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Article

Off-farm income and direct payments—an indispensable diversification strategy of Swiss farmers

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Abstract

Following the theory of a farm household model, the relations between farm and farmer characteristics, including two different kinds of direct payments, and their effects on the off-farm labour allocation decisions of farm operators were analysed. Swiss farm accountancy data network (FADN) data of the years 2017, 2018, and 2019 for the whole sample and two different income groups were used to model both off-farm labour participation and supply decisions. The results show that diversification into off-farm employment is a highly relevant strategy of Swiss farmers and that direct payments are a complementary income source. Above a certain level, biodiversity payments show a substitution effect, meaning that off-farm participation is reduced. Off-farm labour supply is related not to direct payments but to production type and technology, with dairy and organic farmers having spent fewer days engaging in off-farm employment. Education positively correlates to off-farm labour participation. Even though off-farm income and direct payments are an indispensable income source for Swiss farmers, income-related policy goals cannot be considered achieved in terms of either farm or household income. Whether public money would be better spent on education than on unprofitable farm businesses should be analysed in future studies.

Keywords: Farm household model, Off-farm participation, Off-farm labour supply, Direct payments.

JEL codes: Q12, Q18, J22, Q10

1 Background

Diversification into off-farm employment supplements low farm incomes and reduces the income risk of farm families (e.g. El Benni *et al.* 2012; El Benni and Finger 2013; Severini and Tantari 2013; Pastusiak *et al.* 2017). From an agricultural policy perspective, the off-farm labour allocation decisions of farmers can be evaluated differently. On the one hand, an increase in farm income through the allocation of labour to on-farm activities can be seen as a strategy to pursue the viability of rural areas (Bartolini *et al.* 2014); thus, off-farm income can be seen as a less desirable option. On the other hand, if off-farm employment as a necessary complementary income source slows down the exit from agriculture, rural livelihoods can be maintained (Kimhi and Bollman 1999; Breustedt and Glauben 2007; Lips *et al.* 2013). Others argue further that better income prospects on the off-farm labour market may foster a structural change in agriculture (Weiss 1999). The decision to allocate time to off-farm employment depends on many factors, including the income levels

that can be earned on the farm and off the farm, the income needs to allow appropriate consumption levels of the farm family, labour market conditions, labour-intensive types of production, and farmers' skills (Brick 2005; Pastusiak *et al.* 2017). Furthermore, decoupled direct payments can affect farmers' decision-making in several ways, including off-farm labour allocation decisions (Moro and Sckokai 2013; Olper *et al.* 2014). The multiple direct and indirect interactions between the various factors that can influence off-farm labour allocation decisions call for empirical analyses.

This study analyses the off-farm labour allocation decisions of farm operators using Swiss farm accountancy data network (FADN) data of the years 2017–2019. More precisely, the effect of different farm and farmer characteristics, including two different kinds of direct payments, on off-farm labour participation decisions and off-farm labour supply decisions, i.e. working days spent engaging in off-farm employment, is analysed. The results are discussed with respect to their policy implications.

Agricultural policies in Europe have been adapted continuously over the last decades to, apart from other policy goals, ensure appropriate income levels and the long-term economic viability of farms and rural areas (Agrosynergie 2011; Schuh *et al.* 2016). Over time, direct payments have become the main instrument for achieving income-related goals, and market-based income support has been reduced constantly since the 1990s (e.g. Finger and El Benni 2021). Whether direct payments encourage the allocation of the labour force to on- or off-farm work is important information for policy makers. First, current policies aim to increase farm income, which might not be the case if direct payments encourage farmers to earn income off the farm. Second, if earning income off the farm is a commonly used strategy to complement farm income and allow for appropriate consumption levels, then income-related policies might rather target the household incomes of farm families instead of farm incomes. This can be especially important for less productive regions, where income from farming is often low (El Benni and Finger 2013). For instance, in Switzerland, off-farm income has increased considerably over time, and the share of farm household income it constitutes is often higher in less productive regions (El Benni and Finger 2013; Jan *et al.* 2020). However, there are many differences across the farm population with respect to on- and off-farm labour allocation and incomes (Hoop *et al.* 2014).

From a theoretical viewpoint, decoupled payments in contrast to coupled payments do not provide incentives to increase on-farm work, and in the case of a sufficient farm income, i.e. budget constraints are relaxed, farmers reduce off-farm labour (Mishra and Goodwin 1997, 1998; Woldehanna *et al.* 2000; Serra *et al.* 2005; Ahearn *et al.* 2006; Tranter *et al.* 2007; Hennessy and Rehman 2008; Moro and Sckokai 2013). Results of previous studies show that direct payments had both direct and indirect, as well as positive and negative, effects on the off-farm labour allocation decisions of farmers (Brick 2005; Agrosynergie 2011; Schuh *et al.* 2016). Furthermore, differences with respect to the kinds of direct payments were observed. For instance, Corsi and Salvioni (2012) and Douarin (2008) found highly limited or no effects of direct payments on farmers' off-farm labour allocation decisions. Genius (2013) found that Pillar II payments affect off-farm labour allocation positively, and Keeney and Matthews (2000) found that arable payments had no effect, but headage payments had a significant positive effect on the off-farm labour supply. Dupraz and Latruffe (2015) show that Pillar I payments reduced farm labour, while Pillar II agri-environmental payments increased on-farm labour. Further farm and farmers' characteristics that were found to affect off-farm labour allocation decisions include farm type, farm size, the farms' financial characteristics, household size, and the education and age of the farmers (Sumner 1982; Lass *et al.* 1989; Lass and Gempesaw 1992; Kimhi 1994; Woldehanna *et al.* 2000; Hennessy and Rehman 2008).

This study contributes to the existing literature by analysing the effects of two different kinds of direct payments on the off-farm labour allocation decisions of farm operators, namely decoupled direct payments related to hectare agricultural land used for producing

food and feed and biodiversity payments. We used Swiss FADN data that include information on the farm operators' off-farm labour participation by providing information on the working days spent engaging in off-farm employment per year. Two-stage Heckman (1979) selection models are estimated to analyse the effect of different farm and farmer characteristics and direct payments first on the participation of farm operators in off-farm employment and second on the days spent engaging in off-farm employment. The analyses are carried out for the whole sample, as well as for two subsamples that differentiate between a below-average and an above-average farm household income group. This differentiation intends to investigate whether the correlation between direct payments and off-farm labour allocation decisions changes depending on how much the farm depends on off-farm income. All analyses are conducted for three subsequent years, 2017–9, which allows us to check the robustness of the results across years and samples. Results are discussed with respect to the income-related goals of agricultural policy.

The paper is structured as follows. In Section 2, the theoretical and empirical background is described, followed by an overview of the empirical approach used in Section 3. Section 4 provides information on the data, and in Section 5, the descriptive and regression results are presented. Section 6 discusses the results and Section 7 concludes.

