

Exploring within- and between-effects of the factors influencing off-farm work decisions in Switzerland

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Abstract: We examine the determinants of off-farm work in Swiss agriculture between 2003 and 2013. By differentiating between the between-farm effects and the within-farm effects, our model provides new insights into the labour allocation process as compared with standard cross-sectional or panel data models. As regards the between-farm variations, our results show that younger farm families without children and farm households with higher non-agricultural education levels of both the farmer and the partner are more involved in working activities outside the farm. However, the within-farm time effects provided a more differentiated picture: impacts of changes in most variables over time tended to be smaller, and in case of two variables show opposite directions. In addition to a negative between-effect of farm income on the allocation of off-farm labour, our results on within-farm effects suggest that an increase in farm income per annual family work unit could be compatible with a higher share of off-farm work during the analysed period.

Keywords: farm households; heterogeneity; labour allocation; off-farm labour supply; panel data model; within-between model

The decision to engage in off-farm employment is motivated and influenced by various factors, as demonstrated by extensive theoretical and empirical studies in the field of agricultural economics [for a review see e.g. Pastusiak et al. (2017)]. Off-farm work provides additional income and serves as a means of stabilising the farm households' financial situations by diversifying their income sources and reducing reliance on agriculture (Weersink et al. 1998). Given the inherent uncertainties and fluctuations in farm income, off-farm employment plays a crucial role in ensuring the

economic sustainability and viability of farming operations (Vrolijk and Poppe 2020). Moreover, labour allocation decisions are not solely driven by economic considerations but can also be influenced by personal aspirations, lifestyle preferences, and the desire to pursue alternative interests outside of farming (Howley et al. 2014).

In Switzerland, there has been a significant increase in the proportion of off-farm working time among farm households over the last few decades, accompanied by greater participation of farmers' partners

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in off-farm work (Hoop et al. 2014). This period was marked by notable changes in the economic environment, including the elimination of milk quotas and agricultural policy reforms, which implemented ecological standards and the transition from product subsidies to direct payments (El Benni and Finger 2013). All this has facilitated structural changes and resulted in the reduction of product prices and a concentration of production on fewer, more specialised farms (Zorn and Zimmermann 2022). However, the Swiss agricultural sector is still characterised by small-scale family farms and remains one of the countries with the highest levels of government support (OECD 2020). Farmers from less favoured areas, such as hill and mountainous regions of Switzerland, are among the major beneficiaries of state support, compensating for their significantly lower incomes from farming through direct payments and off-farm work (FOAG 2020). Additionally, in recent years, a modernisation in the perception of agricultural families' roles has been observed, with women gaining independence through non-agricultural activities (Contzen and Forney 2017). The interplay between traditional and modern practices, Switzerland's unique agricultural landscape, strong economy, and sophisticated direct payment system provide a conducive environment for exploring the determinants of off-farm employment and understanding how they interact with social, economic, and policy factors.

Existing research in this field has explored various determinants of off-farm work such as demographic characteristics, educational levels of farm managers, family structure of the farm household, farm type, farm size, local labour markets, spatial aspects, financial characteristics, coupled and decoupled direct payments, farm performance as well as risk management (e.g. Huffman 1980; Sumner 1982; Singh et al. 1986; Weersink et al. 1998; El-Osta et al. 2004; Hennessy and Rehman 2008; Bjornsen and Mishra 2012). However, the majority of studies have relied on cross-sectional or panel data models that cannot capture the nuanced dynamics within farm households (Balachandran et al. 2023). Considering the changes in farm and household characteristics over time is crucial when analysing labour allocation decisions in Switzerland. Factors such as technological advancements, shifts in agricultural policies, and changes in the composition of farming households can significantly impact the dynamics of off-farm work participation.

Our study is motivated by the opportunity to analyse the determinants of off-farm work from two perspectives: comparing characteristics between different

farms or farm families and examining the development of these characteristics over time. To achieve this, we employ the within-between (hybrid) model proposed by Bell and Jones (2015), which offers several advantages over the fixed effects and random effects models commonly used in economics and social science literature. This approach enables us to effectively account for unobserved heterogeneity, consider both within- and between-farm effects, and gain a more accurate understanding of the labour allocation process in the context of off-farm work. Despite the numerous advantages associated with this model (which we will discuss in the next chapter), its application in the field of agricultural economics is rare (e.g. Hoop 2022). Furthermore, its application in the context of labour allocation in farm households remains relatively unexplored, indicating the potential for novel insights in this field. Using a comprehensive and detailed panel data set of Switzerland's Farm Accountancy Data Network (FADN) for 2003–2013, our study provides valuable insights into the interrelationships between off-farm activity and changing economic and political conditions. We also consider the observed heterogeneous production systems and family structures while accounting for the potential impact of unobserved characteristics such as preferences and abilities.

