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Culture and agricultural biodiversity conservation

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ABSTRACT

Farmers' behavior towards sustainable agricultural production is key to reducing the environmental footprint of agriculture and conserving biodiversity. We investigate the causal effect of culture on pro-environmental behaviors of farmers, and how policy instruments interact with culture to influence behavior. We exploit a unique natural experiment in Switzerland, which consists of two parts. First, there is an inner-Swiss cultural border between German- and French-speaking farmers who share the same natural environment, economy, and institutions, but differ culturally in their norms and values. Second, we exploit the effects of an agri-environmental policy reform that increased the monetary incentives to enroll land into biodiversity conservation. Using a spatial difference-in-discontinuities design and panel census data of all Swiss farms between 2010 and 2017, we show the following findings: Before the reform, farmers on the French-speaking side of the cultural border systematically enrolled less land into biodiversity conservation, compared to the German-speaking side. With increased monetary incentives following the policy reform in 2014, the French-speaking farmers enrolled relatively more additional land than the German-speaking farmers, shrinking the discontinuity. These findings indicate that while there exist cultural differences in pro-environmental behaviors, increased monetary incentives can reduce the importance of cultural differences. We discuss the implications for policy.

1. Introduction

Agricultural and food systems are main sources of environmental degradation and biodiversity decline globally, and also in Europe (e.g., Foley et al., 2011; Leclère et al., 2020; Pe'er et al., 2014). A shift in farmers' behavior towards sustainable agricultural production is key in reducing the environmental footprint of agriculture and meeting policy goals such as those formulated in the Kunming-Montreal Global Biodiversity Framework and the EU Farm to Fork strategy (e.g., Schebesta & Candel, 2020). Successful attainment of such ambitious policy goals requires agri-environmental policymaking that effectively induce farmers' behavior changes towards increased biodiversity conservation practices. In light of the complexity of farmers' decision-making on adopting sustainable practices, recent research has increasingly advocated designing agri-environmental policies that match with farmers' cultural contexts, which manifest in preferences, values, beliefs, and norms (Dessart et al., 2019; Wuepper et al., 2023). Understanding the interaction between cultural traits and economic factors improves the design of economic policies, and such policies could in turn shape the development of culture via changing the behaviors of individuals and groups (Nunn, 2022). In the context of biodiversity conservation, a key requisite for effective agri-environmental policymaking is a solid understanding of the extent to which farmers' preferences for conserving biodiversity are due to their cultural background, and how policies could alter and account for culture-driven behavioral patterns. However, to date, empirical evidence on the interaction between agri-environmental policy and culture in shaping farmer behavior is scant. This limits our understanding of how accounting for culture in policy design could improve policy outcomes.

In this study, we investigate how the interplay between culture and policy incentives affects farmers' biodiversity conservation behavior under agri-environment schemes (AES). We leverage a unique setting at the inner-Swiss French-German language border, where different native languages represent different cultural backgrounds within common

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political and economic frameworks. The within-country cultural difference, combined with a country-wide policy reform that substantially increased AES payments, creates a unique natural experiment to evaluate the interaction between culture and policy incentives in biodiversity conservation behavior that is free of potential confounding institutional effects in multi-country studies. Our analysis uses data of more than 3,500 farms near the inner-Swiss French-German language border from census panel data over an eight-year period in a spatial difference-in-discontinuities framework (see section 3.1 of Wuepper & Finger (2023) and Butts (2021)).

Cultural and social background shapes a population's economic and political preferences, which in turn affects behaviors and outcomes (Guiso et al., 2006). While culture is a multi-dimensional concept, language serves as a meaningful proxy of culture. As the basis of communication, common language forms the premise for individuals to develop social relationships and social norms. Social interactions shape and spread the preferences, values, and beliefs of individuals that share the same native language, from which a common social identity is developed. Language also carries the preferences, values, beliefs, and norms down from one generation to the next, maintaining consistency in the social identity over time. As such, differences in the behaviors across language groups reflect cultural differences (e.g., Eugster et al., 2011; Filippini & Wekhof, 2021). Previous literature has documented differences in economic behavior and preference across language groups, for example, risk attitudes, savings rates, and health behaviors (e.g., Chen, 2013). In particular, due to the unique institutional setting, natural experiments across language groups within Switzerland have provided evidence of the effect of culture on an array of behavioral outcomes, for example, attitudes towards work and money (Eugster et al., 2017), entrepreneurship (Erhardt & Haenni, 2022), ownership of electric cars (Filippini & Wekhof, 2021), and private provision of public goods (Aepli et al., 2021; Kuhn et al., 2022).

In the context of agriculture and AES, culturally shaped environmental attitudes (e.g., Litina et al., 2016; Schumacher, 2015; Steg, 2016; Videras et al., 2012) affect farmers' willingness for pro-environmental practices such as conservation (Kolinjivadi et al., 2019; Van Hecken et al., 2019). With monetary compensations, AES provide farmers with extrinsic motivations to provide environmental public goods.[1] Farmers' response towards AES further depends on how they perceive the monetary incentives, which reflects their economic and political preferences that are shaped by social and cultural backgrounds (Rode et al., 2015). In particular, culture could influence farmers' demand for economic compensation for pro-environmental practices, as well as how farmers interpret payments offered under governmental schemes, both of which determine their decisions to participate in AES (Rode et al., 2015; Dessart et al., 2019). Understanding how cultural and social backgrounds interact with monetary incentives to influence farmers' behavior therefore contributes to effective agri-environmental policy design and evaluation. However, empirical evidence, especially how culture-driven differences in pro-environmental behaviors change over time and in response to changes in economic policy incentives, remains limited (e.g., Burton et al., 2008; Taylor & Grieken, 2015; Warren et al., 2016; Wuepper, 2020).

Our study contributes to the recently developing literature on the interplay between culture and policy in shaping individual behavior, and how cultural differences may inform effective policy design (see Nunn (2022) for a review, and Wuepper et al. (2023) for discussions specific to agricultural policies). Furthermore, our study contributes to the literature on the pathways towards more sustainable agricultural systems. We provide quantitative evidence of the role of culture in farmers' biodiversity conservation behavior, and how cultural effects interact with policy incentives.

We find systematically different biodiversity conservation behaviors under AES between German- and French-speaking farmers in Switzerland, with the difference partially attributable to farm structural differences developed over time and partially to farmers' inherent values and beliefs, which represent two distinct groups of cultural dimensions. On the interaction between policy and culture, we find that with increased monetary incentives, the relative size of the behavioral difference across the two cultural groups shrank. Our findings buttress placing agri-environmental policy design and policy evaluation in the cultural context, which could improve the outcomes and cost-effectiveness of the policy. We show that cultural effects on environmental behavior apply not only among the general population, but also to sub-populations with a strong common identity such as farmers, and more importantly, policy incentives can help level off culture-driven behavioral differences and help achieve spatially more balanced biodiversity conservation practices.

The rest of this paper is organized as follows: Section 2 provides backgrounds regarding the study; Section 3 details the empirical framework; Section 4 presents the data, Sections 5 and 6 reports and discusses the results, respectively, and Section 7 concludes.

2. Background

In this section we provide backgrounds on the biodiversity conservation AES in Switzerland, the Swiss language regions, and a conceptual background for our empirical analysis.

2.1. AES for biodiversity conservation

Agri-environment schemes (AES) are a key policy instrument to encourage farmers to switch to more environmentally friendly practices and contribute to more sustainable agriculture. In Europe, AES were introduced in the 1990 s (Kleijn & Sutherland, 2003). Most AES in Europe provide payments to farmers to reward their provision of ecosystem services, and to compensate for the income foregone and additional cost incurred in order to comply with higher environmental and ecological standards. Despite a history of over three decades of AES and large government expenditure in Europe, the effects of such schemes in improving environmental quality remain mixed (e.g., Cullen et al., 2018; Mann, 2018; Pe'er et al., 2014; Uthes & Matzdorf, 2013; Wuepper & Huber, 2021).

In Switzerland, AES were first introduced in 1992 (Curry & Stucki, 2010), and in 1993, AES specific for biodiversity conservation became available to counteract the loss of biodiversity habitats in agriculture. In the current Swiss farming systems, various direct payments, including agri-environmental direct payments, exist. These payments represent a key income component for farmers (El Benni et al., 2016). The initial biodiversity conservation AES consisted of voluntary action-based direct payments that reward farmers for land management practices that conserve biodiversity on ecological focus areas (later renamed to biodiversity promotion areas) (Mack et al., 2020). Since 1999, cross-compliance requirements in Swiss agriculture demand farmers to utilize a minimum fraction requirement of agricultural areas under biodiversity conservation AES to receive direct payments. This is 7 % for the entire agricultural land, except for acreage under for special crops, where this is 3.5 % (Mann & Lanz, 2013). In 2001, result-based payments and agglomeration bonuses (also referred to as "network bonuses") were introduced on top of action-based payments. In the Swiss system, result-based biodiversity conservation AES reward farmers for achieving specific biodiversity outcomes, namely occurrence of targeted indicator species (Elmiger et al., 2023). Agglomeration bonuses reward

[1] In addition to monetary compensations, which is the focus of our study, extrinsic motivation can also include non-monetary strategies such as information nudges (e.g., Kuhfuss et al., 2016).

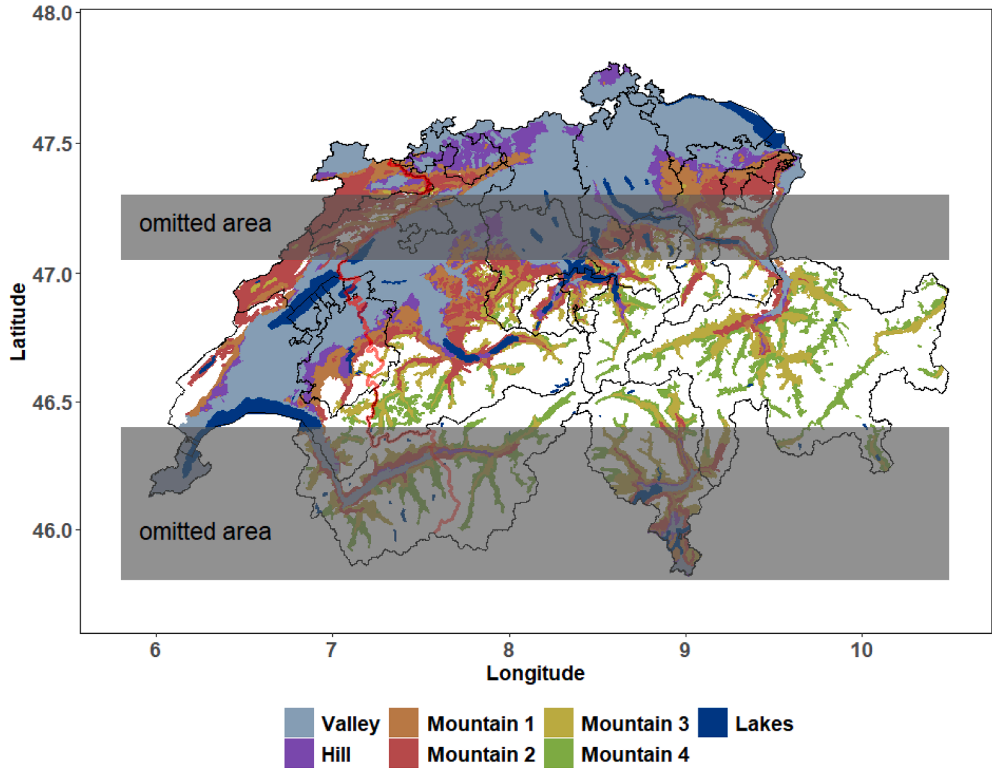

Fig. 1. Study area. Red line marks the French-German language border. Legends indicate agricultural zones and major water bodies. Omitted areas are those where the language border overlaps with the borders of agricultural zones. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

farmers for collective efforts in providing spatially connected biodiversity conservation areas (Huber et al., 2021; Krämer & Wätzold, 2018; Mack et al., 2020; Villamayor-Tomas et al., 2019).[2] Action- and result-based payments comprise the two quality levels under the category "quality" contributions of the biodiversity conservation AES, which are fully funded by the federal government (Wuepper & Huber, 2021). Agglomeration bonuses comprise the "networking" category of the AES (Huber et al., 2021). Our study focuses on the quality contributions since they concern individual enrollment decisions at the farm level.