2 Theoretical and empirical background

2.1 Off-farm labour allocation decisions in a farm household model

The theoretical framework for our empirical analysis is a farm household model that integrates agricultural production, consumption, and labour supply decisions into one single framework (Singh *et al.* 1986). As shown by Brick (2005), this framework has been applied in various empirical studies to analyse the labour allocation decisions of farm operators (e.g. Pfaffermayr *et al.* 1991; Weersink 1992), farm operators and the spouse assuming independent decisions, (Lass *et al.* 1989; Benjamin 1994; Kimhi 1996; Weersink *et al.* 1998) and farm operators and the spouse assuming dependent decisions (e.g. Huffman and Lange 1989; Keeney and Matthews 2000) and to analyse labour allocation decisions at the household level (Woldehanna *et al.* 2000). As proposed by Becker (1965), the farm household is assumed to maximise utility U that is derived from the consumption of goods C and leisure time L

$$\text{Maximise } U = f(C, L) \tag{1}$$

By maximising utility, the farm household is subject to time constraints, as the time that can be allocated to farm work F, off-farm work O, or leisure L is finite,

$$T = F + O + L, \quad \text{whereby} \quad O \geq 0, \tag{2}$$

and to budget constraints

$$CP_c = WO + (P_f Y_f - I_f X_f) + V. \tag{3}$$

Furthermore, it is important to note that farm household members can earn off-farm wages W^*, being a function of human capital H and local employment market conditions Z,

$$W^* = W(H, Z). \tag{4}$$

Consumption goods C are the reward for labour and are purchased at price P_c within the limits of the available household budget comprising income from off-farm employment (determined by the off-farm wage W and hours spent conducting off-farm work O), income from farming (farm profit given by product prices P_f times product volumes Y_f less the cost

of production inputs I_f and volume of inputs X_f), and household wealth V not derived from labour (equation 3). The farm output Y_f is a function of the farm inputs I_f, the time allocated to on-farm work F, and the human capital H.

Off-farm wage rates are often not observed directly, but only indirectly when the farmer takes up off-farm employment. As soon as the farmer engages in off-farm employment, it can be assumed that the hourly off-farm wage rate exceeds the hourly on-farm wage rate. More precisely, the probability of off-farm labour participation $P(O = 1)$ depends on the marginal value of income from on-farm work F^{inc} and off-farm wage rates W^*, meaning that time is allocated to off-farm work when the off-farm wage rate exceeds the wage that can be earned on the farm (Hennessy and Rehman 2008):

$$P\ (O\ =\ 1) =\ P\ \left(F^{\text{inc}} < W^*\right) = \beta'\ X \tag{5}$$

Thereby, $P(O = 1)$ is a function of a vector of exogenous variables X that influences the (latent) on-farm and off-farm wage rates to the extent of the vector of parameters β to be estimated.

Finally, the amount of time allocated to off-farm work is determined by the optimal time spent engaging in on-farm work, and leisure and can be positive or zero (Hennessy and Rehman 2008):

$$O\ =\ T - L - F\ =\ f(W^*,\ \ (P_f Y_f - I_f X_f)\ ,\ V,\ H,\ Z). \tag{6}$$

The time spent engaging in off-farm employment is a function of off-farm wages, farm income, the production technology used, household wealth, human capital, and the local employment market conditions.

2.2 Direct payments and off-farm labour allocation decisions

Direct payments can affect farmers' behaviour in various ways, including their off-farm labour allocation decisions, by changing the marginal value of farm labour, by increasing household wealth, or by reducing income risk (Hennessy and Rehman 2008; Moro and Sckokai 2013). More precisely, direct payments coupled to production increase the marginal value of on-farm labour, thus affecting the relative returns to farm and off-farm labour, with off-farm labour becoming less attractive. In contrast, direct payments decoupled from production are an off-labour (exogenous) income source that can lead to the decision to either increase off-farm labour or increase leisure (El Osta *et al.* 2004). As shown by Hennessy and Rehman (2008), the change from coupled to decoupled direct payments can provoke both more off-farm involvement that can be explained by the substitution effect or less off-farm involvement and eventually even less farm work but more leisure, as explained by the wealth effect. The substitution effect can be observed if the change from coupled to decoupled direct payments decreases the return to farm labour relative to non-farm labour and if the utility-maximizing farmer decides to participate in off-farm employment or increase time spent engaging in off-farm employment. The wealth effect can be observed if the change from coupled to decoupled direct payments relaxes the budget constraint and thus enables the farmer to work less and enjoy more leisure without affecting consumption levels.

Nowadays, different kinds of decoupled direct payments exist, including those paid per hectare of agricultural land used to produce agricultural goods and agri-environmental payments targeting, e.g. biodiversity. Whether these types of direct payments increase or decrease off-farm labour participation and off-farm labour supply and thus show substitution or wealth effects depend on their various direct and indirect effects on farmers' decision-making (Moro and Sckokai 2013). For instance, higher household wealth can have a

risk-reducing effect or self-insurance effect, respectively, if farm households with higher wealth are less risk-averse than those with lower wealth. As farmers are typically risk-averse (Iyer *et al.* 2020), they allocate more time to relatively safer, i.e. less risky, activities. This can include the avoidance of risky on-farm decisions, such as choosing organic farming with often higher yield variability (Gardebroek *et al.* 2010), choosing to work off the farm as a non-volatile income source compared with farm income (Barlett 1991; Mishra and Goodwin 1997, 1998; El Benni *et al.* 2012; de Mey *et al.* 2016), or choosing to take higher risks in production due to an increase in income from a relatively risk-free governmental payment (Hennessy 1998; Cafiero *et al.* 2007). In addition, investment decisions can be affected (Moro and Sckokai 2013). Due to manifold and complex interactions, analysing these effects is an empirical issue, and identifying causal relationships is hardly possible.

2.3 Effects of farm and farmer characteristics on off-farm labour allocation decisions

According to the farm household model described and based on empirical evidence from previous studies, the following factors were shown to influence the off-farm labour allocation decisions of farmers.

Labour market conditions affect participation and hours spent engaging in off-farm employment and are represented in empirical applications by variables such as the distance from a metropolitan area, the local unemployment rate, regional dummies, average county salaries or market wage rates (Sumner 1982; Tokle and Huffman 1991; Woldehanna *et al.* 2000; Serra *et al.* 2005; Hennessy and Rehman 2008).

Farm type is a frequently used variable to explain off-farm employment decisions either as a dummy variable for labour-intensive farm types, such as milk production, or as a dummy for several different farm types (Lass *et al.* 1989; Kilkenny 1993; Kimhi 1994; Serra *et al.* 2005; Hennessy and Rehman 2008).

Farm income affects the off-farm income allocation decisions of farmers, as shown by the farm household model described and existing empirical studies, with increasing on-farm income having a significant negative effect on off-farm labour participation and off-farm labour supply (Brick 2005).

Production technology can affect the need for labour input on the farm. As organic production is considered more labour-intensive than conventional farming (Padel and Lampkin 1994), this production technology is expected to affect off-farm labour participation and off-farm labour supply, respectively.

Farm size was found to affect off-farm employment decisions and is usually included as agricultural area in labour allocation decision models (Woldehanna *et al.* 2000; Serra *et al.* 2005; Hennessy and Rehman 2008).

Financial characteristics were found to influence labour allocation decisions, with a high level of farm debt, measured as debt-to-asset ratio, having a positive impact on off-farm employment to reduce capital constraints (Furtan *et al.* 1985; Serra *et al.* 2005).

Household size, measured as the number of farm family members or number of children, likely affects off-farm employment decisions, but the effect differs, and it can be positive (Lass *et al.* 1989; Woldehanna *et al.* 2000; Hennessy and Rehman 2008) or negative (Mishra and Goodwin 1997; Serra *et al.* 2005).

Education may positively influence the off-farm employment of farmers by increasing their reallocative ability (Huffman 1980) or increasing the wage rate and thus changing the quantity of labour supplied to off-farm work. Higher education was found to have positive effects on the supply of off-farm labour (e.g. Lass and Gempesaw 1992; Goodwin and Mishra 2004).

