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Abstract

Effects of a number of information technology applications were quantified empirically which were implemented on Dutch and Israeli dairy farms. Data comprised annual farm performances from 1987 to 1996, and included both adopters and nonadopters as well as farm results before and after adoption. Significant effects were estimated, making a differentiation between the different technologies.

Key words: information technology, panel analysis, dairy farming

Introduction

Information technology (IT) applications have increased the opportunities for effective management support on dairy farms. Automation of the cow recording system with a

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management information system (MIS) offers the ability to improve utilization of individual cow production records in order to support managerial activities and decision making. More recently, advancements in information technology have made it possible to capture additional on-line cow side data (Spahr). The use of these new technologies enhanced the possibilities to monitor production, reproduction, feeding and health on an individual cow basis. However, all of these information technology applications incorporate some kind of automated cow recording system. In addition, technical and economic benefits may differ between countries in which farmers are operating under different production systems (e.g., climate, herdsize and management of the farm).

Three subsequent objectives were studied. First, the benefits of automated concentrate feeders, on-line milk production measurement and animal activity measurement implemented on Dutch dairy farms were quantified. Second, the benefits of MIS adoption and use in Dutch dairy farming were quantified in order to determine the potential effects of the automated cow recording component. Third, benefits of a similar system implemented on Israeli kibbutzim were quantified to determine the extent to which these effects were influenced by a different production system.

Study population

Yearly production and performance data were obtained from the Royal Dutch Cattle Syndicate (NRS) and the Israeli Holstein Herdbook. The IT applications under research in The Netherlands (operating under a milk quota system and relative small farms) were automated concentrate feeders (ACF), on-line milk production measurement (MPM), activity measurement (AM) and management information systems (MIS). The Israeli data set (relative large farms but also operating under a milk quota system) comprised farms that adopted the AFIMILK system (SAE Afikim, Kibbutz Afikim, Israel) in which MPM, AM and electrical conductivity of milk (ECM) are recorded on-line. Data of 167 farms which adopted ACF were available in the Dutch data set (at least 1 concentrate feeder per 25 cows at the time of installation). The number of farms that adopted MPM and AM was 153 and 59 respectively. Another Dutch data set comprised 357 farms that adopted an MIS. Since farm size, operator age and education level are important determinants of adoption (Putler and Zilberman), adoption herds might not be seen as a random sample but represent bigger farms with above average management levels. To ensure that the control herds were initially similar, in both data sets adopters (cases) were individually matched with similar herds (controls) from the NRS data base. The Israeli data set contained 162 kibbutzim with 3 times milking daily of which 74 kibbutz dairies adopted the AFIMILK system.

Data analysis

Empirical methods to evaluate MIS have been explained by Lazarus, Streeter, and Jofre-Giraudo and Verstegen et al. For this study, panel data sets were analyzed which included cross-sectional data (different variables in the same temporal interval) and time series data (annual periods from 1987 to 1996) of adopters and nonadopters, as well as farm results before and after adoption. Analyzing this kind of data makes it possible to compare at the same time “before and after” and “with and without” and hence provides an opportunity to estimate the effect of an adoption on herd performances, eliminating the influence of trend and herd-specific effects. In addition, panel data design makes it possible to estimate technology effects for each year after adoption, clarifying whether the particular technology utilization acts like a trend over several years or occurs as an instant jump at the time of adoption (Mundlack).