In an agricultural policy reform launched in 2014, the Swiss biodiversity conservation AES were redesigned with the objective of increasing effectiveness in biodiversity conservation. With this redesign, both action- and result-based payments increased. Given the new focus of the agricultural policy on result-oriented schemes, expansion in result-based payments was particularly substantial and applicable to large land area (Mack et al., 2020, also see Table A2 for an overview). In addition, since result-based payments primarily apply to ecological focus areas based on grassland, the redesigned payment schemes essentially place more weight on biodiversity conservation in grasslands.[3]

Since action- and result-based biodiversity conservation AES differ in their requirements to farmers (and likely their efforts), we expect that farmers perceive the two types of schemes differently and that this difference also depends on culture. Furthermore, with differences in the payment increase between the two types of AES after the policy reform, the change in the extrinsic motivation provided by the two schemes also differs. As a result, we hypothesize that culture plays different roles in farmers' responses to the payment increases in the two types of AES. Therefore, we separately examine farmers' response to the policy reform in action- and result-based payment schemes.

2.2. Swiss language regions and culture-driven behavioral differences

Switzerland is a linguistically diverse country with four official languages. According to official statistics in 2019, German is the native language for 62.6 % of Swiss citizens, followed by French (22.9 %), Italian (8.2 %), and Romansch (0.5 %). Each of the 26 Swiss cantons (federated states that comprise the Swiss Confederation) can determine its official language(s), and in some cantons, each municipality (a municipal unit below the cantonal level) can determine its own official language(s). As such, the Swiss language regions often do not overlap with administrative regions. Especially relevant for our study, the German-French language border runs through the cantons Bern, Fribourg, and Valais (BFS, 2017). In our study, the German-French language border is primarily defined by borders between German- and French-speaking municipalities, with the exception of a small number of bilingual municipalities, in which case the language border runs within the municipality (Fig. 1 in the Data section).

We focus our analysis on the German-French language border because the Alps, running west-east, largely coincides with the language borders between German, Italian, Romansch language regions (see, e.g., Filippini & Wekhof, 2021). This natural barrier also leads to different climate conditions, and thus different agricultural activities. By contrast, the German-French language border runs largely north–south and does

[2] For the role of agglomeration bonus in biodiversity conservation and farmers' participation in such schemes, also see, e.g., Banerjee et al., (2021); Kremen & Merenlender, (2018); and Parkhurst et al., (2002).

[3] Other landscape types to which the payment schemes are applicable include cropland and woody elements. Cropland-based ecological focus areas are only eligible for action-based payments, and woody elements are eligible for both levels of payments. Furthermore, grapes (vineyards) are eligible for result-based payments.

Table 1
Cultural dimensions relevant to biodiversity conservation based on previous literature.

Cultural dimension	Corresponding to factor in conceptual model	Characteristics of Swiss German-speaking region (relative to French-speaking)	Relevance to biodiversity AES participation	Expected difference in biodiversity conservation	Study
Environmental attitude	Intrinsic motivation	Lower support for popular initiatives on energy /environmental issues	Environmental preference	German < French	Filippini & Wekhof (2021)
Attitude on the responsibilities of the state vs. individual	Intrinsic motivation	Stronger preference for individual responsibilities and private provision of public goods	Willingness to improve biodiversity (a public good) as an individual or a private party	German > French	Kuhn et al. (2022);Aepli et al. (2021); Eugster & Parchet (2019); Eugster et al. (2017); Eugster et al. (2011)
Time preference	Intrinsic motivation	More patient	Result-based schemes require long-term investments, and expected outcome in the future	German > French	Herz et al (2021); Brown et al. (2018); Guin (2017)
Risk preference	Intrinsic motivation	Mixed findings	Uncertain payoff to investment in result-based schemes	Undetermined	Brown et al. (2018); Erhardt & Haenni (2022
Entrepreneurship/ work attitudes	Perception on monetary incentives	Greater values for opportunities to take initiatives and economic rewards for work	Motivation to seize monetary incentives	German > French	Erhardt & Haenni (2022); Eugster et al. (2017)
Money attitude	Perception on monetary incentives	Weaker association of money with freedom	AES offer payments that demand certain practices	German > French	Brown et al. (2018)

not coincide with natural barriers. Furthermore, as discussed above, a large part of this language border runs within rather than along canton borders.[4]

The Swiss language borders create natural experiments to test how culture influences behaviors independent of political and economic background, which eliminates confounding effects in these dimensions. Since native language is passed down in the family rather chosen by an individual, it is also unlikely for sorting to occur near the language border. Examples of behavioral differences across language regions include the preference for imported goods from different countries (Egger & Lassmann, 2015), family values and informal care for elderly family members (Gentili et al., 2017), financial literacy (Brown et al., 2018), demand for social insurance (Eugster et al., 2011), work attitudes (Eugster et al., 2017), household savings (Guin, 2016), entrepreneurship (Erhardt & Haenni, 2022), and ownership of electric cars (Filippini & Wekhof, 2021). Difference in culture, in particular social norms, also lead to different firm behaviors in terms of providing training positions within the firms across the two Swiss language regions (Aepli et al., 2021; Kuhn et al., 2022). Furthermore, empirical evidence shows that culture-driven differences in preference and behavior could influence the effects of policy interventions. Eugster & Parchet (2019) study the interaction between culture-driven tax preference differences and tax policies across Swiss language groups and find that tax competition can counteract the difference in tax preference across cultural groups. Carattini et al. (2018) show that the cultural barrier near the Swiss language border hinders the diffusion of technology in the face of a policy intervention.

Although the above-mentioned studies are primarily based on the general population, knowledge of the behavioral differences across the Swiss German-French language border and the underlying mechanisms provides insights into how different cultural traits could link to farmers' decisions to participate in biodiversity conservation AES. In the next subsection, we discuss the relevant cultural dimensions in more detail in a conceptual analysis.

2.3. *Conceptual background*

In the context of biodiversity conservation, culture may shape not only farmers' intrinsic motivations for biodiversity conservation, but also how farmers react to (changing) incentives that promote biodiversity conservation via both economic and political preference channels (Guiso et al., 2006). In our study, the policy reform in 2014 allows us to compare the behavioral changes between farmers of different cultural backgrounds in response to changing incentives. This is especially relevant given that AES have been established for decades in many countries, and under increasing social and environmental pressure, agri-environmental policies might expand in the future and to meet policy goals like the Kunming-Montreal Global Biodiversity Framework and the Farm to Fork strategy of the European Union (e.g., Schaub et al., 2020; Schebesta & Candel 2020).

Conceptual framework. Consider two groups of farmers with different cultural backgrounds. Let $C_{k\tau}$ denote the biodiversity conservation effort of culture k at time τ, and $C_{k\tau} = M_{k0} + \sum_{t=1} a_{kt} P_t$, where M_{k0} is farmers' intrinsic motivation to conserve biodiversity in absence of monetary incentives, a_{kt} is a "response parameter" to monetary incentives for cultural group k at each period t from 1 up to τ,[5] and P_t is the monetary incentives at time period t. For the initial period 0 before monetary incentives are introduced, conservation effort only depends on farmers' intrinsic motivation. At $t = 1$, monetary incentives are introduced under an AES, and for each subsequent period from $t = 2$ up to τ, a change in the monetary incentives is introduced.

Thus, starting from period 1, conservation effort reflects a combination of i) farmers' initial intrinsic motivation to conserve biodiversity and ii) how farmers respond to monetary incentives provided under AES. Both of these two factors depend on farmers' culture. In addition, both factors depend on current farming practices, which may impose physical constraints for biodiversity conservation. For instance, farms with more intensive input use face greater direct cost (e.g., from displacing labor or machinery) and greater opportunity cost since these farms are likely to be more profitable (e.g., Huber et al., 2021). Let B_{kt} denote cost-related physical constraints for biodiversity conservation,

[4] Since apart from federal-level policies, agricultural policies only exist at the cantonal level, the effects of cantonal agricultural policies on farmers' decision-making are unlikely to confound with cultural effects.

[5] We expect that, in general, $a_{kt} > 0$, that is, monetary incentives enhance farmers' conservation effort. The case that $a_{kt} < 0$ correspond to a crowding-out effect of monetary incentives.

Table 2
Variable description.

Variable	Unit	Description	Data source
Farm-level			
Action-based payment	CHF/ha	Action-based biodiversity conservation payment	
Result-based payment	CHF/ha	Result-based biodiversity conservation payment	Swiss agricultural census 2010–2017
Total payment	CHF/ha	Sum of action- and result-based payments	
Farm size	ha	Area of farm	
Labor intensity	SAK/ha	Standard labor unit (SAK) per ha	
Land use intensity	LSU/ha	Livestock unit (LSU) per ha	
Municipality-level			
Share French-speaking	percent	Share of French speakers in overall population	2000 Swiss census
Distance	m	Shortest distance between municipality and language border, negative for French-speaking region; positive for German-speaking region	Engist (2021)
Precipitation	mm/year	Annual precipitation measured at centroid of municipality	MeteoSuisse (2017)
Elevation	m	Average elevation of a municipality	SRTM
Slope	degree	Average slope of a municipality	SRTM
Tree cover potential	percent	Tree cover potential without human impact	Bastin et al. (2019)
Population density	heads/ha	Population per hectare of each municipality	2000 Swiss census

then $M_{k0} = M_{k0}(k, B_{kt})$, and $a_{kt} = a_{kt}(k, P_t - B_{kt})$. [6] Since the development of farm structure and management is also driven by culture (Inwood, 2013), we may consider culture to play an indirect role in shaping the physical constraints for biodiversity conservation, characterized by existing farming practices that reflect farm structure and management strategies. Last but not least, the second factor, response to policy incentives under AES, further depends on the magnitude of incentives provided to farmers under the AES, P_t.

To summarize, our stylized conceptual framework indicates that $C_{k\tau} = M_{k0} + \sum_{t=1} a_{kt}P_t$, with $M_{k0} = M_{k0}(k, B_{kt})$, and $a_{kt} = a_{kt}(k, P_t - B_{kt})$. That is, farmers' decision to participate in biodiversity conservation AES depends on farmers' i) intrinsic motivation, and ii) response to monetary incentives. Both i) and ii) depend on culture and current farm structure and management (as proxies for physical constraints for conservation practices), and ii) further depends on the magnitude of monetary incentives. We next discuss how each of the three sets of determinants, namely culture, farm structure and management, and monetary incentives could affect our outcome of interest (i.e., participation in biodiversity conservation AES) through intrinsic motivation and response to monetary incentives for biodiversity conservation.

a. Culture. While culture comprises a multitude of dimensions, existing knowledge of culture-driven behavioral differences between the Swiss German- and French-speaking regions allows us to conceptually analyze relevant dimensions of culture that could influence either farmers' intrinsic motivation or their perception of monetary incentives for biodiversity conservation. In Table 1 we summarize these cultural dimensions from previous studies, and the possible implications for agricultural biodiversity conservation. A more comprehensive summary of this literature with elaborated findings is presented in Table A1 in the Appendix.

