad (4)$$

The more sustainable value is created, the more the value added of a firm exceeds the opportunity cost of its capital base (Figge and Hahn, 2005). The cost of the sustainability capital of company *i* is given by the difference between the value added and the sustainable value of company *i*. The sustainable efficiency of a firm equals unity if the value added corresponds to the cost of all forms of capital (sustainable capital). A sustainable efficiency higher than one means that the company is overall more efficient than its benchmark. In contrast to single capital efficiencies, the sustainability efficiency considers all forms of capital simultaneously and relates them to the value created (Figge and Hahn, 2005).

The choice of the benchmark reflects a judgement as it determines the cost of all capital forms. This means that the benchmark level determines the explanatory power of the results of the sustainable value analysis. It should therefore be chosen with great deliberation (Figge and Hahn, 2005). Different efficiency figures can be considered as benchmark: national economies, regions, performance targets, a sector or a company. Consider the following four possibilities.

First, the weighted average return on capital of a sample of companies can be used. This benchmark is calculated as the total sum of the value added of all companies in the sample divided by the total resource use of the capital form of all firms. Note that that the weighted average return on capital represents the average over all the years considered.

Second, an alternative benchmark is the best performance on each capital form using the highest return on capital realised by a company. Using for each capital form the best scoring farm as benchmark, we create a virtual 'super-farm' as benchmark. The fact that this farm does not exist in the real world is not a problem. A possible disadvantage of this benchmark is the higher risk of using only one observation: the benchmark observation could be an outlier or a wrong observation.

Third, another possibility to benchmark is applying for every capital form a performance target. Such an objective performance target for sustainable dairy farming in Flanders is e.g. 150 kg N ha⁻¹ for the farm-gate N surplus (Nevens et al., 2006). In this way the method can easily be related to attempts to define sustainable farming systems in a region.

Fourth, in a last benchmark system, the unweighted average return on capital can be used. In this case, every farm will be taken into account regardless of size. This benchmark is calculated as the total sum of return on capital of all companies in the sample divided by the number of companies.

In this research, the weighted average of a set of dairy farms is used as first benchmark to calculate the sustainable value of each dairy farm. But, the results will also be compared with the results obtained using other types of benchmarks. We opted for the weighted average as benchmark because an important aim of this study is to understand why farms differ in their creation of sustainable value and to analyze the evolution of the sustainable efficiency. By weighting the use of resources a benchmark is obtained which is much closer to how resources are really used. Using the unweighted average would imply that every farm (regardless of size) gets the same share if resources are put on the market, which is rather unrealistic.

The sector benchmark for assessing the sustainable value is calculated by the total sum of the value added of all observations in the sample divided by the total resource use of the capital form of all observations covering all years. It might seem unusual to take the average of several periods as benchmark (opportunity cost), because strictly speaking farmers do not have to choose between using a specific resource in year 1 or 2; they can use it in both years. Thus farmers do not have to make an exclusionary choice and using a resource in year 2 is therefore strictly speaking not an opportunity cost for year 1. However, in this research we use the average of all periods as benchmark because we try to understand the differences in sustainable efficiency and to identify trends in the variation of sustainability performance of the observations during the observed period. Note that data of the different capital forms are expressed in physical amounts (or if necessary in deflated monetary amounts) in order to eliminate price effects, which can trouble comparisons between years. A possible drawback of using the benchmark covering all years is that we do not take technical change into account. Finally, using the weighted average covering all years as benchmark results in a better representation of the sector (647 observations) because in some years we have limited observations (e.g. 69 observations in 2001).

3.2. Explaining differences in sustainable efficiency

To analyse which factors influence sustainable value creation, an econometric model can be formulated. The essential structure for an effect model using panel data is:

$$y_{it} = \alpha_i + \gamma_t + \beta x_{it} + \varepsilon_{it} \quad (5)$$

The dependent variable (y_{it}) is the sustainable efficiency of each farm in each year, the independent variables (x_{it}) are the potential determinants. Eq. (5) can be estimated using unbalanced panel data via an effect model (random or fixed) or via ordinary least squares (OLS) regression. In effect models, variation across farms or time is captured in simple shifts of the regression function (changes in intercepts). Traditionally, there are fixed effects models and random effects models. In

fixed effects models α_i is a separate constant term for each unit ($y_{it} = \alpha_i + \beta x_{it} + \varepsilon_{it}$). In random effects models we have an individual specific disturbance ($y_{it} = \alpha + \beta x_{it} + \varepsilon_{it} + u_i$). To identify the most appropriate estimation the Breusch and Pagan's Lagrange multiplier statistic and the Hausman's chi-squared statistic can be used (Wooldridge, 2002). The Breusch Pagan's Lagrange multiplier statistic can be used to test the use of the effect model against the classical regression with no group specific effects. High values of the Lagrange multiplier statistic argue in favour of one of the effects models (fixed or random). The Hausman test can be used to test the use of the fixed effects model against the random effects model. A low Hausman chi-squared statistic argues in favour of the random effects model.

