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Direct payments and on-farm employment: Evidence from a spatial regression discontinuity design

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Abstract

Direct payments are regarded as a suitable instrument to safeguard jobs in the agricultural sector. However, empirical findings to date do not unambiguously support this expectation. We further empirically investigate this research question on dairy farms with a focus on family work. Using a spatial regression discontinuity design, we rely upon selection on unobservables assumptions. The Swiss direct payments system creates a discontinuous jump near the border of agricultural production zones for the amount of public subsidies a farm receives. Using two-stage least squares (TSLS) to estimate the policy-relevant effect, we find that an additional CHF 50,000 can generate a job for a female family worker in the dairy sector. Male employment is not affected. These results show that direct payments can safeguard traditional family farming.

Keywords: Direct payments, Agricultural policy, Spatial regression discontinuity design, On-farm employment, Switzerland

JEL codes: Q12, Q18, J43

1. Introduction

Agricultural employment in Europe decreases, a phenomenon particularly relevant in livestock farming (Hostiou et al. 2020). Direct payments are regarded as a counteracting instrument, as they are found to slow down structural change in the agricultural sector (Key and Roberts 2006; Breustedt and Glauben 2007) and may also safeguard on-farm employment. They reward the provision of public goods and serve as income support for lower-paid jobs in the agricultural sector (e.g. Petrick and Zier 2012; Mann and Lanz 2013, for Switzerland and the European Union). For example, in Switzerland, the median labour income of a farm family worker is about CHF 60,000 (valley region); in the secondary and tertiary sector, the median salary is about CHF 15,000 higher (Federal Office for Agriculture Switzerland FOAG 2020). Since the argument of a decent agricultural entrepreneurial income is also relevant to the security of food supply and rural development (Finger and El Benni 2021; Wuepper, Wimmer, and Sauer 2021), policymakers frequently use it to defend public expenditure on farming (European Commission 2017).

Strengthening employment outside of urban regions is especially important in predominantly rural countries such as Switzerland, where commuting to larger towns with better job opportunities is often time-consuming. Agricultural policy aims to contribute to decentralising settlement in Switzerland (Federal Assembly Switzerland 2021). In international comparisons, Switzerland highly subsidises its agricultural sector (Organisation for Economic Co-operation and Development OECD 2015). Thus, the question is whether government expenditure via direct payments can truly enhance employment prospects.

From a theoretical and empirical point of view, the answer to this question remains ambiguous. Following neoclassical theory, an increase in direct payments that are completely decoupled from production, such as a lump-sum payment, leads to a parallel upward shift in a household's budget constraint. Thus, overall employment (off- and on-farm) is expected to decrease through an income effect (El-Osta, Mishra, and Ahearn 2004; Ahearn, El-Osta, and Dewbre 2006). Key and Roberts (2009) explain that this decline will reflect in off-farm employment, as farm households optimise on-farm labour supply such that the value marginal product of labour equates the off-farm wage rate irrespective of the household's income. Including non-pecuniary benefits from farming in the optimisation problem, their model shows that on-farm employment increases while labour supply off-farm decreases (see e.g. Moro and Sckokai 2013, for a review). In addition, Garrone et al. (2019) emphasise the role of pathways other than income, such as investment in capital, land, or education, through which indirect effects of direct payments on employment can be expected. Deviating from the assumption of perfect markets, there might also be other reasons why workers do not reduce labour supply, e.g. mobility constraints or transaction costs.

These different theoretical considerations may also explain why empirical findings differ. Several articles analyse the employment effects of the Common Agricultural Policy (CAP) in the European Union (EU). Olper et al. (2014) find that coupled and decoupled CAP payments attenuate the out-migration from the agricultural sector in 150 EU regions. Grassland support in Sweden is found to have a positive effect not only on jobs in the agricultural sector (Nordin 2014), but also on jobs off the farm (Blomquist and Nordin 2017). Similarly, Rizov, Davidova, and Bailey (2018) estimate positive off-farm employment effects of decoupled subsidies for small and medium-sized enterprises. Petrick and Zier (2011) explain that decoupled payments have the potential to release labour and find a negative impact on on-farm employment in Germany (Petrick and Zier 2011, 2012). The same can be found for France (Dupraz and Latruffe 2015).

Another explanation for different empirical findings is the variety of econometric methods used in these articles, implying different identifying assumptions and parameters of interest that are estimated. For example, Petrick and Zier (2011) use an estimator that allows for time-constant unobserved heterogeneity. Endogeneity issues may arise, for example, whenever the amount of direct payments a farmer receives is a strategic decision that depends on management skills. If these skills cannot be observed and also affect on-farm employment, selection on observables assumptions are violated.

In this article, we exploit the implementation of the Swiss direct payments system and apply a spatial regression discontinuity (RD) design that relies on less strong identifying assumptions (e.g. Imbens and Lemieux 2008; Lee and Lemieux 2010). We use two-stage least squares (TSLS) and a local linear regression approach for estimation. Our analysis focuses on dairy farms as a labour-intensive farm type, about two percent of which abandon farming each year or implement diversification strategies such as the more labour-extensive suckler cow husbandry (Zorn and Zimmert 2022), direct marketing or agritourism (Hochuli, Hochuli, and Schmid 2021). In contrast to prior studies, we use detailed geo-referenced farm-level data rather than data sources from some more aggregated administrative units. The data set allows to distinguish between male and female employment. This aspect is especially interesting, because we focus on family employment as the main source of labour force in Switzerland. Thus, we can analyse the intra-family division of labour (between female and male members). The distinction between gender has been neglected in existing

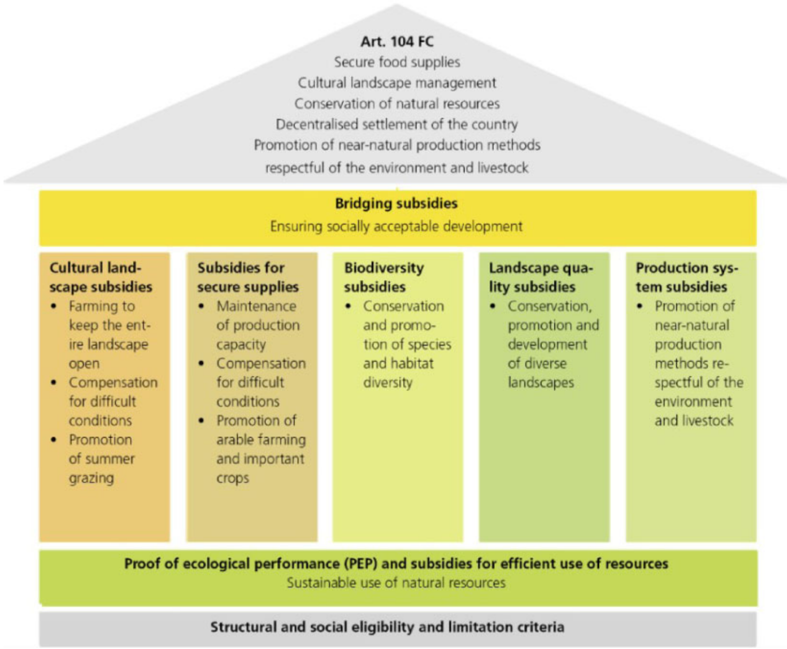


Figure 1. Direct payments in Switzerland.
Notes: We translate cultural landscape subsidies into farmland subsidies in the same way as the Organisation for Economic Co-operation and Development OECD (2015).
Source: FOAG, https://www.blw.admin.ch/blw/en/home/politik/direct_payments.html.

literature and provides new insights to the question if and how direct payments affect farm employment.

This article is structured as follows. Section 2 presents the institutional background that we use for the effect identification, as well as the estimation strategy. Section 3 deals with the data basis, followed in Section 4 by the results of our analysis. Sections 5 and 6 contain a discussion and conclusion.

2. Empirical strategy

To investigate the effect of direct payments on agricultural employment, we exploit the implementation of the Swiss direct payments system and apply a spatial regression discontinuity (RD) design. Before turning to methodological details, we briefly explain the institutional background in Switzerland.

2.1 Institutional background

The Swiss direct payments system consists of different programmes with special foci covering the maintenance of the cultural landscape, the security of food supply or biodiversity issues (see Fig. 1).[1] In general, the amount of direct payments a farm receives is proportional to the size of the utilised agricultural area (UAA). Additionally, as the production conditions in Switzerland are diverse, the direct payments system compensates for diverging production conditions. The Federal Office for Agriculture (FOAG) maintains an agricultural production cadastre in which agricultural land is classified according to these conditions (climate, transport situation/accessibility, topography, altitude, exposure; see Federal Office for Agriculture Switzerland FOAG 2008).

