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Survival Analysis for the Adjustment Phase Following Investment in Swiss Dairy Sheds

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Abstract: We analysed the adjustment phase following a dairy shed investment. On the basis of farm observations from both the Swiss Farm Accountancy Data Network (FADN) and a database of government-supported investments from 2003 through 2014, we focused on the imputed profit, the farm income minus opportunity costs for family labour and family capital. After investment, the analysed farms needed three years to return to the same profit level as that before the investment (median value). A Cox proportional-hazards model (survival analysis) showed that the probability of reattaining the imputed profit increased with equity capital. A reduction of the probability was related to a high imputed profit, a high off-farm income, high expenses for purchased animals and, in particular, a greater use of family labour before the investment. We conclude that the use of family labour after investment should be addressed more thoroughly during the planning process prior to an investment.

Keywords: investment; dairy cattle; imputed profit; Switzerland

1. Introduction

Building a new dairy shed or investing substantially in an existing one is a decisive step in the development of a dairy farm. An investment is likely to go along with some technical progress. Given the small size of Swiss dairy farms, the labour input per cow can thus be roughly halved if the form of husbandry is converted from tethered to loose housing [1]. That many farms in Switzerland have taken this step is demonstrated by the increase in the number of cows kept in loose housing [2].

At the farm level, an investment may result in sunk costs [3] potentially forcing the farm to stay in the dairy business. According to Balmann et al. (2006) [3], this effect is also relevant for the dairy sector as a whole, because a suboptimal sectoral structure may persist for decades. As a consequence of specific investments, farmers may even accept a negative capital productivity before starting to disinvest [4]. Generally speaking, the locked-in situation may put into question whether the investment is leading to an economic improvement at all.

In fact, there is evidence that investments in dairy sheds are not, at least immediately, an economic success. Several studies have shown that the cattle population only grows with some delay following investment in dairy sheds [5–7]. Sauer and Latacz-Lohmann (2015) [8] point to the fact that an investment is followed by a phase of efficiency improvement that lasts for two years. In Switzerland too, there is evidence of unused capacity following investment in a dairy shed [9]. Investments with a longer-lasting learning effect and a subsequent increase in efficiency are also known from the downstream agricultural sector [10].

Kramer et al. (2019) [7] analysed the impact of a dairy shed investment on profitability focusing on imputed profit as an evaluation criterion. This paper goes one step further, analysing whether the imputed profit before an investment is reattained afterwards. In detail, two questions were answered. Firstly, how many years are necessary to recover the imputed profit before investment? Secondly, which factors favour or hamper the recovery of the imputed profit? The analysis of factors was carried out by means of a survival analysis, i.e., a Cox proportional-hazards model. As to our knowledge, a survival analysis has never been applied to investigate the course of an agricultural investment.

The paper is organised as follows. The subsequent methodological section deals with the variables used and the description of the Cox proportional-hazards model. Section 3 presents the results, followed by the discussion in Section 4. The final section puts forward the conclusions.

2. Materials and Methods

2.1. Dataset

Similar to Kramer et al. (2019) [7], the analysis was based on two data sets. Firstly, we selected farms limited to the farm types "dairying" and "combined dairy/arable crops" from the Swiss Farm Accountancy Data Network (FADN) from 2003 to 2014 [11]. We focused on farms from the valley and hill regions, allowing for the analysis of specialised dairy farms with comparable natural conditions. The FADN data contain information only on the presence and amount of investment loans, not on their intended use. Hence, there is no indication about the type of investment (e.g., dairy shed, machine shed or another farm enterprise than dairy). Neither is the year or the years the investment has taken place available. Such information is provided by the second data base, MAPIS (Meliorations-und Agrarkredit-ProjektInformations-System [12]) including all subsidised investments in dairy sheds.

We matched both data sources by means of municipal code, loan amount and—if necessary—potential year(s) of investment. The resulting data set contained 103 farms with 544 observations. Due to the panel mortality in the FADN, the number of farm observations decreased with each subsequent year after the investment.

2.2. Imputed Profit

Because most dairy farms are family-run, they show a high share of family-owned factors, labour and capital. The latter also includes own land. Accordingly, the farm profit is highly dependent on the (assumed) remuneration of own factors. The imputed profit corresponds to the agricultural or farm income minus opportunity costs for family labour and family capital and is well suited as a criterion for economic success. The imputed profit is derived from FADN observation for farm j and year t according to Formula 1:

$$\textit{Imputed profit}_{j,t} = \textit{Agicultural income}_{j,t} - \textit{Opportunity costs labour}_{j,t} - \textit{Opportunity costs capital}_{j,t} \quad (1)$$

The agricultural income corresponds to the difference of all revenues including direct payments less all third-party costs. The latter include all direct costs and the costs for borrowed capital and non-family labour. Accordingly, agricultural income represents the remuneration of the family-owned factors.

