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Exploring the regional efficiency of the Swedish agricultural sector during the CAP reforms – multi-directional efficiency analysis approach

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ABSTRACT

When designing structural reforms for rural areas, the regional dimension is crucial. This study implemented a multi-directional efficiency approach in a regional, rural development context with the aim of analysing the regional efficiency of agricultural resources. The efficiency patterns of each input and output were observed over three Common Agricultural Policy (CAP) periods (1998-2013). Efficiency of labour, assets and diversified output vary the most. Over the CAP periods, the efficiency gap across the counties decreases, indicating that changes in the policy help for regions cohesion. Future policies should keep compensating for generation of public goods, and creating opportunities for diversification.

1. Introduction

Inefficient farm structures, where agricultural resources are not fully utilised, are problematic for rural areas (Anania et al., 2003). Improving the potential for utilising agricultural resources supports farm development and facilitates rural development (Anania et al., 2003; Ezcurra et al., 2011). In the European Union (EU), balanced development across rural areas is maintained by the Common Agricultural Policy (CAP), covering aspects such as farming, land use, management of natural resources, and economic diversification in rural communities (European Commission, 2016).

To provide a sound background for decision making in agricultural policy, a number of empirical studies have analysed the impact of the CAP on the efficiency of the agricultural sector, and summarised the findings to explain differences between regions. Findings show that the impact of the CAP varies across different CAP periods, and depends on both the CAP programme/support and the regional/country specifics (Lakner, 2009; Lakner et al., 2014; Latruffe et al., 2016; Minviel and Latruffe, 2017; Špička and Smutka, 2014; Zhu and Milán Demeter, 2012). The recent meta-analysis on empirical studies analysing the impact of public subsidies on technical efficiency by Minviel and Latruffe (2017), shows that in most of these efficiency studies, assumptions about the characteristics of regional efficiencies in the agricultural sector and the impact of the CAP are based on farm-level efficiency analysis. Furthermore, in most of the efficiency studies, the best input-output combinations are presented as “single efficiency estimates”, averaged[1] for sample firms operating in the region/sector/industry. However, CAP reforms do not necessarily impact the use of each input and output in the same way. For instance, measures stipulating uptake of agro-environmental practices are more labour intensive and may initiate changes in labour need (Nordin and Manevska-Tasevska, 2013). At the same time, extra agricultural or diversified output might be produced by minor adjustments in the use of the remaining inputs (e.g. fixed costs), leading to efficiency improvements in these inputs and outputs. Hence, ranking the regions based on one overall efficiency measure calculated at farm level does not provide information about how regions are performing with respect to each individual available input and output used in the region. Last, but not least, the existing studies mainly focus on change before and after the decoupling, (i.e. coupled vs decoupled support), but not on the other reforms that bring rurality and environmental concerns (Latruffe et al., 2016).

The present study moves beyond the existing literature by implementing the variable-specific, multi-directional efficiency analysis

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[1] The arithmetic/geometric average of farm-level efficiencies by region does not necessarily reflect the efficiency of the corresponding region, unless the size and performance of firms included in the analysis are uncorrelated For example, average efficiency is lower than aggregate efficiency, group (regional, industry *etc.*) efficiency where larger units are more efficient than smaller ones and *vice versa.* Karagiannis, 2015. On structural and average technical efficiency. Journal of Productivity Analysis 43, 259 – 267.

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(MEA) (Asmild et al., 2003) in a regional, rural development context. The aim of the study is twofold. First, to analyse the regional efficiency of agricultural resources in Sweden. Second, to explore how efficiency patterns of the Swedish regions evolved during the last three CAP programmes: CAP 1 (for 1998 – 2002); CAP 2 (for 2003 – 2007); and CAP 3 (for 2008 – 2013). CAP 1 covers the coupled income support and agri-environmental payments to farmers who voluntarily complied with ecological practices. CAP 2, starts with the Fischler reform in 2003, when decoupled direct payments dependent on cross-compliance were introduced. Finally, CAP 3 includes new challenges of rurality and environmental conditions, e.g. climate change, renewable energy, biodiversity, and water management, in rural development programmes.

This study adds to the existing efficiency literature linking CAP reforms and regional efficiency, and the discussion about the ability of the CAP to achieve its objectives. MEA is an accepted approach (e.g. Wang et al., 2013) for evaluating how the implementation of policies relate to both input reductions and output improvements, without prioritising some resources and outputs over others. We provide evidence for 16 years over three CAP reforms (1998–2013), and thereby opportunities for making sound policy recommendations for further improvements in input- and output-specific efficiencies, with geographical differentiation in policy.

Estimating the potential improvement of each input and output, i.e. variable-specific efficiency, by means of a non-parametric MEA approach was first suggested by Bogetoft and Hougaard (1999), and initially implemented by Asmild et al. (2003), in order to measure the efficiency of Danish dairy farms. In agricultural sector applications, the MEA approach is becoming a common tool for analysing farm-level efficiency (e.g. Asmild et al., 2016b; Hansson et al., 2020; Kapelko et al., 2017; Labajova et al., 2016). Kapelko et al. (2017) emphasised that the farms in different regions are likely to face different production environments, and included the regional aspect by using a meta-frontier approach at farm level. MEA in a regional context has applications on, for example, energy and environmental efficiency (Wang et al., 2013; Wang et al., 2015; Zhu et al., 2019). Non-parametric Data Envelopment Analysis (DEA) -based approaches have been used to analyse regional efficiency since the pioneering study on multi-regional economic planning by Macmillan (1986). However, the majority of these studies refer to other sectors, e.g. socio-economic development (Martić and Savić, 2001), the use of infrastructure and human capital (Schaffer et al., 2011), the tourist industry (Suzuki et al., 2011), regional sustainability (Gerdessen and Pascucci, 2013), research and development (Han et al., 2016), recycling (Expósito and Velasco, 2018), and so on. Due to the methological limitations of DEA, all of these provide an aggregated indicator on either input efficiency (e.g. Han et al., 2016; Špička and Smutka, 2014) or output efficiency (Expósito and Velasco, 2018; Gerdessen and Pascucci, 2013; Martić and Savić, 2001; Schaffer et al., 2011), whereas the use of MEA results in variable-specific indicators of efficiency.

Benchmark analysis of regions are useful to learn from when public policy recommendations are offered (Expósito and Velasco, 2018). Compared with farm-level analysis, a regional-level analysis may be better suited to rural policy decision making, updated in line with CAP reforms (Ezcurra et al., 2011), and is expected to become increasingly important in the future, in order to support decision making, related to rural development policy (Gerdessen and Pascucci, 2013). The need for regional indicators is apparent, as public policy making is done at community or regional level. Regional governments tend to select policy objectives or priorities based on specific regional features (Anania et al., 2003; Esposti and Sotte, 2013; Galinienė and Dzemydaitė, 2012; Trouvé and Berriet-Solliec, 2010). The effectiveness of the policy depends on the institutional capacity to select priorities and measures that would lead to the desired objectives, and to encourage farmers to comply with these policies (Esposti and Sotte, 2013). Here, we thus contribute to regional-level analysis by providing an MEA in a regional, rural context.

The CAP is ‘spatially targeted’, defining targets in terms of a combination of geographical, sectoral, and socioeconomic attributes of the regions, and thus has a spatial impact (Crescenzi and Giua, 2016). The regionalisation of policy-making in the EU has been underway for over half a century (Trouvé and Berriet-Solliec, 2010), and the regional dimension is central when designing structural reforms for rural areas (Marsden and Sonnino, 2008). The regionalisation of the CAP is promoted for both the first and second pillar measures (Trouvé and Berriet-Solliec, 2010). In particular, the distribution of CAP support, e.g. direct payments, payments to environmentally sensitive regions, etc., are designed to fit regional production potential and rurality, but not the costs of individual farms (Manevska-Tasevska et al., 2016; Marsden and Sonnino, 2008). Over the last two decades, the regional focus of CAP became evident with the Fischler reform of 2003, when the distribution of direct payments was based on regional historical returns for agricultural activity, making the most productive regions larger recipients of direct payments per hectare. The Health Check reform in 2008 focused on environmental and rural development protection, providing targeted measures to address economic and/or environmental disadvantages in certain regions. The regional focus of CAP continued after 2013, especially with the regional adjustments of direct payments (which represent around 70–75 % of total CAP funding), i.e. “flat-rate”. The new “flat-rate” regionalisation implies a uniform amount per hectare for direct payments, to be implemented by 2019 in all EU countries. The aim is to ensure a more equitable distribution of the CAP support (European Commission, 2015). Proper regionalisation of the CAP may reduce the inequalities, and the probability of agriculturally productive regions to benefit from the CAP. The balance across the regions questions the degree of commonality of the CAP (Trouvé and Berriet-Solliec, 2010), and its contribution to the EU’s objectives for regional cohesion. With the regional-level MEA of this study, we contribute insights of regional development in Sweden across three CAP periods.

