



Productive performance of organic crop farms in Finland 2010–2017

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Abstract Increasing organic production is one of the strategic objectives of the Finnish agricultural policy. Despite the positive developments observed during the last decade, reaching the objectives set by the Finnish government remains challenging. The contributions of this study are twofold. Firstly, this study provides new empirical evidence on productive performance of organic crop farming in Finland and explains observed gap between average output of organic and conventional farms. Specifically, we use the most recent available farm-level data and analyze the performance of organic crop farms over the period 2010–2017. Secondly, to estimate the performance gap between the organic and conventional crop farms, we apply one-stage semi-nonparametric regression. This approach alleviates the endogeneity problem of the commonly used two-stage estimation approaches, providing robust

estimates without restrictive functional form assumptions. Our results reveal a significant performance gap between organic and conventional farming. However, the difference between productive performance of organic and conventional crop farms has been decreasing over the years. Moreover, a positive trend is revealed in organic production at the end of the study period.

Keywords Organic agriculture · Performance gap · Convex regression · Data envelopment analysis

Introduction

The European Commission defines organic production as “an overall system of farm management and food production that combines best environmental practices, a high level of biodiversity, the preservation of natural resources and the application of high animal welfare standards, and a production method in line with the preference of certain consumer for products using a natural substances and processes” (COM 2014). Against this background, promoting and increasing organic agriculture in the EU Member States is seen as a feasible and promising pathway that plays a dual societal role. Firstly, organic farming satisfies consumer demand for organic products and, secondly, it contributes to the protection of the environment and animal welfare, as well as to rural development (Regulation EU 2018/848).

In line with the EU regulation (COM 2014), the aim of the Finnish governmental program on organic production is to motivate the production of products that are

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not harmful to the environment or to the welfare and health of humans, plants, and animals (MMM 2014). In fact, fostering and supporting organic farming in Finland has been one of the strategic objectives of the Finnish agricultural policy since the early 2000s (see e.g., MMM 2001; YM 2005). The role of organic food was particularly emphasized since 2010 in attempt to improve the competitiveness of the Finnish food sector. For instance, the Finnish government adopted a resolution, entitled “More organic! Government development programme for the organic product sector and objectives to 2020” (MMM 2014). The main strategic objectives of this latest development strategy were to increase organic production to meet the demand, to diversify the range of organic foods available, to develop the organic food chain, and to improve access to organic food through the retail sector.

According to the Finnish Organic Food Association Pro Luomu, organic production in Finland has increased during the last decade (see Pro Luomu 2018, 2019). However, despite the observed positive developments, the quantitative goals set in the resolution *More Organic* for year 2020 have not been fully reached (see e.g., Nuutila 2019). We discuss the statistics on the recent developments of organic production in Finland in further details in the next section. To understand the reasons why reaching the goals for organic production is challenging, it is essential to consider a number of different interrelated aspects. Firstly, it is important to recognize what motivates farmers for conversion to organic production and more sustainable agricultural practices (Karali et al. 2014) keeping in mind that transition takes time and requires farmers’ learning (Sipiläinen and Oude Lansink 2005). Secondly, while organic yields are typically lower than conventional yields (De Ponti et al. 2012; Seufert et al. 2012; Ponisio et al. 2015), organic farming is significantly more profitable than conventional agriculture (Röös et al. 2018). Thus, there is a yield gap and a price gap between organic and conventional farming, which should be considered. Thirdly, there is a difference in productive performance between organic and conventional farms. In fact, a large body of agricultural economics literature focuses on studying those differences (e.g., Oude Lansink et al. 2002; Madau 2007; Serra and Goodwin 2009; Marchand and Guo 2014; Kramol et al. 2015; Tiedemann and Latacz-Lohmann 2013). In the case of Finland, there are only few studies that analyze and compare the performance of Finnish organic and

conventional farms (Oude Lansink et al. 2002; Sipiläinen and Oude Lansink 2005; Sipiläinen et al. 2008; Kumbhakar et al. 2009).

Even though the contributions discussed above provide valuable information on the development of organic production as such, there is still no evidence about the net effect of different aspects on productive performance of organic farming. While organic yields are lower but prices for organic products are higher, the net effect on farmer revenue is still unclear. As the prices obviously depend on the quality of crop, it is difficult to draw a distinction between the “quality” and “quantity” effects. The overall effect on farm revenue is of the key interest of this study. Thus, this study seeks to answer the following research questions:

- 1) How large is the average output of organic crop farms in Finland compared to that of conventional farms?
- 2) To what extent the observed output gap is explained by the differences in the input use between the two groups?
- 3) Is there a significant gap in productive performance of organic and conventional farms? If yes, how large is the performance gap?
- 4) How do the output gap and the performance gap develop over time?

We believe that the answers to these questions would provide further insights into the current state of organic production in Finland and its recent developments. This knowledge would help policymakers to better understand the impacts of current policies and organic subsidies on the development of organic production in Finland, and to develop more effective and cost-efficient policies in the future.