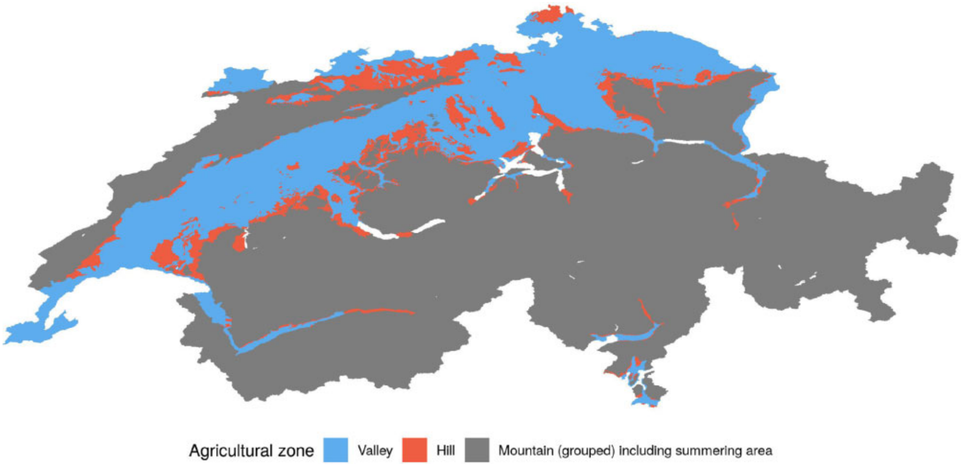


Figure 2. Agricultural zones in Switzerland.
Notes: White polygons represent lakes which are not labelled as an agricultural zone.
Source: Authors' illustrations using data from
https://data.geo.admin.ch/ch.blw.landwirtschaftliche-zonengrenzen/.

The cadastre distinguishes between three areas: valley, mountain, and summering (seasonal alpine farming). The area of our study is the valley area, which represents 61% of Switzerland's UAA and is further differentiated into two zones: the valley zone (78% of the area) and the hill zone (22%). These zones can be described by non-contiguous polygons of different size (see the blue and red polygons in Fig. 2).[2]

The valley zone is characterised by arable farming, intensive forms of production and a relatively small proportion of biodiversity areas (Federal Office for Agriculture Switzerland FOAG 2020). The hill zone represents a transitional area between valley zone and mountain region. In the hill zone, which is favoured in terms of both climate and accessibility, the topography of the land, i.e. its slope, limits arable farming. Livestock farming predominates in this zone (Federal Office for Agriculture Switzerland FOAG 2008). The valley and hill zones are mainly located in the Swiss Plateau and its fringes with the Jura and Alps. Our analysis focuses on these two zones, since the majority of Swiss farms are located there, leading to a sufficiently large sample size.

2.2 Effect identification and estimation

We are interested in the causal effect of direct payments on the number of workers on-farm and assume a linear model for the potential outcome such that:

$$Y(T) \equiv f(T) = \sigma_0 + T\gamma + V_0, \tag{1}$$

where Y is the outcome variable (number of persons working on-farm) depending on a continuous 'treatment' variable T (the amount of direct payments a farm receives; see Angrist and Pischke 2008). T can take on any positive value.[3] σ_0 is a constant and V_0 represents an error term. Then, our parameter of interest is depicted by γ.

Under selection on observables assumptions, any estimator of γ would be biased if we cannot fully observe all relevant variables that influence T and Y. Hence, we relax assumptions and rely on an instrumental variable (IV) strategy. Plots characterised by harder production conditions receive higher subsidies, notably reflected in the programme for preservation of cultural landscape ('farmland payments'; Federal Office for Agriculture Switzerland FOAG 2021). In the following, we restrict to two zones: the valley zone with less difficult production conditions and the hill zone with more difficult conditions. We argue that farms with production sites in different zones close to the zone boundary face similar production conditions while their direct payments discontinuously differ as a function of a running variable Z due to the design of the direct payments system. In the analysis, we will use two different continuous 'treatment' variables;[4] one is the amount of farmland payments only and the other the total amount of direct payments a farm receives. The discontinuity of the latter is mainly based on the jump of the farmland payments. The binary indicator of farm location D serves as an instrument for the amount of direct payments T a farm receives. D is one if the distance to the zone boundary (the running variable Z) exceeds a threshold c and it is zero otherwise:

$$D = \mathbb{I}[Z \geq c]. \tag{2}$$

We define the zone boundary as $c = 0$ which translates into all farms in the hill zone having a positive distance to the boundary ($D = 1$), while those in the valley zone are characterised by negative distance measures ($D = 0$; see Eugster et al. 2011; Egger and Lassmann 2015; Keele and Titiunik 2015).

Zone assignment is a relevant instrument for the amount of direct payments only if both are highly correlated. The direct payments system determines that plots in the valley zone are not eligible for farmland payments designated for the maintenance of cultivated landscape. Plots in the hill zone, on the contrary, are eligible for CHF 100 per hectare of UAA as a contribution to maintain an open landscape. Additionally, they are eligible for payments for farming on steep slopes: CHF 410 per hectare of UAA with a slope of 18 to 35%, CHF 700 for more than 35 to 50% slope and CHF 1,000 for more than 50% slope.[5] These characteristics ensure that the amount of direct payments discontinuously differs at the threshold and make the zone assignment a relevant instrument. As farms may have plots of UAA in several zones, those with production sites in the valley zone ($D = 0$) can also receive farmland payments. We call this a fuzzy design, of which the continuous treatment case represents a special form (Dong, Lee, and Gou 2021). Figure A.2 in the appendix shows that the main UAA is located in the same zone as the farm site, generating a discontinuous jump of the treatment.[6]

The key assumption in an IV design is that D must not be directly correlated with Y conditional on observables X, but only affects Y via T. That is, the IV estimator uses that part of the variation in T which is induced by the instrument. In general, the farm site may be a relevant predictor for on-farm employment when considering more difficult production conditions that demand higher labour input. However, with the RD approach we limit the farms to a small region around the zone boundary such that the production conditions are likely to be very similar and only T discontinuously differs. Figure 3 illustrates one such zone assignment. The bright green area is defined as hill zone and the pale area as valley zone. Zone boundaries can be located in forests and limited by roads (red box) or cross a settlement area (blue box). Hence, a zone boundary does not necessarily translate into a sharp change of topographical conditions, which underpins our empirical strategy. In addition, we include different control variables X which serve as a further relaxation. They make it more plausible that we cover possible differences between valley and hill zone farms apart from the farmland payments that may confound the effect identification. We control for different farm characteristics such as other direct payments programmes (that are also a good summary of the farm characteristics such as form of production), the size of the UAA and the number of LU.

Another violation would be if farmers manipulate the location of the production site in expectation of individual gains. Due to the immobility of capital, this seems to be very unlikely. Additionally, we test the null hypothesis of continuity of the running variable according to McCrary (2008) and find that it cannot be rejected (see Fig. A.3 in the appendix).

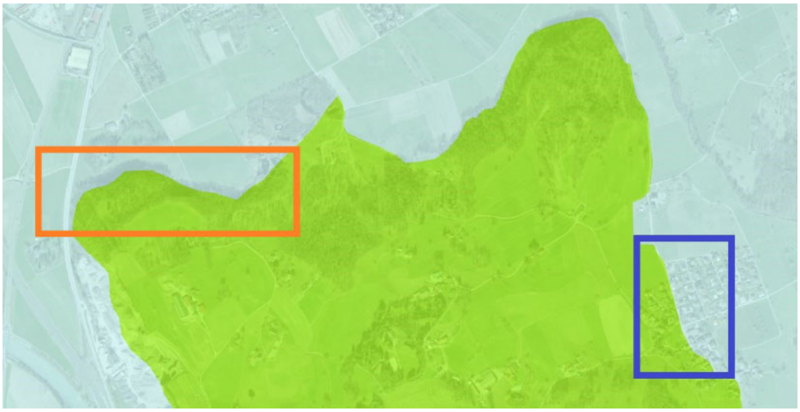


Figure 3. Assignment between valley and hill zone.
Notes: The figure represents an example of zone assignment. The bright green area is defined as hill zone and the pale area as valley zone.
Source: Authors' illustrations using data from https://map.geo.admin.ch/.

To obtain the parameter of interest, we use TSLS and estimate the following two equations for the subset $c - h < Z \leq c + h$ with h being the chosen bandwidth around the zone boundary and $\hat{T}$ representing the vector of the predictions of Equation (3):

$$\text{First stage: } T = \tau_1 + D\phi + Z\lambda_1 + X\delta_1 + V_1. \tag{3}$$

$$\text{Second stage: } Y = \tau_2 + \hat{T}\gamma + Z\lambda_2 + X\delta_2 + V_2. \tag{4}$$

τ_1 and τ_2 are constants, V_1 and V_2 error terms. Hahn, Todd, and Van der Klaauw (2001) show that the TSLS estimator without controls can be numerically identical to an estimator of the following estimand, commonly known as the RD estimand or local Wald ratio:[7]

$$\gamma = \frac{\lim_{\epsilon \downarrow 0} \mathbb{E}[Y|Z = c + \epsilon] - \lim_{\epsilon \uparrow 0} \mathbb{E}[Y|Z = c + \epsilon]}{\lim_{\epsilon \downarrow 0} \mathbb{E}[T|Z = c + \epsilon] - \lim_{\epsilon \uparrow 0} \mathbb{E}[T|Z = c + \epsilon]}. \tag{5}$$

Equation (5) reflects the ratio of the gap at the threshold for outcome and treatment variable that is a more intuitive representation of the idea of an RD design. The equality holds if Equation (5) is estimated with local linear regression using a uniform kernel and the same bandwidth choice in denominator and numerator (Imbens and Lemieux 2008).[8]We also provide estimates for Equation (5) with different kernel specifications. For estimation, we use the R-function RDestimate of the package rdd[9] and follow the suggestion of Imbens and Kalyanaraman (2012) for the determination of the bandwidth h.[10] We also use this bandwidth for TSLS estimation.