Age is often found to have a quadratic effect on off-farm employment, with an increase in earlier years and a decrease in later years (Weersink 1992; Serra *et al.* 2005),

supporting the life-cycle hypothesis that assets are accumulated in earlier years (Huffman 1980; Sumner 1982) and human capital is built up (Mishra and Goodwin 1998), but the ability and willingness to work off the farm decrease over time.

3 Empirical approach

3.1 Descriptive analysis

In the first step, we descriptively analyse the distribution of income from farming, direct payments, off-farm employment, and household income across the sample of Swiss farmers.

This is done first by dividing the sample into deciles of 'household income per farm family consumption unit' and second by dividing the sample into a below-average (first–fifth decile) and an above-average (sixth–tenth decile) household income group, measured in household income per farm family consumption unit. This grouping of farmers allows differentiation between farmers with more or less need to earn income off the farm and to observe relations between different components, including direct payments. Mann–Whitney U tests are used to test for significant differences across the two farm household income groups.

3.2 Modelling off-farm labour participation and off-farm labour supply decisions

Based on the theoretical framework of the farm household model described in Section 2 and existing empirical research, we focus our analyses on the farm operators' off-farm labour allocation decisions. We analyse two decisions: first, the decision to participate in off-farm employment as described by equation (5), i.e. the labour participation decision; second, the decision on how much time is allocated to off-farm employment following equation (6), i.e. the off-farm labour supply decision.

The off-farm participation decision is modelled as follows:

$$p_i = x_{i2}\,\beta + e_{i2}, \tag{7}$$

where p_i is a dummy variable whose value equals 1 if the farm operator spends $y_i > 0$ days engaging in off-farm employment and zero otherwise. The probability of off-farm employment p_i is modelled by a probit model, with x_{i2} being the explanatory variables for which a vector of parameters β is estimated. For an easier interpretation of the model results, the R package mfx (Fernihough and Henningsen 2019; R Core Team 2019) is used to estimate marginal effects following Greene (2002) and heteroscedasticity-corrected standard errors, i.e. e_{i2}, applying the White (1980) correction. More precisely, we calculate the average of the sample marginal effect of each explanatory variable on the probability that the farm operator will participate in off-farm employment, i.e. the change in off-farm employment after a one-unit change in one of the explanatory variables.

The off-farm labour supply decision is modelled as follows:

$$y_i = x_{i1}\,\beta + e_{i1}, \tag{8}$$

where y_i is the time spent engaging in off-farm employment by the farm operator, measured in working days per year, being an incidentally truncated variable; x_{i1} are the farm-specific explanatory variables; β is the vector of parameters to be estimated; and e_{i1} is the error term.

As described by Hennessy and Rehman (2008), labour decision models can face the problem of a sample selection bias, as the income from on-farm work W^r is a latent variable that cannot be observed directly but becomes, at least partly, visible only if the farm operator participates in off-farm employment, meaning that the off-farm wage rate W^* exceeds W^r.

Being a latent variable, the income from on-farm work cannot be specified in the model and is thus captured by the error term. However, as income from on-farm work influences both the decision to participate in off-farm employment and the decision of how much

off-farm labour will be supplied, the error terms of the labour participation model (equation 7) and the labour supply model (equation 8) may be correlated with each other. Following Hennessy and Rehman (2008), we applied the two-stage procedure of Heckman (1979) to test for the existence of a sample selection bias. More precisely, we derive the inverse Mills ratio from the vector of the estimated parameters of the labour participation model, add this ratio as a regressor to the labour supply model, and use a *t*-test on the estimated coefficient. If this coefficient is not significantly different from zero, no sample selection bias is expected and the Ordinary Least Squares (OLS) model can be regarded as consistent.

3.3 Model selection procedure

From the theoretical framework of the farm household model, as described in Section 2 and in existing empirical research, we know that various factors can affect the off-farm labour allocation decisions of farm operators, but analyses for Switzerland are missing. To identify the factors that contribute to the off-farm labour allocation decisions of Swiss farm operators, we follow El Benni *et al.* (2016) and apply a genetic algorithm approach using the package glmulti of the R Development Core Team (Calcagno and Mazancourt 2010; R Core Team 2019). Using this approach, we aim to prioritize the possible independent variables and find those best suited to explain Swiss farmers' labour allocation decisions by, at the same time, minimizing problems with multicollinearity and a possible correlation between off-farm labour participation and the off-farm labour supply decision. In contrast to forward and backward variable selection procedures, which depend on starting values that influence the outcome of the model selection (i.e. changing the order of variables in the model can change the model results), the genetic algorithm approach simultaneously explores different combinations and arrangements of variables.

Therefore, all variables found by previous empirical studies to affect off-farm labour allocation decisions (see Section 2 and Table 1) are considered with their linear effects in the spectrum of possible models. The models with the lowest corrected Akaike information criterion values are selected for the next steps of the analysis

This variable selection procedure is applied to the data of the whole sample and to both off-farm labour allocation decisions separately, i.e. once for the labour participation and once for the labour supply model. Once the best model for each of the decisions (based on data from the whole sample) is selected, we test for the existence of a sample selection bias, as described in Section 3.2. For the final models, we also consider quadratic effects of specific variables that were found to influence off-farm labour allocation decisions non-linearly in existing empirical studies. Finally, we re-estimate off-farm labour participation and the off-farm labour supply models separately for both the below-average and above-average farm household income groups (classified as household income per consumption unit of the farm family) to investigate whether direct payments affect off-farm labour allocation differently depending on the necessity to earn income off the farm. In addition, for these separate models, we test for the existence of a sample selection bias. To test for significant differences among coefficients across the above-average and below-average income groups, *z*-tests are applied to both the participation and the labour supply models.

3.4 Robustness checks

As described in Section 2, many factors can influence the on-farm and off-farm labour allocation decisions of farmers, and declaring a causal relationship between on-farm income and off-farm labour allocation decisions is demanding in empirical analyses, given the available data sets. Despite having information on farmers' off-farm labour participation and off-farm labour supply for several years, we do not have a panel data set. To check the robustness of our results, we therefore conduct all analyses for three subsequent years with a different sample composition each year. More precisely, both the variable selection procedure and the

Table 1. Descriptive statistics of the data used for the regression analysis for the years 2017–2019.

Variable	Definition	2019 Mean (SD) [min–max]	2018 Mean (SD) [min–max]	2017 Mean (SD) [min–max]
Dependent				
Part	Dummy variable indicating off-farm employment of the farm operator (yes = 1, no = 0)	0.51	0.49	0.50
Supply	Number of days the farm operator works off the farm (as employee)	31 (55) [0–256]	31 (56) [0–250]	32 (58) [0–285]
Off-farm participation (Part) and quantity of off-farm labour supplied (Supply) are the independent variables in the regression analysis. The number of days spent engaging in off-farm (employed) activities is measured as the working days of a fully efficient adult person that correspond in non-agricultural employment largely to the specified working days. In the annual Swiss farm income survey, farmers self-declare the days spent in off-farm employment. Off-farm labour participation is indicated when the labour force is observed to be allocated to off-farm employment activities.				
Independent				
Farm_Inc	Annual work income from farming activities per work unit of family labour in CHF	60,093 (44,923) [−240,688 to 322,264]	70,729 (53,889) [−222,037 to 792,553]	55,072 (50,602) [−319,516 to 421,492]
Farm income is represented by the agricultural work income for the compensation of a full-time family labour unit on the farm. It is calculated as agricultural income less remuneration for personal equity capital invested in the farm enterprise. The agricultural income consists of the return less the external costs.				
DirectPay	Direct payments in CHF per hectare of agricultural land	2,479 (1,657) [0–53,833]	61,867 (1,654) [0–229,229]	2,473 (1,795) [0–274,283]
To analyse the effect of direct payments being decoupled from production outputs (but coupled to the hectares of agricultural land), we sum all area-based direct payments received by a farm and divide these payments by the hectares of agricultural land to exclude the size effects of this variable. This variable includes the following payments: food supply security payments (Möhring and Mann 2020), cultural landscape payments (these differ between regions), landscape quality payments and production system payments for (1) grassland-based milk and meat production (Mack *et al.* 2017, 2019) and (2) extensive crop production (Finger and El Benni 2013).				