The main contributions of this study are the following. First, we use the most recent farm-level data from the Farm Accountancy Data Network (FADN) obtained from the Natural Resources Institute Finland (Luke) to empirically estimate the performance gap between organic and conventional crop farms in Finland. Note that previous related empirical applications focusing on performance of organic farms in Finland are available only up to year 2002. To our best knowledge, there is currently no empirical evidence for more recent years. Second, our empirical application relies on a more advanced estimation strategy. A well-known problem of the conventional two-stage estimation strategy, where

one first estimates efficiency at farm level and subsequently regresses efficiency estimates on some explanatory variables (e.g., a dummy variable for organic farms), is that the second-stage regression is subject to the endogeneity bias (e.g., Wang and Schmidt 2002) and that the conventional statistical inferences are invalid (Simar and Wilson 2007, 2011). To address these problems, Johnson and Kuosmanen (2011, 2012) developed a one-stage nonparametric estimator based on convex regression. Unlike the deterministic data envelopment analysis (DEA), this method allows for stochastic noise in data. In contrast to stochastic frontier analysis (SFA), this method does not rely on restrictive functional form assumptions regarding the production function or the distribution of the inefficiency term.

The rest of the paper is organized as follows. The “**Background**” section firstly reviews some relevant literature on different aspects of organic production in general, and then presents some stylized facts describing the recent developments of organic farming in Finland during the last decade. The “**Production function and its estimation**” section briefly introduces the theoretical model to be estimated together with one-stage convex regression estimator and its underlying assumptions. The “**Application to Finnish crop farms**” section describes the empirical application of this study and the results. The “**Conclusions**” section presents concluding remarks and offers possible avenues for future research.

Background

The purpose of this section is firstly to provide the reader with a brief literature review on different aspects related to the development of organic farming in general. Secondly, for the background information of the empirical application of this study, we present few stylized facts about the most recent developments of organic farming in Finland.

Literature review on different aspects of organic farming

In order to increase organic production, one should understand what motivates farmers to participate in more sustainable agricultural practices at the first place. As plenty of studies show, there are multiple reasons that influence farmers’ decision to switch from conventional farming to organic farming methods (see e.g., Padel 2001; Koesling et al. 2012; Karali et al. 2014).

The incentives for choosing organic farming usually rely on several factors such as concern for the environment, ethical and social responsibility, and of course economic considerations. For instance, Koesling et al. (2012) confirms that farmers’ motivation relies on a complexity of reasons including technical, economic, social, and cultural. Decision to convert to organic production can be classified to farming-related and/or personal motives (Padel 2001). Farming-related motives usually include husbandry and technical reasons such as animal health and financial motives, whereas personal motives consist of personal health and more general concerns like food conservation and environmental issues. Interestingly, the motives for conversion to organic production have been changing over time. Whereas “earlier” organic farmers were more strongly motivated by moral, social, and religious concerns than financial benefits (Rigby et al. 2001; Padel 2001), the “newer” ones see organic farming as a professional challenge; they are concerned about the environment, but also the economic reasons are very important (see Padel 2001 for a review).

As for the case of Finnish farmers, economic incentives play a significant role in their decision. Higher output prices of organic products and direct subsidies trigger Finnish farmers to switch to organic farming (Pietola and Oude Lansink 2001). As further confirmed by the case of Swiss farmers (Karali et al. 2014), the decision to participate in environmental management practices is based on social and political factors, household and individual profile characteristics, and concern for the natural environment, but financial considerations remain important. Thus, even though government policies for sustainable agriculture development encourage conversion to organic farming and to environmentally friendly farm management practices, there is still no clear evidence that farmers’ motivation is based on long-term commitment to environmentally responsible management plans, or a short-term need to adapt to recent agricultural policy reforms with the associated financial benefits (Karali et al. 2014).

Regarding the economic competitiveness of organic agriculture, several studies find organic farming to be more profitable compared to conventional agriculture (e.g., Nemes 2009; Rööös et al. 2018). However, profitability of organic production varies considerably across products, regions, and farms (Nemes 2009). The key explanations for profitability of organic agriculture cited in the literature include higher producer prices for

organic products, higher agricultural subsidies paid for organic farming, and for most inputs, lower costs per unit of output (Crowder and Reganold 2015; Luke 2017). In particular, consumers' willingness to pay price premium for organic products is critically important for the long-term profitability of organic farming (e.g., Crowder and Reganold 2015; Rööös et al. 2018).

Concerning productivity, organic agriculture is heavily criticized for its inefficiency in terms of land use (Rööös et al. 2018). In the light of rising demand for food, when global population is increasing, shortage of agricultural land is expected, and any further expansion of organic land area could be problematic (Kirchmann and Bergström 2008; Connor and Mínguez 2012). Even though organic farming is seen as a potential way of producing food with minimal harm to the environment, animals, or humans, whether organic agriculture can face the needs of growing population and produce enough food to feed the world is still questionable. Several studies analyzed yield gap between organic and conventional farming and concluded that organic yields are typically lower than conventional yields (see e.g., De Ponti et al. 2012; Seufert et al. 2012; Ponisio et al. 2015). However, the yield gap very much depends on the system and site characteristics, crop types, and applied management practices (Seufert et al. 2012). The importance of management, marketing skill, and challenges related to the farmer's professional competence and learning process needed in organic farming has also been investigated and highlighted in several studies (e.g., Seufert et al. 2012; Rööös et al. 2018; Cranfield et al. 2010; Koesling et al. 2012).

Stylized facts of organic production in Finland

The resolution adopted by the Finnish government (MMM 2014) on organic production aimed at year 2020 and included the following specific quantitative goals: (i) the share of organic production should be 20% of the total agricultural land area, (ii) the share of organic food served in schools and day-care centers should be 20%, (iii) national organic production should cover at least national consumption, and (iv) organic food sales should triple in the retail and catering sectors. We next look at the available statistics related to the development of organic production and organic sales in Finland during the last decade.