3. Data

We use farm-level data from the FOAG called *agricultural policy information system* (AGIS) for the years 2014 to 2016 (Federal Office for Agriculture Switzerland FOAG 2018). The data originates from the administration and management of direct payments and contains information on the farm, its labour force, the farmed area and animal numbers. The panel dataset corresponds to a census of all Swiss farms that receive direct payments. Our analysis focuses on the most important Swiss farm enterprise, dairy, and includes specialised dairy

Table 1. Summary statistics.

Variable	Mean	Standard deviation
Farms located in the hill zone (binary)	0.296	0.457
Outcome variables		
Number of male family workers	1.613	0.680
Farms with at least one male family worker (binary)	0.994	0.076
Number of female family workers	0.986	0.638
Farms with at least one female family worker (binary)	0.805	0.396
Treatment		
Total amount of DP (*DP_tot*)	57.454	33.276
Farmland payments (maintenance of cultural landscape *DP_CL*)	3.214	5.044
Control variables *X*1: DP for		
biodiversity (BD)	8.033	8.481
landscape quality (LQ)	1.822	2.852
production system (PS)	10.848	9.168
resource efficiency (RE)	0.467	1.115
ensuring food supplies (FS)	26.784	15.304
a socially acceptable transition (TS)	6.287	3.684
Control variables *X*2		
Utilised agricultural area (UAA) in hectare	25.990	14.583
Number of livestock units (LU) of cattle	32.265	21.731
Number of livestock units (LU) of pigs/poultry	0.627	2.618

Notes: $N = 26,437$. DP = direct payments measured in CHF 1,000.
Source: Authors' calculations with AGIS data 2014–2016.

farms and combined farms with a focus on dairy production (the criteria for farm type classification are documented in Meier 2000). We further restrict to farms that cultivate at least one hectare of farmland. Finally, we have 26,437 observations from 9,760 farms. As we estimate an effect close to the threshold c, we also check the number of observations around it. In the closest 0.2 km bin to the right of the threshold, we observe 1,357 data points, and 1,691 to the left of it.

As outcome variables we use the number of farm family workers (including the farm operator), differentiating between male and female persons.[11] The data collection distinguishes three different categories of employment: less than 50%, 50 to 74%, and more than 74% of a full-time equivalent. In line with the existing literature on on-farm employment, we do not distinguish between part- and full-time employment, such that one part-time worker is counted as one worker (e.g. Petrick and Zier 2011; Garrone et al. 2019). Table 1 gives summary statistics of the data set. In the following section, we also provide a more detailed graphical comparison between valley and hill zone farms for these variables. About 30% of the observed farms are located in the hill zone. On average, 1.6 male family workers and about one female family worker are employed per farm. Men work on almost all farms (almost every farm has a male farm operator), while the proportion of farms with female workers is 80%. Corresponding to the specification and as already mentioned above, we use two distinct treatment variables: the total amount of direct payments a farm receives (on average CHF 57,454 per year) and the amount of farmland payments (on average CHF 3,214 per year). The latter is a subset of the total amount for which we can observe the largest jump at the zone boundary. The remaining types of direct payments are used as control variables. These are payments for biodiversity (BD), landscape quality (LQ), for environment-/animal-friendly production systems (PS), resource efficiency (RE), and ensuring food supplies (FS; see Organisation for Economic Co-operation and Development OECD 2015, for a more detailed explanation). Food security payments make up the bulk

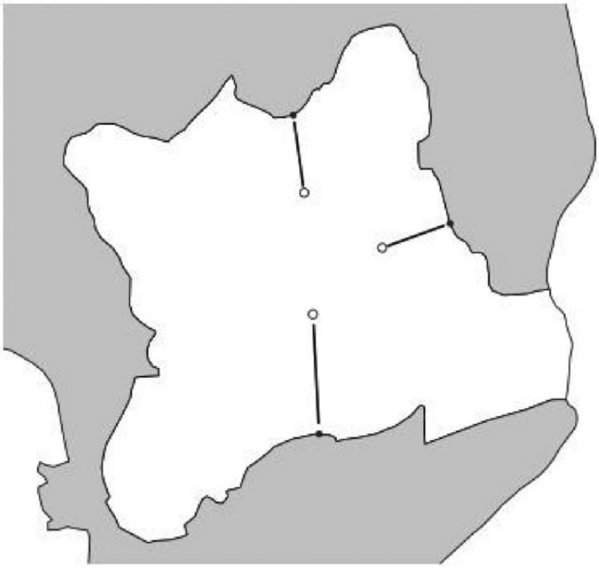


Figure 4. Running variable is shortest distance from farm to next polygon.
Notes: Circles represent farm coordinates in one polygon of the hill zone (white) with Euclidean distance (lines) to the nearest polygon of the other zone (grey).
Source: Authors' illustrations using AGIS data 2014–2016 and data from https://data.geo.admin.ch/ch.blw.landwirtschaftliche-zonengrenzen/.

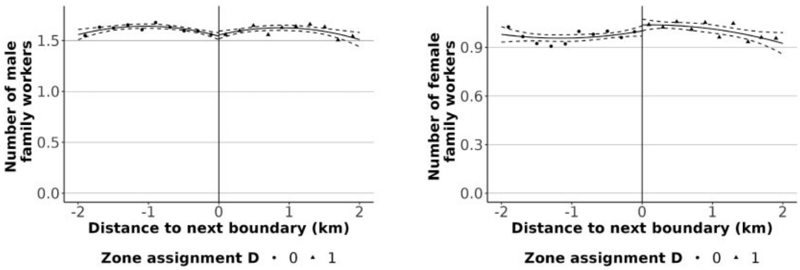
of the total amount and consist mainly of area payments. For a transitional period after implementing the new direct payments system in 2014, additional payments (TS) are provided which decrease over time. These different types of direct payments give a good indication of the farm's production process. For example, production system payments reward organic farming or free-range animal husbandry, while biodiversity payments are paid for ecological focus areas. The second set of covariates consists of structural farm characteristics such as the UAA (on average 26 hectares), the number of livestock units (LU) of cattle (on average 32 cattle) as well as those of pigs/poultry (on average less than one).

To calculate the running variable, we use the coordinates of the farm site and determine the Euclidean distance to the agricultural zone boundary.[12] As the farms are located in multiple polygons in the two zones (61 polygons in the valley zone, 283 polygons in the hill zone), we have more than one potential threshold. Hence, for farms located in a polygon of the valley zone ($D = 0$), the running variable is calculated as the shortest distance from the farm coordinates to the next polygon boundary of the hill zone. For farms in the hill zone ($D = 1$), the distance is calculated to the nearest boundary of the valley zone. Figure 4 shows an illustrative example for the same polygon as in Figure 3 and for three farms each represented by a circle. The white polygon belongs to the hill zone and the grey polygon to the valley zone. The shortest distance is calculated to the large grey polygon within which the white polygon is located.

4. Results

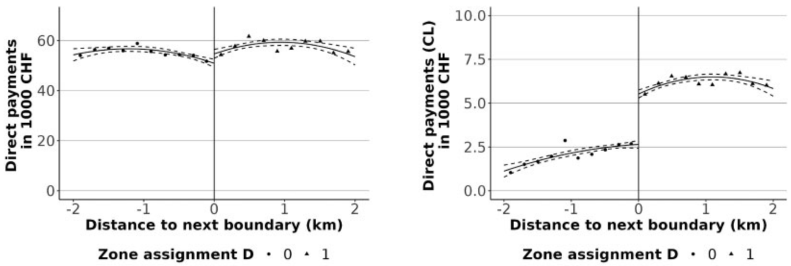
4.1 Graphical analysis

Before turning to the point estimates of the RD approach, a graphical analysis will illustrate our findings. Figure 5 shows mean values of the outcome variables by zone assignment D calculated for different bins of the running variable. Additionally, a regression line with



(a) Number of male family workers (b) Number of female family workers

Figure 5. Outcome variables.
Notes: The solid line corresponds to fitted values of a linear regression on the distance measure with a polynomial of degree two. The dashed lines limit the 95%-confidence band of the fitted values. The dots represent mean values in 0.2 km bins. $N = 16, 249$.
Source: Authors' illustrations using AGIS data 2014–2016.



(a) Direct payments (total) in CHF 1,000 (b) Farmland payments (CL) in CHF 1,000

Figure 6. Treatment variables.
Notes: The solid line corresponds to fitted values of a linear regression on the distance measure with a polynomial of degree two. The dashed lines limit the 95%-confidence band of the fitted values. The dots represent mean values in 0.2 km bins. $N = 16, 249$.
Source: Authors' illustrations using AGIS data 2014–2016.

its confidence bands is plotted representing predictions of a regression with polynomials of order two of the outcome variable on the distance measure. The calculated means and the regression line are almost symmetric for the number of male workers. However, for the number of female workers we can detect a jump at the threshold. Farms located to the right of the threshold have on average more female family workers. The extent of the jump of the treatment variables can be seen in Figure 6. We distinguish two related treatment variables described in Section 3. For both measures, the mean values discontinuously change at the threshold by about CHF 3,000.