The effects on milk, protein and fat production as well as calving interval were quantified with the PROC MIX procedure of SAS with the following models:

```
PROC MIXED DATA=DUTCH_IT METHOD=REML; CLASS herd YR adjusted;
  MODEL y = year herd adjusted HF FH herdsize ACF MPM AM;
  RANDOM YR(adjusted) ACF*herd MPM*herd AM*herd;

PROC MIXED DATA=DUTCH_MIS METHOD=REML; CLASS herd YR adjusted;
  MODEL y = year herd adjusted HF FH herdsize MIS;
  RANDOM yr(adjusted) MIS*herd;

PROC MIXED DATA=ISRAEL_AFIMILK METHOD=REML; CLASS herd YR;
  MODEL y = YR herd herdsize AFIMILK;
  RANDOM year*herd AFIMILK*herd;
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The regression model estimates Y for herd i and year j with the following independent main variables: year (e.g., $year_{ij}$ = 1987, if observation is in 1987 and is defined as a class variable), herd (e.g., $herd_{ij}$ = unique herd code, if observation is from that particular herd and is a class variable), ACF (e.g., $ACF_{ij} = 0$ if herd i did not used ACF in year j), MPM (e.g., $MPM_{ij} = 0$ if herd i did not used MPM in year j), AM (e.g., $AM_{ij} = 0$ if herd i did not used AM in year j), HF (percentage Holstein-Friesian breed), FH (percentage Friesian-Holland breed), herdsize (number of cows) and an error term. The terms ACF x herd, MM x herd, AM x herd, MIS x herd, AFIMILK x herd and a nested term YR(adjusted) were incorporated as random effects because these factors represent only a random sample of the total farms. Adjustment (e.g., adjustment = 0, if observation is before 1992; otherwise adjustment = 1) was introduced in the Dutch regression models because yearly production records were redefined in 1992. Production records before 1992 were on basis of lactation production, and, from 1992 onward, records were based on 305 d lactations (records with < 305 d but ≥ 200 d were unmodified incorporated). Notice that year is a class variable and YR is a linear variable.

Estimators of the variance components were obtained with the REML and ML methodology. However, the methods produced almost identical estimates and associated standard errors, therefore, only REML results are presented

Two different models were analyzed in which the independent variables (ACF, MPM, MIS and AFIMILK) were incorporated as a linear or as a class variable, respectively. In the first model, the adoption variables have the values of 0 (for nonadopters and for herds before adoption), 0.5 (year of adoption), and 1 (herds after 1st yr adoption). Use of the year in which the application is introduced allows adjustment for the fact that a farmer does not effectively utilize the application at the starting point (learning effects) and the application was not used the entire year. In the second model, class 0 (nonadopters and herds before adoption) has been compared with three classes: 1 (year of adoption); 2 and 3 (yr 2 and yr 3 after adoption) and > 3 (> 3 yr after adoption).

Technical effects on farm performances

In Table 1 the number of adopters and characteristics of the data sets in year 1987 is presented. The cases and controls closely matched each other in 1987 with respect to the variables under research. Herdsize over years for adopters and nonadopters was similar, indicating a randomness in adoption with respect to the autonomous growth of the farms. Faster increasing herds were not more inclined to adopt than slower increasing control herds. Dutch farms were smaller with a lower production than the Israeli kibbutzim.

INSERT TABLE 1

In The Netherlands, an automated concentrate feeder resulted in an improvement of the annual milk (carrier), protein and fat production of 102 kg, 4.95 kg and 5.52 kg per cow respectively (Table 2). In contrast, on-line milk production measurement did not have a significant effect on milk production records. Calving interval was reduced by 6 days after adoption of an activity measurement system, and was not affected by adoption of an automated concentrate feeder or on-line milk production measurement.

INSERT TABLE 2

Adoption and use of an MIS resulted in a significant annual increase in milk (carrier) and protein production of 62 kg and 2.36 kg per cow respectively. Calving interval was shortened by 5 days. To make a clearer comparison between the two Dutch data sets, the MIS data set was further analyzed with two subsets which differed in herdsize. Only the estimated effect on calving interval was significantly affected for the relatively bigger farms, while milk, protein and calving interval were significantly effected for the relative smaller farms. The relatively bigger farms could be characterized similar to farms which adopted ACF, MPM and AM. Apparently, the automated cow recording component improved calving interval almost as much as a system in which in addition AM is implemented.