4. Sustainable efficiency and value creation by Flemish dairy farms: an empirical application

As explained in the previous section, several frameworks to calculate the sustainable value creation of firms exist. These frameworks are mostly tested by calculating the sustainability of only a limited amount of companies. In our analysis, we use an extensive sample of data of a large amount of Flemish dairy farms. In this way, we apply and test the methodology developed by Figge and Hahn (2005). The 'value contribution', the 'sustainable value' and the 'sustainable efficiency' are used as indicators to analyse the farm sustainability. Furthermore, an econometric model is constructed to analyse the impact of several managerial and structural farm characteristics on farm sustainability.

4.1. Data and variables

There are three questions that need to be addressed for the application of the sustainable value methodology (Figge and Hahn, 2005): (i) the choice of the economic activity or entity to be analyzed; (ii) the choice of the forms of capital to be taken into account; (iii) the choice of the benchmark.

In this research, we focus on Flemish dairy farms (specialist grazing livestock). Farm accountancy data from a group of dairy farms in Flanders is used during the period 1995–2001. This gives 647 observations (unbalanced panel data) and a balanced panel data set of 41 dairy farms during 7 years (287 observations). These data were collected by the European FADN database (Farm Accountancy Data Network). The Belgian FADN-data are collected and managed by the Centre for Agricultural Economics (presently taken over by the monitoring division of the Agricultural Monitoring and Study service of the Flemish Ministry for Agriculture). Descriptive statistics of the sample data are given in Table 1.

The different forms of capital that we take into account are: (i) labour, (ii) farm capital, (iii) utilized land, (iv) energy use and (v) nitrogen surplus. Labour, farm capital and land are the traditional capital forms. Farm capital (assets) is calculated as total capital minus land capital, in this way overlap is avoided. Energy use and nitrogen surplus are environmental capital forms. In Flanders, as in other European regions, N losses are a major concern in agricultural practice. High stocking rates in the Flemish region result in a very high N pressure on the

Table 1 – Descriptive statistics of the data set of dairy farms (yearly basis)

Variable	Mean	Minimum	Maximum	SD
Total output (Euro)	150,124.94	20,445.00	622,791.00	68,751.36
Land use (hectares)	31.71	6.72	83.08	11.28
Labour (full-time equivalent)	1.48	0.63	3.50	0.34
Farm capital (Euro)	284,135.90	37,338.00	789,404.00	152,101.91
Intermediate consumption (Euro)	66,323.53	13,600.00	295,465.00	31,508.36
Energy consumption (MJ)	1,772,540.29	268,185.00	287,532,492.00	11,453,723.50
Nitrogen surplus (kg N)	8878.60	1934.45	25,569.75	3878.17
Farmer's age	43.13	23.00	68.00	10.27
Solvency ^a	0.42	0.00	1.00	0.30
Size unit ^b	16.44	5.00	59.00	6.47
Subsidies interest ^c (Euro)	2944.98	0.00	15,111.00	3062.26
Subsidies revenues ^d (Euro)	143.98	0.00	5512.00	530.40
Subsidies income ^e (Euro)	4415.21	0.00	28,579.00	2678.04
Value added (Euro)	83,801.41	6845.00	327,326.00	42,892.15

^a Measured as own capital divided by total capital.

^b Calculated for all farms in the dataset based on standard gross margin (FADN, s.d.).

^c Subsidies on investments (interest support).

^d Subsidies on animal products (subsidies on sale and purchase of animals are not included).

^e Direct payments to producers: suckler cow premium, slaughter premium, set-aside premium, arable crops hectare aid, etc...

utilized agricultural area. These five different forms of capital are found to be critical for the sustainability performance of a dairy farm (Reinhard et al., 2000; Meul et al., 2005; Nevens et al., 2006). Information on other important capital forms (e.g. social aspects and other environmental aspects) was not available in our data set and could not be taken into account.

4.2. The evolution of the value contribution, sustainable value and sustainable efficiency of Flemish dairy farms

Using the balanced data set, the value contribution for the five different capital forms (Eq. (2)) and the sustainable value (Eq. (3)) can be calculated for each dairy farm in each year. The average value contributions and the average sustainable value of the 41 dairy farms in the balanced panel data set can be calculated for each year during the period 1995–2001. As explained in Section 3.1 the weighted average return on capital covering all years is used as benchmark. The sustainable value approach assesses how efficiently companies use their resources (capital forms). Farms use capital forms to create a return. This return is compared to the opportunity cost of the resources, in this case the weighted average return of all farms in the dataset. This means that a farm only creates sustainable value if it creates more value added with its resources than the weighted average.