According to the Finnish Food Authority, the number of organic farms in Finland has been gradually growing

since 2010 from about four thousand farms to over five thousand farms in 2018 (see Table 1). In terms of the share of organic farms in the total number of farms in Finland, organic farms accounted for over 10% in 2018. Note that the average size of organic farms was about 59 ha, which is about 10 ha larger than that of conventional Finnish farm (source: Finnish Food Authority). The cultivated land area under organic production has also grown steadily in Finland over the recent years (see Table 1). In 2018, for example, the land area used for organic cultivation amounted to about 300 thousand hectares, which is mainly arable land. As the share to the total agricultural land area, organically cultivated land area accounted for over 13% of all agricultural land in 2018.

Despite the consistent growth observed both in the number of organic farms and in the organic agricultural land area (Table 1), the share of agricultural land under organic cultivation remains relatively small and is still lagging behind specific target defined by the Finnish government (MMM 2014). Recall that the aim is to increase the share of organic production to 20% of the total agricultural land area by 2020. As already noted by Nuutila (2019), reaching the quantitative goals set by the Finnish authorities for organic production and consumption seems to be challenging. In fact, some recent studies analyze the reasons for why Finnish organic food system cannot reach the stated goals and identify the deficiencies within the Finnish organic food chain (see Nuutila and Kurppa 2016, 2017).

Looking at the consumption side, a steady increase in organic sales has been observed in Finland during the last decade. The value of the sale of organic products in grocery stores reached 336 million euros in 2018 (Table 1). Even though the organic market in Finland is still lagging behind the frontrunning EU member states (Nuutila 2019), the current conditions of the Finnish market and Finns' attitude towards organic agriculture and organic foods seem to be favorable for the growth of the Finnish organic sector. This can be seen in the positive development of the Finnish organic market during the last years (see Pro Luomu 2018, 2019). Though the market share of organic food in the retail is still low (only about 2.4% in 2018), the sales of organic food have grown all through the 2010s. Note that most organic food in Finland is sold through supermarkets (about 86% in 2018), while other sources include farm markets, speciality stores, and directly from organic farms (KANTAR TNS 2017).

Table 1 Development of organic farming and sales in Finland during 2010–2018

Year	Number of organic farms	Share of organic farms, %	Organic agricultural land, 10 ³ ha	Share of organic agricultural land, %	Organic sales, M€	Organic market share, %
2010	3939	6.1	170.9	7.5	-	-
2011	4036	6.6	184.8	8.1	163	-
2012	4260	7.2	197.8	8.7	202	1.6
2013	4215	7.4	206.2	9.0	215	1.6
2014	4180	7.9	212.7	9.4	225	1.7
2015	4251	8.3	224.7	9.9	240	1.8
2016	4415	8.8	240.6	10.7	273	2.0
2017	4587	9.5	259.5	11.4	309	-
2018	5039	10.6	296.7	13.1	336	2.4

Source: Finnish Food Authority

In general, consumption of organic products by Finnish consumers is expected to continue increasing in the near future and the use of organic products will become more and more common and widespread in Finland (KANTAR TNS 2017). The Finnish farmers also see organic production as a challenging but at the same time viable management practice and thus consider converting to organic production (Pro Luomu 2018). In light of this background, we next turn to the research questions of the current study and present a theoretical production model to be used in our empirical application.

Production function and its estimation

Consider the generic production model with a single output and multiple inputs (Kuosmanen et al. 2015):

$$y_i = f(x_i) + z_i'\delta + \epsilon_i, \text{ for } i = 1, \dots, n. \tag{1}$$

In this equation, y_i denotes the output of farm i , $x_i \in \mathbb{R}_+^m$ is an m -dimensional input vector, the function $f : \mathbb{R}_+^m \rightarrow \mathbb{R}_+$ is the continuous, monotonic increasing and concave frontier production function, and ϵ_i is an error term that captures all deviations from the best-practice production function. Further, a column vector $z_i \in \mathbb{R}^r$ denotes contextual variables that characterize the measured values of operational conditions and practices of farms i such as selected technology or management practice. For the purposes of the present study, let us assume that the first element of vector z_i , denoted by z_{i1} , is a dummy variable that takes the value of 1 if farm i is an organic farm and 0 if farm i is a conventional farm.

The vector of unknown parameters $\delta = (\delta_1 \dots \delta_k)'$, and especially the first element δ_1 , is of particular interest in this study: Coefficient δ_1 is the average net effect of organic management practice on farm output y_i .

Organic management practices can influence the technology, the operative efficiency, or both. To clarify this point, note that our theoretical model (1) can be equivalently stated as

$$\begin{aligned} y_i &= [f(x_i) + z_i'\delta] + \epsilon_i \text{ (technology gap interpretation)} \\ &= f(x_i) + [z_i'\delta + \epsilon_i] \text{ (inefficiency gap interpretation)} \end{aligned} \tag{2}$$

Equation (2) illustrates that one can interpret the impact of the contextual variables as “technology shifters” that are a parametric part of the production function, or equivalently, as explanatory variables of the inefficiency term that is implicitly present in the composite error term. However, it is not self-evident whether the net effect of organic management practice is due to the technology gap or to the inefficiency gap, or possibly both. Since the true production frontier f is unknown and must be estimated from the data, these two equivalent interpretations are not distinguishable from empirical data. Instead of trying to solve this identification problem by making some strong assumptions that cannot be tested empirically, we find it more theoretically grounded to focus on the net effect of organic farming on the revenue.