Relevant to farmers' intrinsic motivation to conserve biodiversity, the French-speaking Swiss population has shown stronger support for environment-related initiatives, which may translate to greater intrinsic motivation for biodiversity conservation. Conversely, the German-speaking Swiss population tends to have stronger preference for individual responsibilities and private provision of public goods, and greater patience. These traits may also link to higher intrinsic motivation for biodiversity conservation (a public good), especially by engaging in projects that require longer-term investment, such as those under result-based AES. In terms of farmers' response to monetary incentives for biodiversity conservation, the German-speaking Swiss population attach greater value to being able to take initiatives and receive economic rewards for their work, and associate money with freedom to a lesser extent compared to their French-speaking counterparts. These cultural traits imply possibly higher appreciation of payments in exchange for certain practices among German-speaking farmers, and therefore higher participation in the AES.

The summary of potential relevant cultural dimensions suggests that manifestations of cultural differences in various dimensions may not uniformly influence farmers' decision to participate in biodiversity conservation AES. Thus, at a given time period, we expect a difference in biodiversity conservation between German- and French-speaking farmers, but remain agnostic about the sign of the difference and do not hypothesize on it. We expect that the mixture of the abovementioned cultural differences jointly shape both farmers' intrinsic motivation and their response to policy incentives for biodiversity conservation. We cannot further disentangle the contributions of the individual cultural dimensions, but we can disentangle their effect from the effect of culturally evolved, physical explanations, such as farm structures and management styles.

b. Farm structure and management. While the evolution of farm structure and management strategies are shaped by culture (Inwood, 2013), they can be described by observed farm characteristics such as farm size, land use intensity, and labor intensity, and therefore disentangled from the inherent cultural dimensions listed in Table 1. We discuss the strategy in more detail in the Empirical Strategy section.

c. Monetary incentives. The change in monetary incentives for biodiversity conservation due to the 2014 policy reform constitutes a key component of our empirical natural experiment. First of all, for a given time period, we can estimate the difference in biodiversity conservation between the French- and German-speaking farmers under identical monetary incentives. Such a difference comprises combined effects of culture-driven intrinsic motivation and response to monetary incentives. Second, and perhaps more interestingly, over multiple time periods, we are able to examine the interaction between policy and culture, namely whether there is a difference in the responses of farmers to the shifted incentives that were identical to farmers on both sides of the language border. The comparison of responses to the policy reform by farmers of different cultural backgrounds provides insights into the effectiveness of policy in mitigating the culture-driven behavioral difference, that is, how a policy intervention interacts with the effect of culture on farmer behavior. Given that monetary rewards has been shown to mitigate the difference in farmers' motivation for nature conservation based on values and beliefs (Lokhorst et al., 2011), we hypothesize that increased monetary incentive under the 2014 policy reform reduces the culture-driven difference in biodiversity conservation.

3. Empirical strategy

In this section, we detail our estimation strategies for the difference in biodiversity conservation between French- and German-speaking farmers, and their response to increased monetary incentives over time.

[6] B_{kt} reflects the short-term adjustment potential for biodiversity conservation for culture k at period t due to physical constraints. In the long run, restrictions in adjustments for biodiversity conservation imposed by these constraints could be relaxed.

Table 3
Descriptive statistics of covariates by language region.

Farm-level						
	Mountain			Valley		
Variable	French	German	Difference	French	German	Difference
Farm size	32.28	21.53	10.75***	35.25	25.83	9.42***
	(22.68)	(13.42)	(1.07)	(25.68)	(32.07)	(1.33)
Labor intensity	0.84	0.82	0.02*	0.82	0.91	−0.09***
	(0.26)	(0.19)	(0.01)	(0.72)	(0.59)	(0.03)
Land use intensity	1.35	1.13	0.22***	0.99	1.12	−0.13***
	(0.82)	(0.49)	(0.04)	(0.9)	(1.16)	(0.05)

Municipality-level						
	Within 10 km bandwidth			Entire study area		
Variable	French	German	Difference	French	German	Difference
Share French-speaking	0.85	0.03	0.82***	0.89	0.01	0.88***
	(0.1)	(0.04)	0.01	(0.07)	(0.02)	(0.004)
Precipitation	966.09	989.18	−23.09	957.48	1116.67	−159.19***
	(174.41)	(183.22)	(27.3)	(182.34)	(274.87)	(12.7)
Elevation	716.61	698.65	17.96	683.33	684.93	−1.60
	(233.48)	(367.78)	(46.2)	(215.92)	(394.7)	(21.5)
Slope	9.88	10.09	−0.21	7.21	10.04	−2.83***
	(5.99)	(6.72)	(0.97)	(4.57)	(6.82)	(0.41)
Tree cover potential	80.88	76.35	4.53***	82.87	77.60	5.27***
	(7.55)	(12.3)	(1.53)	(8.71)	(13.26)	(0.73)
Population density 1	2.71	1.54	1.17*	2.62	3.77	−1.15***
	(5.58)	(1.29)	(0.65)	(6.02)	(5.18)	(0.44)
Population density 2	2.15	2.51	−0.36	2.68	3.59	−0.91***
	(4.37)	(4.66)	(0.51)	(5.88)	(4.91)	(0.32)

Descriptive statistics are based on the study area (Fig. 1) unless otherwise specified. Farm-level statistics are based on 2014 census and are shown within the 10 km bandwidth. See Table 1 for the years at which municipality-level covariates are measured. Farms in the French-speaking region on average have larger farm sizes. In the mountain zones, labor intensity and land use intensity are higher in the French-speaking region, whereas the opposite applies to the valley zone. Within the 10 km bandwidth, the natural conditions characterized by precipitation, elevation, and slope are comparable across language regions, which do not hold in the entire study area. Natural condition characterized by tree cover potential differs significantly in mean values. Population density 1 is based on study area; population density 2 includes omitted areas (Fig. 1). Overall population density (accounting for all areas) is comparable across language regions.

3.1. Culture-driven discontinuities in biodiversity conservation and responses to policy reform

We use a difference-in-discontinuities design to quantify the extent to which culture leads to farmers' behavioral differences in participating in biodiversity conservation AES, and how cultural difference interacts with changing policy incentives. Our analysis utilizes a large and fully representative panel dataset covering all Swiss farms over eight consecutive years, a period within which a natural experiment occurred, i.e., a sudden increase of agri-environmental payments under a policy reform. The data covering this natural experiment allow us to identify the effect of culture on farmers' response to increased economic incentives for biodiversity conservation. To identify this effect, we use a (fuzzy) spatial difference-in-discontinuities design. The cultural background of the farmers is proxied by their native language, and we define farmers with a French-speaking background as the treatment group and farmers with a German speaking background as the control group. In the simplest case of only two periods, we would then have a 2 × 2 design with a pre- and a post-treatment period (before and after the policy reform), and we estimate whether the discontinuity in biodiversity conservation at the inner-Swiss language border changed from before to after the treatment.[7] With multiple periods, the logic remains the same, only that we estimate for each year the discontinuity in biodiversity conservation at the language border, and how these dynamics changed from all the pre-treatment periods to all the post-treatment periods (see also e.g., Garg & Shenoy, 2021; Grembi et al., 2016 for examples of the application).

[7] Note that the policy reform applied to all farms in Switzerland. Thus, the treatment in our setting is the *interaction* between the policy reform and having a French-speaking background.

Since the language border largely lies within canton boundaries, comparable institutional environments (e.g., legal frameworks, direct payments, taxation, and extension services) apply to farms on both sides of the language border within each canton.[8] In other words, within canton boundaries, discontinuities observed at the language border are free from confounding treatment effects due to cantonal policies. In addition, farms near the language border face the same markets and comparable economic opportunities. In particular, all products are normally labeled in both French and German, and thus markets are not divided by language. In Table 3 in the Data section, descriptive statistics of population density also suggest that farms across the language border face similar demands. In the context of agriculture, one may also be concerned that the choice of agricultural practices is driven by the suitability of natural conditions, for instance, soil, climate, and topographical features. If these features would be different across language regions, each language region may for these reasons focus on different specialty crops or region-specific agricultural practices that influence farmers' choice of biodiversity conservation practices. We contend that this would not be an issue in our case because first, natural conditions are continuous near the language border (Table 3). Second, the distributions of farm types are comparable across the two language regions,

[8] In some aspects, the institutional and economic environments are not exactly identical, albeit comparable within the same canton across the language border. For instance, while tax schedules are decided on the cantonal level, municipalities are allowed to set tax multipliers that shifts the cantonal tax schedule. However, Eugster & Parchet (2019) have shown that local competition among adjacent municipalities help align the economic conditions near the language border, even though the Swiss German- and French-speaking populations have different preferences for tax rates. In particular, there is no discontinuity in tax multipliers at the language border (see Fig. 3 in Eugster & Parchet, 2019).

especially near the language border (Fig. A3).[9] As such, the difference in the choice of farming practices across language regions, which influence farmers' biodiversity conservation effort, can be attributed to cultural differences that drive farmers' preferences. Because the native language of the population does not perfectly correspond to the language region, that is, a small fraction of German-speaking nationals resides in the French-speaking region and vice versa (BFS (2017), also see Fig. A1), we apply a fuzzy regression discontinuity design.[10] We use language region (defined by distance to the language border) as an instrument for the treatment, i.e., having French as the native language, which proxies for the cultural effect. Our outcomes of interest are AES payments (total payment, action-based payment, and result-based payment) for biodiversity conservation in CHF per hectare.[11] The running variable is distance to the language border.

For each year in our sample period t, we estimate the reduced-form model for the fuzzy spatial regression discontinuity design where we use the language region of a municipality to instrument for having French (compared to German) as the native language:

$$y_{im}^{(t)} = \beta_0^{(t)} + \beta_1^{(t)} F_m + \beta_2^{(t)} Dist_m + \beta_3^{(t)} F_m Dist_m + \beta_4^{(t)} X_{im} + u_{im}^{(t)}$$

where y_{im} is the per-hectare biodiversity conservation AES payment received on farm i in municipality m in year t, F_m is a dummy variable that equals 1 if municipality m is in the French-speaking region, $Dist_m$ is the distance from the centroid of municipality m to the language border, X_{im} is a set of covariates, and u_{im} is an error term. In the baseline regression discontinuity design, we include in X_{im} canton effects, farm type, spatial coordinates of the municipality, slope, elevation, and precipitation. These covariates ensure that we identify β_1, the cultural effect on biodiversity conservation, by comparing farms in the French- and German- speaking regions that are comparable in these respects. To account for spatial autocorrelation, we cluster standard errors at a level between the canton and municipality level, which approximately corresponds to the district subdivisions in some cantons.[12] Within the 10 km bandwidth, there are 33 districts on which we cluster the standard errors.

A tradeoff between precision and bias lies in the choice of bandwidth around the border. A larger bandwidth allows for more farms to be included, at the potential risk of comparing over a more heterogeneous landscape. As our study spans over multiple years, we apply the same bandwidth for all years to ensure comparability of the estimated effects over time. We start with the optimal robust bias-corrected bandwidth (Calonico et al., 2020) of the year 2010, which is approximately 10 km. Since the choice of agricultural practice largely depends on natural conditions such as climate and topographical features, we also consider the bandwidth within which these features are comparable. We test whether there exist discontinuities in terms of climate and topographical features across the language border within the bandwidth in our study area (discussed in detail in the Data section). Table A3 shows that within a 10 km bandwidth, there is no statistically significant discontinuity in slope, elevation, and precipitation on the two sides of the language border within the study area.

3.2. Discontinuities in biodiversity conservation due to farm structure and management strategies

To disentangle the effects from "inherent" cultural dimensions that shape farmers, values, norms, and beliefs (summarized in Table 1) from culturally evolved, physical explanations such as farm structure, we examine the roles of farm structure and management practices in driving the discontinuity of biodiversity conservation. We do so by including additional covariates, namely farm size, land-use intensity (measured by livestock unit per hectare), and labor intensity (measured by standard labor unit per hectare) in the regression discontinuity design.[13] As we discuss in the conceptual background, these characteristics provide proxies for farm profitability and mechanization, which affects the costs of conservation practices and could impose physical constraints for conservation. In the case that additional covariates eliminate or reduce the baseline discontinuities, we could consider such covariates to explain the discontinuities (Noack et al., 2022). Note that unlike natural conditions such as elevation, slope, and precipitation, farm structural conditions and management strategies are results of farmers' choices and preferences, which are driven by the social and cultural background (Inwood, 2013). Therefore, these characteristics do not constitute confounding effects as characteristics of natural conditions; rather, through these farm characteristics, culture indirectly influence biodiversity conservation by shaping the constraints for conservation.