Fig. 1 shows the evolution of the average sustainable value as well as the value contributions of each form of capital, calculated for the balanced set of 41 dairy farms during the period 1995–2001. The average sustainable value of each year is calculated as the sum of the sustainable value of all observations in one year divided by the number of observations in that year. We observe a negative sustainable value in 1995, increasing to a maximum in 1999. Afterwards, the sustainable value decreases. The value contributions show how much more or less value added the (average) farm has created with a resource compared to the benchmark. Our analysis enables to identify which capital forms highly contribute to value creation and which capital forms are not

used in a value-creating way. For example the contributions of land capital and farm capital are low in 1995 and in 2000. We can also see in Fig. 1 that the capital form nitrogen surplus can be identified as a critical resource and value driver in both 1997 and 2000. Furthermore, the evolution of the value contributions of capital forms can be analysed. Nitrogen surplus has had an important bad impact during the first 3 years (1995–1997). Later on, the improvements of nitrogen use result in a positive contribution of the capital form nitrogen surplus on the sustainable value. This shows that the method is able to take into account the reduction of nitrogen surpluses in specialized dairy farms (Nevens et al., 2006). As mentioned earlier, larger farms can be expected to create higher (positive or negative) sustainable value than small farms. To correct for this size effect, the sustainable efficiency can be calculated. In

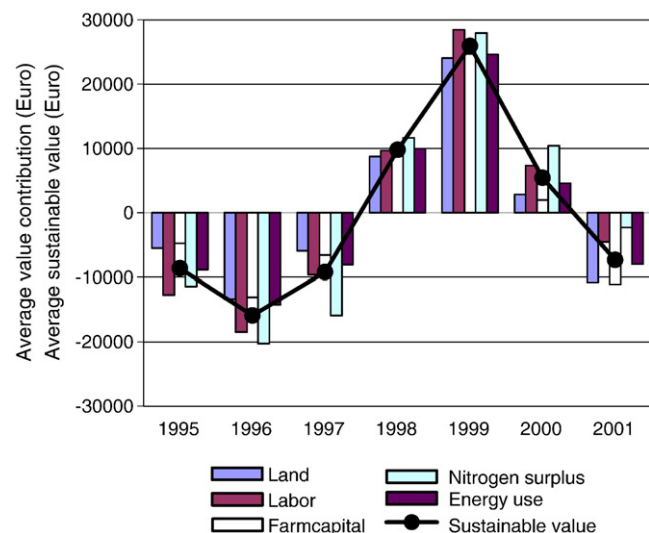


Fig. 1 – The average value contribution of each capital form considered and the sustainable value of dairy farms in Flanders (1995–2001).

this way we can compare the sustainability performance of farms irrespective of their size. Calculating the average sustainable efficiency (Eq. (4)) for each year, a low average sustainable efficiency of 0.8 is found in 1996. From 1996 on, the average sustainable efficiency increases, to almost 1.3 in 1999. This top was followed by a decrease in 2000 and 2001. A possible explanation of this decline is the decrease in profitability that has been observed during this period in the specialized dairy sector in Flanders (CAE, 2003). The average sustainable efficiency of each year is calculated as the sum of the sustainable efficiencies of all observations in one year divided by the number of observations in that year. Note that we used our benchmark covering all 7 years (1995–2001), in this way the trends in the variation of the sustainable efficiency can be identified during this period.

4.3. Benchmark choice and robustness of the indicators

As explained in Section 3.1, the choice of the benchmark is important in calculating the ‘sustainable value’ and the ‘sustainable efficiency’ indicators. We choose as benchmark the weighted average return on capital of our data sample (benchmark 1 (base)). To analyse the robustness of the sustainable efficiency calculations, we will compare our results with the results obtained using other types of benchmarks described in Section 3.1. A first alternative benchmark is the best performance on each capital form (benchmark 2). Another possibility to benchmark is applying a performance target (benchmark 3). A nitrogen surplus target of 150 kg N per ha is used and the weighted average return on capital is applied for the other capital forms. Finally, we used the unweighted average return on capital as benchmark (benchmark 4).