One of the conventional approaches to estimating theoretical model such as indicated by Eq. (1) would be a two-stage approach where one first estimates efficiency scores using data of inputs x and outputs y , and in

the second stage, the efficiency estimates are regressed on the contextual variables \mathbf{z} . The conventional approaches to efficiency estimation include SFA and DEA. The endogeneity problem of the two-stage estimation approach is clearly recognized in the SFA literature (e.g., Wang and Schmidt 2002). Note that ignoring the impacts of contextual variables \mathbf{z} from the first-stage efficiency estimation results as omitted variable bias when the inputs correlate with the contextual variables. The omitted variable bias can also affect the DEA estimator, although in a more subtle way through the finite sample bias of DEA (see Johnson and Kuosmanen 2012, Theorem 2 and the related discussion). In the DEA literature, the two-stage estimation procedure has been sharply criticized by Simar and Wilson (2007, 2011), who stress that the conventional statistical significance tests are invalid in the second-stage regression. Clearly, one-stage estimation of the production function f jointly with the impacts of the contextual variables is the preferred estimation strategy.

In this study, we rely on the one-stage nonparametric estimator that combines the nonparametric DEA-style frontier with a regression model of the contextual variables, developed by Johnson and Kuosmanen (2011, 2012), building on the results by Kuosmanen (2008), Kuosmanen and Johnson (2010), and Kuosmanen and Kortelainen (2012). Importantly, this estimator is statistically consistent under more general assumptions than those required by the two-stage DEA; it allows the conventional methods of statistical testing and confidence intervals to be applied to its resulting estimates (see Kuosmanen et al. 2015, Section 7.7 for further discussion). In practice, to estimate Eq. (1), we need to solve the following nonparametric least squares problem:

$$\min \sum_i \left(y_i - \hat{y}_i \right)^2 \quad (3)$$

subject to

$$\begin{aligned} \hat{y}_i - \hat{y}_j &\geq (\mathbf{x}_i - \mathbf{x}_j) \cdot \beta_i + (\mathbf{z}_i - \mathbf{z}_j) \cdot \delta \text{ for all } i, j = 1, \dots, n \\ \beta_i &\geq \mathbf{0} \text{ for all } i = 1, \dots, n \end{aligned}$$

Problem (3) is a quadratic programming problem with a system of linear inequality constraints. Note that the coefficients β_i are farm specific, whereas the parameters δ are common to all farms, like in standard linear regression. Analogous to DEA, the coefficients β_i characterize a monotonic increasing and concave piece-wise linear production function, as formally shown in

Kuosmanen (2008) and Kuosmanen and Johnson (2010). This one-stage nonparametric estimation strategy allows joint estimation of an axiomatic DEA-style production function with a linear regression model for the contextual variables. In the empirical application of this study, problem (3) has been solved by using the MATLAB software and the computational codes provided by Johnson and Kuosmanen (2015).

The optimal solution to problem (3) provides the parameter estimates $\hat{\delta}$ that are common to all farms and the predicted values of the production function $\hat{y}_i = \hat{f}(\mathbf{x}_i)$ for each farm. A convenient feature of the one-stage estimation approach is that the statistical significance of the parameters $\hat{\delta}$ can be tested by using the standard t test (see Johnson and Kuosmanen 2011).

In the empirical part of this paper, we further decompose the average output gap between the groups of organic and conventional farms as follows:

$$\bar{y}_o - \bar{y}_c = \hat{\delta}_1 + \left[\hat{f}(\bar{\mathbf{x}}_o) - \hat{f}(\bar{\mathbf{x}}_c) \right] + \sum_{j=2}^r (\bar{z}_{jo} - \bar{z}_{jc}) \cdot \hat{\delta}_j \quad (4)$$

where \bar{y}_o and \bar{y}_c denote the average outputs of the groups of organic and conventional farms, respectively, and similarly, $\bar{\mathbf{x}}_o$ and $\bar{\mathbf{x}}_c$ are the vectors of average inputs in the two groups. This equation demonstrates that the average output gap on the left-hand side of Eq. (4) is the sum of the three components on the right-hand side.

The first component $\hat{\delta}_1$ can be interpreted as the estimated performance gap between the organic and conventional farms. Note that $\bar{z}_{1o} = 1$ and $\bar{z}_{1c} = 0$ by construction. A positive value of $\hat{\delta}_1$ indicates that organic farms yield higher output than conventional farms, if both groups use the same amounts of inputs \mathbf{x} and operate under the same level of contextual variables \mathbf{z} . Conversely, a negative value of $\hat{\delta}_1$ would indicate that conventional farms perform better than organic farms, controlling for the inputs \mathbf{x} and contextual variables \mathbf{z} .

The second component $\hat{f}(\bar{\mathbf{x}}_o) - \hat{f}(\bar{\mathbf{x}}_c)$ will be referred to as the potential output gap.¹ Note that $\hat{f}(\bar{\mathbf{x}}_o)$ is the predicted value of the production function obtained with the average inputs of the organic farms, which represents the potential output in the group of average farms. The difference between the predicted average outputs indicates the extent to which the differences in the input resources can explain the observed output gap.