Figures A.4 a to A.4 f in the appendix represent the comparative analysis between farms located in the valley or hill zone for the remaining types of direct payments. We cannot detect any major difference, suggesting that these variables are well balanced at the threshold. Additionally, we present the mean differences between the two bins around the threshold of these controls in Table A.1 which turn out to be close to zero. These findings underpin our identification strategy, as other direct payment programmes do supposingly not drive the results. A similar argumentation holds for the other set of control variables (Figures A.4g to A.4i and final rows in Table A.1). Although farms in the valley zone ($D = 0$) increase in terms of UAA and the number of animals, the more distant they are from the threshold, the closer the means approach. For any significant differences, we will check the role of

Table 2. First stage (TSLS) estimation results of a fuzzy RD design.

Estimates for	1st order		2nd order		1st order		2nd order	
	polynomial of Z							
	Men				Women			
ϕ_{DP_tot}	5.054	(1.066)	4.503	(1.073)	4.927	(0.956)	4.313	(0.967)
$\phi_{DP\_tot,X2}$	7.205	(0.335)	7.245	(0.338)	7.079	(0.303)	7.245	(0.306)
ϕ_{DP_CL}	3.077	(0.151)	3.051	(0.152)	3.117	(0.135)	3.095	(0.137)
$\phi_{DP\_CL,X1}$	2.799	(0.134)	2.816	(0.135)	2.840	(0.121)	2.862	(0.123)
$\phi_{DP\_CL,X2}$	3.262	(0.132)	3.291	(0.133)	3.329	(0.119)	3.369	(0.121)
h	1.139		1.139		1.512		1.512	
N	12,133		12,133		14,050		14,050	

Notes: TSLS regression with the R-package AER. $\phi(\cdot)$ is the estimate of (3) in different specifications. ϕ_{DP_tot} (ϕ_{DP_CL}) represents the coefficient of a regression in which DP_tot (DP_CL) is the outcome variable. Control variables X1: DP for biodiversity (BD), landscape quality (LQ), production system (PS), resource efficiency (RE), ensuring food supplies (FS), and transitional payments (TS). Control variables X2: UAA in hectare, LU of cattle, LU of pigs/poultry. Bandwidth (h) choice as in Imbens and Kalyanaraman (2012). Standard errors in parentheses. According to the choice of h and the chosen kernel, the number of observations N changes. The F-statistic can be computed by squaring the ratio of the first stage estimate to its standard error. *Source:* Authors' calculations with AGIS data 2014–2016.

the covariates by estimating both conditional and unconditional effects and find that the estimates are quite close.

4.2 Point estimates

The graphical analysis in Section 4.1 suggests a zero effect on the number of male family workers and a positive impact on female family employment. Before investigating this effect further, we analyse the strength of the instrument. Table 2 shows the ordinary least squares coefficient of the instrument as in Equation (3). We estimate different specifications depending on the left-hand side variable (either DP_tot or DP_CL) and the control variables included (ranging from none, to $X1$ or $X2$).[13] As the bandwidth choice h depends on the outcome variable, we provide estimates for both.[14] Additionally to the specification of Z as in Equation (3), the last columns contain the results of a specification with a second order polynomial.

In the specification without controls the total amount of direct payments DP_tot is about $\widehat{\phi_{DP\_tot}} * 1,000 \approx 5,000$ CHF higher for hill zone farms. The estimate is slightly smaller for a more flexible form of Z. For the second variable DP_CL the difference between hill and valley zone is less pronounced and amounts to $\widehat{\phi_{DP\_CL}} * 1,000 \approx 3,000$ CHF. All coefficients are statistically significant on conventional levels, suggesting that the zone assignment is a relevant instrument for the amount of direct payments. The largest difference from the specifications with controls can be seen in the estimate for $\phi_{DP\_tot,X2}$. This finding may hint at a negative correlation of the variables included in $X2$ with the zone dummy D, but a positive correlation with the amount of direct payments.

In Table 3, we provide TSLS estimates of γ, the parameter of interest, for the different specifications as explained for Table 2. They all support the graphical findings of the previous section in showing an estimate close to zero for the number of male workers and a bigger, positive effect on female employment that is also statistically significant. For example, additional CHF 1,000 in direct payments (aggregated measure DP_tot) increases female on-farm employment by 0.009 in the specification without controls. Considering the amount of farmland payments (DP_CL) as a treatment variable, the effect is larger and amounts to 0.014. Including control variables $X1$ (other direct payments programmes) or $X2$ (UAA in hectare, LU of cattle, LU of pigs/poultry) slightly changes the effect size—it ranges between

Table 3. Second stage (TSLS) estimation results of a fuzzy RD design.

Estimates for	1st order		2nd order		1st order		2nd order	
	polynomial of Z							
	Men				Women			
γ_{DP_tot}	0.002	(0.004)	0.001	(0.005)	0.009	(0.004)	0.012	(0.005)
$\gamma_{DP\_tot,X2}$	0.003	(0.003)	0.003	(0.003)	0.007	(0.003)	0.008	(0.003)
γ_{DP_CL}	0.004	(0.007)	0.001	(0.007)	0.014	(0.006)	0.017	(0.006)
$\gamma_{DP\_CL,X1}$	0.002	(0.008)	0.001	(0.008)	0.018	(0.007)	0.021	(0.007)
$\gamma_{DP\_CL,X2}$	0.007	(0.006)	0.006	(0.006)	0.014	(0.006)	0.017	(0.006)
h	1.139		1.139		1.512		1.512	
N	12,133		12,133		14,050		14,050	

Notes: TSLS regression with the R-package AER. $\gamma_{(\cdot)}$ is the estimate of (4) in different specifications. Control variables X1: DP for biodiversity (BD), landscape quality (LQ), production system (PS), resource efficiency (RE), ensuring food supplies (FS), and transitional payments (TS). Control variables X2: UAA in hectare, LU of cattle, LU of pigs/poultry. Bandwidth (h) choice as in Imbens and Kalyanaraman (2012). Standard errors in parentheses. According to the choice of h and the chosen kernel, the number of observations N changes.
Source: Authors' calculations with AGIS data 2014–2016.

Table 4. First and second stage (TSLS) estimation results with alternative variable 'farm coordinates'.

Estimates for	First stage				Second stage			
	Men		Women		Men		Women	
ϕ/γ_{DP_tot}	2.835	(0.556)	3.287	(0.528)	−0.006	(0.007)	0.013	(0.005)
$\phi/\gamma_{DP\_tot,X2}$	8.531	(0.193)	8.673	(0.181)	0.002	(0.002)	0.006	(0.002)
ϕ/γ_{DP_CL}	3.914	(0.083)	4.047	(0.077)	−0.004	(0.005)	0.011	(0.004)
$\phi/\gamma_{DP\_CL,X1}$	3.696	(0.075)	3.791	(0.070)	−0.003	(0.005)	0.014	(0.005)
$\phi/\gamma_{DP\_CL,X2}$	4.400	(0.073)	4.514	(0.069)	0.005	(0.004)	0.012	(0.004)
h	1.139		1.512		1.139		1.512	
N	12,133		14,050		12,133		14,050	

Notes: TSLS regression with the R-package AER. $\phi_{(\cdot)}$ and $\gamma_{(\cdot)}$ are the estimates of (3) and (4) in different specifications. Control variables X1: DP for biodiversity (BD), landscape quality (LQ), production system (PS), resource efficiency (RE), ensuring food supplies (FS), and transitional payments (TS). Control variables X2: UAA in hectare, LU of cattle, LU of pigs/poultry. Bandwidth (h) choice as in Imbens and Kalyanaraman (2012). Standard errors in parentheses. According to the choice of h and the chosen kernel, the number of observations N changes.
Source: Authors' calculations with AGIS data 2014–2016.

statistically significant 0.01 and 0.02, but increases the precision of the estimates (Imbens and Lemieux 2008).

To test the sensitivity of our findings with respect to the choice of the running variable, we estimate a model using a flexible form of a farm's coordinates instead of the distance to the zone boundary (compare Wuepper, Wimmer, and Sauer 2020). This specification includes first and second order polynomials of latitude and longitude as well as their interaction and hence, accounts for the spatial structure of the data. In this way, similar production conditions like climate or soil characteristics, that closely located farms face, can be controlled for. However, this modelling approach does not explicitly account for a threshold at which the treatment probability discontinuously changes. Thus, we consider this specification as an additional sensitivity test and use the model with the distance measure as baseline. Table 4 shows the first and second stage estimates. They are all quite close to the findings of Tables 2 and 3 and support the general result of a zero or positive effect for male or female employment, respectively.

As an additional comparison, we show the estimation results with local linear regression using a triangular kernel in Table 5.[15] This estimation procedure differs from TSLS by giving more weight to the observations close to the threshold for specific choices of the kernel

Table 5. Estimation results of a fuzzy RD design with local linear regression.