The descriptive statistics of the sustainable efficiency using different benchmarks can be found in Table 2. Using the nitrogen surplus as benchmark (benchmark 3) results in a lower maximum and mean sustainable efficiency compared to the base benchmark. The reason is that only eight observations reach the target level of 150 kg N per ha. The sustainable efficiencies using the best performance of each capital form as benchmark (benchmark 2) are much lower. Using this benchmark, the maximum possible sustainable efficiency is 1. A sustainable efficiency of 1 would mean that the ‘super-farm’ exists or in other words that one of the farms scores best on all capital forms. From our data, we obtain a maximum sustainable efficiency of 70% (Table 2). The descriptive statistics of the sustainable efficiency using the unweighted average return on capital as benchmark (benchmark 4) are very similar to the statistics of the sustainable

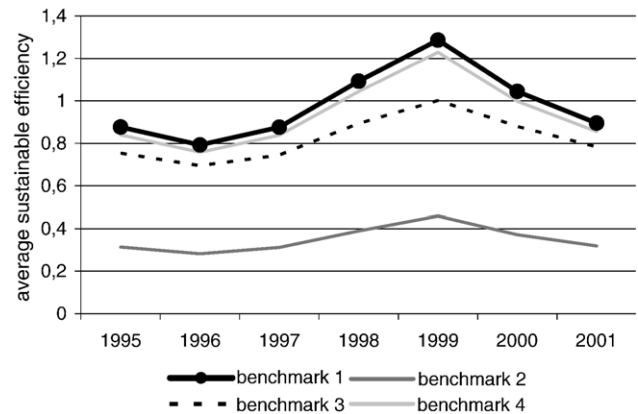


Fig. 2–The average sustainable efficiency using different benchmarks (1995–2001).

efficiency using the weighted average of eco-efficiency as benchmark (benchmark 1 (base)). This seems to lead to the conclusion that farm size does not matter, although the significance of the impact of farm size on sustainable efficiency should be analyzed in more detail (see Section 4.5).

Fig. 2 shows the evolution of the average sustainable efficiency (during the period 1995–2001). Depending on the applied benchmark, the values of the sustainable efficiencies differ but the year to year variation is very similar.

To test the robustness of the sustainable efficiency measure, the rank correlation (Spearman’s rho) of sustainable efficiency using different benchmarks is calculated (Table 3). The correlations are very high and significant. This indicates that the ranking of the dairy farms does not differ much using the other benchmarks to calculate the sustainable efficiency. Similar results are obtained analysing the robustness of the sustainable value measure (not reported). Notice the fact that the best scoring farm (maximum) is the same farm using the four different benchmarks. Also the worst scoring farm (minimum) is the same farm.

Note that within the scope of policy analysis the choice of an accurate benchmark is more important. In that case, using benchmark 2 (the best performance on each capital form) or benchmark 3 (performance targets) can be very useful to analyse the efforts of farms in their aim to reach the targets or the best performance.

4.4. The existence and tenacity of frontrunners and laggards

For the balanced set of 41 Flemish dairy farms, the sustainable efficiency for seven successive years (1995–2001) could be calculated. Again, the weighted average return on capital is used as benchmark but this time for each year separately. However, in contrast to the other sections where the benchmark covered all years, we now use the weighted average return on capital from a specific year as benchmark for that year. From this, it follows that the average sustainable value is equal to zero for each year. We changed our benchmark choice because in this section the aim is to analyze the existence of frontrunners and laggards. In other words, we want to know if

Table 2–Descriptive statistics of the sustainable efficiency using different benchmarks

Sustainable efficiency	Mean	Minimum	Maximum	SD
Benchmark 1 (base)	0.98	0.28	1.91	0.28
Benchmark 2	0.35	0.10	0.70	0.10
Benchmark 3	0.82	0.32	1.61	0.19
Benchmark 4	0.94	0.27	1.83	0.27
Number of observations: 287 (41 dairy farms during 1995–2001).				

Table 3 – Correlation between the rankings of sustainable efficiency using different benchmarks

Sustainable efficiency	Sustainable efficiency			
	Benchmark 1 (base)	Benchmark 2	Benchmark 3	Benchmark 4
Benchmark 1 (base)	1.000	0.9967***	0.9336***	0.9994***
Benchmark 2		1.000	0.9415***	0.9986***
Benchmark 3			1.000	0.9365***
Benchmark 4				1.000

*Significant at 10%; ** significant at 5%; *** significant at 1%.

farms with a high (low) sustainable efficiency in 1 year also have a high (low) sustainable efficiency in the other years. To test the hypothesis that the same farms are obtaining high values of sustainable efficiency each year, the rank correlation coefficients (Spearman's rho) between the different years are calculated (Table 4).