The remainder of the paper is structured as follows: section two describes the model framework and data; empirical results are presented and discussed in section three; and conclusions and policy recommendations are presented in section four.

2. Model framework

2.1. Data and variables

For the present analysis, data from the Swedish Farm Accounting Data Network (FADN) provided by the Swedish Board of Agriculture for the period 1998–2013 (17,188 observations, representing 2397 farms) were aggregated[2] to fit the regional approach.

In total, 21 Swedish counties were studied, following the NUTS 3 regional division (as in Schaffer et al., 2011). See Fig. A1 in the Appendix for more details. FADN data were aggregated by Esposti (2007) to create regional series of CAP payments at NUTS 2 and NUTS 3 levels. Indeed, the data collection procedure for the FADN follows a methodology that aims to reflect the heterogeneity of farming and provide representative data covering different regions, economic sizes, and types of farming (i.e. a three-way stratification). Therefore, regional aggregation of the FADN data was considered appropriate for the present analysis.

In this study, the aggregate values of the outputs and inputs of each county were obtained as a sum of the corresponding outputs and inputs of each farm in that county. Thus, aggregate values do not reflect the total use of inputs and production of inputs in the county, but a share that, owing to the three-way stratification used to collect the FADN data, can be taken to be representative of the county. All inputs and outputs were calculated based on standard FADN definitions (European Commission, 2018).

Output selection followed the multifunctional aspect of agricultural activity in the counties. Two outputs were included: i) agricultural output (AO), representing the total revenue from sales of agricultural products in the counties, and ii) diversified output (DO), representing the total revenue from on-farm activities outside conventional agriculture, such as farm shops and tourism, and renting out machinery, buildings and livestock for insemination, or on-farm processing of farm products using agricultural resources (such as land holdings, buildings, machinery, and labour) (Barnes et al., 2015). Both output variables are expressed in thousand SEK.[3]

For each county, inputs were represented by: i) variable costs (VC), containing the total specific costs of plant and animal production (expressed in thousand SEK); ii) fixed costs (FC), representing depreciation, rents and interests (expressed in thousand SEK); iii) labour (L), considering the total hours of unpaid and paid labour engaged (expressed in thousand working hours); and iv) assets value (A), reflecting the size of the opportunity costs of the capital not covered in FC, and including the total asset value of land, machinery, buildings, breeding and non-breeding livestock, (expressed in thousand SEK). All input and output variables expressed in monetary values were deflated using the respective price index of Statistics Sweden (Statistics Sweden, 2019), with 2000 as the base year. The means of input and output variables at sample and county level over the three CAP periods are given in Table A1 in the Appendix.

2.2. Estimating the multi-directional regional efficiency of Sweden's agriculture

MEA, which has the advantage of simultaneously providing multi input-output efficiency[4] estimates (Asmild et al., 2016b; Hansson et al., 2020), was used in this study. That approach allowed us to estimate the efficiency of both inputs and outputs included in the production, but also to analyse how the efficiency evolves along the CAP reforms (see section 2.3). The benefit of using a non-parametrical approach is mainly explained through the uncertainties of proper selection of the underlying regional production function, which is necessary when the parametric approach is used (Schaffer et al., 2011; Suzuki et al., 2011).

Regional efficiency studies have been conducted using both constant returns to scale (CRS) and variable returns to scale (VRS) (Han et al., 2016; Maudos et al., 2000). Gerdessen and Pascucci (2013) assessed the sustainability of regional agricultural systems and showed that the results are not particularly sensitive to assumptions concerning CRS and VRS, and barely affected by choosing an input or output-orientated model. In the current study, VRS was considered theoretically more appropriate in order to allow for economies of scale because inputs such as agricultural land are only available in a certain extent (included as part of total asset value) in each region. Pooled data for the period 1998–2013 were used to facilitate direct comparisons of efficiency scores between periods and to boost the sample size, thereby strengthening the method's discriminatory power (Asmild et al., 2016c; Wang et al., 2013). In estimating multi-directional efficiency (ME) scores, the set of territorial units/counties ($c = 1, \ldots, 21$) in the dataset were considered in each study year t, where ($t = 1, \ldots, 16$). A county c in year t uses four production inputs $x_{j,c}^{t} (j = 1, \ldots, 4)$ to produce two outputs $y_{i,c}^{t} (i = 1, 2)$. Linear programming equations used for calculating VRS-ME scores (Eqs. 1–4) were solved using the benchmarking package in the R programme. First, for a given time = t and for each input $j = 1, \ldots, 4$ and county $(x_{jc_0}^{t}, y_{ic_0}^{t})$ the following was solved:

$$\begin{aligned} & min_{\lambda_c, a_{j,c_0}^t} \; a_j^t \\ & s.\ t. \\ & \sum_c \lambda_c x_{j,c}^t \le a_{j,c_0}^t \\ & \sum_c \lambda_c x_{-j,c}^t \le x_{-j,c_0}^t \\ & \sum_c \lambda_c y_{i,c}^t \ge y_{i,c_0}^t \; i = 1, 2, 3 \\ & \sum_c \lambda_c = 1 \\ & \lambda_c \ge 0 \end{aligned} \tag{1}$$

In Eq. (1),($-j$) denotes all inputs except input j.

Second, for a given time = t, for each output $i = 1, 2$ and county $(x_{j,c_0}^{t}, y_{i,c_0}^{t})$ the following was solved:

$$\begin{aligned} & max_{\lambda_c, \alpha_{i,c_0}^t} \; \alpha_i^t \; s.\ t. \\ & \sum_c \lambda_c x_{j,c}^t \le x_{j,c_0}^t j = 1, \ldots, 4 \\ & \sum_c \lambda_c y_{i,c}^t \ge \alpha_{i,c_0}^t \\ & \sum_c \lambda_c y_{i,c}^t \ge y_{-i,c_0}^t \\ & \sum_c \lambda_c = 1 \\ & \lambda_c \ge 0 \end{aligned} \tag{2}$$

In Eq. (2),($-i$) denotes the outputs except output i. The solutions to Eq.s 1 and 2 resulted in an ideal reference point $(a_{1,c_0}^{t*}, \ldots, a_{4,c_0}^{t*}, \alpha_{1,c_0}^{t*}, \alpha_{2,c_0}^{t*})$ for county $(x_{c_0}^{t}, y_{c_0}^{t})$. The values $(a_{1,c_0}^{t*}, \ldots, a_{4,c_0}^{t*})$ refer to the solutions to the input minimisation problems, and the values $(\alpha_{1,c_0}^{t*}, \alpha_{2,c_0}^{t*})$ refer to the solutions to the output

[2] In proceeding with the aggregation of farms in each Swedish region, it is implicitly assumed that each farm is characterised by a homothetic technology represented by an appropriate (Gorman polar form) cost function. Then, as stressed by Chambers (1988), all these farms' cost functions can be aggregated to form an aggregate cost function for each region. This is the basis to justify the possibility to define an aggregate technology for each Swedish region through which the efficiency analysis reported in this paper is conducted. Chambers R. G. (1988). Applied Production Analysis. A Dual Approach. New York: Cambridge University Press.

[3] SEK is the currency symbol for the Swedish krona; 1 SEK ≈ 0.09 euros in 2019.

[4] Data in this study are expressed in costs comprising both the amounts of production factors and outputs (technical efficiency) and their prices (allocative efficiency). Therefore the term economic efficiency (or simply efficiency), which reflects both technical and allocative aspects, is appropriate. Thus this

(*footnote continued*)
study refers to efficiency rather than technical efficiency (as in Hansson et al., 2020).

maximisation problems. Next, the ideal reference point for (x^t_{c0}, y^t_{c0}) calculated in the first step was used to solve the following programme:

$$max_{\lambda_c, \beta^t_{c0}} \beta^t_{c0} \text{ s.t.}$$

$$\sum_c \lambda_c x^t_{j,c} \leq x^t_{j,c} - \beta^t_{c0} (x^t_{j,c0} - a^*_{j,c0}),\ j = 1,\ 2,\ 3,\ 4$$

$$\sum_c \lambda_c y^t_{i,c} \geq y^t_{i,c} + \beta^t_{c0} (\alpha^*_{i,c0} - y^t_{i,c0}),\ i = 1,\ 2$$

$$\sum_c \lambda_c = 1$$

$$\lambda_c \geq 0 \quad (3)$$

Finally, the solution $(\lambda^*_C, \beta^{t*}_{c0})$ was used to determine the vector of relative variable-specific ME scores for county (x^t_{c0}, y^t_{c0}) as:

$$\left(\frac{x^t_{1,c0} - \beta^{t*}_{c0}(x^t_{1,c0} - a^{t*}_{1,c0})}{x^t_{1,c0}}, \frac{x^t_{4,c0} - \beta^{t*}_{c0}(x^t_{4,c0} - a^{t*}_{4,c0})}{x^t_{1,c0}}, \frac{y^t_{1,c0}}{y^t_{1,c0} + \beta^{t*}_{c0}(a^{t*}_{1,c0} - y^t_{1,c0})}, \frac{y^t_{2,c0}}{y^t_{2,c0} + \beta^{t*}_{c0}(a^{t*}_{2,c0} - y^t_{2,c0})}\right) \quad (4)$$

ME scores take a value between zero for totally inefficient and 1 for totally efficient regions.