Estimates for	Optimal bandwidth		Twice that bandwidth		Optimal bandwidth		Twice that bandwidth	
	Men				Women			
γ_{DP_tot}	0.004	(0.008)	0.001	(0.005)	0.015	(0.006)	0.019	(0.006)
$\gamma_{DP\_tot,X2}$	0.005	(0.004)	0.004	(0.002)	0.009	(0.003)	0.010	(0.002)
γ_{DP_CL}	0.004	(0.009)	0.001	(0.006)	0.019	(0.007)	0.022	(0.005)
$\gamma_{DP\_CL,X1}$	0.006	(0.009)	0.001	(0.006)	0.023	(0.007)	0.027	(0.006)
$\gamma_{DP\_CL,X2}$	0.011	(0.008)	0.008	(0.005)	0.019	(0.006)	0.022	(0.005)
h	1.139		2.278		1.512		3.024	
N	12,133		17,237		14,050		19,184	
kernel				triangular				

Notes: Local linear regression with the R-package rdd. $\gamma_{(\cdot)}$ is the estimate of (5) in different specifications. Control variables X1: DP for biodiversity (BD), landscape quality (LQ), production system (PS), resource efficiency (RE), ensuring food supplies (FS), and transitional payments (TS). Control variables X2: UAA in hectare, LU of cattle, LU of pigs/poultry. Bandwidth (h) choice as in Imbens and Kalyanaraman (2012). Optimal bandwidth and twice that bandwidth is shown. Standard errors in parentheses. According to the choice of h and the chosen kernel, the number of observations N changes.
Source: Authors' calculations with AGIS data 2014–2016.

Table 6. Second stage (TSLS) estimation results of a fuzzy RD design for specialised dairy farms.

Estimates for	1st order		2nd order		1st order		2nd order	
				polynomial of Z				
	Men				Women			
γ_{DP_tot}	−0.010	(0.018)	−0.009	(0.018)	0.019	(0.010)	0.019	(0.01)
$\gamma_{DP\_tot,X2}$	0.001	(0.005)	0.001	(0.005)	0.009	(0.003)	0.009	(0.003)
γ_{DP_CL}	−0.009	(0.013)	−0.008	(0.013)	0.021	(0.009)	0.022	(0.009)
$\gamma_{DP\_CL,X1}$	−0.008	(0.013)	−0.008	(0.013)	0.025	(0.010)	0.025	(0.01)
$\gamma_{DP\_CL,X2}$	0.002	(0.010)	0.002	(0.010)	0.021	(0.008)	0.021	(0.008)
h	0.837		0.837		1.469		1.469	
N	5,987		5,987		8,224		8,224	

Notes: TSLS regression with the R-package AER. $\gamma_{(\cdot)}$ is the estimate of (4) in different specifications. Control variables X1: DP for biodiversity (BD), landscape quality (LQ), production system (PS), resource efficiency (RE), ensuring food supplies (FS), and transitional payments (TS). Control variables X2: UAA in hectare, LU of cattle, LU of pigs/poultry. Bandwidth (h) choice as in Imbens and Kalyanaraman (2012). Standard errors in parentheses. According to the choice of h and the chosen kernel, the number of observations N changes.
Source: Authors' calculations with AGIS data 2014–2016.

function. We find that the TSLS estimates are very similar to the estimation results with local linear regression, albeit slightly smaller. For the number of female family workers, the local linear regression estimates also range between 0.01 and 0.02. Thus, we conclude that our estimates are little sensitive to the chosen estimation strategy.

One might also argue that the control variables included are not sufficient to depict the production process of a farm. Hence, we estimate our parameter of interest only for specialised dairy farms, such that the subsample is more homogeneous. Table 6 summarises these second stage TSLS estimates. The results are quite similar to the TSLS estimates in Table 3, albeit a little larger for specialised dairy farms only. We conclude from this subsample analysis that the main findings are quite robust with respect to the choice of control variables.

5. Discussion

These different findings for male and female family workers may be surprising at first glance. However, since 99% of the farms considered have a male family worker and since the majority of Swiss farm managers are male, additional family employment applies to the (female) partner or spouse. Hence, we conclude that direct payments may safeguard traditional family farming. The effect size amounts to one additional family workforce on the farm generated by CHF $\frac{1}{0.02}*1{,}000 =$ CHF 50,000 (about EUR 50,000) of farmland payments if we assume a linear effect of 0.02 or to about two percent of the mean right at the threshold (1.041). Although the economic importance of the effect seems to be small at first glance, it is realistic regarding the average annual remuneration per family work unit. For specialised dairy farms in the Swiss valley area (i.e. in the valley and hill zone), the amount of CHF 50,000 corresponds to around 80% of this measure during the period 2017–2019 (Federal Office for Agriculture Switzerland FOAG 2020). However, given a mean level of farmland payments of about CHF 5,500 right at the threshold, per-hectare payments have to increase on average by ten times to effectly generate an additional job (all else equal). These findings apply to a country where farming is small-structured. Furthermore, as the parameter of interest is a *local* effect (i.e. at the threshold), our estimates may differ for more distant values of the running variable. Besides, we concentrate on farms with dairy production. These conditions can question the external validity of our findings. However, a direct comparison with the findings of Nordin (2014), who also uses an IV strategy, shows that the results are quite similar. Compared to our calculation of CHF 50,000 (about EUR 50,000), he concludes that additional grassland support of 250,000 Swedish krona (about EUR 25,000) generates one job. Our findings contrast with the results of Petrick and Zier (2011, 2012) showing negative employment effects for the agricultural sector in Eastern Germany. However, Eastern German agriculture is dominated by large structures and a higher degree of hired labour. Hence, our findings add to the literature by providing empirical evidence for small-structured farming strongly relying on family labour.

These results are especially relevant for dairy farming, which involves a constant and intensive workload. Cows must be milked twice a day, resulting in long working days. This might also reflect in the finding that dairy farms are less engaged in off-farm employment compared to other farm types (El Benni and Schmid 2022). Hence, our findings regarding the positive effect of direct payments on the family workforce can translate into a lighter workload for farmers. In line with the result of El Benni and Schmid (2022) and given the high preferences of Swiss dairy farmers for their occupation (Lips, Gazzarin, and Telser 2016), we expect small or even negative effects on dairy farmers' off-farm employment for increasing levels of direct payments. This expectation is in line with the theoretical work of Key and Roberts (2009) who consider the role of non-pecuniary benefits to farming for on- and off-farm labour supply. In this context, our local effect on on-farm employment might also differ to the response of farmers in more hilly regions with worse off-farm job opportunities. To those farmers working on the farm gets even more attractive compared to farmers with better outside options who tend to be more willing to accept off-farm jobs.

At the same time, agricultural income per family work unit in Switzerland is particularly low in dairy farming (Hoop et al. 2019). For this and other reasons, with the exception of farm managers, the majority of family members working on-farm are not regularly employed and thus neither receive a classical salary nor are subject to social security contributions. This affects female family members disproportionately (Contzen and Klossner 2015), which is an important issue, as women can play an important role in the development of rural areas, particularly for farm diversification into service activities (European Parliament 2016).

Our findings are also interesting in other contexts. For example, support for family farming may have implications for other outcomes. Firstly, regarding its effect on rural unemployment, Wuepper, Wimmer, and Sauer (2021) uncover a negative relationship between family farms and unemployment based on a regression with cross-sectional data. Using a panel data regression, this coefficient is close to zero. They attribute this finding to different cultural characteristics of the population and conclude that supporting small farms is not effective for sustainable development of rural labour markets. In addition to their findings, it might also be interesting to examine inactivity, including people who are not actively seeking a job. Women in particular on family farms are often assumed to be housewives, who belong to the inactive population. Contzen and Klossner (2015) find for Switzerland that about 95% of female partners are part of the workforce on-farm and more than 50% are unpaid. Although many also have a job off-farm (about 45%), there may be an overlap between those who are neither being paid on-farm nor working off-farm.

Beyond these considerations, small family farming is often regarded as more environmentally sustainable. However, Wuepper, Wimmer, and Sauer (2020) show for Germany that this hypothesis cannot be unambiguously supported and, hence, the authors' findings once again question the implications of family farming.

6. Conclusion

This article analyses whether direct payments affect on-farm family employment on Swiss dairy farms. We find significantly positive effects on female family employment. This effect applies to the total of direct payments and is even larger considering farmland payments only. Male family employment, on the contrary, is not affected.

From a political perspective, this is a double-edged result: direct payments increase female family employment on-farm, although female family members in particular are often unpaid. Hence, our findings cast doubt on the social sustainability of female family employment on-farm. The new Swiss agricultural policy proposal (AP 22+) aimed to improve the social security of partners working on-farm by linking the receipt of direct payments to the existence of social security coverage for the partner. With the Swiss parliament's suspension of the agricultural policy reform process, this important adjustment has been delayed. Further research should focus on the detailed forms of employment that are stimulated by direct payments. Another question in this context is whether female family workers would also find and accept a suitable job off-farm. Such questions go beyond the focus of our paper and require additional data.

In the end, the positive employment effects of direct payments found in our analysis show that farmland contributions can be an effective tool with respect to various direct or indirect objectives of Swiss agricultural policy (Federal Assembly Switzerland 2021). They strengthen rural (female) on-farm employment and may also contribute to the objective of decentralised settlement of the country.