All correlations are significant and positive (Table 4), indicating that on average the same farms have high sustainable efficiencies during the observed period. Hence, we can say that there are in general frontrunners and laggards. In Table 5 the descriptive statistics of the frontrunners (farms with a sustainable efficiency higher than 1 in each year) and the laggards (farms with a sustainable efficiency lower than 1 in each year) can be found. Nearly 22% (9/41) of all farms have a high sustainable efficiency each year; also almost 30% (12/41) of all farms have a low sustainable efficiency each year.

Observing the descriptive statistics (Table 5), we found that the 'laggard' farms have older farm managers with a lower education level. These farms are smaller in size and more dependent on support payments, on the other hand the solvency rates are higher and they have a bigger share of land in property. The 'frontrunner' farms are bigger in size and less dependent on support payments. A more profound analysis of the differences in sustainable efficiency can be found in the following section.

4.5. Explaining differences in sustainable efficiency

In Section 4.4 we found that there are frontrunners and laggards. In this section the reasons behind the differences in sustainable efficiency between farms are analyzed.

Table 4 – Correlation between the rankings of sustainable efficiency (1995–2001)

Sustainable efficiency	Sustainable efficiency						
	1995	1996	1997	1998	1999	2000	2001
1995	1.00	0.58***	0.65***	0.59***	0.41***	0.51***	0.56***
1996		1.00	0.75***	0.74***	0.66***	0.67***	0.60***
1997			1.00	0.79***	0.77***	0.80***	0.70***
1998				1.00	0.70***	0.68***	0.61***
1999					1.00	0.84***	0.67***
2000						1.00	0.67***
2001							1.00

*Significant at 10%; ** significant at 5%; *** significant at 1%.

Among the 647 observations during 7 years (unbalanced panel data), a large difference in the level of sustainable efficiency is found (Fig. 3). The performance of dairy farming differs clearly a lot. Possible determinants in our dataset which can partly explain the differences in performance are: (i) farm size, (ii) farmer's age, (iii) the education of the farm manager, (iv) the dependency on farm support, (v) having a successor willing to take over the farm, (vi) the share of land owned and (vii) farm solvency. To analyse these differences, we calculate the average value of some determinants of all dairy farms and of the 10%-best-scoring-farms and of the 10%-worst-scoring-farms. The descriptive statistics are provided in Table 6.

Analyzing the data in Table 6, some important differences arise. On average, good scoring farms are larger and have younger managers with a higher education level. The solvency on the best 10% farms is also lower (these farms have more debts) and they depend less on subsidies.

Table 5 – Descriptive statistics of all farms, frontrunners and laggards

Variable (average values)	All farms	Farms with a SE > 1 (for all 7 years) (frontrunners)	Farms with a SE < 1 (for all 7 years) (laggards)
Sustainable value (Euro)	0.00	19,298.81	–16,677.60
Age of manager	42.77	43.16	48.40
Solvency ^a	0.42	0.42	0.60
Size unit ^b	16.41	17.70	13.90
Subsidies dependency ^c (in %)	4.95	4.37	5.08
Share own land ^d (in %)	28.82	22.48	34.13
Higher education (in %)	65.85	77.78	25.00
Number of observations	41	9	12

SE stands for sustainable efficiency.

^a Measured as own capital divided by total capital.

^b Calculated for all farms in the dataset based on standard gross margin (FADN, SD).

^c Calculated as the total amount of received subsidies divided by the total revenues, indicating the dependency on support payments.

^d Measured as land in property (in ha) divided by total land (in ha).

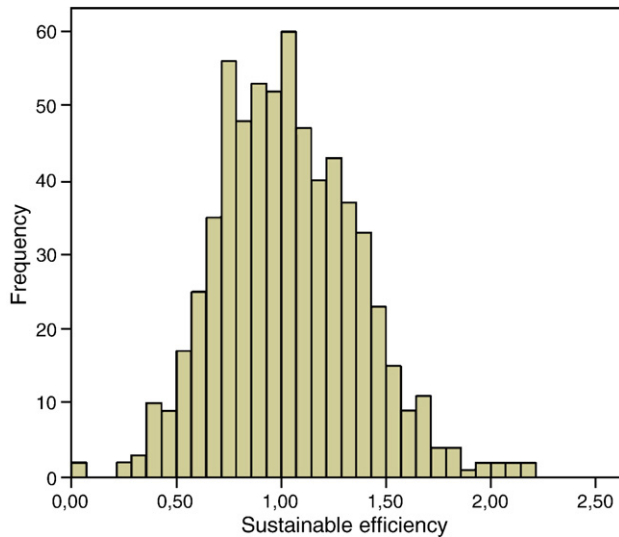


Fig. 3 – The frequency distribution of sustainable efficiency of all specialized Flemish dairy observations in the FADN-dataset (all farms during 1995–2001).