Table 1. Continued

Variable	Definition	2019 Mean (SD) [min–max]	2018 Mean (SD) [min–max]	2017 Mean (SD) [min–max]
BioDivPay	Share of biodiversity payments on total agricultural revenues in percentage	4.4 (4.6) [0–46.5]	4.2 (4.7) [0–102.0]	4.2 (4.4) [0–46.1]
With biodiversity payments, farmers are remunerated for the voluntary ecological services they provide, such as extensively and low-intensively used meadows and pastures, high-stemmed trees, flower strips beside crops, etc. To analyse whether the provided ecological services (also meaning less agricultural production) differently correlate with off-farm labour allocation decisions as compared with direct payments provided per hectare of agricultural land for the production of food and feed, we use the share of biodiversity payments on total revenues from agricultural production (including revenues from crop and animal production and all direct payments) as an independent variable in our regression analyses.				
FarmSize	Standard output of the farm holding in CHF	243,075 (223,552) [15,854–3,184,837]	245,256 (234,377) [15,096–3,394,620]	255,869 (255,172) [24,257–3,797,359]
To represent the (economic) size of a farm, we use the standard output (SO), as defined by the Commission Regulation (EC) No. 1242/2008 (867/2009). The SO is the average monetary value of the agricultural output at the farm-gate price of each agricultural product in a given region. The SO of the holding is calculated as the sum of the SO of each agricultural product present in the holding multiplied by the relevant number of hectares or heads of livestock of the holding, and it excludes direct payments.				
Wealth	Assets per consumption unit in CHF	369,143 (340,308) [0–5,436,439]	370,278 (332,556) [0–4,453,212]	357,347 (327,483) [−351,250 to 4,515,285]
The wealth of the farm is represented by the farm's assets that are in the service of the farm operation for a long period and are normally not intended for sale. These include financial assets, mobile and tangible fixed assets, and intangible assets.				
Debt	Debt-to-asset ratio	0.48 (0.29) [0–2.96]	0.49 (0.29) [0–3.1]	0.49 (0.30) [−0.1 to 3.1]
The financial characteristics of the farm operation are represented by the debt-to-asset ratio.				
Dairy	Farm type is dairy (yes = 1, no = 0)	0.26 (0.44) [0–1]	0.26 (0.44) [0–1]	0.25 (0.44) [0–1]
Whether a farm is defined as being dairy or mixed dairy/crop, we use a dummy variable to indicate the involvement in labour-intensive dairy production.				

Table 1. Continued

Variable	Definition	2019 Mean (SD) [min–max]	2018 Mean (SD) [min–max]	2017 Mean (SD) [min–max]
Organic	Farm is an organic farm (yes = 1, no = 0), applying respective production technologies.	0.17 (0.38) [0–1]	0.16 (0.37) [0–1]	0.14 (0.34) [0–1]
HHSize	Number of consumption units of the farm household	2.76 (1.2) [1–8.1]	2.73 (1.19) [1–6.8]	2.75 (1.2) [1–8.7]
Consumption units are defined as the share of private expenditure of unpaid labour of the household that is paid by the farm manager, multiplied by an age-dependent factor. This variable describes the farm household size.				
Age	Age of the farm operator in years	48.76 (9.32) [21–73]	48.6 (9.40) [20–77]	48.77 (9.23) [21–76]
The farmer's age is measured in years. When interpreting the results, it must be kept in mind that Swiss farmers receive direct payments up to the age of 65 and no payments afterwards, affecting the distribution of age across the sample.				
EduFarm	Level of education in farming in ascending order (levels 1–11 included as continuous variable)	6.48 (1.84) [1–11]	6.37 (1.98) [1–11]	6.38 (1.87) [1–11]
EduNonFarm	Level of education unrelated to farming in ascending order (levels 1–11 included as continuous variable)	2.25 (2.36) [1–11]	2.26 (1.37) [1–11]	2.19 (2.3) [1–11]
Farming and non-farming education are measured in eleven ascending categories, with category 1 being 'no vocational education' and category 11 being master's degree and higher qualifications from a university in applied sciences or diploma at the university level.				
Region	Regional dummy variable (valley = 0, hill = 1, mountain = 2)	0 = 872 1 = 649 2 = 542	0 = 944 1 = 732 2 = 635	0 = 908 1 = 585 2 = 554
The variable region describes the location of the farm in the valley, hill, or mountain region and is included in the analysis as a factorial variable to indicate labour market conditions.				
Separating variable to divide sample into farm household income groups				
HHinc	Household income per farm family consumption unit in CHF	44,931 (31,814) [−39,246 to 527,214]	43,753 (32,614) [−91,442 to 695,298]	42,183 (27,431) [−229,195 to 231,496]
Household income is determined by adding the farm income and the off-farm income of all household members and dividing by the farm family consumption unit living in the farm household. This variable describes the income level of the household adjusted to the size of the household.				
Number of observations		2,063	2,311	2,047

regression analyses, i.e. the labour participation and labour supply models, are estimated for 2017, 2018, and 2019 each to check the robustness of the results. When interpreting the results, we are mainly interested in the recurring effects on off-farm labour allocation decisions over all three years. Because this does not solve the endogeneity problem, the effects should be interpreted as correlations rather than causal.

4 Data

We use farm-level data from the random sample 'Income Situation' of the years 2017, 2018, and 2019 from Swiss agricultural income monitoring (Renner *et al.* 2018): The Income Situation sample forms the basis for the income estimation of the Swiss agricultural sector overall, as well as of the plain, hill, and mountain regions. Whole-farm key figures from financial accounting supplemented with details from the tax declaration, as well as the income situation of the household, are collected, e.g. non-agricultural income and working days spent in off-farm employment. The farms are randomly selected from the target population, so statistically reliable results can be published. The experience of recent years shows that about 70–80 per cent of the farms from the previous year remain in the sample in the following year (Schmid *et al.* 2019; Jan *et al.* 2020, 2021). The basic population of the farms consists of all farms in Switzerland that are captured in the annual Farm Structure Surveys of the Agricultural Policy Information System. The target population only includes commercial sole proprietorships and group farming businesses from a particular size onwards, whereby farm size is measured by standard output. These farms are to be represented by the Income Situation sample. Because household-level information is only available for individual enterprises, we exclude observations from farm associations for this study. Finally, we use 2,047, 2,344, and 2,063 farm observations for the years 2017, 2018, and 2019, respectively, which comprise data of all individual enterprises available for these years. The variables used to model off-farm labour allocation decisions are shown in Table 1.