Given the heterogeneity in size and the composition of the family-owned factors labour and capital, a standardisation is necessary. In order to enable a comparison of the farms, we deducted the opportunity costs for both factors, labour and capital [11]. The opportunity costs are defined by law [13], taking account of regional differences (valley vs. hill region). For family labour, the agricultural reference wage is applied. The latter corresponds to the income achieved in other sectors (industry and services), implicitly assuming a similar qualification of workforces. For equity capital, the interest rate on 10-year (Swiss) Federal bonds is applied as opportunity cost.

It is important to note that Swiss FADN was applying constant depreciation at the period of the data used. Accordingly, the depreciation was independent of the course of business.

2.3. Model

In order to analyse the determinants of the adjustment phase following the investment, the methods of survival analysis are suited. Survival analysis examines the time up to the occurrence of an event [14] and the influencing factors. The Cox proportional-hazards model is one of the models frequently used for survival analyses. It allows the analysis of variables with and without time variance and has been used in agricultural economics before [15,16]. The use of survival models is attractive for the data structure under consideration, as it takes into account the right censoring of data [14,17]. Right censoring means that individuals withdraw from a study without the event of interest being observed. In the case of the observed events, we knew the time to the event, but in the case of withdrawals, we knew that farms had not recovered the imputed profit at least up to the observation point. The survival method takes this into account by considering these two cases separately [14,18]. A critical step in survival analysis is the definition of a starting point at which a specific event may occur [14]. The specific event occurred when a farm returned to at least the imputed profit from the year prior to the investment. In the available data, the starting point could be precisely defined as the time of the investment. The Cox proportional-hazards model calculates the hazard for a farm j with properties x_j as follows:

$$h\left(t\middle|x_j\right) = h_0(t)\exp\left(x_j\beta_x\right) \tag{2}$$

Here, β_x stands for the regression coefficients established from the data, and $h_0(t)$ for the baseline hazard [14]. The hazard represents the probability that an event will occur at time t, assuming that it has not occurred until (infinitesimally) shortly before time t [15]. The survival function in the model is an exponential function. The hazard for this exponential distribution is appropriate in this case, since no dependence of the hazard on the elapsed time is expected [15]. "Proportional hazards" means that the proportional change in hazards due to a change in an explanatory variable does not depend on time [15]. This assumption was checked using the test for proportional hazards according to Grambsch and Therneau (1994) [19] and could not be rejected.

2.4. Independent Variables

Table 1 provides an overview of the independent variables used, including their mean value and standard deviation.

Table 1. Overview of the independent variables used, with abbreviations and units.

Variable	Unit	Mean Value	Standard Deviation
Investment	10 kCHF	7.05	21.7
Imputed profit before investment	10 kCHF	−1.86	3.40
Equity capital	10 kCHF	62.0	37.0
Annual family work units	FWU	1.31	0.34
Off-farm income	10 kCHF	1.47	1.81
Grassland	Ha	20.0	8.56
Stocking rate	LU/ha	1.48	0.42
Ratio of offspring to dairy cows (in LU)	-	0.25	0.16
Animal purchases	10 kCHF	1.44	2.24
Milk produced	t/a	211	101
Type of farm (dummy)	-	0.72	0.45

The mean investment of the farms under investigation was CHF 70,500. (CHF denotes Swiss francs. The average exchange rate in 2017 of the currency towards USD and Euro was 1 CHF = 0.90 Euro = 1.02 USD, as retrieved from https://data.snb.ch on 29 January 2018). Because the actual number of dairy shed places created by the investment was not apparent from the data, the level of investment was used as a proxy in order to control for this. The observed slow increase in livestock numbers after the investments [5–7] is an indication that the increased dairy shed capacity initially remained unutilised [9]. Accordingly, it is expected that size (of an investment) has a negative impact on the adjustment phase.

The use of own production factors directly influences the imputed profit, as a central factor in the analysis, via the opportunity costs. Equity capital, including own land, in tens of thousands of CHF, and family labour, in annual labour units, were therefore included in the model as explanatory variables. Opportunity costs should also be included in the model because they are perceived as being less important than financial accounting costs [20]. If the owners and managers of a farm are generally satisfied with lower remuneration of production factors or have made extensive investments in the past, it can be expected that the profit—and thus also imputed profit—will be at a lower level. To take this into account, the imputed profit before the investment was introduced in the model as a variable. A low starting position should also be easier to reattain and should therefore increase the probability of reattainment.