To determine the significance of the determinants of sustainable value creation, we can estimate an effect model or an ordinary least squares regression. We found a large Breusch and Pagan's Lagrange multiplier statistic; hence, the use of an effect model is preferred. Furthermore, we found a large Hausman's chi-squared statistic, which argues in

favour of the fixed effects model. Therefore, Eq. (5) can be rewritten as:

$$\begin{aligned} \text{Sustainable efficiency}_{it} = & \alpha_i + \beta_1(\text{Size unit})_{it} + \beta_2(\text{Diploma})_{it} \\ & + \beta_3(\text{Age})_{it} + \beta_4(\text{Age}^2)_{it} \\ & + \beta_5(\text{Solvency})_{it} \\ & + \beta_6(\text{Subsidies interest})_{it} \\ & + \beta_7(\text{Subsidies revenues})_{it} \\ & + \beta_8(\text{Subsidies income})_{it} \\ & + \beta_9(\text{Shareland})_{it} \\ & + \beta_{10}(\text{Successor on farm})_{it} \\ & + \beta_{11}(\text{Doubt about succession})_{it} \\ & + \sum_{j=1}^{n=6} (\text{Yeardummy})_j + \varepsilon_{it} \end{aligned}$$

The results of the calculation of the one way fixed effects model can be found in Table 7. Both structural and managerial farm characteristics have an impact on the sustainable efficiency of the farms (Table 7). A significant structural farm characteristic is size. Larger farms have a higher sustainable efficiency. Further, life cycle aspects determine the sustainable performance of farming. Age, a managerial characteristic, has a significant negative effect on the sustainable efficiency of dairy farms. Generally, younger farmers have a higher sustainable efficiency. However, from a certain age the negative impact of age is decreasing (indicated by the squared age term in the model). Finally, higher dependency on support payments results in a lower sustainable efficiency. It is important to notice that the used approach is unconditional. We assume that subsidies have an impact on efficiency but

Table 6 – Descriptive statistics of all observations, best scoring and worst scoring observations

Variable	All observations (mean value)	Best 10% observations (mean value)	Worst 10% observations (mean value)
Sustainable efficiency	1.03	1.66	0.49
Sustainable value (Euro)	0.00 ^a	58,107.22	−81,640.09
Age of manager	43.13	40.57	47.28
Solvency ^b	0.42	0.39	0.57
Size unit ^c	16.44	20.31	13.05
Subsidies interest ^d (in %)	1.93	1.46	1.96
Subsidies revenues ^d (in %)	0.13	0.01	0.45
Subsidies income ^d (in %)	3.05	3.10	4.27
Share own land ^e (in %)	28.56	28.22	33.19
Higher education (in %)	55.49	58.46	35.39
Successor on farm (in %)	10.66	7.69	7.69
No successor on farm (in %)	40.03	41.54	33.85
Doubt about succession (in %)	49.30	50.77	58.46
Number of observations	647	65	65

^a The mean sustainable value equals zero which is the consequence of choosing the weighted average return on capital as benchmark.

^b Measured as own capital divided by total capital.

^c Calculated for all farms in the dataset based on standard gross margin (FADN, SD).

^d The subsidies are calculated as a percentage of total revenues, indicating the dependency on support payments.

^e The share of own land is measured as land in property (in ha) divided by total land (in ha).

Table 7 – Panel data estimation of determinants of sustainable efficiency

Variable	Coefficient	St. Error	Variable	Coefficient	St. Error
Size unit ^a	0.0098*	0.0054	Successor farm	0.0060	0.0440
Diploma	0.0151	0.0532	Doubt succession	0.0258	0.0306
Age	–0.0285**	0.0144	Dummy 1995	–0.0202	0.0310
Age ²	0.0003**	0.0002	Dummy 1996	–0.1013***	0.0302
Solvency ^b	–0.0775	0.0863	Dummy 1997	–0.0471	0.0323
Subsidies interest ^c	–1.8350***	0.6617	Dummy 1998	0.1386***	0.0332
Subsidies revenues ^c	0.4483	3.6737	Dummy 1999	0.4362***	0.0276
Subsidies income ^c	–2.0540***	0.6664	Dummy 2000	0.1053***	0.0307
Share own land ^d	0.0050	0.1081			
Number of observations		647	Lagrange multiplier		394.35
Adjusted R-squared		0.79	Hausmann statistic		35.84

Dependant variable: sustainable efficiency.

*Significant at 10%; ** significant at 5%; *** significant at 1%.