3.3. Discontinuities in farmers' response to policy reform

Our main analyses allow us to observe the changes in the discontinuities in biodiversity conservation AES participation across cultures over time. An alternative strategy to investigate the difference across cultural groups in farmers' response to the policy reform is to estimate whether there are discontinuities in farmers' response to the 2014 policy reform. We do so with a regression discontinuity design on differenced per-hectare AES payment across the pre- and post-reform time periods. We follow Butts (2021) and take the first difference over time at the farm level, and then use the differenced outcomes in a regression discontinuity design. To do so, we first need to restrict our sample to farms that appeared in the census at least one time both before and after the policy reform in 2014. We then calculate the difference in the average AES payments per hectare between the periods before and after 2014 (that is, 2010–2013, and 2015–2017), and estimate if there are discontinuities in this average time difference at the language border. A drawback of this approach is that farms that appeared in only one period need to be

[9] Take dairy farming, which comprises about a quarter of total Swiss agricultural production value, for example, the language border runs through the two largest regions of specialty artisan cheese production in Switzerland (Finger et al., 2017). This also implies similar market opportunities for farmers across the language border.In addition, given continuous natural conditions and farm types, we assume farms across the language border to face comparable costs of conservation. The exact cost of biodiversity conservation is very difficult to calculate at the farm level, and only costs of particular conservation practices for typical farms have been calculated (Mack, 2017). Furthermore, the costs for result-based schemes depend on the approaches farmers choose to reach to desired outcomes, which are not observed.

[10] Hahn et al. (2001) provides detailed discussions on the difference between sharp and fuzzy regression discontinuity designs. Also see Wuepper & Finger (2022) for examples in the context of agricultural and environmental economics.

[11] Note that we focus on payment rather than area enrolled, because each payment category is also a proxy for the ecological value and farmers' effort in the associated practice assigned by the payment provider. See also Data section for details.

[12] In 18 out of the Swiss 26 cantons, "district" ("Bezirk" in German) is an administrative unit between the canton and municipality level, whereas in the other (mostly small) cantons, municipalities are subdivisions directly below cantons. To ensure the unit of clustering are well-balanced, we apply manual adjustment by splitting large districts and cantons where the district level does not apply, and combining very small districts, such that the size of the units as well as the number of farms in them are comparable. For example, the district Obersimmental-Saanen in the canton Bern is of size 575 km^2, and we split this district into two roughly equal-sized units for clustering; another district Bern-Mittelland is of size 947 km^2, and we split it into three roughly equal-sized units.

[13] We note that while land use intensity is closely associated with biodiversity conservation for livestock farms, it is not the only measure of the ecological values provided by a farm (see Table A2). Thus it is not the same as our outcome variable, rather, since current land use intensity affects the opportunity cost of biodiversity conservation, we consider it as a covariate.

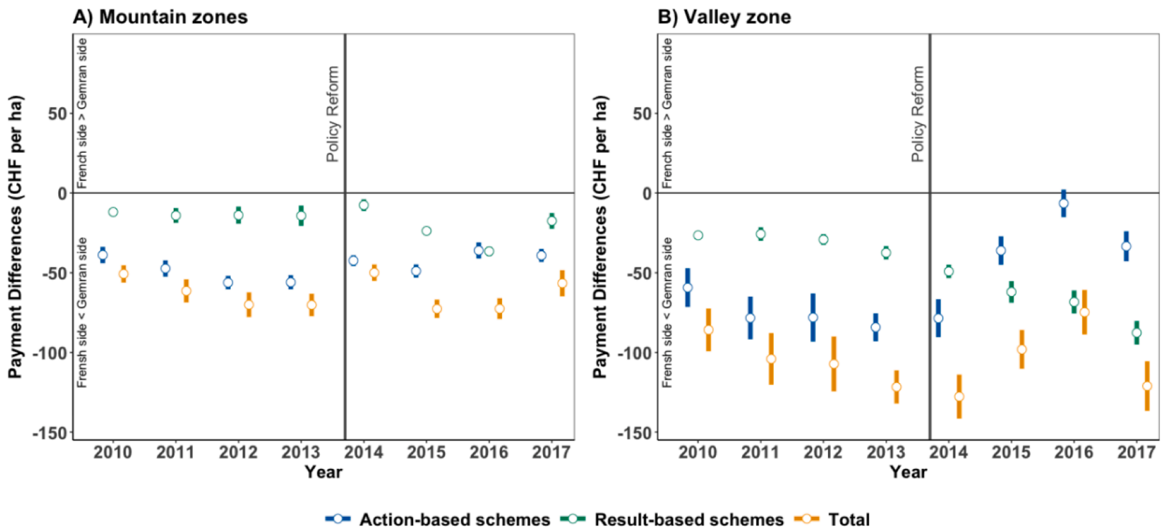

Fig. 2. Coefficient estimates of discontinuities in biodiversity conservation payment (baseline). Farms in the French-speaking regions on average received less AES payment for biodiversity conservation per hectare over both Period 1 (2010–2013) and Period 2 (2015–2017). For both mountain and valley zones, the discontinuities in action-based payments decreased after the policy reform, whereas the opposite trend applies to result-based payments.

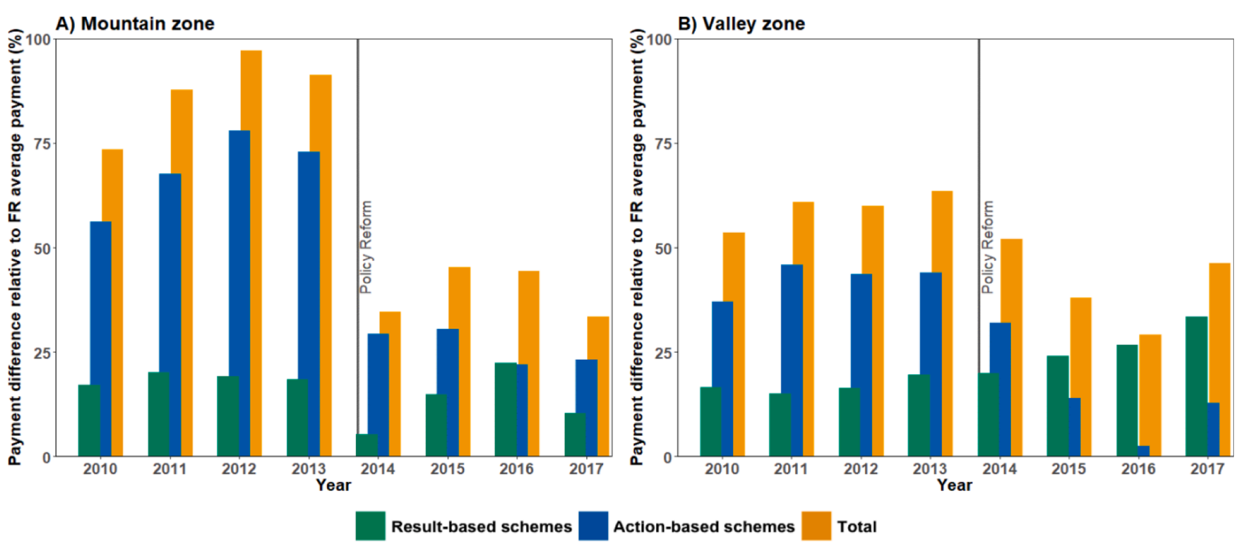

Fig. 3. Estimated discontinuity relative to average total payment received by French-speaking farmers. Relative payment gaps (negative estimated discontinuity in payment divided by average total payment received by French-speaking farmers) for action-based payments decreased from Period 1 (2010–2013) to Period 2 (2015–2017). For result-based payments, the relative difference maintained similar scales in the mountain zones, and increased in the valley zone.

dropped. Furthermore, some farms dropped out of the census due to farm-restructuring, for example, purchased by another farm.[14] This implies that structural information such as farm size and labor unit under farms of the same identifier changed over time for some farms. Therefore, for farms that experienced restructuring, the first-differenced per-hectare AES payments also reflect structural changes over time. Also because of the change in farm structure in some farms, we only estimate the baseline specification without including farm structural information as covariates. Nonetheless, this approach provides direct estimates on the response to the policy reform in 2014 by farms that remained in the census both before and after the reform.

3.4. Robustness checks

Alternative specifications. To test whether our estimates in the difference-in-discontinuities design are sensitive to the specification, we perform robustness checks with several alternative specifications. First, we estimate the regression discontinuity design with several alternative configurations to test the sensitivity of the results to the choice of estimator, bandwidth, and type of design. These sensitivity checks include using a local polynomial instead of a local linear estimator for the baseline analysis (without additional covariates), changing the bandwidth from 10 km to 7.5 km and 12.5 km, and performing a sharp rather than fuzzy regression discontinuity design. Second, we adopt an alternative measure of natural conditions and check whether our results are robust. Instead of separate measures of precipitation, slope, and elevation, we use an alternative variable, tree cover potential from Bastin et al. (2019), to control for the difference in natural conditions in absence of human influence. This variable is created based on ten soil and climate variables, and thus may contain information not covered by

[14] The structural change in Swiss agriculture is overall modest, especially if compared with other European countries. In the period 2000–2018, on average 1.76% of farms disappear (Zorn, 2020).

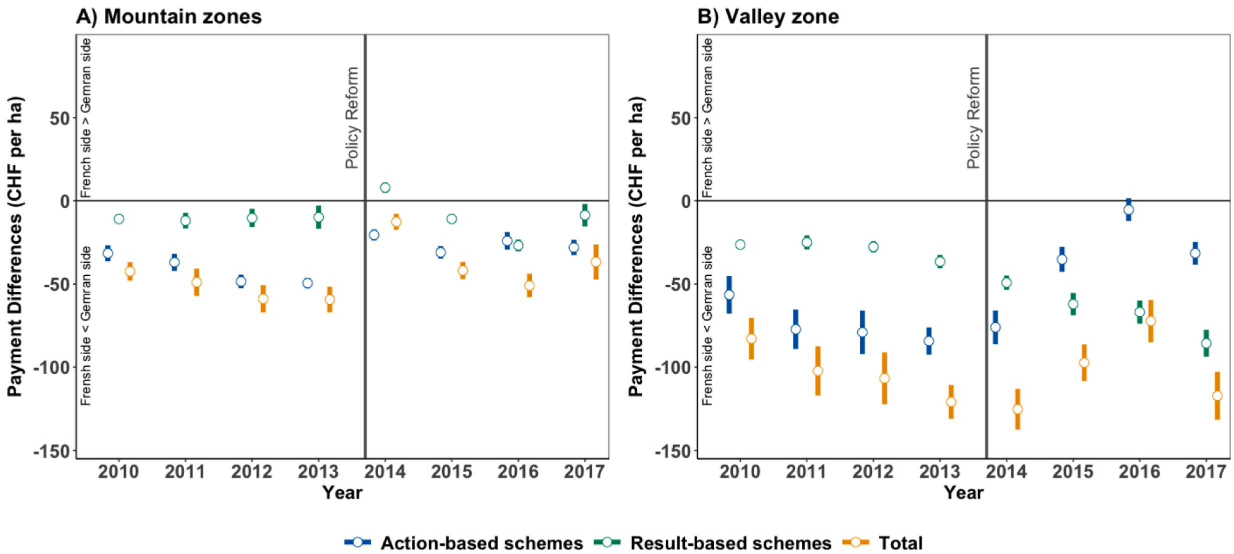

Fig. 4. Coefficient estimates of discontinuities in biodiversity conservation payment (additional covariates: farm size, labor intensity, land-use intensity). Estimated payment gaps decrease in magnitude with additional covariates added for mountain zones but not for valley zone. For mountain zones, discontinuity in biodiversity conservation can be partially attributed to difference in farm structural conditions and management practices.