¹ In macroeconomics, the term “output gap” similarly refers to the difference between the actual GDP and potential GDP of a country.

The third component captures the impacts of other contextual variables on the output gap, except for the organic dummy, which we have separated above as the first component. The interpretation of this component depends on the specification of \mathbf{z} . If the contextual variables represent the operating environment (e.g., different soil or climate conditions), then the third component reflects the average impact of the operating environment on the output gap. If the elements of vector \mathbf{z} represent management practices of farms, other than the organic dummy, then the third component can be interpreted as the average impact of management. Note that in the empirical application presented in the next section we do not have other contextual variables than the dummy variable for the organic farms, and therefore, the third component is excluded. We assume that other factors that affect the revenue, but are not explicitly controlled for in the model, are uncorrelated with the dummy variable for organic management practice.

Since model (1) includes the error term ϵ_i , it is worth asking why the decomposition (4) does not depend on ϵ_i ? This is because the sum of residuals in the group of organic farms is always equal to zero in the optimal solution to problem (3); that is, $\sum_{i \in O} e_i = \sum_{i \in O} (y_i - \hat{y}_i) = 0$. The same is true for the group of conventional farms: $\sum_{i \in C} e_i = \sum_{i \in C} (y_i - \hat{y}_i) = 0$. Therefore, the impacts of the random error term ϵ_i cancel out as we average over the two groups of organic and conventional farms. In other words, the decomposition stated in Eq. (4) is not an approximation; it holds as an identity.

Finally, note that Eq. (4) decomposes the average output gap in monetary units (e.g., €). It is also possible to decompose the average gap in relative terms as a percentage. Dividing both sides of Eq. (4) by the average output of the conventional farms, we can express the relative output gap as

$$\frac{\bar{y}_o - \bar{y}_c}{\bar{y}_c} = \frac{\hat{\delta}_1}{\bar{y}_c} + \frac{[\hat{f}(\bar{\mathbf{x}}_o) - \hat{f}(\bar{\mathbf{x}}_c)]}{\bar{y}_c} + \sum_{j=2}^r (\bar{z}_{jo} - \bar{z}_{jc}) \cdot \hat{\delta}_j \quad (5)$$

In the following section, we will examine the average output gap both in monetary units and as a percentage.

Application to Finnish crop farms

We next apply the one-stage nonparametric estimator described in the previous section to the sample of

Finnish crop farms. The empirical application is based on the most recent farm-level data and covers the period 2010–2017. By solving the nonparametric least squares problem (3), we estimate the net effect of organic management practices on the farm revenue for each year and for the whole study period. The purpose of this exercise is twofold. Firstly, we analyze the productive performance gap between organic and conventional crop farms in Finland and its development over time. Secondly, we decompose the observed average output gap into two components: the performance gap and the potential output gap. This provides additional understanding to which extent the observed gap in output is due to the contribution of inputs and which part is due to the contribution of the performance gap.

Data

The empirical application of this study relies on the farm-level production data from the Farm Accountancy Data Network (FADN), obtained from the Natural Resources Institute Finland (Luke).² The data sample covers the period of 8 years from 2010 to 2017. It is an unbalanced rotating panel with the total number of observations of about two thousand farms (210–250 observations per year), from which about 200 are organic farms. More specifically, in this study, the term “rotating panel” refers to spontaneous rotation of farms in and out of the FADN sample: While no farms are excluded from the Finnish FADN by the survey design, responding to the survey is voluntary, and some proportion of farms exit the survey every year. Therefore, the yearly cohorts of farms differ from 1 year to another, which can cause large yearly fluctuations especially in the smaller sub-cohorts of organic farms. It is important to keep this in mind when interpreting the results.

The farms are selected based on principal type of farming (TOF) class 15 *specialist cereals, oilseeds, and protein crops* and 16 *general field cropping*.³ These two general types of farming are represented further by more specific types of farming: class 151 *specialist cereals, oilseeds, and protein crops* (further referred as specialist cereals), class 162 *cereals, oilseeds, protein crops, and root crops combined*, and class 166 *various*

² For further information, see Economy Doctor: <http://luke.fi/economydoctor>.

³ For details of the type of farming, see the Farm Accountancy Data Network (FADN): http://ec.europa.eu/agriculture/rica/detailtf_en.cfm?TF=TF14&.

field crops combined (further referred as field crops). The estimations are performed for three samples of farms: (1) all observed farms in classes 151, 162, and 166, (2) specialist cereals (class 151), and (3) field crops (class 166). The estimations are not performed separately for class 162 due to few observations available in this sample.

Regarding the selected variables, output is specified as total output of crops and crop products, livestock and livestock products (in thousand €, constant prices of 2010). As input factors, we use the following: labor (thousand hours), the farm capital (thousand €, constant prices of 2010), the utilized agricultural area (UAA, ha), and energy (thousand €, constant prices of 2010). For the sake of comparability, we only consider inputs that are similar for both conventional and organic farms. Descriptive statistics of the output and the inputs, including the mean values and the standard deviation values, is presented in Table 3 in the Appendix.

Results

As discussed in the previous section, one of our objects of interest is the net effect of organic management practice, which is represented by coefficient δ in model (1) and estimated using the semi-nonparametric estimator (3). The net effect represents the average performance gap between organic and conventional farms. Based on the farm-level data described in the previous subsection, we estimate the average performance gap for the three data samples: (1) sample containing all crop farms, (2) a subsample of specialist cereal farms, and (3) a subsample of field crop farms. Table 2 presents the results for each sample for each year and for the whole study period 2010–2017. The results are represented in thousand euros.