The present study was based on panel data for 16 years, but did not disaggregate the efficiency into technological and efficiency change. Thus the MEA Malmquist approach (Asmild et al., 2016a) could be used.

2.3. Exploring patterns of efficiency scores across the main CAP reforms

The patterns within the ME scores were explored both visually and statistically. First, to visualise the changes in the ME scores across the CAP periods, non-parametric kernel-based density functions were used. Kernel-based density functions can visually represent results obtained from non-parametric efficiency analysis, and are favoured over commonly used histograms for providing smoother density estimates and not depending on the width and number of bins (Baležentis et al., 2014).

Second, to identify the presence of statistically significant differences between the medians of each ME score across the three CAP periods for the sample and each county separately (as the assumption of normality was not met)[5], the Kruskal-Wallis test (Kruskal and Wallis, 1952) was applied as a non-parametric alternative to one-way ANOVA, i.e. as a one-way ANOVA on ranks. The conclusions from the Kruskal-Wallis test were that the medians of at least two CAP periods were different, but no information was provided on which specific CAP periods groups were statistically significantly different from one another. Since three groups were defined, one for each CAP period, it was important to determine whether these groups differed from one another. For that purpose, the post hoc Dunn's test (Dunn, 1964) is suggested as an appropriate procedure after the Kruskal-Wallis test (Dinno, 2015). Furthermore, since the decision to reject the null hypothesis (that no variation exists in medians of each ME score across the three CAP periods) in rank tests depends both on the p-values of each pairwise test and the rank, the Holm adjustment (Holm, 1979) was specified to identify the significance.

3. Empirical results and discussion

3.1. Multi-directional efficiency scores

Table 1 presents the average ME scores for the overall sample and for each of the counties included in the analysis for each of the three CAP periods. Considering all sample means (see Table 1), the average ME of the inputs ranged from 0.90 to 0.94 for ME variable costs (ME_{VC}), 0.84 – 0.95 for ME fixed costs (ME_{FC}), 0.86 – 0.90 for ME assets (ME_A), and 0.84 – 0.92.ME labour (ME_L). At sample level, there were only small differences in ME_{VC}, both across CAP periods, and across the counties. Larger variations among the counties were found for the utilisation of assets (ME_A) and labour (ME_L). The sample means for the efficiency of outputs ranged from 0.61 to 0.82 for diversified output (ME_{DO}) and from 0.90 to 0.94 for agricultural output (ME_{AO}). Both at sample and especially at county level, the potential for further improvements was greatest for $ME_{DO.}$

Patterns from our findings are in line with the results from recent studies applying ME at farm level. For example, Hansson et al. (2020) and Labajova et al. (2016) found that dairy and pig farms in Sweden are most efficient in utilising the variable inputs, and in producing outputs from the main agricultural activity. Similar results have also been presented for two other ME input-specific efficiency studies, where Kapelko et al. (2017) and Asmild et al. (2016b) found that the efficiency of the European dairy manufacturing firms, and the efficiency of Lithuanian farms is highest for the utilisation of materials, followed by labour and fixed assets.

Studies focusing on output efficiency, e.g. Schaffer et al. (2011), found that improvements in regional efficiency are driven by growing outputs, rather than decreasing inputs. Among the different outputs, diversified output has been identified as one of the most important for efficiency at regional level, especially in regions where farm growth is restricted (Lakner et al., 2014). However, in both studies (Lakner et al., 2014; Schaffer et al., 2011), efficiency is observed as aggregated output efficiency, which prevents observation of the efficiency potential of inputs.

The result showing high efficiency in material use, i.e. small differences in variable costs, can be an indication of a greater focus and available knowledge of the technological requirement of agricultural production organised in the counties. Assets are less adjustable in the short run, but lower efficiency could also be related to non-use values (Hansson et al., 2020). More knowledge in terms of utilisation of assets is needed, likely supported with possibilities for structural development across the counties. The lower efficiency in labour can indicate possibilities for further substitution of labour with capital (as in Špička and Smutka, 2014). However, the larger gap in labour utilisation across the counties can also be an indication for activities related to generating public good in these counties (Špička and Smutka, 2014), i.e. where the uptake of environmental friendly approaches is greater. In regard to output efficiency, it seems there is a common knowledge shared for the agricultural activities, but that knowledge might be lacking about the possibilities/and know-how for generating diversified income from the available agricultural resources. This could be a signal that future county efficiency can be expected to be driven by improvements in the efficiency of diversified output (as in Lakner et al., 2014).

Among the counties, over the three CAP periods, the best-performing in terms of efficiency were those located in the agriculturally most intensive areas and those with large cities (i.e. Skåne, Halland, Västra Götaland, Stockholm, and Uppsala). Lower efficiency of inputs, particularly ME_L, and underproduction of outputs, mainly ME_{DO}, was found for some counties in central and northern Sweden (see geographical regions 'Västerås', 'Mitt', and 'Norr' in Fig. A1 in the Appendix), especially during CAP 1 and CAP 2. These findings support the literature showing that regional efficiency is unevenly distributed across space, whereas the structural characteristics, economies of scale (e.g. Špička and Smutka, 2014), agglomeration (e.g. Lakner, 2009), and local environmental and institutional context (Latruffe et al., 2016), can be among the main drivers. Our findings are partly in line with, for example with, Lakner et al. (2014), who found that multifunctional farming is typical in regions with relatively low or marginal agricultural production potential. Among the counties with agricultural disadvantages, Norbotten was found to have relatively high ME across the

[5] The normality of ME scores was tested using both skewness and kurtosis tests and the Shapiro-Wilks W test for normal data. Results are available upon request.

Table 1
Mean multi-directional efficiency (ME) of inputs and outputs over the three CAP periods for the sample (country) and for each county.

		CAP 1: 1998-2002						CAP 2: 2003-2007						CAP 3: 2008-2013					
		INPUTS				OUTPUTS		INPUTS				OUTPUTS		INPUTS				OUTPUTS	
		ME_{VC}	ME_{FC}	ME_L	ME_A	ME_{AO}	ME_{DO}	ME_{VC}	ME_{FC}	ME_L	ME_A	ME_{AO}	ME_{DO}	ME_{VC}	ME_{FC}	ME_L	ME_A	ME_{AO}	ME_{DO}
Sample mean		**.90**	**.84**	**.84**	**.86**	**.86**	**.61**	**.92**	**.91**	**.89**	**.89**	**.91**	**.75**	**.94**	**.95**	**.92**	**.90**	**.94**	**.82**
County mean																			
Syd	Blekinge	.90	.84	.86	.85	.89	.60	.95	.93	.92	.90	.94	.82	.94	.90	.90	.82	.93	.73
	Skåne	.95	.85	.84	.91	.95	.75	.97	.93	.93	.93	.97	.90	.99	.99	.98	.96	.99	.97
Väst	Halland	.91	.87	.86	.87	.85	.58	.93	.92	.90	.93	.94	.78	.98	.99	.98	.95	.99	.96
	Västra Götaland	.93	.81	.79	.86	.93	.63	.95	.90	.86	.90	.94	.84	.98	.97	.95	.94	.98	.95
Syd-ost	Gotland	.91	.88	.84	.84	.87	.55	.89	.88	.85	.82	.88	.74	.93	.93	.90	.88	.95	.77
	Jönköping	.90	.88	.81	.94	.91	.74	.91	.91	.83	.92	.94	.83	.97	.97	.92	.96	.98	.92
	Kalmar	.90	.86	.84	.86	.88	.73	.92	.89	.85	.89	.90	.81	.98	.97	.95	.95	.97	.92
	Kronoberg	.90	.85	.82	.84	.90	.52	.90	.90	.86	.86	.89	.78	.92	.94	.89	.85	.99	.88
	Östergotland	.91	.82	.83	.83	.88	.75	.94	.89	.90	.86	.91	.89	.93	.93	.95	.88	.94	.88
St oc	Stockholm	.95	.88	.93	.96	.82	.91	1	1	1	1	1	1	.96	.94	.96	.92	.95	.89
Västerås	Södermanland	.85	.76	.78	.75	.75	.63	.88	.85	.85	.80	.83	.71	.92	.91	.90	.84	.92	.70
	Uppsala	.95	.90	.90	.90	.92	.58	.97	.96	.97	.96	.96	.86	.97	.97	.95	.91	.97	.94
	Västmanland	.91	.84	.88	.87	.86	.62	.91	.88	.92	.84	.84	.80	.94	.95	.97	.93	.94	.95
	Värmland	.85	.77	.80	.81	.81	.40	.85	.85	.85	.82	.86	.56	.88	.92	.88	.83	.88	.76
	Örebro	.86	.80	.83	.76	.86	.36	.92	.90	.92	.85	.92	.45	.93	.93	.95	.88	.92	.82
Mitt	Dalarna	.98	.91	.93	.95	.96	.74	.98	.95	.95	.95	.89	.70	.91	.90	.89	.84	.92	.57
	Gävleborg	.84	.79	.76	.81	.77	.50	.87	.92	.80	.87	.90	.74	.88	.94	.84	.86	.90	.85
	Jämtland	.87	.84	.82	.90	.83	.50	.91	.90	.89	.95	.93	.73	.91	.94	.88	.91	.94	.80
	Västernorrland	.84	.77	.78	.79	.74	.43	.86	.88	.81	.86	.88	.65	.91	.95	.90	.91	.89	.83
Norr	Norrbotten	.99	.98	.96	.98	.94	.93	.99	.97	.98	.98	.96	.93	.93	.94	.93	.94	.96	.80
	Västerbotten	.83	.76	.74	.78	.80	.24	.85	.85	.78	.83	.88	.38	.96	.97	.89	.95	.98	.65

