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Economic consequences of investing in sensor systems on dairy farms

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ABSTRACT

The objective of this study was to investigate the impact of investment in sensor systems on productivity change, using farm accounting data.

Farm accounting data for the years 2008–2013 was available for 217 Dutch dairy farms. In addition, information was available on the adoption of sensor systems on these farms. For each farm, 5 input variables (number of dairy cows, number of hectares, total capital costs, total variable costs, and total labor costs) and 1 output variable (total revenues) were defined for each year. The Malmquist Total Factor Productivity index was used to examine productivity change for three categories of farms: farms without sensor systems, farms with sensor systems at an automatic milking system, and farms with sensor systems at a conventional milking system. The Malmquist index measures how the productivity of an individual farm changes over time and enables the contributions of technical change and technical efficiency change to be identified.

Productivity did not change after investment in sensor systems on dairy farms. Furthermore, no technical change was found after investment in sensor systems, suggesting that the potential technological improvement claimed by producers of sensor systems does not materialize on dairy farms. Providing more information and guidance on how to use the output of sensor systems might improve the technical performance of the farms.

1. Introduction

A sensor system for dairy farming can be defined as a device that measures a physiological or behavioral parameter of an individual cow and enables automated, on-farm detection of changes in this parameter that are related to a health event and which require action on the part of the farmer (Rutten et al., 2013). A sensor system is used to improve cow management. The number of dairy farms with sensor systems is growing for two reasons: farms with a conventional milking system (**CMS**) are increasingly adopting sensor systems (Steeneveld and Hogeveen, 2015) and more farms are switching to automatic milking systems (**AMS**), both in Europe and North America (Jacobs and Siegford, 2012; Lawson et al., 2011). Available sensor systems on both CMS and AMS farms include activity meters, which are used to detect estrus (e.g., Firk et al., 2002; O'Connell et al., 2010; Holman et al., 2011) and lameness (Pastell et al., 2009; Chapinal et al., 2010; Miekley et al., 2012). More recently, sensors that measure rumination time (Buchel and Sundrum, 2014) and the weight of cows (Van der Tol and Van der Kamp, 2010) have been introduced to obtain insight in the health of cows. On farms with an AMS, mastitis detection sensor systems are implemented, such as electrical conductivity sensors, color sensors, and somatic cell count sensors.

The performance of sensor systems is frequently investigated (see for an overview Rutten et al., 2013). Results show that sensor systems are able to detect diseases and estrus. The effect of using sensor systems in daily management on measures of health and production (e.g., average milk production per cow, days to first service, first calving age, and somatic cell count of the herd) was investigated empirically in a previous study (Steeneveld et al., 2015). Using data from 414 Dutch dairy farms, the average days to first service and first calving age were not lower after the introduction of sensor systems for estrus detection. Furthermore, average milk production per cow did not increase after the introduction of sensor systems (Steeneveld et al., 2015). A probable explanation for these findings is that improving measures of health and production was not an important reason for investing in sensor systems. The most frequently mentioned reasons for investing in sensor systems were reducing labor and easing management (Steeneveld and Hogeveen, 2015). These reasons are associated with the increasing herd size of dairy farms, which makes it

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challenging for the farmer to use physical observations to monitor individual cows.

Sensor systems did thus not influence the health and production of the cows (Steeneveld et al., 2015). An economic effect of using sensor systems, however, might be observed. Especially because farmers mentioned that reducing labor and easing management were important reasons for investing. If dairy farmers systems use their labor more efficiently after the investment in sensor systems, then a change in the use of inputs and a change in productivity would be expected. In ex-ante studies, Bewley et al. (2010) and Rutten et al. (2014) mentioned that investment in an automatic body condition scoring system and in activity meters was profitable, respectively. As these studies were normative, prior assumptions were made about the change in the amount of labor after the investment in sensor systems. An empirical ex-post analysis of the economic consequences of investing in sensor systems has not yet been performed. An empirical ex-post analysis will provide new insights in the economic consequences of the on-farm application of sensor systems. Reasons mentioned for not investing in sensor systems were economically related (Russell and Bewley, 2013; Steeneveld and Hogeveen, 2015). Therefore more insight in the economic consequences of investing in sensor systems may increase the adoption of sensor systems.

The objective of this study was to investigate the impact of investment in sensor systems on productivity change, using farm accounting data. Productivity is a measure of the ability of a farm to use inputs to produce outputs.