Table 4
Coefficient estimates from regression discontinuity design on differenced per-hectare AES payments before and after policy reform.

Outcome	Mountain zones	Valley zone
Total payment per hectare	18.9***	33.1***
	(2.4)	(8.2)
Action-based	14.9***	62.2***
	(2.4)	(9.2)
Result-based	4.0	−29.1***
	(2.3)	(2.9)

Positive estimates indicate stronger response to policy reform by farmers in the French-speaking region. Sample consists of farms that appeared in the dataset at least one year over Period 1 (2010–2013) and one year over Period 2 (2015–2017). Farms in the French-speaking region responded more strongly in action-based biodiversity conservation, and less strongly in the valley zone in result-based biodiversity conservation.

the measures in the baseline analysis, though it is highly correlated with slope and elevation in our dataset (and thus we do not include it in the baseline analysis). In addition, one may consider that the room for agricultural biodiversity conservation is limited by the demand for agricultural production in the region, such that differences in farm structural conditions and practices reflect economic activities (e.g., due to difference in urbanization and market size) rather than farmers' preferences. To test whether this could be an alternative explanation to the potential mechanisms behind difference in biodiversity conservation across language regions, we include population density as a measure of economic activities and market size, and check whether the results are sensitive to the inclusion of this covariate.

Placebo tests. To examine whether discontinuities in AES participation at the language border in fact reflect spurious effect, we conduct placebo tests by running the same analysis within arbitrary parts of the study area where the natural conditions are continuous. This approach is a slight variation of a most common approach for a placebo test of a spatial regression discontinuity design, namely artificially shifting the cutoff of the running variable (i.e., the "border") by an arbitrary distance (e.g., Egger & Lassmann, 2015; Filippini & Wekhof, 2021; Noack et al., 2022). Under the standard approach, systematic difference detected at the artificial border would imply that the discontinuity at the actual border could be a spurious effect, because a discontinuity could arise regardless of the presence of a treatment. In our study, due to natural barriers throughout the study area (e.g., borders of agricultural zones, see Fig. 1 and discussion in the Data section), using the standard approach could easily result in the artificial language border coinciding (partially) with borders between agricultural zones. In this case, we could detect differences in biodiversity conservation at the artificial border due to differences in natural conditions and/or different direct payment rates across agricultural zones. Thus, we restrict the placebo test within areas of continuous natural conditions, namely within the same agricultural zones. The basic idea of our approach nonetheless follows the standard approach, that is, near an artificial border where farmland characteristics are continuous, but the treatment (i.e., culture) is absent, we should not expect a discontinuity in biodiversity conservation behavior.

Specifically, we select two areas in the French-speaking region, and two in the German-speaking (Fig. A10, also see descriptions of the agricultural zones in the Data section). For each of these areas, we draw an artificial border roughly in the middle of the area, and perform the regression discontinuity design. Since these areas are located within either the French- or German-speaking region, the share of French speakers is either close to zero or one. For the former case, a fuzzy regression discontinuity design would inflate the coefficient estimates to unrealistically large values. We therefore conduct a sharp regression discontinuity design for the placebo tests. We continue to use a 10 km bandwidth in the placebo tests.

4. Data

Our primary data source is annual agricultural census data on all Swiss farms from 2010 to 2017, which contains farm structural information and biodiversity conservation AES payment received by farmers. In the year 2010, over 51,600 farms appeared in the census, of which over 3,500 lay within the 10 km bandwidth in valley or mountain zones with at least one hectare of grassland. In the main analyses, we focus on payment levels (per hectare of overall farm size) rather than areas enrolled, because each payment category is also a proxy for the ecological value and farmers' efforts in the associated practice assigned by the payment provider. Thus, the payment a farm receives shall also reflect the overall ecological value it provides. For instance, a farm can receive payments for managing grassland less intensively, and for planting flower strips between plots of land. The former payment category often applies to relatively large areas with low per-hectare

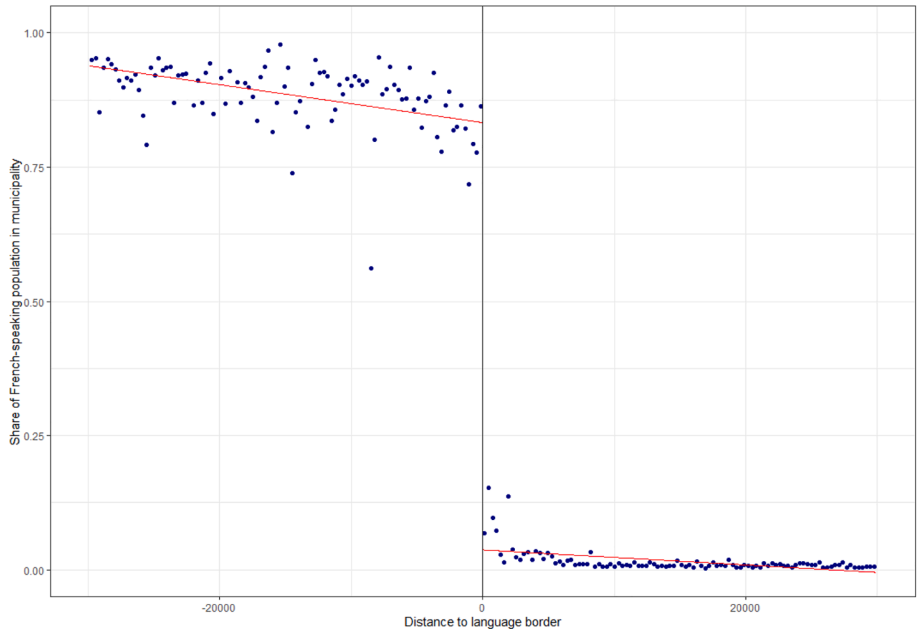

Fig. A1. Share of French-speaking population across the inner-Swiss French-German language border. Negative distance corresponds to French-speaking region; positive distance corresponds to German-speaking region.

payment, while the latter only applies to small areas, but the per-hectare payment is much higher (Table A2). Using area enrolled as the outcome would add up the two types of enrollment without distinguishing the ecological values. Since the participation in AES is often associated with farm size (e.g., Mann, 2005), and farms in the French-speaking parts of Switzerland are on average larger than farms in the German-speaking parts, we use per-hectare payment as the outcome variable. That is, the outcome measures the average ecological value per hectare of land a farm provides. Fig. A2 presents the regression discontinuity plots for each outcome variable in the year 2010 and 2017 (i.e., before and after the policy reform) within the 10 km bandwidth. Overall, payments increased for farms in both French- and German-speaking regions after the policy reform in 2014. For total payment and action-based payment, farms in the German-speaking region received more biodiversity conservation payment per hectare, particularly before the policy reform. After the policy reform, the difference appeared to narrow.

Within specific payment categories, payments for the same conservation practice also vary across different topographical zones to reflect the difference in difficulty to deliver the ecological value. The main topographical zones include valley, hill, and four mountain zones. Agricultural lands are classified into these zones to reflect production conditions, including climate, slope, altitude, and transport accessibility (FOAG, 2021). In general, payments are lower in mountain zones where the provision of extensive grassland is associated with lower (opportunity) costs (Huber et al., 2021). Since suitable agricultural activities and conservation practices vary across agricultural zones, participation in biodiversity conservation AES also differs: the fraction of ecological focus areas in the mountain zones are much higher than that in the valley (FOAG, 2020). Furthermore, the payment changes under the 2014 policy reform differed across agricultural zones, which could lead to different responses of farmers that cannot be captured by agricultural zone fixed effects. Therefore, we examine biodiversity conservation in different zones separately.

Historically, land characteristics that define agricultural zones may also influence the formation of the borders of cultural regions. An example would be that a mountain ridge overlaps with the border that divides two language regions, such that cultural differences across language regions would confound with topographical and biophysical differences. To avoid such confounding effects, we restrict our study area to sections of the language border that run through rather than along the borders of agricultural zones (Fig. 1). This step ensures the production conditions across the language border to be comparable. We omit farms in hill zones since hill zones are unevenly distributed across the language border. As such, our sample comprises farms in valley and mountain zones in the study area.[15]

Since some payment categories apply only to grassland while others both to grassland and cropland, the payments farms receive depend on the farming activities. The distribution of farm types is similar across the border (Fig. A3), such that any difference in biodiversity conservation is unlikely to be due to large differences in the distribution of farming activities in the two language regions. Furthermore, we restrict the sample of farms to those that contain at least one hectare of grassland, such that the payment increases in 2014 which focused on grassland are relevant to all observations.

The running variable for our regression discontinuity design is the shortest distance between each municipality to the language border (in the year 2021). Since a number of Swiss municipalities went through mergers since the year 2000, we follow Engist (2021) and account for the municipality merges over the sample period.

We obtain municipality-level share of French-speaking population and population density from the 2000 census. Slope and elevation information are measured by Shuttle Radar Topography Mission (SRTM), and annual precipitation is measured in 2017 by MeteoSuisse. Table 2 provides descriptions of our outcome and treatment variables, covariates, and the running variable.

Table 3 provides descriptive statistics of the covariates. For the mountain zones, farms in the French-speaking region on average have larger farm size, labor intensity, and land use intensity (measured by livestock unit per hectare); for the valley zone, labor intensity and land use intensity are on average lower in the French-speaking region. At the municipality level, the natural conditions characterized by precipitation, elevation, and slope are comparable across language regions, which is also confirmed by the covariate balance test (Table A3). The

[15] Since topographical and payment differences are both smaller within the four mountain zones compared to mountain-valley differences, we combine the mountain zones I through IV into one mountain zone.