MATERIAL AND METHODS

In this study, we use data from the Swiss FADN (Farm Accountancy Data Network) of the so-called 'reference farm' sample from the period 2003–2013. This time period is characterised by a consistent agricultural policy and the use of the same survey methodology (no data breaks). This unbalanced panel data set contains 20 419 observations of 2 102 individual farms. We considered only farms which participated in the survey for at least seven years. In addition to the standard FADN variables such as income and costs from financial accounts, this dataset contains information on the farm household, such as the off-farm income of the farm manager and their partner, and time spent on the farm and in off-farm activities. Various sociodemographic characteristics of the farmer and their family are also available.

Based on this dataset, we estimated an off-farm labour supply function, which is theoretically derived from the farm household model (Sumner 1982), to investigate the impact of different characteristics of the farms, farm managers, and their families on the share of days worked off-farm in the total worked days of the

farm household. Following the established procedure, we used Heckman's two-step model (Heckman 1976) to account for possible selection bias in the decision to work off-farm. In the first step, we estimated the probability of a farmer's decision to participate in off-farm work (selection function) by using a probit model with variables determined by the stepwise selected model. If the inverse Mills ratios obtained from the first step indicated the presence of the selection bias, we estimated the off-farm labour supply function in the second step, correcting for the selection bias identified in the first step.

Sample selection bias is not the only potential source of bias when analysing the determinants of off-farm work. Another important issue is the presence of relevant but unobserved variables omitted from the labour supply model, leading to biased estimates, commonly known as omitted variable bias. For instance, availability of job opportunities, access to transportation and infrastructure, and individual preferences and motivations are usually not observed but might influence the working decisions of farmers and other family members. Addressing these issues becomes challenging when relying on cross-sectional data alone. However, the availability of panel data, which involves repeated observations of the same farm over multiple years, such as in the Swiss FADN survey, offers a valuable opportunity to mitigate these biases.

In panel data analysis, researchers often turn to a fixed effects model (FE), which incorporates the individual fixed parameter into the model to account for unobserved heterogeneity at the individual (farm) level. However, the FE model primarily focuses on within-variation in the data, effectively removing all between-variation (both observed and unobserved). In our case, this approach was not appropriate because it can potentially diminish the explanatory power of the model if a significant portion of the variation in off-farm labour supply can be attributed to differences in characteristics across farms and farming households. Both within and between variations are considered when applying the random effects model (RE). However, the RE model usually suffers from heterogeneity bias, which occurs when covariates are correlated with a time-invariant component of the composite random error, which captures unobserved individual heterogeneity. To overcome the limitations of FE and RE models, a hybrid approach known as the within-between model has been proposed (Bell and Jones 2015). The within-between model can be seen as an extension of the standard RE model:

$$y_{it} = \beta_0 + \beta_1 x_{it} + \beta_2 z_i + (u_i + e_{it}) \quad (1)$$

where: y_{it} – dependent variable observed by the farm i in the year t ; β_0 – intercept term; x_{it} – (a vector of) time-variant variables with coefficients β_1 estimating the mixed effect; z_i – (a vector of) time-invariant variables with coefficient β_2 estimating the between effect; the 'random' part of the model (in brackets) consists of u_i , the individual-level random effect for farm i , and e_{it} , the time-variant component of the error.

Bell and Jones (2015) suggested extending the RE model analogously to the Mundlak transformation (Mundlak 1978) by adding the individual-specific means \bar{x}_i to the Equation (1). However, and in contrast to the Mundlak transformation, Bell and Jones (2015) replaced the original time-variant variables x_{it} with their group-mean centring ($x_{it} - \bar{x}_i$). As a result, the within-between RE model (1) is transformed as follows:

$$y_{it} = \beta_0 + \beta_w(x_{it} - \bar{x}_i) + \beta_b \bar{x}_i + \beta_2 z_i + (u_i + e_{it}) \quad (2)$$

where: β_w – within effect (identical to the coefficients estimated in the FE model); β_b – between effect of x_{it} (Bell and Jones 2015).