2. Materials and methods

2.1. Data collection

A survey on the use of sensor systems was conducted in the Netherlands during 2013. A link to the survey was sent by email to 1672 Dutch dairy farmers. The list with email addresses was provided by a Dutch accounting agency (Accon AVM, Leeuwarden, The Netherlands). The farms were located all over the Netherlands, but most were located in the north of the country. In total, 512 farms completed the survey (response rate of 30.6%); 202 farms had sensor systems and 310 farms did not have sensor systems. Farms were divided into three categories for the analysis: farms without sensor systems, AMS farms with sensor systems, and CMS farms with sensor systems. The information available for each category of farm is presented in Table 1. The data collection is further described in Steeneveld and Hogeveen (2015).

Accon AVM provided accounting data for 217 of the 512 dairy farms for the years 2008–2013. The accounting data included information on revenues (e.g., revenues from milk and other farm activities), depreciation (e.g., depreciation of buildings and machinery), fixed costs (e.g., costs for maintenance of buildings and machinery), variable costs (e.g., costs for feed, breeding, and energy and water) and general farm information, such as the number of cows, number of hectares, amount of milk quota, and the available labor in full-time equivalents (**FTE**).

Table 1
Information available for the three categories of farms: farms without sensor systems, for farms with sensor systems at an automatic milking system (AMS), and for farms with sensor systems at a conventional milking system (CMS).

	No sensor system	Sensor system at AMS	Sensor system at CMS
Sensor information[a]		✓	✓
Change in time for cow management			✓
Age of the farmer	✓	✓	✓
Availability of successor	✓	✓	✓

[a] Including type of sensor system, whether the sensor system is part of an AMS, and the year of investment.

2.2. Data editing

For every farm and for every year (2008–2013), 5 input variables (number of dairy cows, number of hectares, total capital costs, total variable costs, and total labor costs) and 1 output variable (total revenues) were defined. Total capital costs covered expenses and depreciation on buildings, expenses and depreciation on machinery and equipment, and miscellaneous costs. Total variable costs consisted of costs for forage, concentrates, substitutes for concentrates, milk products, minerals, fertilizer, pesticides, breeding, health care, energy and water, manure removal, fuel costs, and miscellaneous costs. Total labor costs consisted of costs for contract work and paid labor, and calculated costs for own labor, which were calculated by using the available FTE and assuming 52 weeks, 40 h a week, and a hourly rate. The hourly rate differed across the years 2008–2013, and varied between €19.80 and €21.89 (CBS, 2014a). Total revenues consisted of milk revenues, livestock revenues, revenues from other farm activities, and miscellaneous revenues.

Prices of inputs and outputs vary across time. For instance, the milk price varied highly from 2008 to 2013, and in 2009 the milk price was extremely low. Price indices were used to remove the effects of changes in prices, to ensure that the productivity measures only captured changes in physical inputs and outputs. The price indices for milk for the years 2008–2013 were 109.4, 79.6, 100.0, 111.8, 105.7, and 122, respectively (LEI, 2014). The year 2008 was chosen as base year, and the price indices were adjusted accordingly. The final price indices for the years 2008–2013 were 100, 72.8, 91.4, 102.2, 96.6, and 111.5, respectively. Subsequently, the milk revenues were multiplied with the price indices of the corresponding year. The same method was used for total labor costs, total capital costs, and total variable costs. The price indices for total capital costs and total variable costs were obtained from a Dutch agricultural economic institute (LEI, 2014) and the price indices for total labor costs were obtained from Statistics Netherlands (CBS, 2014b).

For each farm, the average costs and revenues for the period 2008–2013 were calculated. The profit before financial costs was also calculated for all farms. Profit before financial costs takes into account all costs except the interest on capital goods (which was not available).

A record was developed for each farm, which included data for two succeeding years (two time periods). Not all farms had accounting data available for all years, and 25 farms only had accounting data available for a single year. Therefore, the final dataset consisted of 646 records from 193 farms. For each record it was determined whether the farm had sensor systems in the two succeeding years. For instance, when a farm invested in sensor systems in 2009 then the records for the succeeding years 2008–2009 and 2009–2010 were defined as records without sensor systems. The records for the succeeding years 2010–2011, 2011–2012, and 2012–2013 were defined as years with sensor systems. In total, there were 497 records without sensor systems, 103 records with sensor systems at AMS farms and 46 records with sensor systems at CMS farms. Sensor systems were present at 82 farms (48 farms with an AMS and 34 farms with a CMS). Data editing was performed using SAS version 9.3 (SAS Institute Inc., Cary, NC).

2.3. Measuring productivity change

The Malmquist Total Factor Productivity index was used to calculate productivity change for the three categories of farms (with-