5 Results

5.1 Results of the descriptive analysis

Ordered by deciles of household income per farm family consumption unit, Table 2 shows the off-farm participation rate and the days that Swiss farm operators are working off the farm on average across the whole sample and for the years 2017, 2018, and 2019. Furthermore, mean decile values of household, farm, off-farm, and direct payment incomes are shown, as well as the mean values of the different income components in the below-average and above-average farm household income groups. Significant differences at the 1 per cent level of significance between farm household income groups exist for all income components, i.e. household income, off-farm income, farm income, and income from direct payments, but not for the off-farm participation and labour supply figures. This is true for all three years considered.

For the year 2019 and regarding the off-farm participation rate, it is shown that between 50 per cent (first household income decile) and 52.6 per cent (tenth household income decile) of Swiss farm operators participate in off-farm employment. The days they spent engaging in off-farm employment in 2019 vary between 23.9 (first decile) and 39.3 days (tenth decile).

The results show substantial differences in household incomes per farm family consumption unit across the sample. For instance, in 2019, about 112,300 CHF per family member (unit) is available for consumption in the tenth income decile, but only 13,600 CHF is available in the first income decile. Off-farm income and farm income are positively correlated with household income per farm family consumption unit, as shown by the increasing figures of both income components across deciles.

Table 2. Off-farm labour allocation and incomes across deciles of household income per consumption unit 2017–2019.

	Decile of household income per consumption unit in 1,000 CHF									
	2019									
	2018									
	2017									
	1	2	3	4	5	6	7	8	9	10
	Below average: 1st–5th					Above average: 6th–10th				
Household income per consumption unit in 1,000 CHF	13.6	21.4	26.2	30.3	34.9	40.3	46.9	55.4	67.8	112.3
	10.2	20.5	25.1	29.6	34.3	39.3	45.4	53.1	66.1	111.6
	11.9	20.4	24.6	29.1	33.7	38.4	44.3	52.1	64.1	103.1
			25.0					64.0		
			24.7					63.7		
			24.0					60.4		
Off-farm labour allocation										
Off-farm participation rate of farm operators in percentage	41.6	48.5	52.9	54.4	53.1	52.4	53.9	47.5	53.9	55.1
	36.2	47.6	46.3	50.2	50.2	51.5	53.3	49.8	52.4	54.1
	41.5	48.8	46.6	53.7	52.2	47.6	47.8	50.0	54.6	52.7
			50.0					52.6		
			46.2					52.2		
			48.5					50.5		
Days spent engaging in off-farm labour per year	23.9	26.5	29.7	34.8	31.7	26.9	29.2	29.5	39.0	39.3
	17.8	26.7	27.5	30.9	29.8	31.4	33.8	31.4	39.0	41.3
	20.8	32.0	34.9	29.1	32.1	27.9	29.1	33.7	40.3	38.8
			29.5					32.9		
			26.5					35.6		
			29.8					34.0		
Income from different sources										
Household income in 1,000 CHF	52.4	75.5	85.8	92.0	101.8	108.0	118.4	124.6	138.6	179.8
	47.6	74.1	79.8	90.4	96.9	106.3	109.0	121.4	133.9	174.4
	46.3	73.1	80.6	91.3	97.2	100.7	115.0	115.7	129.8	161.8
			81.0					133.3		
			78.1					129.8		
			77.7					124.6		
Off-farm income in 1,000 CHF	10.9	17.4	24.0	24.1	20.6	22.8	24.7	28.3	29.4	26.6
	10.2	16.4	16.8	20.1	22.1	22.9	27.4	26.5	27.5	27.2
	12.1	17.7	20.7	17.5	21.2	22.0	22.5	25.3	29.4	24.9
			19.4					26.1		
			17.2					26.5		
			17.8					24.8		
Farm income in 1,000 CHF	37.9	48.0	54.9	58.7	73.7	76.2	84.0	86.1	97.3	127.6
	29.6	49.7	53.7	59.8	65.8	75.0	73.2	81.6	94.9	124.3
	28.8	46.4	50.7	62.3	67.0	68.8	79.6	80.9	87.6	119.3
			54.0					94.0		
			52.1					90.2		
			51.0					87.3		

Table 2. Continued

	Decile of household income per consumption unit in 1,000 CHF									
	2019									
	2018									
	2017									
	1	2	3	4	5	6	7	8	9	10
	Below average: 1st–5th					Above average: 6th–10th				
Direct payments in 1,000 CHF	55.6	63.3	67.3	74.1	72.2	72.7	80.0	76.3	75.6	79.0
	56.9	67.2	67.2	68.1	72.5	77.1	69.1	74.4	72.6	80.2
	57.6	61.7	65.1	70.8	73.0	72.1	72.0	76.3	72.1	75.7
			66.1					76.9		
			66.8					74.4		
			65.7					73.36		
Biodiversity payments in 1,000 CHF	7.8	8.9	9.8	11.9	11.4	11.7	13.2	12.3	11.9	13.8
	7.4	9.4	9.5	9.8	10.5	11.4	10.0	12.1	11.2	14.2
	8.4	8.7	8.9	10.5	10.3	10.4	10.8	12.3	11.3	11.8
			10.0					12.6		
			9.3					11.8		
			9.4					11.3		

Direct payments are an important income source for Swiss farmers, especially for those with lower incomes. For instance, in 2019, farms of the first household income (per farm family consumption unit) decile received about 55,600 CHF in direct payments, but income from farming—taking costs into account—was only about 37,900 CHF. In fact, in 2019, direct payments exceeded agricultural incomes up to the fourth to fifth household income (per consumption unit) decile and even household incomes of the first decile. Financial means provided to farmers through voluntary participation in the biodiversity programme make up only a small share of all direct payments.

5.2 Results of the off-farm labour participation model

Applying a genetic algorithm variable selection procedure to the whole data set of the years 2017, 2018, and 2019 shows that for each of the years the following variables were selected for the off-farm labour participation model: Farm_Inc, DirectPay, BioDivPay, FarmSize, Region, Age, EduFarm, EduNonFarm, and Days worked by spouse. Some variables were only selected for individual years: Dairy was selected in 2018 only, Organic and Debt in 2017 only, and Wealth in 2019 only. HHSize was not selected in any of the years.

The final model, determined based on the whole data set (per year), is also used for the analyses, separated according to farm household income classes. A comparison of the results across samples and years shows that the direction of the estimated effects of the individual variables remains the same, but the level of significance differs partly between the samples.[1]

Results of the off-farm labour participation model of the years 2017, 2018, and 2019 are presented for the whole sample and for the below-average and above-average farm household income groups to identify potential differences between households that are more or less restricted in consumption levels. For interpretation reasons, the estimated coefficients of the off-farm labour participation model are presented as marginal effects representing the change in the probability of off-farm employment with a one-unit increase in the respective variable.

As shown in Table 3, the participation in off-farm labour of Swiss farm operators is significantly negatively correlated to farm income, and the results are robust across

Table 3. Results of the off-farm labour participation model for the whole sample and for the below- and above-average farm household income groups: average of the sample marginal effects with robust standard errors 2017–2019.