Note that parameter β_b is different from the parameter of the individual-specific mean used in the Mundlak transformation, which in turn represents the 'contextual' effect modelling the difference between the within and between effects.

Thus, the within-between model explicitly integrates farm heterogeneity by including both the within-farm effects (capturing time-variant variables) and the between-farm effects (accounting for differences in characteristics among farms). This model offers several advantages over the FE and RE models, as it provides more reliable and comprehensive results by considering both sources of variation. Moreover, we can test whether it is reasonable to separate them rather than use the simpler model specifications.

Additionally, we applied the Hausman-Taylor model in order to check for other possible sources of endogeneity (for example, simultaneity of labour allocation and production decisions or reverse causality problems). The model first estimated the FE model with instrumental variables and then estimated the reduced form equation to capture the exogenous variation in the endogenous variables [see the Electronic Supplementary Material (ESM) for more details].

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We also checked the robustness of the results by using some alternative specifications of the models for fractional dependent variable (e.g. Limited Dependent Variable Random Effects model, see the ESM for more details).

For the empirical specification, we divided the set of explanatory variables of the off-farm labour model into time-invariant (z_i) and time-variant (x_{it}) variables (Table 1). By incorporating both the theoretical analysis, such as the farm-household model and its further

Table 1. Descriptive statistics.

Variable	Description	Year 2003 mean (SD)	Year 2013 mean (SD)	Share of variance within/between (%)
Farmer with off-farm work	1 if farmer works outside the farm, 0 otherwise	0.51 (0.50)	0.49 (0.50)	29.1 70.9
Partner with off-farm work	1 if partner works outside the farm, 0 otherwise	0.25 (0.43)	0.32 (0.47)	26.3 73.7
Off-farm work	share of days worked off-farm in total worked days of the farm household (%)	12.49 (15.73)	13.07 (16.88)	17.0 83.0
Time-invariant explanatory variables				
Age of farmer	first year of observation minus the year of birth	42.68 (7.74)	41.11 (7.53)	0.0 100.0
Farmers' agricultural education		3.20 (0.85)	3.25 (0.80)	0.0 100.0
Farmers' non-agricultural education	5 levels: 1 indicating no formal education and 5 the university education	1.15 (0.54)	1.19 (0.62)	0.0 100.0
Partners' non-agricultural education		1.75 (1.25)	1.80 (1.30)	0.0 100.0
Time-variant explanatory variables				
Farmers' off-farm wage	wage for off-farm work of the farmer (EUR*/day)	437.41 (353.46)	404.58 (273.16)	55.5 44.5
Partners' off-farm wage	wage for off-farm work of the partner (EUR*/day)	335.56 (168.51)	340.54 (196.84)	45.8 54.2
Children	number of children under 16	1.63 (1.51)	0.8 (1.21)	26.1 73.9
Hired labour	share of hired labour workdays in total workdays (%)	17.25 (19.75)	18.75 (20.61)	20.3 79.7
Extensive farm type	1 if the farm belongs to a labour-extensive farm type and 0 if not	0.08 (0.27)	0.13 (0.34)	13.9 86.1
Equity	share of equity in total capital (%)	53.71 (22.38)	55.92 (23.7)	11.3 88.7
Direct payments	share of direct payments in total farm revenue (%)	24.81 (13.21)	28.04 (12.94)	9.9 90.1
Farm income	annual farm income from agricultural work per family work unit (EUR* 1 000)	62.38 (46.65)	63.15 (50.39)	36.6 63.4
Diversification	Berry diversification index (revenue share for each enterprise in total farm revenue)	0.64 (0.10)	0.63 (0.10)	16.8 83.2

*Original monetary variables are expressed in Swiss francs and converted into EUR for the presentation of descriptive statistics using the average annual exchange rate of the European Central Bank (2003: 1 CHF = 1.52 EUR; 2013: 1 CHF = 1.23 EUR)

Source: Own calculations

developments, and empirical findings from previous studies, we identified the most relevant variables that are expected to influence off-farm labour decisions and included them in the empirical model.