Recall that our dataset is an unbalanced rotating panel. It is important to bear in mind when interpreting the results that farms observed in 1 year are not necessarily present in another year. Therefore, intertemporal comparisons of the output gap and its components require careful caution. Despite this observation, some general remarks can still be made.

As can be seen from Table 2, the results reveal a significant performance gap between organic and conventional farming. Even though the values vary between the years and between the samples, the common feature is that the average net effect of organic management practice on farms' revenue is negative in all years,

Table 2 Estimated performance gap $\hat{\delta}_1$ between organic and conventional farms in 10^3€

Year	All farms	Specialist cereals	Field crops
2010	-20.36***	-14.48*	-16.41**
2011	-13.99***	-3.71	-16.02**
2012	-19.06***	-16.78**	-19.89***
2013	-9.87***	-0.84	-5.69
2014	-20.59***	-22.88*	-7.50
2015	-17.40***	-10.82	-22.49**
2016	-11.39***	-22.35**	-5.12
2017	+1.05***	+4.95	+0.92
2010–2017	-10.96***	3.95	-13.19***

Significance level: *** 1% significance, ** 5% significance, * 10% significance

except for the last year 2017. The difference in performance is ranging from about five thousand euros up to twenty thousand euros. Interestingly, the productive performance of organic farms turns positive in 2017 indicating that, using the same amount of inputs, the sample of organic farms in this year performed somewhat better compared to the sample of conventional farms. Even though the gap is just about one thousand euros (considering the sample all crop farms), this positive trend is an interesting observation as such. Whether this trend is going to continue in the further, it would be interesting to study more recent farm-level data.

Considering the sample of all crop farms reported in the second column of Table 2, we find that all results are statistically significant at the 0.01 level. Looking at the performance gap during the whole study period from 2010 until 2017, we find that organic crop farms produced on average about eleven thousand euros less output than conventional farms using the same amount of inputs. Regarding the two subsamples of crop farms, the specialist cereals and field crops reported in the third and the fourth columns in Table 2, the statistical significance of the estimated results varies. This is mainly explained by much smaller size of these subsamples: 130–170 specialist cereal farms and 60–100 various field crop farms per year including both conventional and organic farms. Looking at the performance of organic specialist cereal farms during the period 2010–2017, the performance gap was positive and amounted to about four thousand euros (though statistically insignificant). Further, the performance gap of farms specializing in field crops during the same period was negative and resulted in about thirteen thousand euros. In

conclusion, the results presented in Table 2 suggest that the performance gap between the conventional and organic crop farms has been decreasing over time. Positive values in year 2017 indicate that organic farming is in the process of improving its performance.

Having estimated the performance gap between organic and conventional farms, we next decompose the observed average output gap by using Eqs. (4) and (5). This decomposition allows for a natural interpretation and a breakdown of the observed output gap into relative contribution of the performance gap and the potential output gap, which takes into account the input use. Under potential output, we mean a feasible output that can be produced with these input resources. In other words, we can see the relative contribution of inputs, i.e. the potential output, and the performance gap to the observed difference in output of organic and conventional crop farms. While Table 2 presents the results in monetary terms, the following diagrams depict the decomposition in relative terms using Eq. (5).

Consider first the largest sample of all crop farms depicted in Fig. 1. Since our data is an unbalanced rotating panel that includes different farms each year, we use the bar chart to illustrate the percentages of the estimated contributions of the potential output gap and the performance gap for each year during the period 2010–2017. The continuous line represents the observed gap in the average output of organic and conventional farms: By Eq. (5), this line is equal to the sum of the performance gap and the potential output gap. This

is easy to see in years 2011–2013 where the both components had a negative contribution to the output gap.

In contrast, in the years 2010, 2014–2016, the positive contribution of the potential output gap was offset by the negative performance gap. In those 4 years, the potential output of the organic farms (estimated based on the input use) was on average higher than that of the conventional farms. In 2017, the situation was reversed as the performance gap was positive, and the observed output gap is almost completely explained by the difference in the input use. While the differences in the input use can partly explain the observed gap in the average output of the organic and conventional farms, Fig. 1 illustrates that the performance gap $\hat{\delta}_1$ is a more critical factor. The estimated performance gap fluctuates heavily from 1 year to another in this rotating panel of farms, but the performance gap seems to be decreasing over time, particularly in the last 4 years of our study period.

Consider next the sub-group of specialist cereal farms. Similar to Fig. 1, a decomposition of the average output gap to the components of performance gap and the potential output gap for this sub-group is presented in Fig. 2. In this sub-group, we see that the observed output gap is mainly driven by the potential output gap, which means that the differences in the input use can explain a lion’s share of the output gap. In 2014–2015, the average output of the organic farms exceeded that of the conventional farms, but this was mainly due to the inputs: The performance gap was negative in all year except for 2017.