Variable	Whole sample			Below-average income group			Above-average income group		
Year	2017	2018	2019	2017	2018	2019	2017	2018	2019
Farm_Inc[a]	−0.008***	−0.007***	−0.007***	−0.020***	−0.006*	−0.011***	−0.006*	−0.011***	−0.011***
Std error	0.003	0.002	0.002	0.006	0.004	0.003	0.004	0.003	0.003
z value	−2.713	−2.944	−2.923	−3.362	−1.653	−3.435	−1.653	−3.435	−3.087
DirectPay[b]	0.013	0.024**	0.018**	0.091***	0.009	0.018*	0.009	0.018*	0.012**
Std error	0.008	0.012	0.008	0.031	0.007	0.008	0.007	0.008	0.005
z value	1.577	1.997	2.197	2.954	1.339	2.293	1.339	2.293	2.406
BioDivPay	0.025***	0.019***	0.012**	0.027***	0.026***	0.023***	0.026***	0.023***	0.023**
Std error	0.005	0.005	0.005	0.007	0.009	0.008	0.009	0.008	0.009
z value	4.819	3.647	2.565	4.058	2.928	2.984	2.928	2.984	2.231
BioDivPay^2	−0.001***	−0.001***	−0.0002	−0.001***	−0.001**	−0.001**	−0.001**	−0.001**	−0.001*
Std error	0.000	0.0002	0.0002	0.0002	0.0005	0.0004	0.0005	0.0004	0.0005
z value	−3.829	−2.782	−1.611	−3.650	−2.341	−2.829	−2.341	−2.829	−1.723
FarmSize[c]	−0.002***	−0.001	−0.001*	−0.002	−0.002***	−0.001	−0.002***	−0.001	−0.003
Std error	0.001	0.001	0.0006	0.001	0.001	0.001	0.001	0.001	0.0008
z value	−3.293	−1.632	−1.705	−1.535	−2.853	−0.808	−2.853	−0.808	−0.36
Wealth[a]	Not selected	Not selected	−0.0004	Not selected	Not selected	Not selected	Not selected	Not selected	−0.001*
Std error			0.0003						0.0004
z value			−1.315						−1.791
Debt	−0.048	Not selected	Not selected	0.039	−0.107*	Not selected	−0.107*	Not selected	Not selected
Std error	0.038			0.055	0.056		0.056		
z value	−1.250			0.712	−1.904		−1.904		
Dairy	Not selected	−0.061***	Not selected	Not selected	Not selected	−0.084**	Not selected	−0.084**	Not selected
Std error		0.023				0.035		0.035	
z value		−2.605				−2.377		−2.377	
Organic	−0.064**	Not selected	Not selected	−0.092**	−0.068	Not selected	−0.068	Not selected	Not selected
Std error	0.032			0.046	0.045		0.045		
z value	−1.960			−2.014	−1.524		−1.524		

Table 3. Continued

Variable	Whole sample			Below-average income group			Above-average income group		
Year	2017	2018	2019	2017	2018	2019	2017	2018	2019
Region: hill	−0.012	−0.039	−0.036	−0.080*	0.034	0.022	0.034	0.022	0.019
Std error	0.027	0.025	0.026	0.046	0.038	0.034	0.038	0.034	0.035
z value	−0.458	−1.528	−1.375	−1.937	0.892	−0.633	0.892	−0.633	−0.533
Region: mountain	−0.058*	−0.066**	−0.066**	−0.134***	−0.013	−0.075*	−0.013	−0.075*	−0.13***
Std error	0.030	0.030	0.030	0.046	0.043	0.042	0.043	0.042	0.042
z value	−1.958	−2.211	−2.165	−2.906	−0.311	−1.798	−0.311	−1.798	−3.087
Age	0.030***	0.041***	0.043***	0.053***	0.030**	0.046***	0.030**	0.046***	0.051***
Std error	0.010	0.010	0.011	0.019	0.014	0.013	0.014	0.013	0.014
z value	2.924	4.301	4.005	2.722	2.214	3.485	2.214	3.485	3.551
Age^2	−0.0004***	−0.001***	−0.0005***	−0.0006***	−0.0004***	−0.001***	−0.0004***	−0.001***	−0.001***
Std error	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0002
z value	−3.727	-5.022	-4.445	−3.092	−2.910	-4.052	−2.910	-4.052	-3.844
EduFarm	0.030***	0.022***	0.035***	0.025***	0.037***	0.026***	0.037***	0.026***	0.026***
Std error	0.006	0.006	0.006	0.009	0.009	0.008	0.009	0.008	0.009
z value	4.766	3.933	5.456	2.777	4.213	3.372	4.213	3.372	2.966
EduNonFarm	0.017***	0.023***	0.032***	0.016**	0.017***	0.024***	0.017***	0.024***	0.032***
Std error	0.005	0.005	0.005	0.007	0.007	0.006	0.007	0.006	0.007
z value	3.423	4.94	6.535	2.225	2.582	3.939	2.582	3.939	4.865
Days worked by spouse	0.0003	0.0003	0.0003	0.0001	0.0002	0.0002	0.0002	0.0002	0.0004
Std error	0.0002	0.0002	0.0002	0.0003	0.0002	0.0003	0.0002	0.0003	0.0003
z value	1.541	1.613	1.638	0.254	0.935	0.942	0.935	0.942	1.481

[a]In 10,000 CHF.
[b]In 1,000 CHF.
[c]Standard output in 10,000 CHF; ***, **, and * denote the 10 per cent, 5 per cent, and 1 per cent significance levels, respectively.

samples and years. Regarding the whole sample of the year 2019, we find that an increase in farm income of 10,000 CHF per year decreases the probability of off-farm participation by 0.7 per cent. The effect of farm income is higher in the below- compared with the above-average farm household income groups, but the level of significance of the *z*-test is low ($P = 0.090$ for the year 2019) and the magnitude of the effects remains small.

Direct payments per hectare of agricultural land have a positive effect on the off-farm labour participation of Swiss farm operators. Differences in the effects between farm household income groups are rather small; for instance, in 2019, an increase in direct payments of 1,000 CHF per hectare is estimated to increase the probability to participation in off-farm labour allocation by 1.8 per cent across the whole sample and by 1.2 per cent in the above-average farm household income group, but it has no effect on the off-farm labour participation decision in the below-average income group.

The share of biodiversity payments on farm revenues has a quadratic effect on off-farm labour participation across all years and samples. By increasing the relevance of biodiversity payments for farm revenues, off-farm labour participation first increases and then decreases, with a turning point at 13 per cent in 2019. Hardly any differences between farm household income groups can be observed.

Farm size has a negative effect on off-farm labour participation, but the effect is minute, and for some years and samples, the effect is not significant. For instance, an increase in the standard output of 10,000 CHF is estimated to decrease the probability of off-farm participation by 0.1 per cent. From the results, no clear differences can be found between farm household income groups.

The estimated effects of age, education, and region on off-farm labour participation are robust across samples and years. With increasing age, the probability that the farm operator participates in off-farm employment increases, and at the turning point of 43 years (for the year 2019), the probability decreases again. Higher education levels, independent of whether it is farming or non-farming education, increase the probability of the off-farm participation of the farm operator. Meanwhile, being in the mountainous regions reduces the probability of off-farm labour participation by about 6.6 per cent in the 2019 sample. No significant differences between estimated parameters can be observed between farm household income groups.

5.3 Results of the off-farm labour supply model

We applied the genetic algorithm procedure for variable selection to the whole data set, as well as to the supply model, and we used the final model for the analyses, separated according to farm household income classes. For each of the years 2017, 2018, and 2019, the following variables were selected: Farm_Inc, FarmSize, Dairy, Organic, Age, EduFarm, and EduNonFarm. The other variables were selected for some but not all the years: DirectPay and Region were selected in 2017 and 2019 and BioDivPay and Debt in 2018 only. The variables Wealth, HHSize, and the working days spent engaging in off-farm employment by the spouse were not selected for any of the years. For six of the nine estimated models across samples and years, we have found no evidence of correlated error terms. This is true for all the models estimated with data from the year 2017, for two models (whole sample and above-average farm household income sample) estimated with data from the year 2018, and one model (below-average farm household income group) estimated with data from the year 2019. Because comparisons of the results across samples and years show robust effects of the estimated parameters, we present the OLS results here, knowing that the interpretation of significance should be taken with caution.