Regarding equity capital, two effects seem plausible. A higher equity capital reduces the imputed profit, via the interest claim. At the same time, however, it is to be expected that the equity capital stock is closely linked to economic success and enables better farm results. If a farm is comfortably endowed with family labour, expressed as annual family work units (FWU), this could lead to inefficient use, as there is no direct economic pressure to remunerate family workers in full. Given that family labour dominates the labour input in Swiss dairy farms, this variable is also linked to farm size.

Combining agricultural and non-agricultural income sources is not economically optimal and, if farming is not used as the single source of income, it might partly be a lifestyle decision [21]. However, Mittenzwei and Mann (2017) [21] also mentioned that other authors see the decline in agricultural incomes as a justification for combining income sources. In connection with investment, Foltz and Aldana (2006) [22] stated that the level of non-agricultural wages influences the decision whether to generate an off-farm income or to expand the farm. However, whether investments are made if off-farm income is available also seems to depend on who is earning a non-agricultural income, i.e., the farm managers or their partners [23]. The studies referenced here do not distinguish who earns the off-farm income or how high the wage level is. The off-farm income from both independent and dependent employment (in tens of thousands of CHF) is therefore included in the model. Although an off-farm income appears to reduce the probability of investment [22,23], a positive effect could be expected during the adjustment phase. Improving the input/output ratio without expanding the production would free up labour that could be used for the secondary occupation. Hennessy and O'Brien (2008) [23] also postulated a substitution effect of labour by capital in the case of a secondary occupation but found no significant correlation between secondary occupation and level of investment.

In the Swiss dairy production system, grassland forms the basis of milk production because of relatively high costs of concentrates. Due to economies of scale, one would expect more hectares of grassland to have a positive effect. At the same time, the fertiliser regulations set an upper limit for the stocking rate expressed in livestock units (LUs) per hectare (ha) of agricultural land, which could limit the benefit of economies of scale in dairy shed building and thus have a negative effect. Agricultural land includes arable land and grassland. In practice, this can be mitigated by outsourcing the rearing of offspring to other farms. Such a strategy could be identified by a low ratio of offspring to dairy cows, both measured in livestock units. Since a low ratio would correspond to a specialisation, it could be expected to have a positive effect.

In spite of the above-mentioned slow increase in livestock numbers after investment, the additional capacity generated by the investment could be used more quickly by purchasing additional animals. The FADN data record expenditure on animal purchases using a specific reference rate per animal for monetary valuation of the herd, for balance sheet purposes [24]. That this rate may deviate from actual market prices [25,26] must be taken into account for the interpretation of the results.

In order to account for a possible increase in milk yield as a result of the investment, the milk produced on the farm was included in the model.

Since the data referred to two different types of farm ("dairying" and "combined dairy/arable crops"), these two types were differentiated for the analysis using a dummy (1 = "dairying").

3. Results

Out of the 103 farms with investments, 65 were able to reattain the imputed profit from before the investment during the period of observation. The median time to reattainment was three years. The median imputed profit before the investment was CHF −20,843. The production factors were thus not fully remunerated for the majority of farms. For five of the explanatory variables, the *p*-value was below 0.1, so these were regarded as significant. The results are shown in Table 2.

Table 2. Results of the Cox proportional-hazards model.

Variable	Hazard-Ratio	Standard Error	*p*-Value
Investment	1.00	0.003	0.178
Imputed profit before investment	0.86	0.024	**0.000**
Equity capital	1.01	0.003	**0.084**
Annual family work units	0.26	0.090	**0.000**
Off-farm income	0.94	0.035	**0.084**
Grassland	1.02	0.023	0.350
Stocking rate	1.59	0.715	0.302
Ratio of offspring to dairy cows (in LU)	1.22	1.01	0.811
Animal purchases	0.85	0.071	**0.052**
Milk produced	1.00	0.000	0.362
Type of farm	0.67	0.226	0.240

Bold *p*-Value denotes a significant explanatory variable (p-Value < 0.1).

A hazard ratio greater than 1 means that a higher value of the corresponding variable is associated with a higher probability of reattaining the imputed profit. This was desirable in the present case, because the effect on the adjustment phase was positive, i.e., the starting level was reattained. It should be noted that a coefficient larger or smaller than 1 is not tantamount to a shorter or longer adjustment phase, which would only hold true in the case of time-invariant variables [15].

Only an increase in equity capital had a significantly increasing effect on the probability of reattainment, even though the strength of the effect was rather small (hazard ratio close to 1). The hazard ratios of all other significant variables such as imputed profit before investment, annual family work units, purchase of additional animals and off-farm income were below 1, thus reducing the probability of reattainment. While four out of the five significant variables showed a hazard ratio relatively close to 1, the hazard ratio for annual family work units was far below 0.5. To illustrate the interpretation of the hazard ratio, we used the example of imputed profit before investment: For every CHF 10,000 of imputed profit, the probability of re-attainment was reduced by 14%.