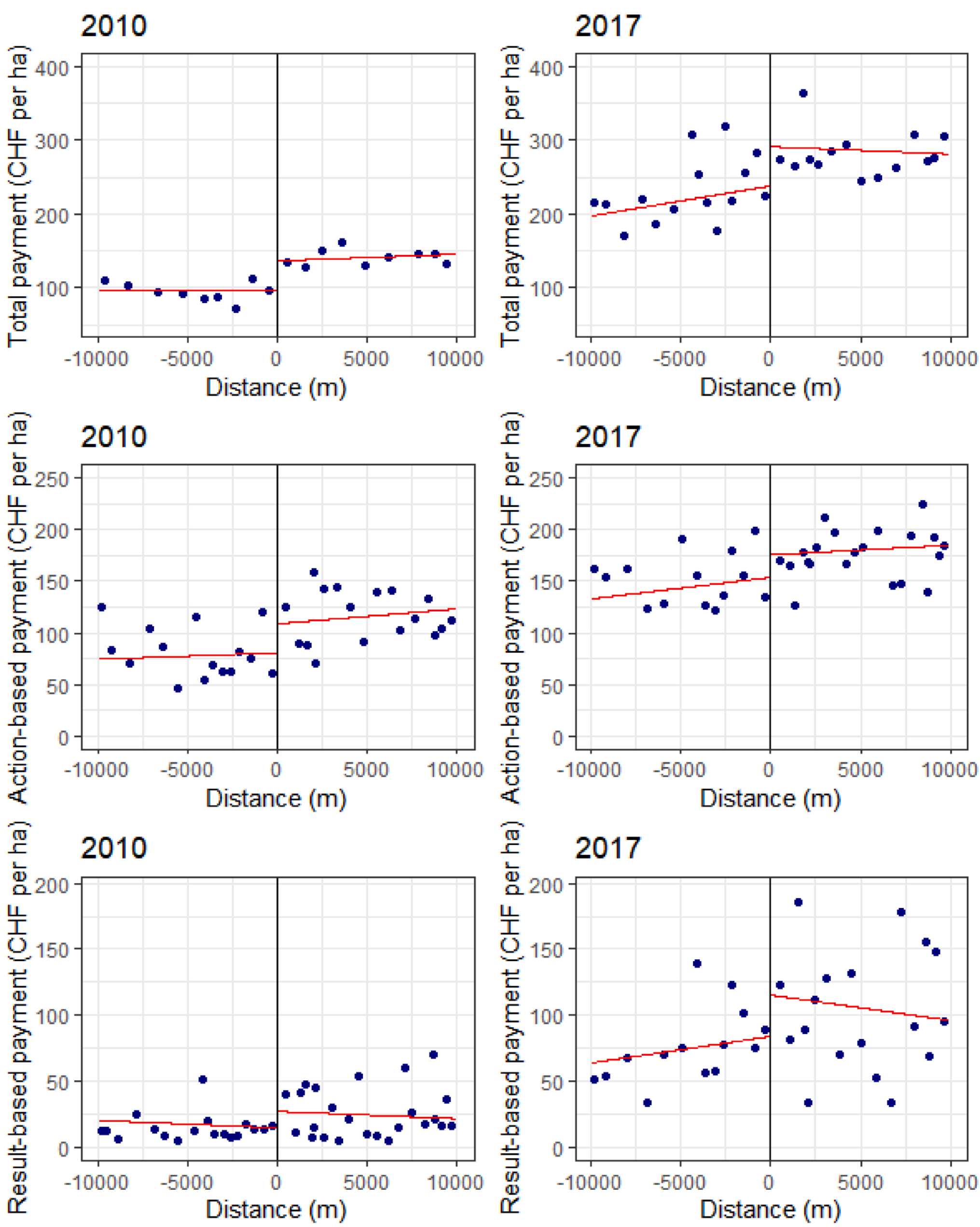

Fig. A2. Regression discontinuity design plots of outcomes. Negative distance corresponds to French-speaking; positive distance corresponds to German-speaking. Outcomes variables are (top to bottom) total biodiversity conservation payment, action-based payment, and result-based payment per hectare.

French-speaking region has overall higher population density and tree cover potential within the 10 km bandwidth in the study area (Fig. 1), though we do not find discontinuities near the language border as we control for the running variable (Table A3). Opposite to the mean difference within the 10 km bandwidth, population density is higher in the German-speaking region in the entire study area. Since population density proxies for economic activity and demand for agricultural products (market size), it is more reasonable to account for the entire regions rather than excluding the omitted areas (Fig. 1) when comparing this variable. We therefore also calculate population density including the omitted areas. We find the overall population density to be comparable across the language border, suggesting comparable market sizes for agricultural products.

5. Results

In this section, we present the results of estimation following the order of the empirical strategies discussed in Section 3.

5.1. Initial discontinuities in biodiversity conservation and response to policy change

Overall, we find that farmers in the Frenching-speaking region of Switzerland participated in biodiversity conservation AES systematically to a lesser extent compared to their German-speaking counterparts. After the policy reform in 2014, however, the relative economic significance of this difference shrank, indicating that increased policy incentives help level off culture-driven behavioral difference. Fig. 2 shows the baseline coefficient estimates of the per-hectare AES payment differences between the two language regions by year. A negative

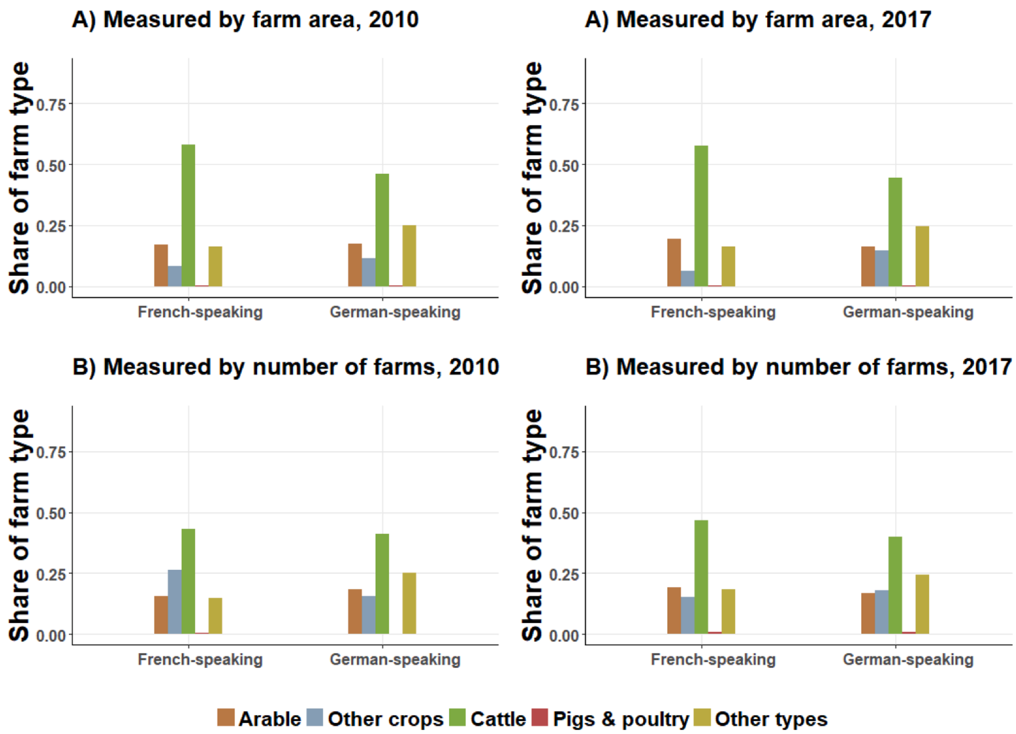

Fig. A3. Distribution of farm type. Farm type distribution within the 10 km bandwidth near the language border.

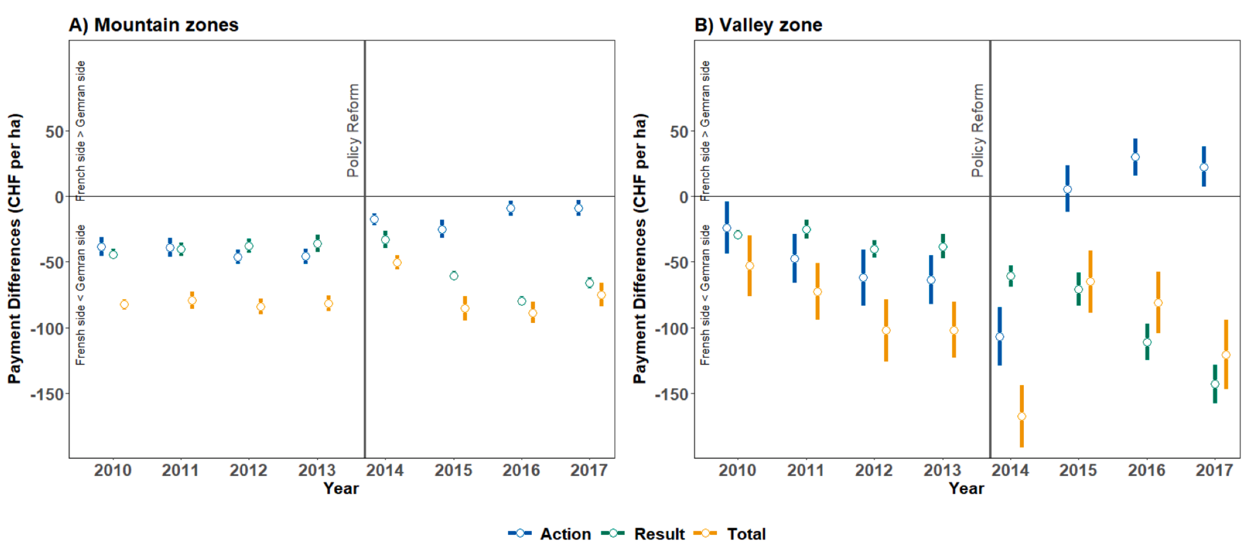

Fig. A4. Coefficient estimates of discontinuities in biodiversity conservation payment (baseline) based on local polynomial estimator.

coefficient indicates a lower amount of payment is received on a per-hectare basis on the French-speaking side. Since the payment increase in 2014 primarily applies to result-based payments, and it takes a different amount of time for farmers to reach the requirement of targeted indicator species on the farmland, the payments received in 2014 may only partially measure farmers' response. We therefore focus our discussion on the payments received in the periods 2010–2013 (Period 1) and 2015–2017 (Period 2). Differences across the two periods (i.e., the difference-in-discontinuities), on the other hand, reflect the difference in farmers' responses to the policy reform across the language groups.

In both mountain and valley agricultural zones, farms in the French-speaking regions on average received less AES payment for biodiversity conservation per hectare than those on the German-speaking side over both Period 1 and Period 2. In Period 1, the magnitude of differences across language regions was larger in action-based payments than in result-based payments. This pattern applied to both mountain and valley zones. However, these differences in the two types of AES gradually converged over Period 2, indicating farmers' different responses in action- and result-based biodiversity conservation practices to the policy reform. Since the payment increases due to the 2014 policy reform applied to all farms, in the case that farms on both sides of the language border responded exactly the same (or if there were no response at all), we would observe an increase in the payment gap from Period 1 to Period 2 simply because of rescaling. Therefore, an increase in the payment gap could arise from either equivalent response to the policy reform from both language regions, or relatively less response from the French-speaking farmers. This is the case for result-based payment,

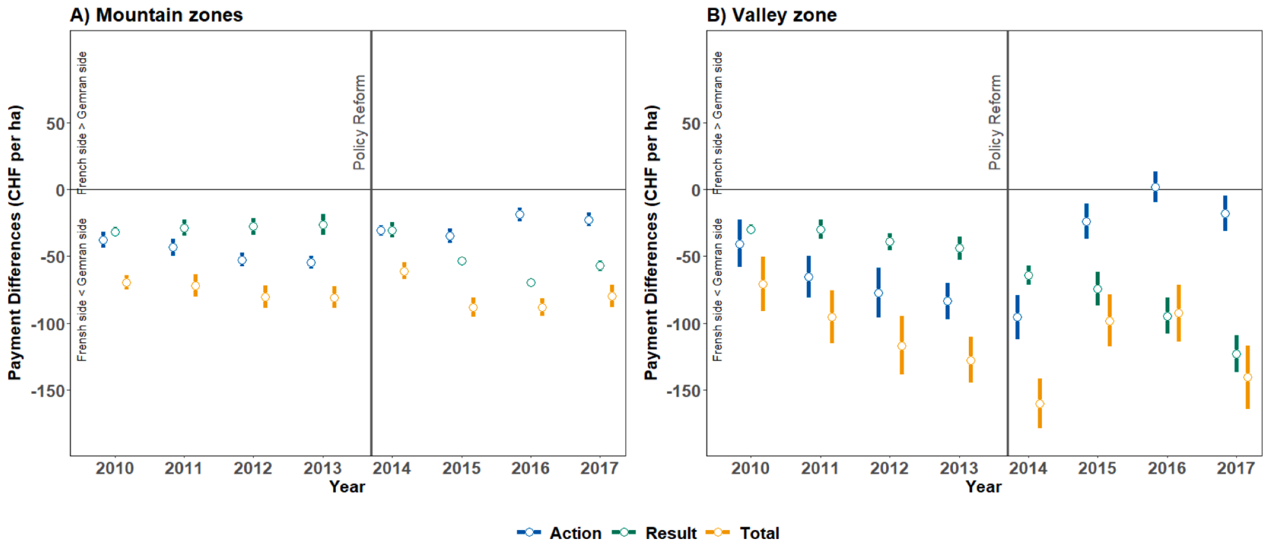

Fig. A5. Coefficient estimates of discontinuities in biodiversity conservation payment (baseline) with 7.5 km bandwidth.