The set of time-invariant variables (z_i) included sociodemographic characteristics such as age, agricultural education of farmers, and non-agricultural education of both farmers and their partners. Age was considered to be a factor influencing the potential and motivation to engage in non-agricultural work, as suggested by the life cycle hypothesis (Huffman 1980; Sumner 1982). Younger farmers, in their efforts to secure funding for their enterprises, may be more inclined to work longer hours and seek off-farm employment compared to older farmers. Several studies suggest that a higher level of education is associated with increased off-farm work due to the resulting higher income and subsequent opportunity costs associated with on-farm work (Huffman 1980; Goodwin and Mishra 2004). However, the specific effects may vary depending on the individual's role within the farm and the field of education pursued. For instance, Weersink et al. (1998) found a positive effect of education on the wife's participation in off-farm work but not for the farm manager. Furthermore, the field of education also plays a role, as Chaplin et al. (2004) found a negative effect of agricultural education on the decision to work off-farm, contrasting with the positive effect of general education. This can be explained by a stronger attachment to farming and a greater preference for on-farm activities by individuals with higher levels of agricultural education, which provides them with specialised knowledge and skills related to farming practices, management, and agricultural production, and reduces the desire to engage in off-farm work. Thus, we consider in our model both the agricultural and non-agricultural education levels of the farmer, along with the non-agricultural education of the partner, as observed in the first year of the survey. As this variable rarely changes over time, we consider it as time-invariant.

The analysis of time-variant variables (x_{it}) involved examining both the between effect, which captures variation among farms, and the within effect, which reflects changes in farm and farm family characteristics over time. According to the farm household model, off-farm wage rates, determined by factors such as human capital and local labour market conditions, were expected to have a positive effect on participation in off-farm activities (Singh et al. 1986). Although some studies have provided empirical support for this theory (Lass et al. 1989; Tokle and Huffman 1991), the

presence of non-monetary benefits and strong affinities with farming may result in labour allocations that appear suboptimal from a purely financial perspective (Howley et al. 2014). Some farmers may be reluctant to allocate their time to off-farm work, even if the marginal returns to off-farm income are higher. Thus, it is important to examine the strength of the relationship between wage levels and off-farm employment not only between different farms but also within the same farm. The substantial within-variation of off-farm wages (as shown in Table 1), particularly among farmers (representing a 55% share of the total variation), can be attributed to their engagement in different types of activities. Farmers may shift between skilled and unskilled work over time, leading to varying wage levels based on changing circumstances, market conditions, or personal preferences.

The farm family structure, characterised by the household size and the number and age of children, has an impact on off-farm activities, although findings from research are mixed. Larger household sizes are generally associated with increased off-farm work due to budget constraints (Hennessy and Rehman 2008). However, the presence of children may create a time-budget conflict between off-farm work and childcare responsibilities. Studies examining spouses separately revealed nuanced results. Phimister et al. (2002) found that as the number of children increased, the spouse's off-farm work hours decreased. Additionally, the age of the children plays a role, with very young children reducing off-farm work for the farmer, while older children increase it for the farmer but decrease it for the spouse (Lass et al. 1989). To capture the relevant information, we focused on the number of underage children, as it provides greater insight than overall household size, although both variables were highly correlated.

The inclusion of hired on-farm labour in the model was also guided by the farm household model (Huffman 1980; Sumner 1982). According to this model, the use of external labour increases until the marginal costs reach the marginal benefit, which is the revenue generated by the off-farm work. For the replacement of own labour with hired labour to be worthwhile and influence the share of off-farm activities, the marginal benefit of engaging in off-farm work must outweigh the benefit of working on the farm. There are two aspects to consider. Firstly, hired on-farm labour can facilitate off-farm activities for household members (Benjamin and Kimhi 2006). Secondly, a higher proportion of hired labour may increase the effort re-

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quired to manage employees (Pollak 1985), potentially reducing off-farm activities. Existing literature suggests that the latter scenario is more likely than the former. However, estimating the exact balance between complementary and substitutive effects was challenging. Nevertheless, it was expected that these effects may tend to outweigh each other to some extent.