Fig. 1 All farms: average output gap and the contributions of potential output gap and performance gap (in percent)

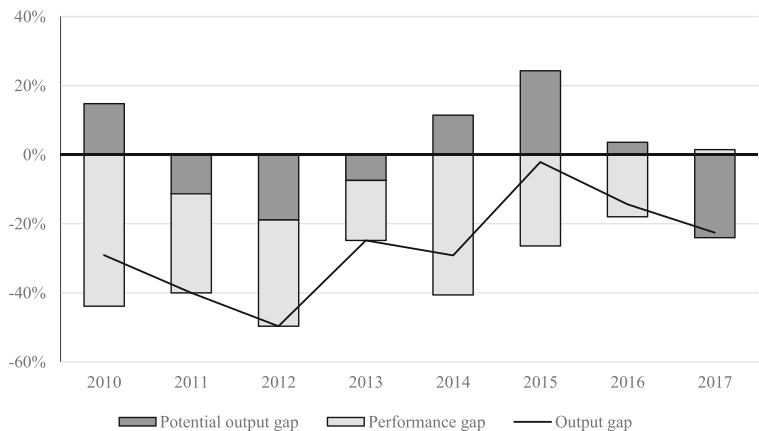
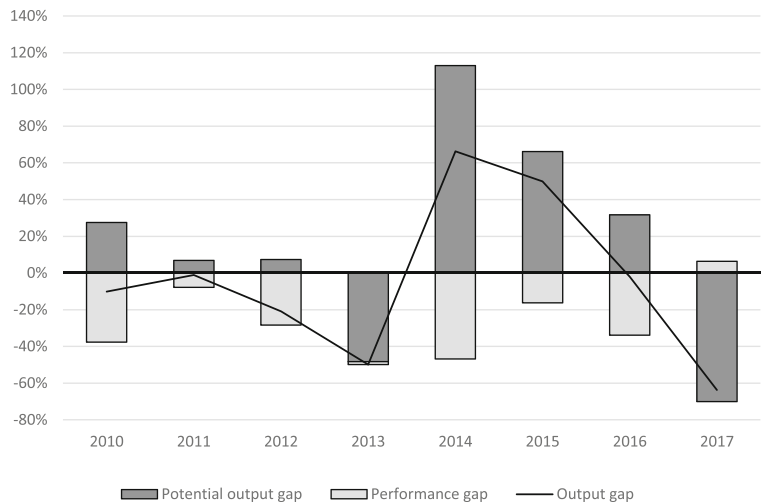


Fig. 2 Specialist cereals: average output gap and the contributions of potential output gap and performance gap (in percent)



Finally, Fig. 3 presents a similar decomposition for the sub-group of field crop farms. In this sub-group, approximately one-half of the output gap is explained by the inputs, and the other half is attributed to the performance gap. In the first 3 years of the study period, both components had a negative contribution to the output gap. In the last 3 years, the potential output of the organic farms exceeded that of the conventional farms, evaluated based on the average input use in the two groups. While in 2015 the negative performance gap is more than offset the potential output effect, which explains the negative output gap, the negative performance gap decreased in 2016 and turned to positive in 2017. Thanks to the improved

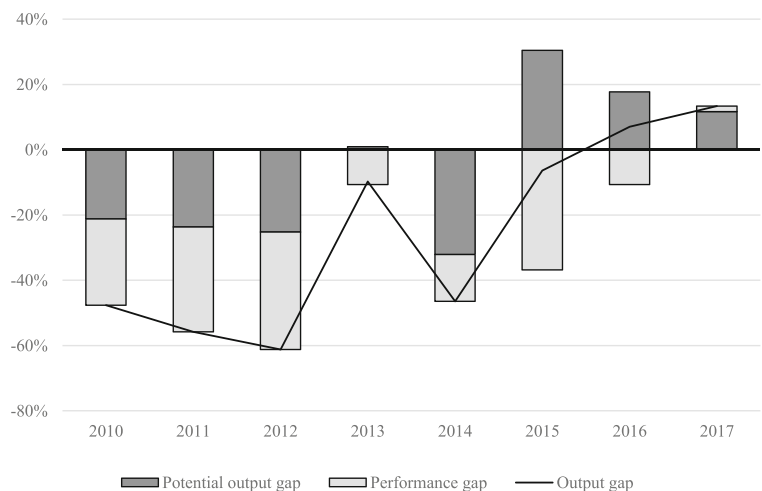
performance, the average output gap turned in favor of the organic farms in the last 2 years of the study periods.

Conclusions

While increasing organic production is one of the strategic objectives of the Finnish agricultural policy, we know very little about the relative performance of organic farming in Finland. This study contributed to the literature of organic agriculture in two ways.

First, we provided new empirical evidence essential for further development of the Finnish organic sector. We analyzed the effect of organic

Fig. 3 Field crops: average output gap and the contributions of potential output gap and performance gap (in percent)



management practice on farms' productive performance for the case of Finnish crop farms during the period 2010–2017. Within the sample of crop farms, we looked at its two major subsamples—specialist cereal farms and various field crop farms. The empirical evidence indicated that the effect of organic management practice is significant, and the productive performance of organic crop farms is lower compared to the conventional farming. This means that using the same amount of input resources, conventional farms produce more economic output than organic farms of the same type. However, empirical evidence also suggest that performance gap has been decreasing over time. In fact, during the last observed year, organic farms performed even better compared to their conventional counterparts.

Second, this study is the first empirical application of the one-stage nonparametric convex regression estimator in the context of agricultural production. The key advantages of this approach include the strong foundations in the axiomatic production theory and the econometric theory, the method's ability to let the data speak for themselves without imposing restrictive functional form assumptions, and its robustness to random noise. As the key limitation for agricultural applications, we note that the method is computationally demanding: Empirical application of this method requires a powerful solver for quadratic programming and some coding skills.