Appendix

Equations

$$(\widehat{\alpha_{yr}}, \widehat{\beta_{yr}}) = \arg \min_{\alpha_{yr}, \beta_{yr}} \sum_{i:c \le Z_i < c+h} (Y_i - \alpha_{yr} - \beta_{yr} * (Z_i - c))^2$$

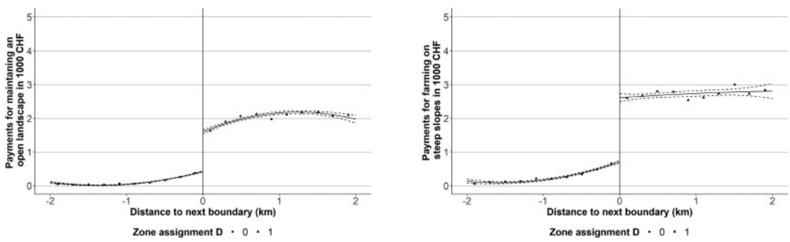
$$(\widehat{\alpha_{yl}}, \widehat{\beta_{yl}}) = \arg \min_{\alpha_{yl}, \beta_{yl}} \sum_{i:c-h < Z_i < c} (Y_i - \alpha_{yl} - \beta_{yl} * (Z_i - c))^2$$

$$(\widehat{\alpha_{tr}}, \widehat{\beta_{tr}}) = \arg \min_{\alpha_{tr}, \beta_{tr}} \sum_{i:c \le Z_i < c+h} (T_i - \alpha_{tr} - \beta_{tr} * (Z_i - c))^2$$

$$(\widehat{\alpha_{tl}}, \widehat{\beta_{tl}}) = \arg \min_{\alpha_{tl}, \beta_{tl}} \sum_{i:c-h < Z_i < c} (T_i - \alpha_{tl} - \beta_{tl} * (Z_i - c))^2 \tag{A.1}$$

$$\text{such that } \hat{\gamma} = \frac{\widehat{\alpha_{yr}} - \widehat{\alpha_{yl}}}{\widehat{\alpha_{tr}} - \widehat{\alpha_{tl}}}. \tag{A.2}$$

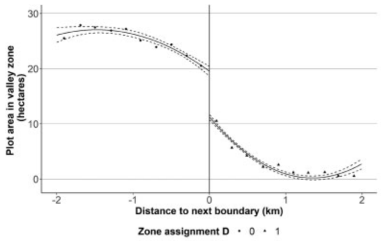
Figures and Tables



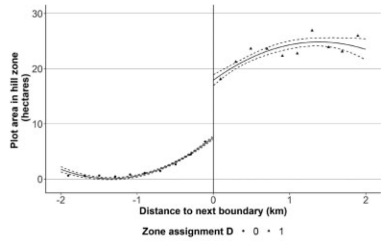
(a) Payments for maintaining an open landscape (hill zone only) in CHF 1,000

(b) Payments for farming on steep slopes (hill zone only) in CHF 1,000

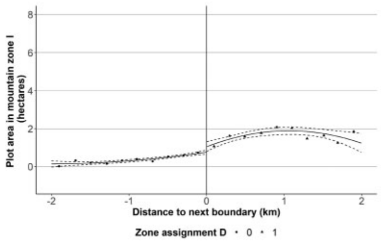
Figure A.1. Farmland payments in detail 2014–2016.
Notes: The solid line corresponds to fitted values of a linear regression on the distance measure with a polynomial of degree two. The dashed lines limit the 95%-confidence band of the fitted values. The dots represent mean values in 0.2 km bins. $N = 16,249$.
Source: Authors' illustrations using AGIS data 2014–2016.



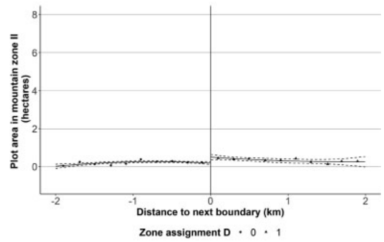
(a) UAA in valley zone



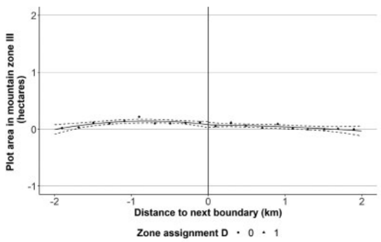
(b) UAA in hill zone



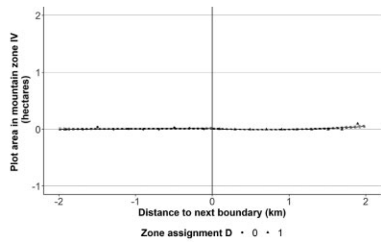
(c) UAA in mountain zone I



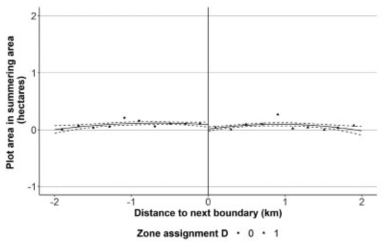
(d) UAA in mountain zone II



(e) UAA in mountain zone III



(f) UAA in mountain zone IV



(g) UAA in summering area

Figure A.2. Zone location of UAA in 2020 (in hectares).
Notes: Zone assignment D related to the location of the farm site. The solid line corresponds to fitted values of a linear regression on the distance measure with a polynomial of degree two. The dashed lines limit the 95%-confidence band of the fitted values. The dots represent mean values in 0.2 km bins. $N = 9,885$. The cantons Appenzell Innerrhoden, Bern, Solothurn, Fribourg, and Wallis are not included due to different data delivery regulations.
Source: Authors' illustrations using spatial plot data originating from AGIS 2020.

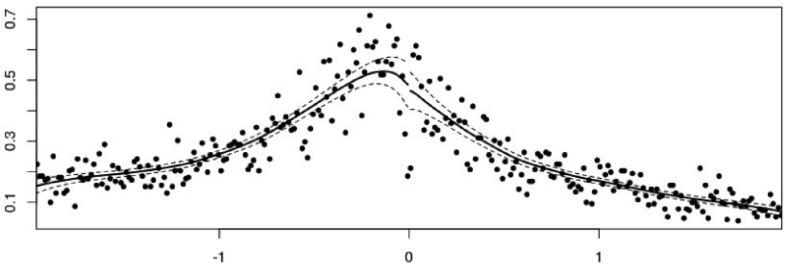


Figure A.3. Test of continuity of the running variable (McCrary 2008).
Notes: Log difference in heights is −0.030 with a standard error of 0.049. This gives a z-statistic of −0.613 and a *P* value of 0.540.
Source: Authors' illustrations using AGIS data 2014–2016 and the R-function DCdensity of the package rdd.

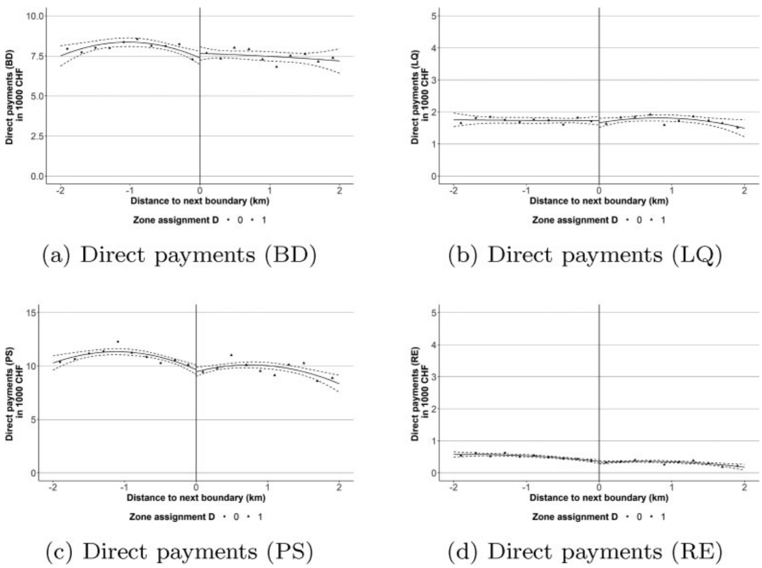
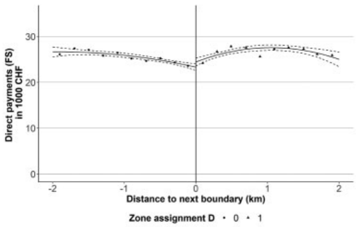
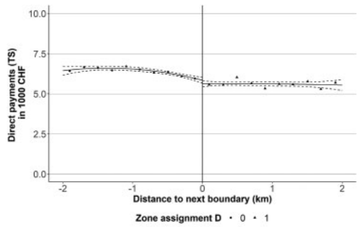


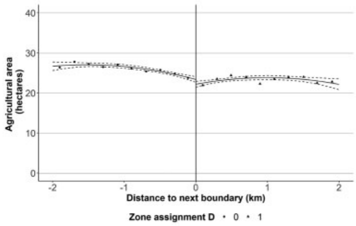
Figure A.4. Covariates.
Notes: The solid line corresponds to fitted values of a linear regression on the distance measure with a polynomial of degree two. The dashed lines limit the 95%-confidence band of the fitted values. The dots represent mean values in 0.2 km bins. $N = 16,249$.
Source: Authors' illustrations using AGIS data 2014–2016.