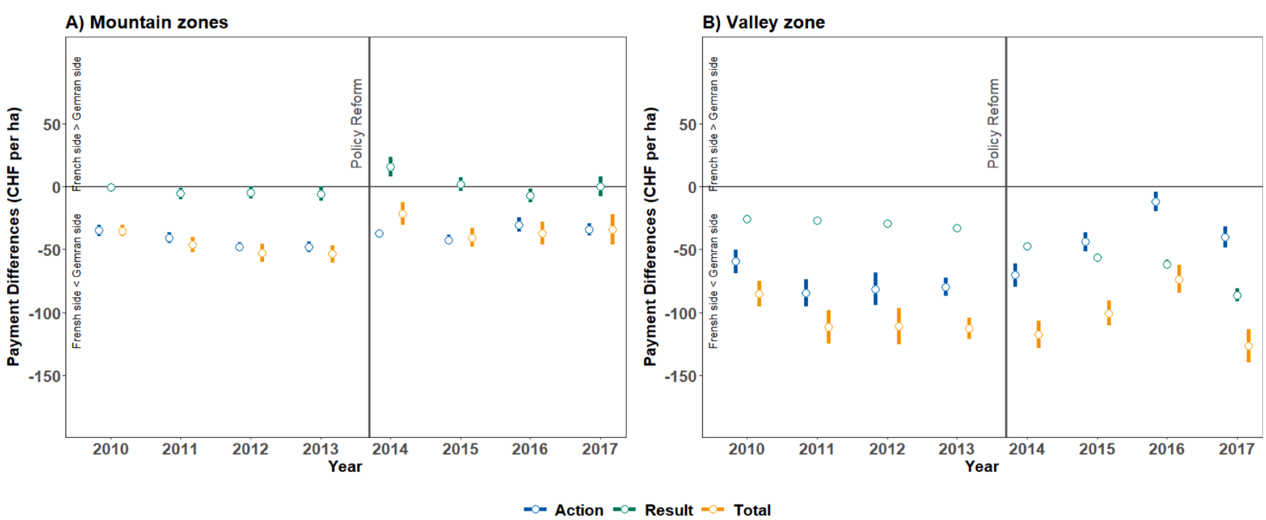

Fig. A6. Coefficient estimates of discontinuities in biodiversity conservation payment (baseline) with 12.5 km bandwidth.

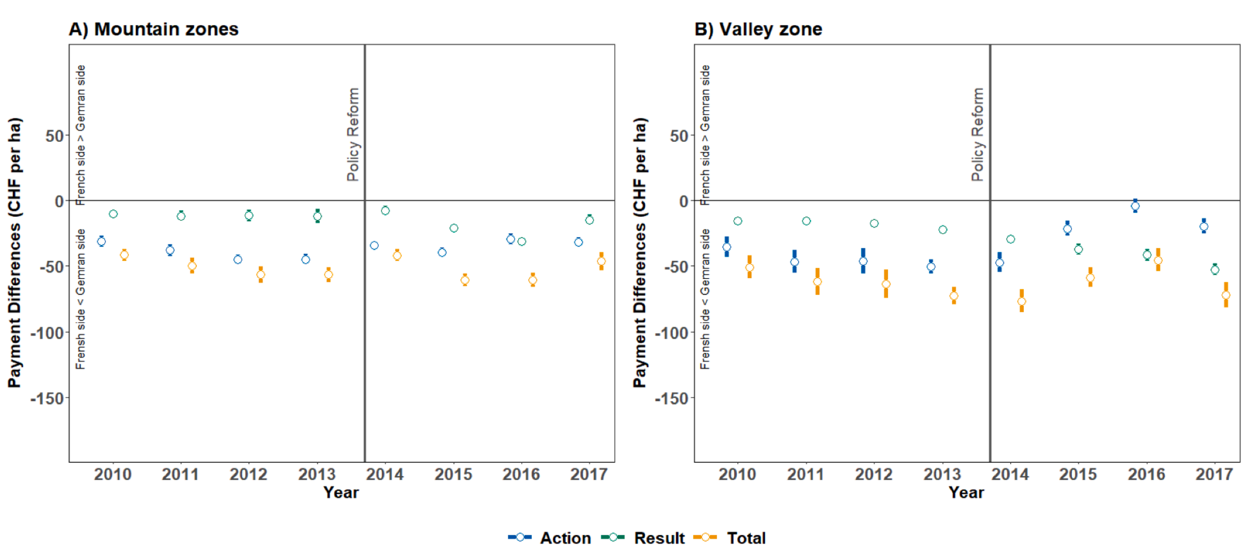

Fig. A7. Coefficient estimates of discontinuities in biodiversity conservation payment (baseline) based on sharp RD design.

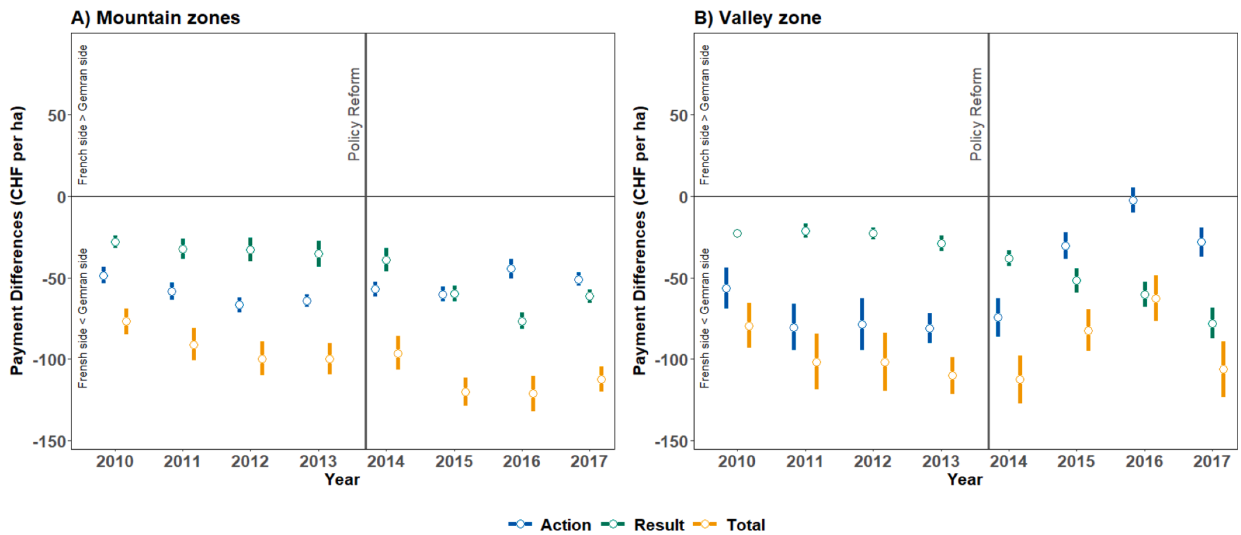

Fig. A8. Coefficient estimates of discontinuities in biodiversity conservation payment (natural conditions controlled by tree cover potential).

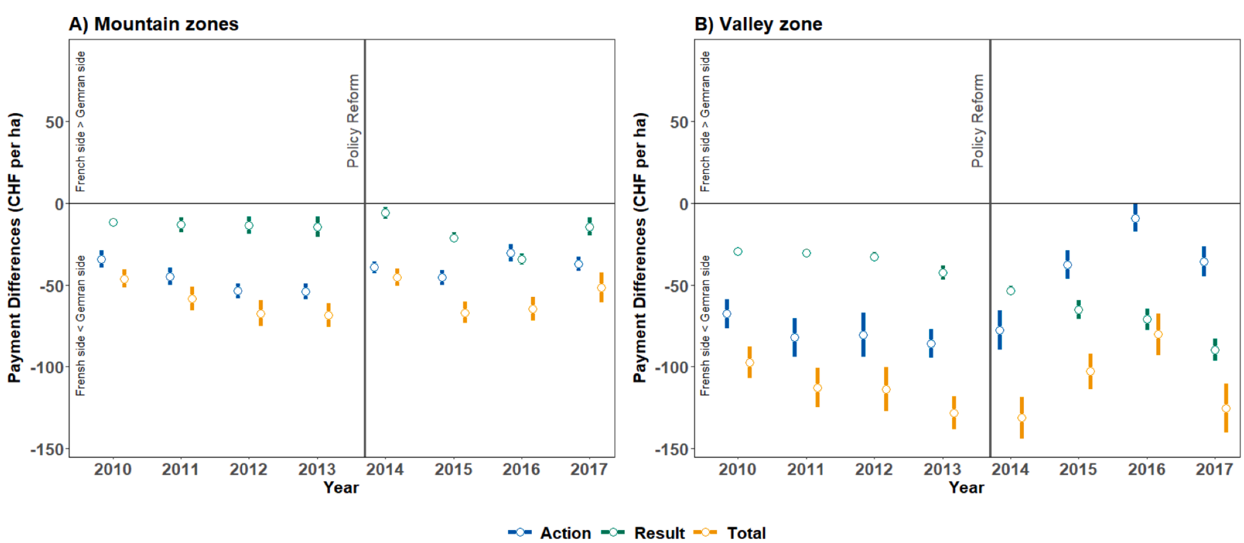

Fig. A9. Coefficient estimates of discontinuities in biodiversity conservation payment (additional covariates: population density).

especially in the valley zone. On the contrary, a decrease in the payment gap from Period 1 to Period 2 indicates relatively stronger response from the French-speaking farmers, which is the case for action-based payments.

Taking a closer look into the effect of culture on biodiversity conservation in the mountain zones (Panel A of Fig. 2), the estimated total per-hectare payment received by French-speaking farmers fell short by 51–70 CHF compared to their German-speaking counterparts on the other side of the language border over Period 1 (with standard errors, *se* henceforth, of 4 CHF or less). Differences in action-based payments largely account for the total payment gap. To place the estimates in context, the unconditional average (i.e., simple group average) per-hectare payment received by mountain farms in the French-speaking regions (within the 10 km bandwidth) over the same period was 73 CHF. A comparison indicates a sizable cultural effect in biodiversity conservation, with the French-speaking farms fell short by up to 99 percent compared to the German-speaking counterparts. In terms of response to the policy reform, over Period 2, the per-hectare payment gap slightly widened for result-based payments yet slightly narrowed for action-based payments. The total payment difference over Period 2 ranged from 57 to 73 CHF per hectare ($se \leq 5$ CHF in each year over this period), and the unconditional average payment received by French-speaking farmers over this period was 165 CHF. To illustrate the change in the relative economic significance of the payment gap, in Fig. 3, Panel A we plot the estimated payment gap (i.e., absolute value of the discontinuity) relative to the average total biodiversity conservation payment each year received by French-speaking farmers. Since the estimated discontinuities are negative, the absolute values simply reverse the sign of the discontinuities. Comparing the payment gaps relative to the unconditional average payments between the two periods, the relative economic significance of the total payment shortfall by French-speaking farmers decreases by roughly 50 % on average after the policy reform. For action-based payments, the relative payment gap shrank more, by around 62 % on average. This indicates that the increased monetary incentives attenuated the effect of culture on biodiversity conservation.