^a Calculated for all farms in the dataset based on the standard gross margin (FADN, SD).

^b Measured as own capital divided by total capital.

^c The subsidies are calculated as a percentage of total revenues, indicating the dependency on support payments.

^d Measured as land in property (in ha) divided by total land (in ha).

that efficiency has no impact on subsidies. To confirm partly the validity of this assumption, the same efficiency model was tested but instead of using the subsidies dependency in year t the subsidies dependency in year $t - 1$ was used. The results of this lagged model were similar and confirm our results. Hence, we are quite confident of our results (Table 7), assuming unconditionality. Finally, observing the year dummy variables in our model, we can demonstrate that the observed differences between the years (Fig. 1) in sustainable efficiency were significant.

4.6. Eco-efficiency, partial productivity and sustainable efficiency

As indicated above, the sustainability efficiency indicator used in this research is an aggregated indicator taken into account different aspects of sustainability. Therefore, it is interesting to compare our results using the sustainable efficiency measure with other measures, such as partial productivity measures or eco-efficiency measures. Partial productivity measures take only one factor into account and are calculated as *value added* divided by *input use*. Examples are labour, capital and land productivity. Eco-efficiency is calculated as *value added* divided by *environmental impact*.

To test the interplay between the sustainable efficiency measure, the partial productivity measures and the eco-

efficiency measures, the rank correlation (Spearman's rho) between these measures are calculated (Table 8). The partial labour productivity, capital productivity and land productivity are used to measure economic performance. The eco-efficiencies of nitrogen surplus and energy use are used to measure environmental performance.

We found that farms with a high sustainable efficiency also have a high productivity (the rank correlation with capital productivity is low but still positively significant) and a high eco-efficiency (Table 8). This indicates that the sustainable efficiency indicator can be a useful indicator to incorporate economic and environmental aspects. The low correlation between capital productivity and the other productivity and efficiency measures may indicate that to increase the efficiency or performance of other capital items, financial capital is needed and thus that increasing land or labour productivity or environmental performance decreases the capital productivity.

In general, our results lead to the conclusion that sustainable efficient farms have both good economic and environmental results. It means that economic performance may go hand in hand with environmental performance, indicated by the positive correlation between the partial productivity measures and the eco-efficiency measures and need not to be opposite to each other as is often thought.

Table 8 – Correlation between the rankings of sustainable efficiency, partial productivities and eco-efficiencies

	Sustainable efficiency	Partial productivities			Eco-efficiencies	
		Labour	Land	Capital	Energy	Nitrogen
Sustainable efficiency	1.00	0.59***	0.58***	0.25***	0.65***	0.69***
Labour productivity		1.00	0.51***	–0.08	0.32***	0.36
Land productivity			1.00	–0.11***	0.51***	0.47***
Capital productivity				1.00	0.02	–0.01
Eco-efficiency energy					1.00	0.67***
Eco-efficiency nitrogen						1.00

*Significant at 10%; ** significant at 5%; *** significant at 1%.

Finally, there is also a positive significant correlation between the eco-efficiency of energy and the eco-efficiency of nitrogen surplus. This confirms the conclusion of Meul et al. (2005) that there is a positive relationship between the nitrogen use efficiency and the energy use efficiency on Flemish dairy farms.

5. Conclusion

Kaufmann and Cleveland (1995, p. 111) pose the following appeal: “Enough with theoretical arguments about sustainability indices! To study sustainability, quantify the economic and ecological determinants of the temporal and spatial patterns of the supply and demand, and model these dynamics. Just do it!” With the presented research, we tried to answer this call by focusing very particularly on the assessment of sustainable value creation in one of the main activities of the Flemish agricultural sector.

Although sustainability is a global concept and a farm is only a small subsystem that interacts in various ways with surrounding systems, companies are essential actors to contribute to the realization of sustainable development. Indicators are needed to know whether a company is moving towards or away from sustainability. Indicators can also be used to educate farmers and other stakeholders about sustainable production. Furthermore, indicators provide farmers with a tool to measure their achievements toward sustainability. Further, indicators allows for comparisons between farms’ performance in the economic, social and environmental aspects of their production. Indicators also inform policy makers about the current state and trends in farm performance or sector performance. Sustainability performance measures can be used as input for policy tools and stimulate better integration of decision-making. Finally, sustainability indices can encourage public participation in sustainability discussions.