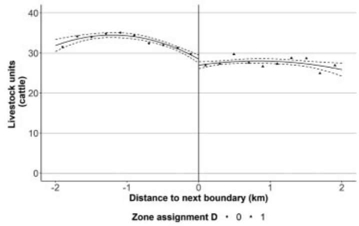
(e) Direct payments (FS)



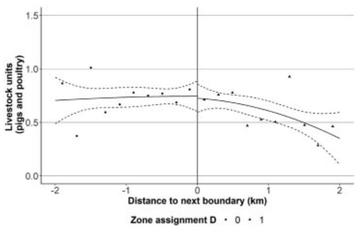
(f) Direct payments (TS)



(g) UAA (hectare)



(h) Livestock units (cattle)



(i) Livestock units (pigs and poultry)

Figure A.4. Continued.

Table A.1. Summary statistics of first bin around the threshold.

Variable	Valley zone $D = 0$		Hill zone $D = 1$			
	Mean	Standard deviation	Mean	Standard deviation	Mean difference	
Treatment						
Total amount of DP (*DP_tot*)	51.718	29.356	54.309	31.637	2.590	(1.117)
Farmland payments (*DP_CL*)	2.680	3.784	5.505	3.753	2.825	(0.137)
Control variables *X*1: DP for						
biodiversity (BD)	7.284	6.104	7.670	7.585	0.385	(0.254)
landscape quality (LQ)	1.710	2.831	1.632	2.398	−0.078	(0.095)
production system (PS)	10.103	7.989	9.439	8.196	−0.664	(0.295)
resource efficiency (RE)	0.377	0.902	0.321	0.770	−0.056	(0.030)
ensuring food supplies (FS)	23.613	13.888	24.178	14.512	0.566	(0.519)
a socially acceptable transition (TS)	5.951	3.419	5.563	3.287	−0.388	(0.122)
Control variables *X*2						
Utilised agricultural area (UAA) in hectare	23.769	13.254	21.919	12.840	−1.850	(0.475)
Number of livestock units (LU) of cattle	29.719	17.593	26.926	16.139	−2.793	(0.612)
Number of livestock units (LU) of pigs/poultry	0.807	3.197	0.712	2.606	−0.095	(0.105)

Notes: The statstics are measured within the first bin (−/+ 200 meters around the threshold).
$N_{0,bin1} = 1,691$ in the valley zone, $N_{1,bin1} = 1,357$ in the hill zone.
The standard errors of the mean differences are provided in parentheses. DP = direct payments measured in CHF 1,000.
Source: Authors' calculations with AGIS data 2014–2016.

Table A.2. Additional estimation results of a fuzzy RD design with local linear regression for different kernels.

Estimates for	Optimal bandwidth		Twice that bandwidth	
Panel A	Men			
γ_{DP_tot}	0.005	(0.008)	0.001	(0.004)
$\gamma_{DP\_tot,X2}$	0.006	(0.004)	0.004	(0.002)
γ_{DP_CL}	0.006	(0.009)	0.002	(0.006)
$\gamma_{DP\_CL,X1}$	0.007	(0.009)	0.001	(0.006)
$\gamma_{DP\_CL,X2}$	0.012	(0.008)	0.008	(0.005)
h	1.060		2.120	
N	11,588		16,734	
	Women			
γ_{DP_tot}	0.014	(0.006)	0.018	(0.005)
$\gamma_{DP\_tot,X2}$	0.008	(0.003)	0.010	(0.002)
γ_{DP_CL}	0.018	(0.007)	0.022	(0.005)
$\gamma_{DP\_CL,X1}$	0.022	(0.007)	0.028	(0.006)
$\gamma_{DP\_CL,X2}$	0.018	(0.006)	0.022	(0.005)

Table A.2. Continued

Estimates for	Optimal bandwidth		Twice that bandwidth	
h	1.407		2.815	
N	13,577		18,663	
kernel			epanechnikov	
Panel B	Men			
γ_{DP_tot}	0.002	(0.010)	0.001	(0.005)
$\gamma_{DP\_tot,X2}$	0.004	(0.004)	0.004	(0.003)
γ_{DP_CL}	0.002	(0.009)	0.002	(0.006)
$\gamma_{DP\_CL,X1}$	0.005	(0.009)	0.002	(0.006)
$\gamma_{DP\_CL,X2}$	0.009	(0.008)	0.008	(0.005)
h	0.417		0.834	
N	26,377		26,434	
	Women			
γ_{DP_tot}	0.017	(0.007)	0.017	(0.005)
$\gamma_{DP\_tot,X2}$	0.009	(0.003)	0.010	(0.002)
γ_{DP_CL}	0.020	(0.007)	0.021	(0.005)
$\gamma_{DP\_CL,X1}$	0.024	(0.007)	0.026	(0.006)
$\gamma_{DP\_CL,X2}$	0.020	(0.006)	0.021	(0.005)
h	0.554		1.107	
N	26,426		26,437	
kernel			gaussian	

Notes: Local linear regression with the R-package rdd. $\gamma_{(\cdot)}$ is the estimate of (5) in different specifications. Control variables X1: DP for biodiversity (BD), landscape quality (LQ), production system (PS), resource efficiency (RE), ensuring food supplies (FS), and transitional payments (TS). Control variables X2: UAA in hectare, LU of cattle, LU of pigs/poultry. Bandwidth (h) choice as in Imbens and Kalyanaraman (2012). Optimal bandwidth and twice that bandwidth is shown. Standard errors in parentheses. According to the choice of h and the chosen kernel, the number of observations N changes. *Source:* Authors' calculations with AGIS data 2014-2016.

Competing interests

No competing interest is declared.

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: agis@blw.admin.ch.

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End Notes

1 After implementing the direct payments system in 2014, a transitional contribution is also provided.
2 Throughout the analysis, we refer to the classification in zones. The Swiss Farm Accountancy Data Network typically uses the larger aggregation ('region').

3 In a recent contribution, Dong, Lee, and Gou (2021) deduce a weighted Q-LATE for continuous treatments that, under certain assumptions, can be written as the standard RD estimand given below in Equation (5).
4 We may also call a continuous treatment variable ‘dose’, but prefer the wording ‘treatment’ (see e.g. Dong, Lee, and Gou 2021).
5 From 2017 onwards plots in the valley zone are also eligible for farming on steep slopes. Hence, we restrict our data set up to the year 2016.
In the appendix we additionally show how these sub-programmes of farmland payments vary between farms located in the hill and valley zones (see Fig. A.1).
6 The plot data presented here has comparable quality for only some cantons and is available only from 2020 onwards. Hence, we do not use it for our main analysis.
7 In the case of a binary treatment, this estimand can be interpreted as a local average treatment effect for complier. The same interpretation does not hold for continuous treatments.
8 For estimation details, see Equations (A.1) and (A.2) in the appendix.
9 https://github.com/ddimmery/rdd/blob/master/RDestimate.R
10 The standard errors for Equation (A.2) are calculated by the default option of the R-function, ‘HC1’. The corresponding estimator with covariates is equivalent to including a matrix X in each regression in Equation (A.1). In the results section we provide findings for both.
11 Non-family farm workers are not empirically very relevant in the dairy sector. About 0.18 male and 0.05 female non-family workers (including apprentices) are employed at an average farm in our sample on both sides of the zone boundary. Hence, we do not analyse these as additional outcomes.
12 To calculate the Euclidean distance we use the R-function gDistance of the package rgeos.
13 We do not estimate a specification in which DP_tot is the outcome variable and $X1$ a matrix of additional control variables, as these are a direct subset of DP_tot.
14 We also conducted a robustness check in which we use the smaller bandwidth to estimate the effect on female employment. Since the estimates are extremely close, we only report those with different bandwidth choices.
15 Additional results for other kernel densities are provided in Table A.2 in the appendix. They are very close to the findings in Table 5.

References

Ahearn M. C., El-Osta H. and Dewbre J. (2006). “The Impact of Coupled and Decoupled Government Subsidies on Off-farm Labour Participation of US Farm Operators’, *American Journal of Agricultural Economics*, 88: 393–408. doi: 10.1111/j.1467-8276.2006.00866.x.

Angrist J. D. and Pischke J.-S. (2008). *Mostly Harmless Econometrics: An Empiricist’s Companion*. Princeton University Press.

Blomquist J. and Nordin M. (2017). “Do the Cap Subsidies Increase Employment in Sweden? Estimating the Effects of Government Transfers Using an Exogenous Change in the CAP’, *Regional Science and Urban Economics*, 63: 13–24. doi:10.1016/j.regsciurbeco.2016.12.001.

Breustedt G. and Glauben T. (2007). “Driving Forces Behind Exiting from Farming in Western Europe’, *Journal of Agricultural Economics*, 58: 115–27. doi:10.1111/j.1477-9552.2007.00082.x.

Contzen S. and Klossner M. (2015). “Analyse der Kapitel C & D der Zusatzerhebung der Landwirtschaftlichen Betriebszählung 2013 betreffend Situation der Frauen in der Schweizer Landwirtschaft’, *Berner Fachschule, Hochschule für Agrar-, Forst- und Lebensmittelwissenschaften (HAFL), Zollikofen*, 35: 1–35.