Note: Own estimation, based on FADN 1998–2013.
Variables definitions follow the standard. VC-variable costs, FC-fixed costs, LL-labour, A-assets, AO-agricultural output, DO-diversified output.
Colours and regions correspond to those in Fig. A1 in the Appendix.

Table 2
Kruskal-Wallis test and Dunn's post-test of multiple comparisons of multi-dimensional efficiency (ME) of inputs and outputs at sample (country) level over the three CAP periods.

ME	Kruskal-Wallis		Dunn's test					
			CAP 2: 2003 – 2007 *vs* CAP 1: 1998 – 2002		CAP 3: 2008 – 2013 *vs* CAP 1: 1998 – 2002		CAP 3: 2008 – 2013 *vs* CAP 2: 2003 – 2007	
	Chi^2 with ties	p-value	z	p-value	z	p-value	z	p-value
Inputs								
ME_{VC}	28.271	.0001*	−2.74	.0031	−5.32	.0000	−2.46	.0070
ME_{FC}	111.70	.0001*	−6.14	.0000	−1.05	.0000	−4.14	.0000
ME_L	79.47	.0001*	−4.88	.0000	−8.91	.0000	−3.81	.0001
ME_A	24.82	.0001*	−3.81	.0001	−4.73	.0000	−0.74	.2285
Outputs								
ME_{AO}	68.87	.0000*	−4.52	.0000	−8.30	.0000	−3.58	.0002
ME_{DO}	68.60	.0001*	−5.09	.0000	−8.23	.0000	−2.91	.0018

Note: For the Kruskal-Wallis Chi^2 statistics, * indicates significance at $p < 0.05$ at least. For Dunn's pairwise z-values, where figures are underlined, the hypothesis that no variation exists in medians of each ME score across the three CAP periods is rejected. VC-variable costs, FC-fixed costs, LL-labour, A-assets, AO-agricultural output, DO-diversified output.

Table 3
Kruskal-Wallis and Dunn's post-test of multiple comparisons of the multi-directional efficiency (ME) of inputs and outputs, by county, over the three CAP periods.

		Syd		Väst		Syd-ost					Stoc	Västerås					Mitt				Norr	
		Blek	Skan	HalL	V.Go	Gotl	Jonk	Kalm	Kron.	O.go.	Stock	Sod	Upp	Väst	Varm	Oreb	Dalar	Gavl	Jaml	V.no.	N.bot	V.bo
ME_{VC}	**Kruskal-Wallis Chi^2**	5.68	5.83*	8.05*	5.45	5.09	9.02*	8.70*	0.58	5.35	5.68	8.78*	1.59	5.45	2.43	4.41	7.42*	2.69	7.07*	5.68	2.42	8.59*
	Dunn: CAP2 vs CAP1	-2.26	-1.17	-0.64	-0.86	1.13	-0.66	-0.86	-0.53	-1.53	-2.32	-1.20	-1.23	-0.86	0.66	-1.73	0.27	-1.00	-2.66	-1.20	-0.35	0.13
	Dunn: CAP3 vs CAP1	-1.83	-2.43	-2.70	-2.30	-1.08	-2.84	-2.85	-0.74	-2.28	-0.55	-2.94	-0.66	-2.30	-0.86	-1.92	2.45	-1.63	-1.48	-2.38	1.17	-2.43
	Dunn: CAP3 vs CAP2	0.53	-1.21	-2.04	-1.40	-2.25	-2.15	-1.95	-0.18	-0.68	1.88	-1.69	0.66	-1.40	-1.54	1.12	2.18	-0.59	1.29	-1.13	1.53	-2.57
ME_{FC}	**Kruskal-Wallis Chi^2**	7.84*	11.17*	8.48*	11.66*	4.71	11.66*	9.97*	6.79*	9.16*	7.42*	12.03*	2.84	11.66*	10.34*	8.22*	1.11	10.11*	11.17*	11.17*	0.97	11.66*
	Dunn: CAP2 vs CAP1	-2.72	-2.04	-0.64	-1.93	-0.07	-1.32	-0.27	-1.59	-1.99	-2.80	-1.85	-1.60	-1.93	-1.73	-1.99	-0.60	-2.32	-1.79	-1.79	-0.14	-1.93
	Dunn: CAP3 vs CAP1	-1.98	-3.35	-2.70	-3.41	-1.81	-3.38	-2.82	-2.59	-2.98	-1.46	-3.47	-1.30	-3.41	-3.21	-2.80	0.43	-3.06	-3.34	-3.34	0.80	-3.41
	Dunn: CAP3 vs CAP2	0.86	-1.22	-2.04	-1.40	-1.88	-1.99	-2.54	-0.92	-0.90	1.46	-1.53	0.37	-1.40	-1.41	-0.72	1.05	-0.64	-1.47	-1.47	0.94	-1.40
ME_L	**Kruskal-Wallis Chi^2**	7.71*	11.49*	8.23*	11.98*	5.21	9.23*	8.70*	7.46*	9.16*	6.78*	11.56*	2.80	11.98*	8.45*	8.77*	2.52	9.11*	9.35*	10.22*	1.39	12.44*
	Dunn: CAP2 vs CAP1	-2.32	-1.97	-0.77	-1.66	-0.13	-1.13	-0.86	-1.66	-1.99	-2.66	-1.73	-1.67	-1.66	-1.66	-2.13	-0.47	-1.52	-3.06	-1.00	-0.69	-1.79
	Dunn: CAP3 vs CAP1	-2.51	-3.41	-2.78	-3.46	-1.87	-2.99	-2.86	-2.72	-2.98	-1.20	-3.40	-1.06	-3.46	-2.90	-2.87	1.05	-3.02	-1.69	-3.11	0.51	-3.53
	Dunn: CAP3 vs CAP2	-0.08	-1.35	-1.97	-1.72	-2.01	-1.82	-1.95	-0.98	0.90	1.58	-1.60	0.68	-1.72	-1.17	-0.65	1.54	-1.42	1.50	-2.07	1.23	-1.65
ME_A	**Kruskal-Wallis Chi^2**	5.40	2.81	3.98	6.39*	3.12	11.66*	9.33*	1.42	5.93*	5.52	9.21*	4.43	6.38*	0.12	5.40	9.33*	6.05*	6.05*	10.19*	1.49	9.90*
	Dunn: CAP2 vs CAP1	-1.26	-1.24	-1.24	-1.46	0.33	-1.92	-0.33	-1.00	-2.06	-1.84	-1.73	-2.07	-1.46	-0.13	-1.93	0.33	-2.26	-2.26	-1.99	-0.28	-1.39
	Dunn: CAP3 vs CAP1	1.01	-1.62	-2.00	-2.52	-1.31	-3.41	-2.76	-0.03	-2.19	0.37	-3.03	-0.71	-2.52	0.34	-2.12	2.77	-2.01	-0.35	-3.17	0.92	-3.13
	Dunn: CAP3 vs CAP2	2.32	0.33	-0.70	-0.99	-1.65	-1.39	-2.41	1.07	-0.03	2.29	-1.23	1.45	-1.00	0.21	-0.10	2.41	0.34	2.01	-1.09	1.21	-1.68
ME_{AO}	**Kruskal-Wallis Chi^2**	3.94	6.24*	11.49*	4.53	9.58*	11.56*	9.35*	7.37*	4.83	8.55*	11.56*	2.43	4.53	5.94*	3.12	2.06	9.02*	9.85*	8.35*	0.23	11.63*
	Dunn: CAP2 vs CAP1	-1.73	-0.90	-1.97	0.53	-0.60	-1.53	-0.33	-0.13	-1.20	-3.00	-1.73	-1.47	-0.53	-1.59	-1.59	1.33	-2.59	-2.46	-2.46	-0.21	-1.93
	Dunn: CAP3 vs CAP1	-1.73	-2.48	-3.41	-2.03	-2.90	-3.39	-2.77	-2.24	-2.20	-1.66	-3.40	-1.23	-2.04	-2.40	-1.48	1.15	-2.64	-2.95	-2.58	0.28	-3.41
	Dunn: CAP3 vs CAP2	0.07	-1.53	-1.35	-1.48	-2.28	-1.79	-2.42	-2.38	-0.95	1.47	-1.60	0.30	-1.48	-0.74	0.18	-0.23	-0.06	-0.38	-0.01	0.49	-1.39
ME_{DO}	**Kruskal-Wallis Chi^2**	4.85	10.16*	9.69*	12.04*	8.72*	9.55*	6.15*	7.71*	8.01*	5.47	1.17	7.92*	12.04*	8.37*	8.22*	1.21	9.97*	10.11*	8.72*	1.22	11.12*
	Dunn: CAP2 vs CAP1	-2.19	-1.77	-1.44	-1.86	-1.39	-1.53	-1.52	-2.32	-2.66	-2.18	-0.86	-2.13	-1.86	-1.26	-0.93	0.80	-2.39	-2.32	-1.39	-0.21	-1.59
	Dunn: CAP3 vs CAP1	-1.33	-3.21	-3.13	-3.47	-2.94	-2.46	-2.46	-2.51	-2.22	0.28	-1.01	-2.69	-3.47	-2.87	-2.80	1.06	-3.01	-3.06	-2.95	0.86	-3.33
	Dunn: CAP3 vs CAP2	0.95	-1.36	-1.62	-1.53	-1.49	-0.87	-0.87	-0.08	0.55	1.99	-0.10	-0.46	-1.53	-1.56	-1.83	-0.23	-0.51	-0.64	-1.49	1.07	-1.66