Specialisation in different production systems with varying labour intensities can influence off-farm work decisions. The consideration of farm types as a potential determinant of off-farm work aimed to capture the relationship between different work intensities or degrees of required time commitment of farm enterprise activities, and their compatibility with off-farm activities (El Benni and Schmid 2021). Empirical results showed that livestock farms, and in particular dairy farms, tended to be less conducive to off-farm work because of the specific time constraints due to milking and feeding (Lass et al. 1989; Hennessy and Rehman 2008). On the other hand, production systems that are less labour-intensive, such as extensive crop farming or suckler-cow farming, may afford farmers more flexibility and spare time. Farmers engaged in these types of farming activities may have greater opportunities to participate in off-farm work.

Utilising the Swiss FADN farm typology, we classified farms into a group characterised by labour-extensive production systems. This group consisted of farms with over 70% arable farming land in the total agricultural area and/or over 25% suckler cows in total beef livestock units. We expected that these farms would have a higher proportion of non-agricultural activity, indicating greater opportunities and flexibility for engaging in off-farm work within these specific farm types.

Farms with higher equity capital are likely to be less dependent on off-farm work, according to studies like Hennessy and Rehman (2008). Greater wealth reduces the financial pressure to seek non-agricultural work, as it serves as a safeguard against potential losses. Farms with lower wealth may rely more on off-farm work to manage risks and secure their livelihoods. To examine this relationship, we utilised the equity ratio, which represents the share of equity in total capital, to avoid multicollinearity with other wealth-related variables such as farm income. In summary, we anticipated a negative coefficient for both the between and within effects. This implies that farms with higher equity are less inclined to engage in off-farm work, and as equity capital increases over time, we expected a decline in off-farm work.

The farm household model suggests that decoupled direct payments can affect off-farm employment positively through a substitution effect (replacing farm work with more profitable off-farm work), or negatively in the case of a wealth effect (reducing farm work for leisure) (Hennessy and Rehman 2008). Most studies have found that higher direct payments resulted in less non-agricultural work (e.g. Ahearn et al. 2006). In the Swiss context, El Benni and Schmid (2021) found that direct payments for biodiversity measures showed a substitution effect for farms with a higher household income. In our study, the share of direct payments in total agricultural revenue was used as an indicator, and an inverse relationship with off-farm work was expected in both cases (between and within).

The relationship between farm income per work unit and off-farm work is influenced by several factors. Higher farm income can be a result of higher on-farm labour productivity or efficient farm management, allowing the farmer to allocate more time to off-farm work (Lass et al. 1989). As farm income per work unit and farm size are positively correlated, it is obvious that the conclusions drawn from theory or empirics regarding the effect of farm size on off-farm work also apply to labour earnings. According to the farm-household model, marginal earnings (wages) decline with increasing farm size, which then leads to a shift from the on-farm to the off-farm work, assuming constant off-farm wages. On the other hand, smaller farms with lower farm income per work unit may rely more on off-farm work to supplement their income, as they may have limited resources and need additional sources of revenue, as confirmed by empirical studies (McNamara and Weiss 2005; Lien et al. 2010). The relationship between farm income and off-farm labour supply is influenced by various factors such as farm size, productivity, and the specific circumstances of each farm.

Diversification of income resources, including both agricultural and non-agricultural activities, is a strategy for maintaining or increasing income stability. Research suggested that greater on-farm diversification was associated with reduced off-farm work, as it provided increased stability to the farm and reduced the need for supplemental off-farm income (Sumner 1982; McNamara and Weiss 2005). To assess the impact of farm diversification, we utilised the Berry index (Jacquemin and Berry 1979), which involved squaring the revenue shares from four crop and seven livestock farming activities, along with two farm-related activities and direct payments. The resulting values were summed, subtracting 1, where higher index val-

ues indicated greater revenue diversification, while lower values indicated a more concentrated revenue structure. We expected a negative within-farm time-variation effect on off-farm employment, i.e. the more diversified a farm becomes, the less off-farm engagement is observed.

RESULTS AND DISCUSSION

The results of the within–between panel regression model of the determinants of off-farm work are presented in Table 2. The first column presents the ‘between’ effect, i.e. the effect based on differences of the considered variables among the farms. These effects were estimated using the parameter β_2 for the time-invariant variables and the parameter β_B at the mean of the time-variant variables according to the Equation (2). The second column presents the ‘within’ effect, simultaneously estimated within the model using the parameter β_W for the time-variant variables in addition to the between effects according to the Equation (2).