Dong Y., Lee Y.-Y. and Gou M. (2021). “Regression Discontinuity Designs with a Continuous Treatment’, *Journal of the American Statistical Association*, 0: 1–14. doi:10.1080/01621459.2021.1923509.

Dupraz P. and Latruffe L. (2015). “Trends in Family Labour, Hired Labour, and Contract Work on French Field Crop Farms: The Role of the Common Agricultural Policy’, *Food Policy*, 51: 104–18 doi:10.1016/j.foodpol.2015.01.003.

Egger P. H. and Lassmann A. (2015). “The Causal Impact of Common Native Language on International Trade: Evidence from a Spatial Regression Discontinuity Design’, *The Economic Journal*, 125: 699–745. doi:10.1111/ecoj.12253.

El Benni N. and Schmid D. (2022). “Off-farm Income and Direct Payments—An Indispensable Diversification Strategy of Swiss Farmers’, *Q Open*, 2: qoab019. doi:10.1093/qopen/qoab019.

El-Osta H. S., Mishra A. K. and Ahearn C. M. (2004). “Labour Supply by Farm Operators Under “Decoupled” Farm Program Payments’, *Review of Economics of the Household*, 2: 367–85. doi:10.1007/s11150-004-5653-7.

Eugster B., Lalive R., Steinhauer A. and Zweimüller J. (2011). “The Demand for Social Insurance: Does Culture Matter?’ *The Economic Journal*, 121: F413–F448. doi:10.1111/j.1468-0297.2011.02479.x.

European Commission. (2017). “The future of food and farming - for a flexible, fair and sustainable Common Agricultural Policy’, URL https://ec.europa.eu/commission/presscorner/detail/en/IP_17_4841.

European Parliament. (2016). “Report on how the CAP can improve job creation in rural areas’, (2015/2226(INI)). URL https://www.europarl.europa.eu/doceo/document/A-8-2016-0285_EN.pdf.

Federal Assembly Switzerland. (2021). Bundesverfassung der Schweizerischen Eidgenossenschaft vom 18. April 1999 (Stand 01.01.2021)’ SR 101. URL http://www.admin.ch/opc/de/classified-compilation/19995395/index.html.

Federal Office for Agriculture Switzerland FOAG. (2008). “Die landwirtschaftlichen Erschwerniszonen der Schweiz’, 16. URL http://www.blw.admin.ch/themen/00015/.

Federal Office for Agriculture Switzerland FOAG. (2018). “Agrarpolitisches Informationssystem AGIS’, (06.11.2018). URL https://www.blw.admin.ch/blw/de/home/politik/datenmanagement/agate/agis.html.

Federal Office for Agriculture Switzerland FOAG. (2020). Agrarbericht 2020. URL https://agrarbericht.ch/download/pictures/e5/2plte5ut0tfsu09ixeh5vf9387njdi/agrarbericht_2020_d.pdf.

Federal Office for Agriculture Switzerland FOAG. (2021). Zonenabhängige Massnahmen 2021.

Finger R. and El Benni N. (2021). “Farm Income in European Agriculture: New Perspectives on Measurement and Implications for Policy Evaluation’, *European Review of Agricultural Economics*, 48: 253–65. doi:10.1093/erae/jbab011.

Garrone M., Emmers D., Olper A. and Swinnen J. (2019). “Jobs and Agricultural Policy: Impact of the Common Agricultural Policy on EU Agricultural Employment’, *Food Policy*, 87: 101744. doi:10.1016/j.foodpol.2019.101744.

Hahn J., Todd P. and Van der Klaauw W. (2021). “Identification and Estimation of Treatment Effects with a Regression-Discontinuity Design’, *Econometrica*, 69: 201–9. URL http://www.jstor.org/stable/2692190.

Hochuli A., Hochuli J. and Schmid D. (2021). “Competitiveness of Diversification Strategies in Agricultural Dairy Farms: Empirical Findings for Rural Regions in Switzerland’, *Journal of Rural Studies*, 82: 98–106. doi:10.1016/j.jrurstud.2021.01.021.

Hoop D., Schiltknecht P., Dux D., Jan P., Renner S. and Schmid D. (2019). “Grundlagenbericht 2018 - Stichprobe Einkommenssituation’, *Ökonomie - Spezialpublikationen*, URL https://www.agroscope.admin.ch/dam/agroscope/de/dokumente/themen/wirtschaft-technik/betriebswirtschaft/za-bh/grundlagenbericht/excel-archiv/grundlagenbericht-2018.xlsx.download.xlsx/GB_2018__DE_v20190925.xlsx.

Hostiou N., Vollet D., Benoit M. and Delfosse C. (2020). “Employment and Farmers’ Work in European Ruminant Livestock Farms: A Review’, *Journal of Rural Studies*, 74: 223–34. doi:10.1016/j.jrurstud.2020.01.008.

Imbens G. and Kalyanaraman K. (2012). “Optimal Bandwidth Choice for the Regression Discontinuity Estimator’, *The Review of Economic Studies*, 79: 933–59. doi:10.1093/restud/rdr043.

Imbens G. W. and Lemieux T. (2008). “Regression Discontinuity Designs: A Guide to Practice’, *Journal of Econometrics*, 142: 615–35. doi:10.1016/j.jeconom.2007.05.001.

Keele L. J. and Titiunik R. (2015). “Geographic Boundaries as Regression Discontinuities’, *Political Analysis*, 23: 127–55. doi:10.1093/pan/mpu014.

Key N. and Roberts J. M. (2006). “Government Payments and Farm Business Survival’, *American Journal of Agricultural Economics*, 88: 382–92. doi:10.1111/j.1467-8276.2006.00865.x.

Key N. and Roberts J. M. (2009). “Non-pecuniary Benefits to Farming: Implications for Supply Response to Decoupled Payments’, *American Journal of Agricultural Economics*, 91: 1–18. doi:10.1111/j.1467-8276.2008.01180.x.

Lee D. S. and Lemieux T. (2010). “Regression Discontinuity Designs in Economics’, *Journal of Economic Literature*, 48: 281–355. doi:10.1257/jel.48.2.281.

Lips M., Gazzarin C. and Telser H. (2016). “Job Preferences of Dairy Farmers in Eastern Switzerland: A Discrete Choice Experiment’, *German Journal of Agricultural Economics*, 65: 254–61. doi:10.22004/ag.econ.284982.

Mann S. and Lanz S. (2013). “Happy Tinbergen: Switzerland’s New Direct Payment System’, *EuroChoices*, 12: 24–28. doi:10.1111/1746-692X.12036.

McCrary J. (2008). “Manipulation of the Running Variable in the Regression Discontinuity Design: A Density Test’, *Journal of Econometrics*, 142: 698–714. doi:10.1016/j.jeconom.2007.05.005.

Meier B. (2000). “Neue Methodik für die Zentrale Auswertung von Buchhaltungsdaten an der FAT’, *Eidgenössische Forschungsanstalt für Agrarwirtschaft und Landtechnik (FAT), Tänikon*.

Moro D. and Sckokai P. (2013). “The Impact of Decoupled Payments on Farm Choices: Conceptual and Methodological Challenges’, *Food Policy*, 41: 28–38. doi:10.1016/j.foodpol.2013.04.001.

Nordin M. (2014) ‘Does the Decoupling Reform Affect Agricultural Employment in Sweden? Evidence from an Exogenous Change’, *Journal of Agricultural Economics*, 65: 616–36. doi:10.1111/1477-9552.12052.

Olper A., Raimondi V., Cavicchioli D. and Vigani M. (2014). “Do CAP Payments Reduce Farm Labour Migration? A Panel Data Analysis Across EU Regions’, *European Review of Agricultural Economics*, 41: 843–73. doi:10.1093/erae/jbu002.

Organisation for Economic Co-operation and Development OECD’, *OECD Review of Agricultural Policies Switzerland*. OECD Publishing, Paris. doi:10.1787/1990004x.

Petrick M. and Zier P. (2011). “Regional Employment Impacts of Common Agricultural Policy Measures in Eastern Germany: A Difference-in-Differences Approach’, *Agricultural Economics*, 42: 183–93. doi:10.1111/j.1574-0862.2010.00509.x.

Petrick M. and Zier P. (2012). “Common Agricultural Policy effects on dynamic labour use in agriculture’, *Food Policy*, 37: 671–78, 2012. doi:10.1016/j.foodpol.2012.07.004.

Rizov M., Davidova S. and Bailey A. (2018). “Employment Effects of CAP Payments in the UK Non-farm Economy’, *European Review of Agricultural Economics*, 45: 723–48. doi:10.1093/erae/jby008.

Wuepper D., Wimmer S. and Sauer J. (2020). “Is Small Family Farming More Environmentally Sustainable? Evidence from a Spatial Regression Discontinuity Design in Germany’, *Land Use Policy*, 90: 104360. doi:10.1016/j.landusepol.2019.104360.

Wuepper D., Wimmer S. and Sauer J. (2021). “Does Family Farming Reduce Rural Unemployment? *European Review of Agricultural Economics*, 48: 315–37. doi:10.1093/erae/jbab002.

Zorn A. and Zimmert F. (2022). “Structural Change in the Dairy Sector: Exit from Farming and Farm Type Change’, *Agricultural and Food Economics*, 10: 1–31. doi:10.1186/s40100-022-00212-z.