Note: Own estimation, based on FADN 1998–2013.
For the Kruskal Wallis Chi^2 statistics, * indicates significance at $p < 0.05$ at least.
For Dunn's pairwise z-values, underlining indicates significance at $p < 0.05$ at least.
VC-variable costs, FC-fixed costs, LL-labour, A-assets, AO-agricultural output, DO-diversified output.
CAP 1: 1998 – 2002, CAP 2: 2003 – 2007, and CAP 3:2008 – 2013
Colours and regions correspond to those in Fig. A1 in the Appendix.

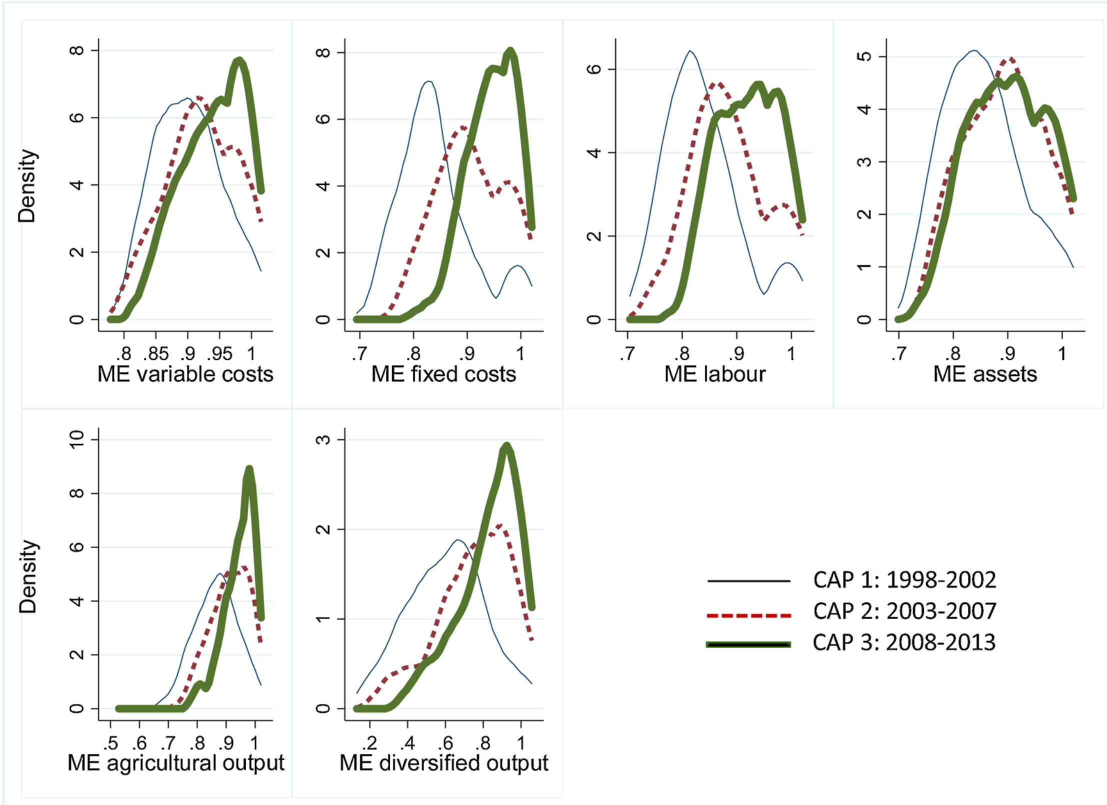

Fig. 1. Kernel density estimates of the multi-directional efficiency (ME) of inputs and outputs over the three CAP periods: 1998-2002, 2003-2007, and 2008-2013.

whole period. However, the efficiency of other counties in the environmentally disadvantaged regions increases continuously, especially under CAP 3. The development of efficiency along the CAP periods is discussed in the next chapter.

3.2. Changes in efficiency scores between CAP periods

Results from the analysis of variance in ME scores across the three CAP periods at sample and county level are given in Tables 2 and 3, respectively. Here, the Kruskal-Wallis test is represented by Chi^2 and p-values (statistical significance at $p < 0.05$). Dunn's test (with Holm adjustment) is represented by z-values (statistical significance at $p < 0.05$). Dunn's test shows the stochastic dominance among multiple pairwise comparisons, but z-values and corresponding p-values do not provide information on magnitude, and the effects of external factors cannot be controlled.

The Kruskal-Wallis and Dunn's tests (see Table 2) for the pairwise comparisons between the CAP periods, and the kernel density estimates of the ME scores over the three CAP periods (see Fig. 1) indicate continuous improvements in the mean efficiency of all inputs and outputs, except for ME_A in CAP 3 relative to CAP 2 (see Table 2). In CAP 3, ME_A did not continue the progress from CAP 2, likely due to slowed-down structural changes in the counties (Nordin and Manevska-Tasevska, 2013). The magnitude of efficiency improvements varies across different CAP periods, and across counties. Efficiency of ME_{AO} and ME_{VC} is high over the whole period, and the improvements are incremental. Improvements are largest for ME_L, ME_{FC}, and ME_{DO}, especially in CAP 3 compared with CAP 1 and CAP 2. Despite the increase in CAP 2, and in CAP 3, in comparison to the remaining ME coefficients, ME_L (in CAP 3) and ME_A (in CAP 2 and CAP 3) have the largest variations from the mean, which can be explained with local differences in use of labour and assets across the counties. Counties in environmentally sensitive regions improved the most (see Table 3); except Dalarna, where the ME coefficients decreased (Table 2), statistically confirmed for ME_{VC}, and ME_A, (Table 3).