Regarding the effect of time-invariant sociodemographic characteristics, we found that younger farm-

ers, farmers with a lower agricultural education level and farmers with a higher non-agricultural education level worked more off the farm. Partners with higher non-agricultural education levels also led to more off-farm work. These results are in line with results of other studies (Huffman 1980; Sumner 1982; Serra et al. 2005). Because education and age of the partner were negatively correlated, we can conclude that younger female partners are more likely to opt for non-agricultural work than for agricultural work, which could be because it is important for them to have their own mainstay outside the farm.

Farmers and partners with higher off-farm wages tended to be more involved in off-farm work, which is consistent with the household model and neoclassical labour theory (Singh et al. 1986). The estimated parameter of the between-effect was much higher for partners, who appear to be more responsive to monetary incentives to maximise utility. On the other hand, the corresponding within-farm effect (second column of Table 2) was much smaller, indicating a weaker response to partners’ wage increases over time. Interestingly, the within-effect of the farmer’s off-farm wage

Table 2. Results of the within–between model estimating the share of days worked off-farm in total worked days of the farm household.

Variable	Between (β_2, β_B)		Within (β_W)	
	coefficient	SE	coefficient	SE
Time-invariant				
Age of farmer	–0.227	0.047***	–	–
Farmers’ agricultural education	–0.780	0.425*	–	–
Farmers’ non-agricultural education	3.638	0.531***	–	–
Partners’ non-agricultural education	0.916	0.264***	–	–
Time-variant				
Farmers’ off-farm wage	0.009	0.002***	–0.004	0.000***
Partners’ off-farm wage	0.028	0.003***	0.002	0.001***
Children	–1.223	0.288***	–0.654	0.090***
Hired labour	0.038	0.019**	0.164	0.007***
Extensive farm type	11.338	1.063***	3.576	0.407***
Equity	–0.056	0.015***	0.003	0.008
Direct payments	0.019	0.029	0.160	0.016***
Farm income	–0.114	0.011***	0.017	0.003***
Diversification	3.468	3.544	2.265	1.569
R-squared ¹		0.266		
Intercept		22.897 (3.753)***		

*, **, *** $P < 0.1$, $P < 0.05$; $P < 0.01$, respectively; ¹marginal coefficient of determination (pseudo-R-squared) for generalized mixed-effects models, represents the variance explained by dependent variables

Source: Own calculations

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was significant and negative. A possible explanation is that finding better-paid job opportunities allows the farm manager to reduce the off-farm work and spend more time on the farm. This result also supports the findings of Howley et al. (2014) that farm managers may choose to allocate more time to on-farm work, even in the face of greater economic returns in the off-farm labour market, due to the additional non-pecuniary benefits that they can obtain from farming.

The negative effect of the number of young children on off-farm work suggests that farmers or partners are more likely to work off-farm before having children. This conclusion holds in both cases, i.e. when comparing farm families with and without children and when comparing the evolution of the life cycle of the same family over time. Even though it does not have to be a problem for working off-farm e.g. when grandparents are nearby, childcare seems to have a high priority.

The positive and significant coefficient of the share of hired labour between farms indicates that substitutive effects of hired labour on the labour of the farmer and his partner might be stronger than complementary effects overall. The within-farm time-variation effect of the share of hired labour showed that a higher share of hired labour is associated with a higher level of off-farm activities. Over the period under consideration, the share of hired labour increased, the farms became larger, some more professional and others more extensive. It is likely that in this period, the substitution of hired labour by the farmer's or partner's own labour outweighed the complementary effect of hired labour.

For the extensive farm types (with more arable land or suckler cows), we found more non-agricultural work. Regarding the changes over time, there was also a positive effect of extensification on the off-farm work. But, this within effect was again smaller than the effect between farms, which was probably due to the smaller variance within farms.

Also in line with literature is the finding that farms with higher equity ratio had less off-farm activities (negative between-effect). However, we did not find any evidence of the impact of changes in the equity ratio over time within a farm.

Regarding the relationship between the share of direct payments in total farm revenue and off-farm work, we did not observe a significant effect between farms. However, we found a higher share of non-agricultural work for the within effect as a result of a higher share of direct payments in total farm revenue. This result seems to reflect the extensification of many farms from dairy farming to suckler-cow farming (Zorn and Zim-

mert 2022) observed during the period under study. Suckler-cow farms received a higher share of direct payments in total revenue from agriculture but had to increase their non-agricultural income because of their smaller farm size or their available labour capacity in order to cover private expenditure.