4. Discussion

The median of three years until the imputed profit was reattained confirmed the results of Sauer and Latacz-Lohmann (2015) [8]. Since, as for opportunity costs, the remuneration of family labour surpassed clearly the remuneration of capital [27], it is not surprising that the use of family labour had a more significant influence than equity capital. The influence of equity capital was significantly positive, but rather small. The influence of family work units was significant and strongly negative. In addition to a less clear perception of opportunity costs [20], another reason for this could be the limited mobility of labour [28]. There may not be an immediate alternative. Due to the learning effects that can accompany investments [10], the final labour requirements may not yet be precisely determined before the investment, meaning that more family labour is held in reserve as it does not entail any direct costs.

As stated in the introduction, more off-farm income can be argued to hamper or increase the probability of re-attaining pre-investment profits. A high off-farm income might facilitate farm investment and, as result, free up labour for more off-farm income, if off-farm work opportunities exist. It might also allow a family to accept a lower labour productivity for the farm, as living expenses are covered by off-farm income. Off-farm income had a negative impact on the probability of attaining pre-investment profits. Its direct effect on liquidity and immediate contribution to covering the cost of living of the family might lessen the need to generate income from farm business. In addition, adopting the argument of combining incomes as a lifestyle choice [21], agriculture would be seen as a hobby, which in turn calls into question the actual applicability of the opportunity costs concept.

There are several potential reasons for the negative effect of a higher imputed profit before investment. Investment in a dairy shed requires long-term planning. Expenditure that reduced the profit and was related to the investment may have been incurred in advance. However, in our analysis, it was not possible to use an average imputed profit over several years before the investment as a benchmark, as this would additionally reduce the number of farms available for analysis. In the case of farms working with depreciated equipment, the lack of depreciation leads to a higher imputed profit before the investment, which is no longer the case after the investment. In addition, such accumulated needs could lead to subsequent investments that reduce the profit.

The acquisition of additional animals had a negative effect on the probability of reattaining pre-investment profits and is therefore contrary to the formulated hypothesis. However, in our analysis, only the monetary value was taken into account, which might bring accounting effects into play. The benchmark value of a cow for balance sheet purposes was, most recently, CHF 2200 [26], while the average price achieved for dairy cows at livestock auctions in the observation period was between CHF 2600 and CHF 3500 [25]. This indicates that market prices were above the reference rates used but does not permit a final conclusion to be drawn. However, if the amount for which animals are purchased is higher than the reference rate, the monetary expenditure is higher than the increase in value of the animals in the balance sheet. This difference has a direct negative effect on the imputed profit as compared to the case in which animals could be purchased at the reference rate.

In addition, dairy cows are generally used over several years, but are not written off in the accounts [24]. As a result, the costs of purchasing additional animals accrue completely in the year of acquisition, although they are also related to other periods, and thus lower the imputed profit in the period of acquisition only. Hence, if animals were purchased closely after the investment, this would artificially reduce imputed profits in that period and thus decrease the probability of reattaining pre-investment profits.

It would also be conceivable that animal purchases are made by farms whose herds show poor physical performance, that purchased animals affect the productivity of the herd negatively due to initial stress or that animals are bought at a young age, not directly being able to positively affect profit. However, all of this cannot be adequately represented by the data.

Since FADN data do not contain enough information on the reproductive characteristics of the dairy herd, we could not fully take into account its natural growth. This left us with the usage of the ratio of offspring to dairy cows as a proxy. The coefficient of this variable showed a positive impact on reattaining pre-investment profits, but not significantly so.

5. Conclusions

By means of a Cox proportional-hazards model, this paper analysed whether Swiss farms, which invested in their dairy shed, reattained their imputed profit prior to investment and which factors affected this process. Although the data set used was relatively small, the analysis provided relevant information for both farm management and agricultural policy. Four out of five significant influencing factors hampered the reattainment of the pre-investment imputed profit, which confirms the finding in the literature that the phase directly after an investment is not rewarded by dominant efficiency improvements [8,10]. Rather, the farms in this study appeared to take only limited advantage of both improved efficiency and increasing imputed profit after the investment. The clearly negative and highly significant influence of family labour points to the fact that family labour is not allocated in an optimal way. We conclude that the use of family labour after investment should be addressed more thoroughly during the planning process prior to an investment of a dairy shed. The shown negative influence of off-farm labour additionally emphasises the importance of planning how the farm manager's family should deploy its work forces in the medium and long run.

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