Policy changes that promote generation of public good and social output (e.g. employment), such as the reform in CAP 3, can be associated with the lower efficiency of labour and capital use. Špička and Smutka (2014) showed that agricultural enterprises in inefficient regions produce more non-commodity output, i.e. public good. Our findings are in line with research showing that environmental concerns slow down the structural development and increase the need for labour, where compliance with such policy is greater (Nordin and Manevska-Tasevska, 2013). Rizov et al. (2013) found that the policy shift in 2003 from coupled to decoupled payments has improved the EU total farm productivity (TFP). In the same study, for Sweden, there is an increase in both the TFP indices and TFP growth. However, findings on the relationship between the decoupling and efficiency are heterogeneous

(Latruffe et al., 2016; Minviel and Latruffe, 2017), depending on the local environmental and institutional context (Latruffe et al., 2016), confirming the need for a regional-based efficiency analysis. Our results are partly comparable with the previous research. First, because existing studies are based on farm-level analysis. Second, studies have analysed the switch before and after the Fischler reform of 2003, but not after the reform of 2008. Third, to the best of our knowledge, none of the existing studies provide details on the shifts of specific inputs and outputs across the CAP reforms.

4. Conclusions and policy implications

This study analysed the regional efficiency of agricultural resources in Sweden in a rural development context, and explored how efficiency patterns of the Swedish regions have evolved across the last three CAP programmes: CAP 1: 1998 − 2002, CAP 2: 2003 − 2007, and CAP 3: 2008 − 2013. MEA allowed an examination and assessment of input-output oriented efficiency of both resource use and production of a multi-dimensional vector of outputs within the agricultural sector (Asmild et al., 2016b; Hansson et al., 2020).

At country level, the efficiency of materials is greatest, with variations from CAP 1 to CAP3 of between 0.90 to 0.94, followed by effciency of fixed costs (0.84 − 0.95), assets (0.86 − 0.90), and labour (0.84 − 0.92). The effciency of agricultural output improved from 0.86 to 0.94, whereas the efficiency of diversified output ranged from 0.61 to 0.82. At county-level, ME scores vary more for the use of assets and labour, for the inputs, and the diversified output from the output varaibles (Table 1).

From a policy point of view, improving efficiency of assets might require measures for developing knowledge in terms of utilisation of assets, and for structural changes across the regions. The gaps in efficiency of labour could be improved by policies supporting structural changes. However, lower effciency in labour might indicate that in some counties extra labour has been used to comply with environmental measures, to generate public good and/or social benefits which are not captured by the ME (Hansson et al., 2020). Thereby, policies compensating for the losses originating from such activities are important. In regard to output efficiency, diversified output has the largest efficiency gap acorss the CAP periods, and the greatet potential for further improvements. Policies designed to encourage the uptake of rural development support to provide proper knowledge with which to build competence and stipulate entrepreneurial activities and infrastructural investments in the less efficient regions, could be relevant.

Over the CAP periods, the efficiency gap across the counties decreases, indicating that changes in policy have helped regional cohesion. Yet, the agriculturally most productive counties and counties containing large cities continue to be among the most efficient. Therefore, further adjustments in regional distribution of CAP support is needed. It is worth mentioning that within the CAP, support for development and improvement of infrastructure for rural development, and diversification activities in farming that aim to provide supplementary incomes, has considerably increased since 1999. It should also be noted that the dynamic of acceptance of CAP payments, especially from Pillar 2, might differ across the regions, and therefore the desired changes and efficiency effects on inputs and outputs become apparent later.

Future research on variable-specific efficiency of regions could focus on several improvements. First, environmental and social output could be considered along with the economics output (to some extend covered in: Yan et al., 2018). The suggested research is in line with the CAP goal for sustainable agriculture, securing economic development while generating social and environmental benefits. Second, the trade-offs between the extra resources used, and the environmental and social output produced, can also be assesed. Third, our study does not provide information around the factors influencing the efficiency. The nature of variable-specific efficiency improvements along the CAP can be assesed by taking into consideration the dynamic perspective of, for example, regional knowledge production (Han et al., 2016), investments (Kapelko et al., 2017; Skevas and Oude Lansink, 2020), the technological change (Asmild et al., 2016a), and the spatial acceptance of rural development CAP payments (Skevas and Oude Lansink, 2020). Last, but not the least, CAP reforms are a continuous process, so it could also be interesting to see an updated analysis containing data for the ongoing CAP programme (2014–2020) and the forthcoming CAP programme (2021–2027) performed in future research.

CRediT authorship contribution statement

Gordana Manevska-Tasevska: Conceptualization, Methodology, Software, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing, Project administration, Funding acquisition. **Helena Hansson:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing. **Mette Asmild:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing. **Yves Surry:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing.

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Appendix A

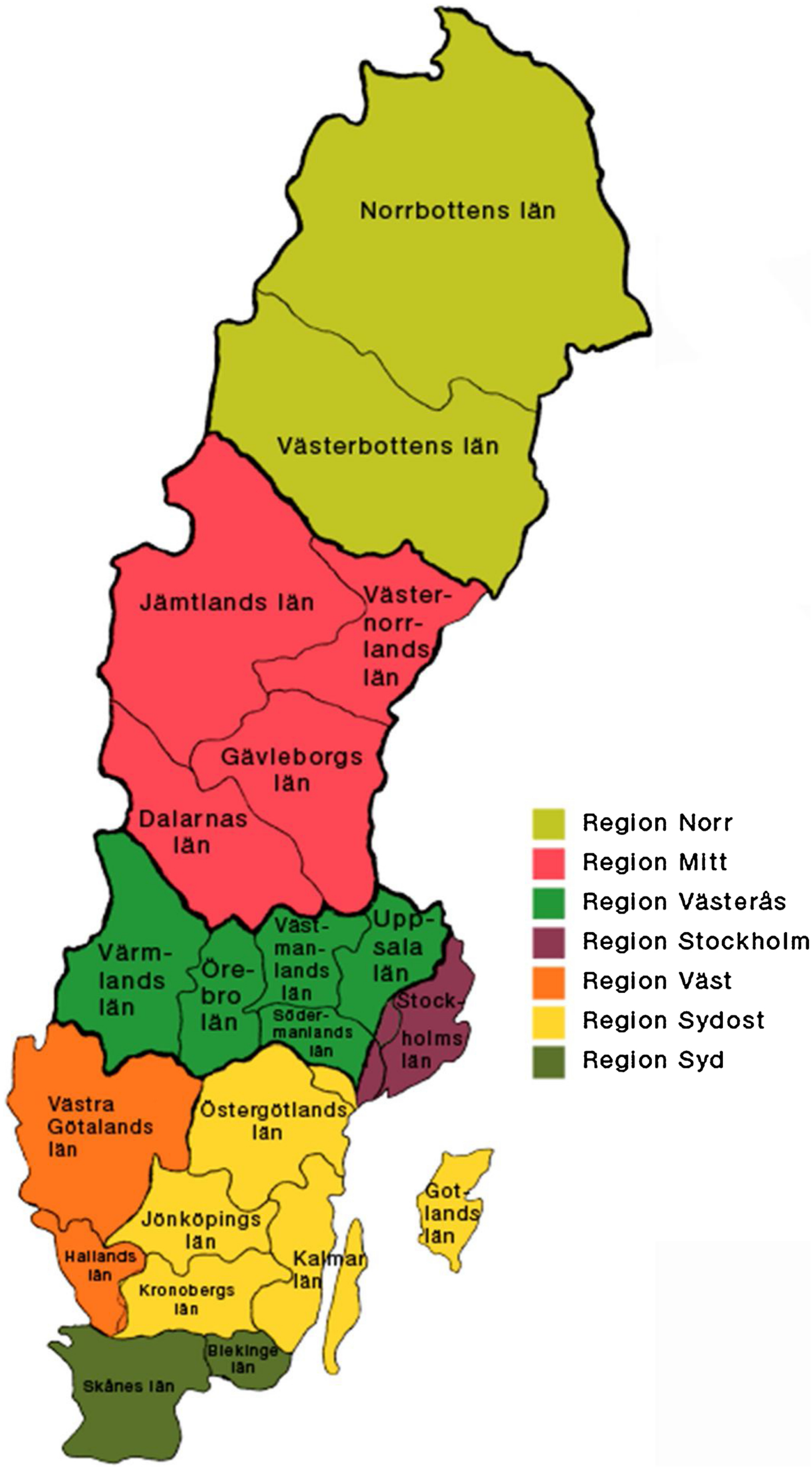

Fig. A1. Geographical division of Sweden (7 regions marked in different colours) and NUTS 3 county divisions (21 separate territorial units).

Table A1
Means of input and output variables across the CAP periods 1998-2013 for the whole sample and for each of the counties individually, kSEK = thousand Swedish krona.