We also found that farms with lower income per work unit generally had a higher proportion of non-agricultural labour, which supports the findings of Kumbhakar et al. (1989) and indicates the need for small farms to supplement the household budget with additional non-agricultural income sources. The slightly positive association between the change in income per work unit and off-farm work found for the within variation could be because farms have shifted their production portfolio towards more productive branches, such as arable farming, while using the time freed from the shift in less labour-intensive production branches for non-agricultural work.

We did not find a general effect of diversification between farms and with respect to the development over time. Conversely, specialisation by focusing on fewer branches did not lead to a different proportion of non-agricultural activity.

To check for possible sample selection bias, we estimated a Heckman two-step selection model based on cross-sectional data for each year and compared the estimated parameters with the results of the within-between model. Although Mills ratio indicated the presence of selective bias, the results of the corrected model did not differ much from the between-parameters of a simple model without correction. Only the farmer education variable was not statistically significant in the Heckman model, contrary to our model. Further, to ensure the robustness of our findings, we also applied the Hausman-Taylor model with various instrumental variables to check for other possible sources of endogeneity and tested models for fractional dependent variables to account for the violation of distributional assumptions. However, the results did not produce significantly different coefficient estimates, validating the robustness of our initial findings. We decided to present the cautious results of the simpler model in our article. The results of these alternative specifications and models are presented in the ESM for further examination.

CONCLUSION

We examined the determinants of the share of non-agricultural work in total labour input by using a panel

data approach that disentangles the so-called between effects and within effects over an 11-year period. The employed model used the methodological advantages of both FE and RE models (i.e. solving endogeneity problems with respect to the unobserved farm-specific heterogeneity). Our results indicated that in younger farm families without children and in farm households with higher levels of non-agricultural education, both the farmer and the partner were more involved in working activities outside the farm. Farms with a higher equity ratio, using less hired labour, and with higher farm income per work unit pursued less off-farm activity.

The analysis of the within effects, focusing on development over time, offered a more differentiated picture; these effects tended to be smaller, and the coefficients deviated in part from the between-farm effects. The approach offers new insights but can be challenging in terms of results interpretation, especially when the within and between effects differ, as it was found for the variables farm income per work unit and farmers' off-farm wage. More specifically, the within-farm time-variation effects indicated that an increasing share of direct payments in total revenue from agriculture was associated with increased off-farm activity. It is interesting to note that the within-effect of the farmer's off-farm wage was significant and negative, while the between-effect was positive. It means that farm managers may choose to allocate more time to on-farm and less off-farm work even if economic returns in the off-farm work became higher. Non-monetary benefits from agriculture may be a possible explanation. In addition, our findings showed how farm income can affect off-farm work differently across farms and over time. This supports different theories from farm household models. One view is that lower farm income makes farm households work more off-farm to meet the household budget. Another view is that higher farm income means higher on-farm productivity or efficiency, which frees up time for off-farm work (see Material and methods). By using between-farm and within-farm effects, we provided evidence for both perspectives.

Because a sufficient income of the farmer is one of the main goals of agricultural policy, an interesting finding was that an increase in farm income per annual family work unit could be compatible with a higher share of off-farm activities during the period under consideration. This result calls for further research to better understand whether this relationship can be explained by the higher productivity, better management skills, greater social capital or other characteristics of the farmer. On the other hand, with regard to efficient use

of public funds, the question arises whether the positive time effect of the share of direct payments in total revenue from agriculture on off-farm work is in line with Switzerland's agricultural policy objectives.

The study suggested that distinguishing between-farm and within-farm effects is important when analysing determinants of off-farm work. The results revealed these effects vary depending on the variable of interest. Our study also showed that it is important to distinguish between the impact of the farmer's and partner's characteristics (education, opportunity costs of farming) on their on-farm and off-farm work decisions, as they may differ across farms and over time. These conclusions have important implications for understanding the labour allocation decisions of farm households in Switzerland and other countries. They show that farm households are not homogeneous in their labour supply behaviour, and that they may have different preferences, motivations, and constraints for on-farm and off-farm work. They also show that farm households are not static in their labour supply behaviour, and that they may adjust their labour allocation over time, depending on their economic environment and circumstances. Therefore, policy makers and researchers need to take these differences and dynamics into account when designing and evaluating policies that affect farm households' income and welfare.

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