The results of the labour supply models are presented in Table 4.[2] It shows that the estimated effects of farm income on the working days spent engaging in off-farm employment are significant, negative, and robust across years and samples. For the year 2019, and even

Table 4. Results of the off-farm labour supply model for the whole sample and the below- and above-average farm household income groups, 2017–2019.

Variable	Whole sample			Below-average income group			Above-average income group		
Year	2017	2018	2019	2017	2018	2019	2017	2018	2019
Intercept	100.754***	135.556***	136.412***	100.984***	136.843***	111.591***	100.677***	151.021***	161.057***
Std error	10.646	15.38	15.30	20.663	22.59	24.54	20.251	20.09	20.60
t value	10.658	8.813	8.918	7.450	6.057	4.547	7.453	7.243	7.819
Farm_Inc[a]	−2.124***	−1.241***	−2.362***	−3.818***	−4.551***	−4.741***	−1.887***	−1.723***	−2.391***
Std error	0.454	0.473	0.464	0.691	0.971	0.871	0.690	0.614	0.619
t value	−4.675	−2.625	−5.089	−5.524	−4.687	−5.444	−2.734	−2.808	−3.863
DirectPay[b]	1.742*	Not selected	1.317*	0.365	Not selected	10.36*	1.596	Not selected	0.761
Std error	1.019		0.876	5.523		4.320	1.057		0.910
t value	1.710		1.504	0.066		2.398	1.509		0.836
BioDivPay	Not selected	0.912*	Not selected	Not selected	1.322*	Not selected	Not selected	0.594	Not selected
Std error		0.468			6.299			0.677	
t value		1.948			2.099			0.877	
FarmSize[c]	−0.712***	−0.450***	−0.444***	−0.805***	−0.634***	−0.982***	−0.699***	−0.344***	−0.323***
Std error	0.105	0.096	0.101	0.162	0.144	0.189	0.141	0.130	0.123
t value	−6.779	−4.637	−4.379	−4.967	−4.418	−5.189	−4.964	−2.654	−2.630
Organic	−10.449**	−22.523**	−14.226**	−8.520	−22.032***	−21.663***	−20.133***	−23.438***	−11.325
Std error	5.833	5.037	4.817	8.597	6.958	6.756	8.061	7.083	6.885
t value	−2.485	−4.472	−2.953	−0.991	−3.166	−3.207	−2.646	−3.309	−1.645
Dairy	−20.106***	−17.290***	−19.754***	−10.839***	−14.841***	−17.138***	−20.042***	−15.548**	−19.804***
Std error	4.591	4.435	4.254	6.121	5.663	5.489	6.948	6.752	6.574
t value	−4.588	−3.898	−4.643	−3.004	−2.621	−3.122	−2.939	−2.303	−3.012

Table 4. Continued

Variable	Whole sample			Below-average income group			Above-average income group		
Year	2017	2018	2019	2017	2018	2019	2017	2018	2019
Region: hill	−1.633	Not selected	3.122	−3.420	Not selected	0.646	0.636	Not selected	1.19
Std error	4.850		4.457	7.546		6.763	6.767		6.059
t value	−0.337		−0.700	−0.453		0.096	0.094		0.196
Region: mountain	−10.825***	Not selected	−10.962**	−20.201**	Not selected	−19.392**	−9.634	Not selected	−9.811
Std error	5.553		5.152	9.063		8.031	8.138		7.625
t value	−3.286		−2.128	−2.428		−2.415	−1.184		−1.287
Debt	Not selected	9.727	Not selected	Not selected	1.622	Not selected	Not selected	18.97**	Not selected
Std error		6.642			9.499			9.067	
t value		−1.464			0.171			2.093	
Age	−1.276***	−1.011***	−0.793***	−1.497***	−1.046**	−0.653**	−1.147***	−1.085***	−1.003***
Std error	0.226	0.220	0.211	0.358	0.332	0.322	0.290	0.289	0.276
t value	−5.654	−4.607	−3.761	−4.182	−3.147	−2.026	−3.949	−3.753	−3.633
EduFarm	−3.943***	−2.934**	−2.712**	−4.738***	−1.395	−1.063	−3.401*	−3.913***	−3.954**
Std error	1.238	0.997	1.093	1.707	1.396	1.542	1.785	1.394	1.530
t value	−3.186	−2.943	−2.482	−2.776	−1.0	−0.689	−1.905	−2.806	−2.584
EduNonFarm	4.294***	3.947***	3.612***	2.906**	3.201***	3.962***	4.888***	4.12***	2.84***
Std error	0.866	0.765	0.766	1.257	1.116	1.112	1.198	1.036	1.044
t value	4.960	5.163	4.713	2.312	2.869	3.563	4.080	3.974	2.721
Adjusted *R*-squared	0.19	0.14	0.15	0.19	0.217	0.21	0.20	0.16	0.15
F statistic	25.09***	22.35***	20.19***	12.89***	13.14***	14.62***	14.5***	14.3***	10.5***

[a]In 10,000 CHF.
[b]In 1,000 CHF.
[c]Standard output in 10,000 CHF; ***, **, and * denote the 10 per cent, 5 per cent, and 1 per cent significance levels, respectively.

if this must be interpreted with caution, a significant difference can be observed between farm household income groups, as shown by the z-test ($P = 0.014$). In the below-average farm household income group, an increase in farm income reduces off-farm labour supply significantly more than in the above-average farm household income group.

Direct payments per hectare of agricultural land have a positive but hardly significant and small effect on off-farm labour supply. In addition, the share of biodiversity payments on farm revenues was found to be significant only in the year 2018. Thus, from our analyses, we cannot conclude any robust effect of direct payments on the working days allocated to off-farm employment.

However, robust results across samples and years are shown for the variables farm size, dairy, and organic production, with all these variables significantly reducing the working days spent participating in off-farm employment. Farm size has a significantly more negative effect on off-farm labour supply in the below-average than the above-average farm household income group, as shown by the z-test ($P = 0.002$ for the year 2019).

Being in the mountainous regions reduces the number of off-farm working days when compared with the valley regions, which is especially true for the below-average farm household income group. The age of the farm operator is significantly negatively correlated to working days spent participating in off-farm employment, and the effect is robust across years and samples. An education in farming has a significant negative effect on the amount of off-farm labour supplied, especially in the above-average farm income group. In contrast, a non-farming education has a positive effect on the number of working days spent participating in off-farm employment, and the result is significant across years and sample.

6 Summary and discussion

Based on the theory of the farm household model, as described in Section 2, the effects of different farm and farmer characteristics, including two different kinds of direct payments, on the off-farm labour allocation decisions of Swiss farm operators were analysed. Off-farm labour participation and off-farm labour supply decisions were modelled for the whole sample and for two different income groups for the years 2017, 2018, and 2019. Income groups were defined based on the farm household income per farm family consumption unit to observe potential differences in off-farm labour allocation decisions that could be attributed to the need to earn income off the farm to allow appropriate consumption levels for the farm family.