CAP period 1998 – 2002	Variable costs kSEK	Fixed costs kSEK	Labour '000 h	Assets value kSEK	Agricultural output kSEK	Diversified output	Share of agricultural output	Share of diversified output
Sample means	33,516,650	21,390,990	165,119	179,805,040	43,029,800	4,492,836	0.91	0.09
Blekinge	15,519,777	8,464,771	72,609	64,527,528	19,667,688	2,142,349	0.90	0.10
Skåne	172,389,152	111,600,064	695,705	993,642,368	234,594,064	22,251,002	0.91	0.09
Halland	55,722,852	32,265,400	248,035	273,259,072	71,964,968	4,859,562	0.94	0.06
Västra Götaland	100,222,864	68,003,632	497,186	585,686,784	137,343,792	11,177,302	0.92	0.08
Gotland	55,722,852	17,718,428	158,527	151,971,696	39,526,376	2,926,342	0.93	0.07
Jönköping	44,073,624	24,824,244	257,096	189,256,032	60,101,112	5,955,633	0.91	0.09
Kalmar	39,672,000	23,287,212	194,881	181,747,344	51,758,520	6,008,894	0.90	0.10
Kronoberg	15,139,364	8,193,627	91,524	75,148,920	19,241,004	2,179,385	0.90	0.10
Östergotland	53,221,096	37,261,828	241,927	314,967,232	66,672,996	9,568,170	0.87	0.13
Stockholm	10,414,855	7,199,905	52,924	42,632,088	11,561,104	2,920,774	0.80	0.20
Södermanland	26,289,408	21,253,994	143,661	184,358,912	27,052,856	5,427,962	0.83	0.17
Uppsala	15,601,606	10,319,348	90,778	87,559,880	18,638,690	3,689,814	0.83	0.17
Västmanland	22,670,564	16,363,272	102,255	115,740,832	27,496,166	5,007,488	0.85	0.15
Värmland	14,780,633	8,798,247	77,835	66,479,088	16,212,769	1,486,032	0.92	0.08
Örebro	26,955,118	17,671,326	121,805	165,498,800	35,757,360	2,264,437	0.94	0.06
Dalarna	4,776,523	3,915,347	32,382	23,403,176	6,606,642	482,074	0.93	0.07
Gävleborg	12,430,371	6,444,059	87,662	58,903,240	11,388,039	1,897,977	0.86	0.14
Jämtland	10,288,702	4,666,359	67,061	34,957,496	10,491,863	852,270	0.92	0.08
Västernorrland	11,042,150	6,273,188	68,625	55,500,464	10,041,763	1,438,576	0.87	0.13
Norrbotten	5,883,101	310,085	41,376	22,525,698	6,388,534	809,081	0.89	0.11
Västerbotten	18,926,358	11,585,667	123,652	88,139,160	21,119,516	1,004,439	0.95	0.05
CAP period 2003 – 2007								
Sample means	43,261,872	22,035,632	173,426	222,412,496	55,621,320	7,211,839	0.89	0.11
Blekinge	14,075,085	7,021,021	62,887	74,107,416	19,610,688	3,069,299	0.86	0.14
Skåne	201,275,920	107,485,992	686,506	1,178,162,944	277,470,784	32,756,386	0.89	0.11
Halland	84,459,160	37,713,748	280,400	365,824,992	109,151,568	10,591,838	0.91	0.09
Västra Götaland	136,175,584	73,668,024	559,212	788,731,072	184,932,528	21,370,104	0.90	010
Gotland	46,560,576	23,875,550	201,629	214,950,272	57,543,952	5,614,262	0.91	0.09
Jönköping	56,927,568	25,759,890	256,978	226,529,040	72,723,088	8,343,706	0.90	0.10
Kalmar	45,928,156	22,948,066	196,615	198,367,056	57,144,136	7,628,928	0.88	0.12
Kronoberg	15,485,584	6,999,192	75,105	77,353,040	17,648,116	3,866,529	0.82	0.18
Östergotland	64,248,020	36,245,596	241,697	399,204,160	78,192,928	15,663,000	0.83	0.17
Stockholm	16,526,341	11,208,813	61,882	62,876,256	28,173,904	4,401,836	0.86	0.14
Södermanland	28,734,258	16,413,213	122,706	185,543,680	32,192,542	6,536,506	0.83	0.17
Uppsala	21,008,272	12,206,022	82,720	109,139,864	26,752,052	8,339,863	0.76	0.24
Västmanland	24,556,956	13,622,747	84,928	142,008,288	29,516,250	6,021,714	0.83	0.17
Värmland	23,732,116	10,520,523	90,796	98,679,480	26,422,774	2,969,394	0.90	0.10
Örebro	29,428,230	17,513,318	112,349	179,880,128	39,721,232	3,758,529	0.91	0.09
Dalarna	8,227,861	3,883,601	51,054	35,190,076	10,699,188	533,992	0.95	0.05
Gävleborg	24,085,934	8,740,578	134,035	92,196,328	25,484,850	3,870,824	0.87	0.13
Jämtland	12,266,900	4,685,762	61,097	36,085,876	13,532,175	1,324,112	0.91	0.09
Västernorrland	19,647,716	7,567,868	97,142	71,969,344	21,037,714	2,514,101	0.89	0.11
Norrbotten	7,234,605	2,825,118	39,955	24,666,976	8,564,385	658,807	0.93	0.07
Västerbotten	27,914,444	11,843,613	142,260	109,196,176	31,532,908	1,614,880	0.95	0.05
CAP period 2008 – 2013								
Sample means	63,480,460	28,144,630	209,210	340,420,992	84,126,672	10,482,598	0.89	0.11
Blekinge	17,593,392	9,505,491	73678.	112,632,952	24,372,586	3,382,510	0.88	0.12
Skåne	249,646,528	121,128,944	747,961	1,524,360,320	359,851,648	39,544,036	0.90	0.10
Halland	93,108,928	33,454,504	251,244	457,359,456	124,161,704	12,343,573	0.91	0.09
Västra Götaland	246,089,472	120,187,472	810,518	1,433,407,872	336,853,184	47,353,440	0.88	0.12
Gotland	76,120,000	32,128,112	247,782	396,303,232	98,468,032	10,010,602	0.91	0.09
Jönköping	81,349,208	31,413,224	290,791	344,758,976	108,572,128	11,347,820	0.91	0.09
Kalmar	98,749,600	42,686,360	291,686	477,204,928	142,036,384	11,743,222	0.92	0.08
Kronoberg	30,484,692	12,550,780	116,979	165,971,152	39,212,656	5,354,781	0.88	0.12
Östergotland	91,626,680	46,623,644	295,260	580,984,512	120,630,192	17,409,960	087	013
Stockholm	8,588,466	4,050,652	33,678	50,428,156	9,807,124	2,396,338	0.80	0.20
Södermanland	33,654,464	15,237,649	126,419	228,347,328	41,598,988	6,416,770	0.87	0.13
Uppsala	27,462,776	12,484,616	98,594	158,792,112	37,887,468	7,798,572	0.83	0.17
Västmanland	34,610,056	16,066,094	103,376	167,106,000	42,838,040	9,170,274	0.82	0.18
Värmland	37,031,932	14,557,691	124,978	187,870,320	41,691,844	5,551,713	0.88	0.12
Örebro	39,908,968	19,755,784	121,530	231,068,208	49,297,904	8,868,052	0.85	0.15
Dalarna	14,244,513	5,476,272	61,525	62,460,000	16,914,830	1,484,182	0.92	0.08
Gävleborg	32,635,578	11,512,494	133,119	143,023,664	33,679,216	5,767,994	0.85	0.15
Jämtland	24,156,802	8,013,163	100,384	85,365,760	26,136,196	3,558,474	0.88	0.12
Västernorrland	34,841,416	12,430,146	125,449	126,099,104	37,861,876	4,653,750	0.89	0.11
Norrbotten	18,067,028	6,884,575	66,841	64,199,696	21,134,760	2,819,423	0.88	0.12
Västerbotten	43,119,200	14,889,554	171,610	151,097,184	53,653,380	3,159,074	0.94	0.06

Own estimation, based on FADN 1998–2013. All inputs and outputs were calculated based on standard FADN definitions (European Commission, 2018).

Appendix B. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.landusepol.2020.104897.

References

Anania, G., Blom, J.C., Buckwell, A., Colson, F., Azcarate, T.G., Rabinowicz, E., Saraceno, E., Sumpsi, J., von Urff, W., Wilkin, J., 2003. Policy vision for sustainable rural economies in an enlarged Europe. Akademie für Raumforschung und Landesplanung Délégation à l'Aménagement du Territoire et à l'Action Régionale (DATAR).