The AFIMILK system in Israel resulted in an improvement of the annual milk (carrier) and protein production of 191 kg and 4.52 kg per cow respectively. Calving interval was reduced by 4 days after adoption. The estimated effects on production variables for Israeli kibbutzim were larger than the combined effects of AM and MPM on Dutch dairy farms, while reproduction was less.

Paired comparisons of the least squares means (0 vs. 1, 0 vs. 2 and 3 and 0 vs. > 3) have been tested for significance (Table 3). Estimates for ACF use showed significant effects on production of milk (114 kg), milk protein (4.98 kg) and milk fat (5.49 kg) for nonadopters compared with adopters after the 2nd and 3rd yr. Changes in the production of milk, milk protein, and milk fat increased significantly in the consecutive years of a particular technology use. In general, 1st yr performances lagged behind that of the subsequent years. Thus, effects increased gradually over several years rather than suddenly at the time of adoption.

INSERT TABLE 3

Economic benefits

Our analysis, conducted with different data sets, clearly demonstrated significant effects on milk production records occurring during the first years after adoption, making a differentiation between the different technologies. Herds with observations before and after adoption with respect to a certain technology provided, together with a control group, the means to distinguish between effects that were farm specific and those that constituted a trend. Net return to labor and management income increased by Dfl. 44 (1US$ = Dfl. 2) per cow /yr as a result of ACF. The use of AM shortened calving interval by 5.7 d, which is estimated to increase net return to labor and management by Dfl. 12 per cow /yr. Net return to labour and management increased by approximately Dfl. 30 per cow /yr as a result of MIS adoption, and Dfl. 66 per cow /yr as a result of AFIMILK adoption. To break even after incurring annual costs of the investment in ACF or AM, in case of a simultaneous investment in ACF and AM, depreciation period should be at least 5-years and 9-years, respectively. To break even the annual costs of investment in an MIS, depreciation period should be at least 5-years, which is also acceptable for this kind of applications with update facilities and therefore appears to be economically profitable. For a typical Israeli kibbutzim of 300 cows, the depreciation period should be at least 6 years.

The panel data analysis has proven to be fruitful to evaluate the benefits of different technologies implemented on dairy farms. Therefore, additional information technology adoptions could (and should) be evaluated in a similar empirical manner to clarify whether these technologies increase profitability.

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Table 1. Characteristics of the data sets in year 1987

	Dutch Data ACF, AM, MPM		**Dutch Data** MIS		**Israeli Data** AM, MPM, ECM (AFIMILK)	
	case n=295	control n=295	case n=357	control n=357	case n=74	control n=88
Cows	63	63	58	58	300	285
Milk (kg)	6605	6604	6581	6572	9089	9216
protein (kg)	226	225	226	224	271	272
fat (kg)	289	281	287	278	283	284

Table 2. Estimated effects of automated concentrate feeders (ACF), milk production measurement (MPM), activity measurement (AM), management information systems (MIS) and the AFIMILK system

	Dutch Data ACF, AM, MPM	**Dutch Data** MIS	**Israeli Data** AM, MPM, ECM
	ACF	MIS	AFIMILK
Milk production (kg)	102	62	191
Protein (kg)	4.95	2.36	4.52
Fat (kg)	5.52	NS[1)]	NS[1)]
Calving interval (d)	NS[1)]	-5.28	-4.1
	AM		
Milk production (kg)	NS[1)]		
Protein (kg)	NS[1)]		
Fat (kg)	NS[1)]		
Calving interval (d)	-5.7		
	MPM		
Milk production (kg)	NS[1)]		
Protein (kg)	NS[1)]		
Fat (kg)	NS[1)]		
Calving interval (d)	NS[1)]		

[1)] Not significant ($P > 0.05$)

Table 3. Estimated effects of years after adoption versus nonadoption of automated concentrate feeders (ACF), milk production measurement (MPM), management information systems (MIS) and the AFIMILK system.

	ACF	MPM	MIS	AFIMILK
Milk production (kg)				
none versus 1 y	87	NS[1)]	NS[1)]	95
none versus 2 & 3 y	114	NS[1)]	47	167
none versus >3 y	176	NS[1)]	69	180
Protein (kg)				
none versus 1 y	2.79	NS[1)]	1.54	NS[1)]
none versus 2 & 3 y	4.98	NS[1)]	1.93	3.75
none versus >3 y	7.19	NS[1)]	2.58	5.88
Fat (kg)				
none versus 1 y	4.55	NS[1)]	NS[1)]	NS[1)]
none versus 2 & 3 y	5.49	NS[1)]	NS[1)]	NS[1)]
none versus >3 y	7.04	NS[1)]	NS[1)]	NS[1)]
Calving interval (d)				
none versus 1 y	NS[1)]	NS[1)]	-2.41	-3.12
none versus 2 & 3 y	NS[1)]	NS[1)]	-3.94	-3.95
none versus >3 y	NS[1)]	NS[1)]	-6.12	-3.91

[1)] Not significant ($P > 0.05$)