An interesting approach to assess firm sustainability is the use of a capital approach and the concept of opportunity costs to determine the company’s value. The calculation of the sustainable value and sustainable efficiency as in Figge and Hahn (2005) is a simplified and quantified expression for the complex farm system. While no measure of sustainability can be perfect, the sustainable value is a useful measure and describes the current sustainability performance. On the other hand, the ‘sustainable efficiency’ indicator can be used to compare and rank farms. Benchmarking can help farmers and policy makers to highlight opportunities for improvement and where best practices might be found. Our analysis shows that this methodology is an interesting approach, because it allows assessing sustainable development of agriculture in such an integrated way that it provides good guidance for decision making.

An important advantage of the methodology is the fact that it gives decision makers environmental information in a form they are familiar with and which can readily be compared with other types of information. The ‘sustainable value’ and ‘sustainable efficiency’ measures link many sustainability issues and thus, the number of decision-making criteria that need to be considered is reduced. A possible disadvantage is that information about some important social and environ-

mental aspects is not available in current data samples and is often not quantifiable.

This methodology has already been tested using large multinational firms (e.g. Figge and Hahn (2005)). Our analysis shows that the methodology is also useable and workable for smaller enterprises. European agriculture is still dominated by family farms and agricultural products are produced by small to medium sized enterprises. Moreover we applied this methodology using a large amount of data. Calculating the sustainable value and efficiency of 41 dairy farms during seven years provides us with several insights. Analysing the evolution of the sustainable value is more accurate than analysing the evolution of the value added, precisely because environmental aspects are incorporated in the calculation of the ‘sustainable value’ measure. For example in our application of the Flemish dairy farms, the improvement of nitrogen use is incorporated in the calculation of the sustainable value.

Not only the performance measurement itself, but also the analysis of reasons why farms differ in relative efficiency may yield new insights and can give feedback to the concerned policies and government interventions. The large amount of data available in the FADN database creates the opportunity to analyse differences in sustainable efficiency using an empirical model. The effect model captures potential determinants of the sustainable efficiency of farming. We found that both managerial and structural farm characteristics explain differences in the sustainable efficiency of dairy farms. Our empirical model shows that farm size, farmer’s age and the dependency on support payments are important characteristics in explaining differences in sustainable efficiency.

The average weighted benchmark is preferred in our analysis because the main objective of this research was to understand why farms differ in their sustainable efficiency. This benchmark is found to be robust. However, within the scope of policy analysis the choice of an accurate benchmark may be more important. In that case using performance targets as benchmark may be very useful to analyse the efforts of farms to reach these targets. Therefore we suggest using either the ideal farm as benchmark or using given policy targets (e.g. the nitrogen target).

Our analysis further revealed that over the observed period (1995–2001), the same farms were found to contribute most towards sustainability. Hence, this proves the existence of frontrunners and laggards among the farms in our data sample. We also found that sustainable efficient farms appear to have both good economic and good environmental results or in other words that economic and environmental performance is not contradictory. Moreover, we found a low correlation between the capital productivity and the sustainable efficiency measure. This may indicate that increasing the sustainable efficiency of dairy farms requires financial capital or in other words that there may be a trade-off or substitution between financial capital and the other capital forms.

Finally, we may draw a couple of lessons for public authorities. Our results reveal that shifts from resources (mainly land) from non efficient farms to efficient farms will improve the performance of the overall sector. Based on the results of our study, policies to improve the exit of farms with elder farmers as well as policies to improve the transition of

their farms and/or production assets to younger and more efficient farms may contribute to an overall improvement in sustainability performance. Hereby subsidies should however been applied with care because our outcomes also suggest a negative correlation of efficiency with subsidies on investments (in which first instalment is comprised). The more a farm depends on support payments, the lower its sustainable efficiency. The reason for this result is not clear. A plausible explanation may be that agricultural policy is encouraging a less competitive agricultural sector by providing grants that give wrong incentives to farmers who stay in non-profitable sectors or farming systems, resulting in e.g. sub-optimal investments. Therefore first installation subsidies could be subject to a more careful examination of the sustainability performance of a farm and made conditional on certain sustainability investments. On the other hand, it may be that subsidies result in certain positive amenities or have social benefits (e.g. survival) which were not included in our analysis. Also the problem of conditionality may be a problem as it is possible that it is an objective of policies to support farmers with a lower (economic) sustainable efficiency.

In this research the sustainable value of a farm is compared within the Flemish dairy sector. In other words an intra-sector comparison (or best in class approach) was made. Note that benchmarking within a sector only shows the potential for improvements within a given activity. This implies that the agricultural structure remains constant and that dynamics are not taken into account. An exercise of comparing sustainability performance of farms of different agricultural sectors would be very interesting but very difficult because of data constraints.

Even though further development is desirable, the methodology employed in this research to measure farm sustainability proofs to be promising. A challenging topic for the future is certainly the consideration of positive externalities and the performance up or down the value chain.

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