In 2019, on average, 50 per cent of all farm operators spent about 31 working days per year participating in off-farm employment, with low variations across the three considered years but substantial differences between individuals. Remarkable is the high dependence of low-income farmers on direct payments that even exceed farm incomes for a substantial proportion of farms.

Our results suggest that in making their off-farm labour allocation decisions, neither the size of the farm household, debt, nor wealth substantially influences Swiss farm operators' participation in off-farm employment or their decision concerning how many working days are spent in off-farm employment. In contrast, and unsurprisingly, farm operators with farms located in the mountainous regions are significantly less involved in off-farm labour employment, in terms of both participation and hours spent. The production type and production technology considered in this study do not influence the decisions of Swiss farm operators whether to participate in off-farm employment or not, but rather the quantity of off-farm labour they will supply. More precisely, dairy and organic farmers spent significantly less time engaging in off-farm employment than farm operators of other farm types or conventionally producing farmers. This result is in line with previous studies (Lass *et al.* 1989; Kilkenny 1993; Kimhi 1994; Serra *et al.* 2005; Hennessy and Rehman 2008), suggesting that dairy production is difficult to combine with off-farm employment. In addition,

organic production is considered more labour-intensive (e.g. Padel and Lampkin 1994), not allowing the allocation of much time to off-farm employment, which is supported by our results.

In line with the theory of the farm household model described in Section 2 and in the existing empirical literature, farm income and farm size (Woldehanna *et al.* 2000; Serra *et al.* 2005; Hennessy and Rehman 2008) are significantly negatively correlated with off-farm labour participation and supply decisions.

The effect of farm size is more important on the off-farm labour supply decision than on the participation decision. Moreover, the influence of farm size on labour supply decisions is stronger, i.e. the magnitude of the estimated effect is bigger, in the group of farm households with below-average incomes per consumption unit. In addition, the magnitude of the negative effect of farm income is bigger in the below- than in the above-average farm household income group. Thus, farm income and farm size have an especially negative effect on off-farm labour supply for farm families with tight budget constraints. It can be assumed that these farms would likely have greater problems with supplementing their household budgets if farm growth severely limited the possibility of working off the farm. This is especially true given the fact that in the below-average farm household income group, farm incomes are scant and even below the direct payments received. Farm growth would thus need to be substantial to improve the farm and household incomes of these farm families. This would imply that an increase in farm household income levels, through either an increase in farm income or an increase in off-farm income, is difficult to achieve for low-income farmers in Swiss agriculture.

Concerning direct payments, our results suggest that the off-farm labour participation but not off-farm labour supply decisions of Swiss farm operators is correlated with governmental subsidies. Direct payments paid per hectare of agricultural land show a significant positive correlation with off-farm labour participation, suggesting that the substitution effects of direct payments might be present in Swiss agriculture. The same is true for biodiversity payments, and our results show that with an increasing share of farm revenue from biodiversity payments, off-farm participation increases. However, when reaching a share of about 13 per cent, the probability that farm operators participate in off-farm employment decreases again, which might indicate the wealth effects of direct payments or at least of certain payment schemes. One possible interpretation is that labour-extensive agri-environmental programmes unrelated to the production of agricultural goods, such as biodiversity conservation, save a considerable amount of working time and allow farmers to enjoy more leisure time. However, the effect of both direct payments and biodiversity payments on off-farm labour participation has been shown to be more relevant for the above-average than the below-average income group. Thus, it can be assumed that substitution effects (on the decision to participate in off-farm employment) of direct payments are more likely to occur in the higher household income classes.

Farmers' characteristics, including age and education, play a crucial role in the off-farm labour allocation decisions of Swiss farm operators. Off-farm participation first increases and then decreases with age, at about 43 years in our samples, which is in line with existing literature and supports the life-cycle hypothesis (Huffman 1980; Sumner 1982; Weersink 1992; Mishra and Goodwin 1998; Serra *et al.* 2005). Our results show that high levels of education, in either farming or non-farming areas, increase the probability of off-farm labour participation. However, farm operators with high levels of education in farming allocate less time to off-farm employment than those with low levels of education in farming, which is in line with findings from Giannakis *et al.* (2018). This is especially true for farmers in the above-average farm household income group. One interpretation could be that such well-educated farm operators run professional and economically successful farm businesses and are less dependent on earning income off the farm. In contrast, farm operators with high

non-farming education levels spent more time in off-farm employment than those with low, non-farming education. These results suggest that the Swiss education in farming prepares students well for the non-agricultural labour market, enabling them to participate in off-farm employment. Furthermore, a good education in farming seems compensatory, allowing farm operators to run an economically successful farm. From an income perspective, it could be advisable to support farm operators with little prospect of running an economically successful farm, due to factors that cannot be influenced by the farmer, with non-agricultural training to allow for adequate farm household income levels. However, measures might be necessary not to provoke the potential risk of a deprofessionalization of the Swiss farming sector.

Even though the robustness of the results for Switzerland were tested by conducting the analyses across different years and samples, challenges with the endogeneity cannot be avoided. Repetitive analyses for different samples, years, and countries would be necessary to prove the results of this study concerning the interrelations between Pillar I and Pillar II payments and off-farm labour allocation decisions and farm incomes. In addition, the interrelationships between off-farm labour allocation decisions and farm and non-farm education are worth analysing in more detail in future research. This would allow the development of programmes that support the viability of farms and rural areas. The results of repeated analyses across countries and time would make it possible in the future to conduct meta-analyses of farmers' off-farm labour allocation decisions.

7 Conclusion

The results presented in this study show that off-farm income is indispensable for Swiss farmers and direct payments are a complementary income source besides off-farm employment. This is true for payments provided per hectare of agricultural land that is used to produce food and feed, as well as for biodiversity payments. However, the latter may also serve as a substitutive income source, resulting in lower off-farm labour participation when a certain threshold is reached. However, earning more income off the farm is not possible for all farmers, and especially low-income farmers seem to have difficulties increasing farm or off-farm labour, remaining low income despite receiving a significant amount from direct payments. If direct payments cannot prevent low farm and household incomes, the income-related goals of agricultural policy cannot be considered achieved. Instead of granting direct payments to farmers that neither cover the costs of production nor allow for an adequate household income, the money might be better invested in non-farm education programmes to improve off-farm labour employment opportunities and thus maintain the viability of rural areas. With the increasing importance of off-farm income and if the viability of rural areas is the goal of agricultural policy, then targeting farm household incomes could become more appropriate in the future than targeting farm incomes. Repeated analyses across countries, years, and samples should test the reliability and robustness of the resultsfound in this study.

Data availability

The data used in this article may be used for study and research purposes by higher education institutions and research institutes. Enquiries about the data sets can be made here: "https://www.agroscope.admin.ch/agroscope/de/home/themen/wirtschaft-technik/betriebswirtschaft/zabh/agrarmonitoring/agrarmonitoring_datennutzer.html" Information für Datennutzer (admin.ch).

End Notes

1 To check further the robustness of our results, we estimated models including all variables from Table 1 for the years 2017, 2018, and 2019 and compared whether differences in the direction of the estimates, the size of the estimates, or the significance levels were observed when compared with the reduced-form models shown in this paper. No differences in the results were observed.

2 To check further the robustness of our results, we estimated models including all variables from Table 1 for the years 2017, 2018, and 2019 and compared whether differences in the direction of the estimates, the size of the estimates, or the significance levels were observed compared with the reduced-form models shown in this paper. Hardly any changes were found in the results, and the interpretation of the results remains the same.

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