In this study, we have deliberately avoided the question of whether the performance gap is due to technology, efficiency, or perhaps relative prices of organic and conventional products. In our view, it is very difficult, if not impossible, to draw a distinction between these three underlying sources of performance differences without making some strong, unrealistic assumptions. To estimate the net effect of organic management practices on the farm revenue, such restrictive assumptions are unnecessary.

We would also argue that the performance gap is highly relevant from the point of view of agricultural policy. If the performance gap is negative, farmers have a strong economic incentive to choose conventional production. Therefore, if the government wants to promote organic production by subsidies, as the Finnish government is currently doing, then the subsidy should be large enough

to offset the performance gap; otherwise, it is ineffective. The significant negative performance gap may help to explain why the higher subsidy levels paid for organic farms in Finland have proved insufficient for meeting the quantitative policy targets of the Finnish government, as discussed in the “[Literature review on different aspects of organic farming](#)” section. On the other hand, it would be cost-inefficient to pay organic product subsidies that exceed the performance gap. Therefore, effectiveness and cost efficiency of the subsidy policy would require that the policy makers systematically monitor the development of performance gap over time and adjust the subsidy levels accordingly. If the performance gap turns to positive in the long run (as it did in the last year of our study period), then there is no reason to subsidize organic production that is competitive enough on its own. While the positive performance gap in the last year of our study period is an encouraging finding, further empirical research is needed to assess whether the positive development continues in the future.

We hope that our study might not only provide insight into the progress of organic production in Finland, but also stimulate further research on this topic. While we have focused on crop farms in Finland, a similar approach can be readily applied to other types of farming (e.g., dairy farms) and to other countries. The optimal design of agricultural policy to offset the negative performance gap presents another fascinating avenue for further research.

Author contributions Kuosmanen N. and Kuosmanen T. are the main contributors of the conception and design of this study. The first draft of the manuscript was written by N. Kuosmanen. Data collection and empirical analysis were performed by Yli-Heikkilä M. Väre M. was responsible for the content of the “[Introduction](#)” and “[Background](#)” sections. Kuosmanen T. was responsible for the “[Production function and its estimation](#)” section and contributed to the final editing. All authors commented on previous versions, and read and approved the final manuscript.

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Appendix

Table 3 Descriptive statistics of output and inputs for three samples: (i) all data, (ii) specialist cereals, and (iii) various field crops. Output, capital, and energy deflated to Consumer Price Index (2010=100)

	Output, 10 ³ €		Labor, h		UAA, ha		Capital, 10 ³ €		Energy, 10 ³ €	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
All farms (210–250 farms per year)										
2010	45.16	60.56	1208.7	979.8	78.0	71.8	198.2	235.7	6.5	6.3
2011	46.66	52.96	1153.2	817.1	73.2	53.9	195.1	180.6	7.5	6.1
2012	58.56	66.77	1181.5	933.6	77.2	58.8	218.9	204.0	11.0	9.8
2013	55.21	65.93	1181.8	892.3	79.0	60.6	225.9	207.3	10.5	10.0
2014	49.01	62.33	1153.1	898.5	80.3	65.2	227.5	220.0	9.4	8.3
2015	65.68	63.83	1439.7	1076.9	84.8	64.2	245.5	203.5	9.8	7.4
2016	62.23	67.51	1435.1	1196.2	90.0	74.9	263.9	232.0	8.7	7.8
2017	69.24	82.84	1441.2	1235.1	90.0	75.4	253.7	232.2	10.7	10.1
Specialist cereals (130–170 farms per year)										
2010	38.30	30.50	1124.3	741.7	75.0	53.5	180.2	152.0	6.1	4.4
2011	47.18	49.16	1116.7	699.1	74.7	50.1	200.5	185.4	7.8	6.0
2012	58.46	55.66	1159.6	813.7	80.1	57.6	228.6	199.6	11.7	9.6
2013	54.16	57.03	1143.2	780.7	80.6	57.6	230.1	191.7	10.5	8.7
2014	49.76	52.44	1201.8	853.7	87.1	70.6	243.1	214.7	10.5	8.7
2015	67.64	57.87	1432.5	940.0	88.8	60.9	265.5	201.5	10.7	7.5
2016	65.95	70.88	1465.1	1143.7	96.3	77.7	288.7	245.7	9.7	8.6
2017	75.15	88.59	1432.9	1169.2	95.7	77.3	280.2	248.8	12.4	11.5
Various field crops (60–100 farms per year)										
2010	54.92	97.94	1303.3	1372.2	84.6	103.9	220.8	351.3	7.1	9.2
2011	42.42	61.16	1133.1	1044.5	69.7	64.7	181.8	177.9	6.8	6.5
2012	46.33	69.38	1103.5	1075.2	67.1	63.4	175.3	198.5	8.2	9.7
2013	51.95	80.88	1209.8	1103.9	74.7	69.2	210.1	245.4	10.2	12.8
2014	45.04	79.55	1022.7	978.4	67.6	53.0	192.9	233.2	7.1	7.2
2015	59.93	75.03	1452.6	1367.4	78.8	72.6	204.7	209.6	7.6	7.1
2016	48.88	52.80	1316.6	1230.0	77.3	67.8	202.0	183.7	6.4	5.2
2017	58.01	75.14	1434.1	1376.3	82.7	75.6	208.6	200.3	8.3	7.5

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