Asmild, M., Hougaard, J., Kronborg, D., Kvist, H., 2003. Measuring inefficiency via potential improvements. J. Product. Anal. 19, 59–76.

Asmild, M., Baležentis, T., Hougaard, J.L., 2016a. Multi-directional productivity change: MEA-Malmquist. J. Product. Anal. 46, 109–119.

Asmild, M., Baležentis, T., Hougaard, J.L., 2016b. Multi-directional program efficiency: the case of Lithuanian family farms. J. Product. Anal. 45, 23–33.

Asmild, M., Kronborg, D., Matthews, K., 2016c. Introducing and modeling inefficiency contributions. Eur. J. Oper. Res. 248, 725–730.

Baležentis, T., Kriščiukaitienė, I., Baležentis, A., 2014. A nonparametric analysis of the determinants of family farm efficiency dynamics in Lithuania. Agric. Econ. 45, 589–599.

Barnes, A.P., Hansson, H., Manevska-Tasevska, G., Shrestha, S.S., Thomson, S.G., 2015. The influence of diversification on long-term viability of the agricultural sector. Land Use Policy 49, 404–412.

Bogetoft, P., Hougaard, J.L., 1999. Efficiency evaluations based on potential (non-proportional) improvements. J. Product. Anal. 12, 233–247.

Crescenzi, R., Giua, M., 2016. The EU Cohesion Policy in context: Does a bottom-up approach work in all regions? Environ. Plann. A Econ. Space 48, 2340–2357.

Dinno, A., 2015. Nonparametric pairwise multiple comparisons in independent groups using Dunn's test. Stata J. 15, 292–300.

Dunn, O.J., 1964. Multiple comparisons using rank sums. Technometrics 6, 241–252.

Esposti, R., 2007. Regional growth and policies in the European Union: does the common agricultural policy have a counter-treatment effect? Am. J. Agric. Econ. 89, 116–134.

Esposti, R., Sotte, F., 2013. Evaluating the effectiveness of agricultural and rural policies: an introduction. Eur. Rev. Agric. Econ. 40, 535–539.

European Commission, 2015. Direct payments: the basic payment Scheme from 2015. Convergence of the Value of Payment Entitlements ('Internal Convergence').

European Commission, 2016. Glossary of Terms Related to the Common Agricultural Policy. European Commission, Agriculture and Rural Development.

European Commission, 2018. Definitions of Variables Used in FADN Standard Results, RI/CC 1750 (ex RI/CC 882). Official Journal of the European Union.

Expósito, A., Velasco, F., 2018. Municipal solid-waste recycling market and the European 2020 Horizon Strategy: a regional efficiency analysis in Spain. J. Clean. Prod. 172, 938–948.

Ezcurra, R., Iráizoz, B., Pascual, P., Rapún, M., 2011. Agricultural productivity in the European regions trends and explanatory factors. Eur. Urban Reg. Stud. 18, 113–135.

Galinienė, B., Dzemydaitė, G., 2012. Spatial data envelopment analysis method for the evaluation of regional infrastructure disparities. Soc. Technol. 2, 390–403.

Gerdessen, J.C., Pascucci, S., 2013. Data envelopment analysis of sustainability indicators of European agricultural systems at regional level. Agric. Syst. 118, 78–90.

Han, U., Asmild, M., Kunc, M., 2016. Regional R&D efficiency in Korea from static and dynamic perspectives. Reg. Stud. 50, 1170–1184.

Hansson, H., Manevska-Tasevska, G., Asmild, M., 2020. Rationalising inefficiency in agricultural production–the case of Swedish dairy agriculture. Eur. Rev. Agric. Econ. 47, 1–24.

Holm, S., 1979. A simple sequentially rejective multiple test procedure. Scand. J. Stat. 6, 65–70.

Kapelko, M., Oude Lansink, A., Stefanou, S.E., 2017. Input-specific dynamic productivity change: measurement and application to European dairy manufacturing firms. J. Agric. Econ. 68, 579–599.

Karagiannis, G., 2015. On structural and average technical efficiency. J. Product. Anal. 43, 259–267.

Kruskal, W.H., Wallis, W.A., 1952. Use of ranks in one-criterion variance analysis. J. Am. Stat. Assoc. 47, 583–621.

Labajova, K., Hansson, H., Asmild, M., Göransson, L., Lagerkvist, C.-J., Neil, M., 2016. Multidirectional analysis of technical efficiency for pig production systems: the case of Sweden. Livest. Sci. 187, 168–180.

Lakner, S., 2009. Technical efficiency of organic milk-farms in Germany -the role of subsidies and of regional factors. Agron. Res. 7, 632–639.

Lakner, S., Kirchweger, S., Hoop, D., Brümmer, B., Kantelhardt, J., 2014. Technical Efficiency of Organic Farming in the Alpine Region–the Impact of Farm Structures and Policies. EAAE Congress 'Agri-Food and Rural Innovations for Healthier Societies, Ljubljana, Slovenia, pp. 26–29.

Latruffe, L., Bravo-Ureta, B.E., Carpentier, A., Desjeux, Y., Moreira, V.H., 2016. Subsidies and technical efficiency in agriculture: evidence from European dairy farms. Am. J. Agric. Econ. 99, 783–799.

Macmillan, W.D., 1986. The estimation and application of multi-regional economic planning models using data envelopment analysis. Papers Reg. Sci. 60, 41–57.

Manevska-Tasevska, G., Rabinowicz, E., Surry, Y., 2016. Pure and compensated technical efficiency of Swedish dairy farms. Agric. Food Sci. 25, 111–123.

Marsden, T., Sonnino, R., 2008. Rural development and the regional state: denying multifunctional agriculture in the UK. J. Rural Stud. 24, 422–431.

Martić, M., Savić, G., 2001. An application of DEA for comparative analysis and ranking of regions in Serbia with regards to social-economic development. Eur. J. Oper. Res. 132, 343–356.

Maudos, J., Pastor, J.M., Serrano, L., 2000. Efficiency and productive specialization: an application to the spanish regions. Reg. Stud. 34, 829–842.

Minviel, J.J., Latruffe, L., 2017. Effect of public subsidies on farm technical efficiency: a meta-analysis of empirical results. Appl. Econ. 49, 213–226.

Nordin, M., Manevska-Tasevska, G., 2013. Farm-level employment and direct payment support for grassland use: a case of sweden. working paper, 2013:5. AgriFood Economic Centre, Lund University.

Rizov, M., Pokrivcak, J., Ciaian, P., 2013. CAP subsidies and productivity of the EU farms. J. Agric. Econ. 64, 537–557.

Schaffer, A., Simar, L., Rauland, J., 2011. Decomposing regional efficiency. J. Reg. Sci. 51, 931–947.

Skevas, I., Oude Lansink, A., 2020. Dynamic inefficiency and spatial spillovers in dutch dairy farming. J. Agric. Econ DOI.10.1111/1477-9552.12369.

Špička, J., Smutka, L., 2014. The technical efficiency of specialised milk farms: a regional view. Sci. World J. 2014, 13.

Statistics Sweden, 2019. Jordbruksverkets statistikdatabas. Prisindex Statistics Sweden 2019.

Suzuki, S., Nijkamp, P., Rietveld, P., 2011. Regional efficiency improvement by means of data envelopment analysis through Euclidean distance minimization including fixed input factors: an application to tourist regions in Italy. Papers Reg. Sci. 90, 67–89.

Trouvé, A., Berriet-Solliec, M., 2010. Regionalization in European agricultural policy: institutional actualities, issues and prospects. Reg. Stud. 44, 1005–1017.

Wang, K., Wei, Y.-M., Zhang, X., 2013. Energy and emissions efficiency patterns of Chinese regions: a multi-directional efficiency analysis. Appl. Energy 104, 105–116.

Wang, K., Yu, S., Li, M.-J., Wei, Y.-M., 2015. Multi-directional efficiency analysis-based regional industrial environmental performance evaluation of China. Nat. Hazards 75, 273–299.

Yan, Q., Wang, X., Baležentis, T., Streimikiene, D., 2018. Energy–economy–environmental (3E) performance of Chinese regions based on the data envelopment analysis model with mixed assumptions on disposability. Energy Environ. 29, 664–684.

Zhu, X., Milán Demeter, R., 2012. Technical efficiency and productivity differentials of dairy farms in three EU countries: the role of CAP subsidies. Agr. Econ. Rev. 13, 66.

Zhu, L., Wang, Y., Shang, P., Qi, L., Yang, G., Wang, Y., 2019. Improvement path, the improvement potential and the dynamic evolution of regional energy efficiency in China: based on an improved nonradial multidirectional efficiency analysis. Energy Policy 133, 110883.