In the valley zone, the estimated total per-hectare payment received by French-speaking farmers was 86–122 CHF ($se \leq 9$ CHF) less than their German-speaking counterparts over Period 1 (Panel B of Fig. 2). The unconditional average per-hectare payment in the valley was 175 CHF in the French-speaking regions. Differences in action-based payments again largely account for the total payment gap. Over Period 2, the payment gap ranged from 75 to 121 CHF per hectare ($se \leq 8$ CHF), while the unconditional average per-hectare payment was 258 CHF in

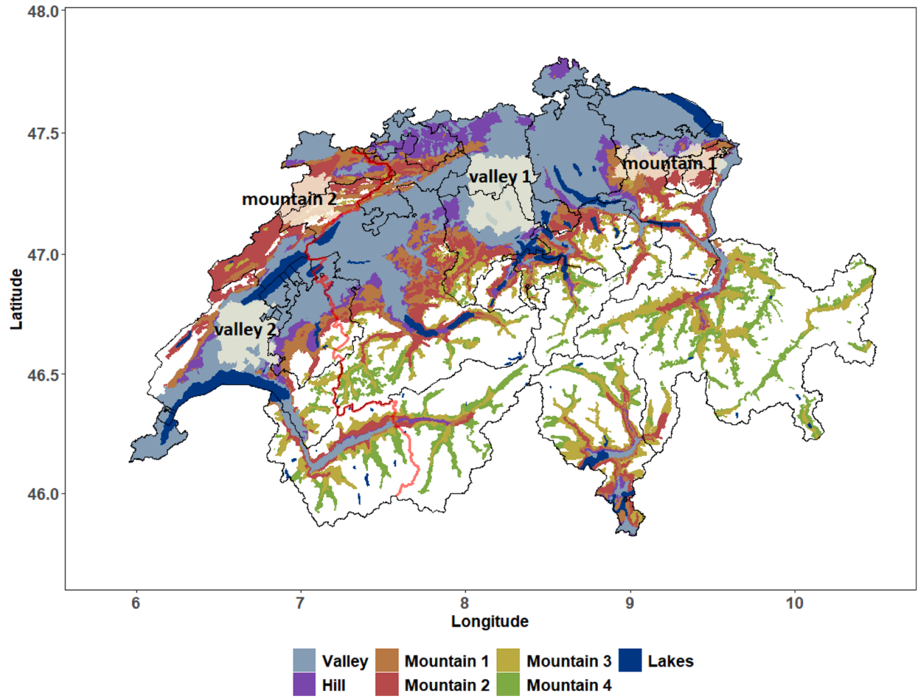

Fig. A10. Placebo test areas. Areas valley 1 and mountain 1 are in the German-speaking region, and valley 2 and mountain 2 are in the French-speaking region.

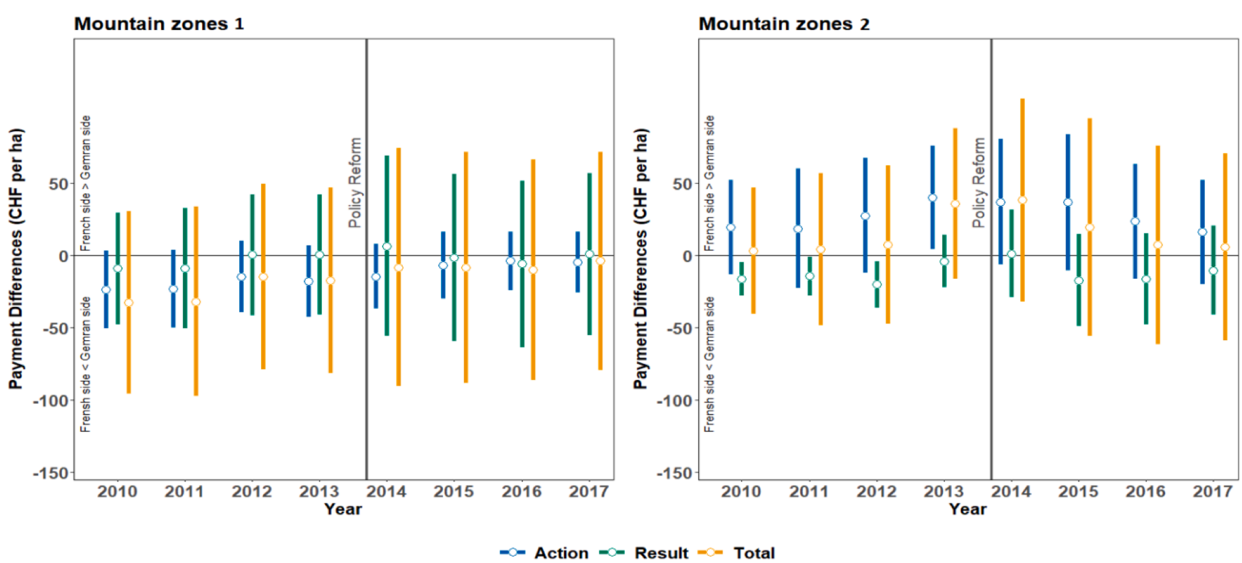

Fig. A11. Coefficient estimates from placebo test – mountain zone areas.

the French-speaking region. The slight decrease in the total payment gap in the valley zone results from opposite trends in the two types of payments. While French-speaking farmers fell further short in receiving result-based payments, the gap in action-based payments narrowed. The relative economic significance of the cultural effect decreased in action-based payments after the policy reform, and increased for result-based payments (Panel B of Fig. 3).

5.2. Disentangling effects of farm structure and management from inherent cultural dimensions

To further understand the extent to which the cultural effects we estimate above are attributable to inherent cultural dimensions that influence farmer behavior via values, beliefs, and norms (Table 1), we next include farm structure and management strategies in the estimation. That is, as we disentangle the effects due to these farm characteristics, the remaining effects are attributable to inherent cultural dimensions. As we discuss in the sections Background and Empirical Strategy, the covariates on farm structure and farm management styles (farm size, labor intensity, and land-use intensity) characterize the cost-related constraints for biodiversity conservation. For ease of comparison, we focus on estimates in Period 2. For the mountain zones, adding covariates results in a payment gap in the range 37–51 CHF per hectare ($se \leq 6$ CHF) over Period 2 (Panel A of Fig. 4, and see Table A4 for ranges of estimates). While the payment gaps are still statistically significant as we include covariates on farm structure and farm management styles, the magnitude of total payment gap decreases by 30–35 percent compared to estimates in the baseline analyses, which ranged from 57 to 73 CHF per hectare over the same period.

These results indicate that for mountain zones, the discontinuities in

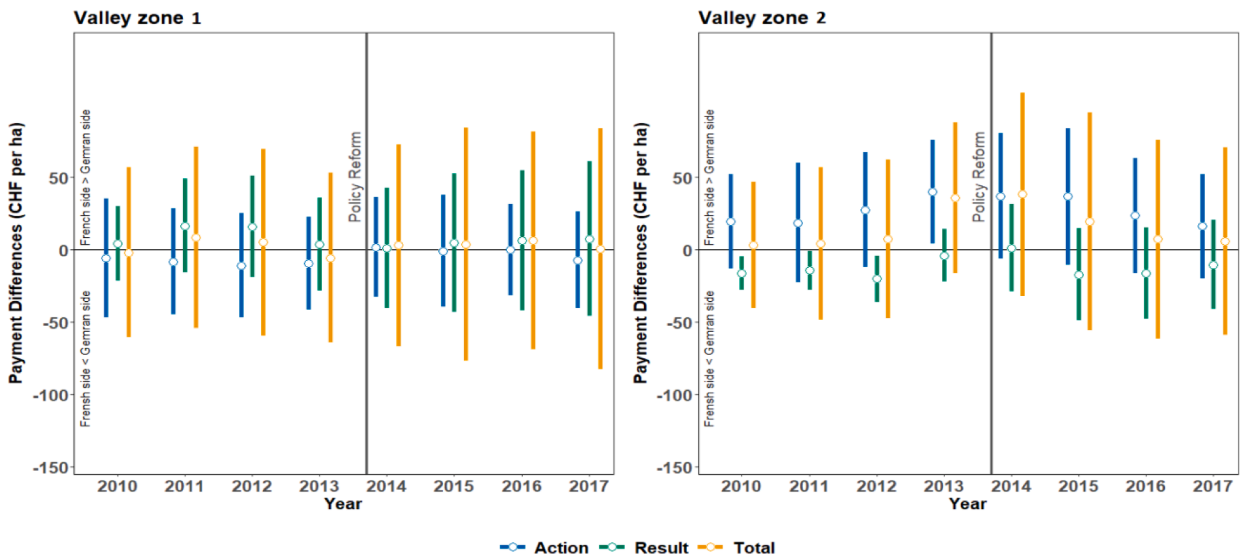

Fig. A12. Coefficient estimates from placebo test – valley zone areas.

Table A1
Summary of literature on behavioral difference across Swiss language regions.

Study	Topic	Unit of study	Findings	Relevant cultural component
Kuhn et al. (2022); Aepli et al. (2021)	Private provision of apprentice training	Firm	Firms located in German-speaking regions, where there is a stronger norm towards the private provision of public goods, are more likely to provide training positions	Attitude on the responsibilities of the state vs. individual
Brown et al. (2018)	Financial literacy	Individual	Financial socialization is stronger among German-speaking students, and they are less encouraged to take debts; French-speaking students connect money more strongly with freedom; French-speaking students are less patient and more risk-seeking	Attitude on money; time preference; risk preference
Eugster et al. (2011)	Demand for social insurance	Individual	Latin-based language speakers demand stronger publicly provided social insurance	Attitude on the responsibilities of the state vs. individual
Filippini & Wekhof (2021)	Ownership of energy-efficient vehicle	Individual	Higher share of energy-efficient vehicle ownership by French-speakers, who had higher support for popular initiatives of: green economy, against nuclear energy, energy strategy 2050	Environmental attitude
Gentili et al. (2017)	Long-term elder care	Individual	More home-based care provided in Latin-based language groups than German-speaking (stronger family ties)	Family ties
Egger & Lassmann	International trade	Individual	Each language region prefers import from countries sharing a common language	Trade preference
Eugster et al. (2017)	Work attitude	Individual	Unemployed Romance language (including French) speakers search for work longer than their German speaking neighbors; German speakers attach more value to economic rewards for their work	Attitude on the responsibilities of the state vs. individual; work attitude
Eugster & Parchet (2019)	Tax	Individual	French-speaking region regularly favours high taxes and large government involvement; German-speaking region favours low taxes, a slim state, and strong individual responsibilities	Attitude on the responsibilities of the state vs. individual
Herz et al 2021	Intertemporal choices	Individual	French speakers are significantly more impatient than German speakers	Time preference
Erhardt & Haenni (2022)	Entrepreneurship	Firm founder	Individuals with cultural origin on the German-speaking side of the Swiss language border found 20 % more firms than their French-speaking counterparts, due to differences in risk aversion (to obtain risky profit) or differences in preferences for being self-employed	Risk preference, work attitude
Guin (2017)	Household savings	Individual	Low- and middle-income households in the German-speaking part are more likely to save than similar households in the French-speaking part.	Time preference

participation in biodiversity-promoting AES at the language border partially manifest in structural differences in farming conditions. Since differences in farm structural conditions can arise from cultural differences (Inwood, 2013), the influence of culture on biodiversity conservation in this case can be considered indirect, that is, via structural differences between farms developed over time. Descriptive statistics of the additional covariates show that, on average, the French-speaking mountain regions have relatively larger average farm size, labor intensity, and land-use intensity (and a possibly higher level of mechanization). These characteristics also imply greater opportunity costs for farmers to adopt conservation practices by forgoing production. This is particularly the case for result-based AES, which involve greater adjustment costs compared to action-based AES. As we account for the structural differences between farms in the two language regions, the magnitude and economic significance in the gap in result-based payments diminishes, especially over the post-reform period. A possible explanation is that the payment increases for large and profitable farms were still not sufficient to compensate for the profit loss and additional cost if farmers were to participate in AES. On the contrary, smaller farms often rely to larger extends (share of income) on direct payments, especially those with relatively lower farm household income and less income from off-farm labor (El Benni & Finger, 2013; El Benni &

Schmid, 2021). Therefore, they were more responsive to the policy reform to implement extensive measures.[16]

Turning to the valley zone, additional covariates do not incur substantial changes in the estimated payment gaps both before and after the policy reform (Panel B of Fig. 4). Descriptive statistics show that compared to the mountain zones, there exist less systematic differences in these covariates in the valley zone. While farm size is consistently larger in the French-speaking region, other covariates show mixed patterns. Land-use intensity is higher in the French-speaking region prior to the policy reform yet slightly lower afterwards. While this pattern aligns with the change in the action-based payment gap, the difference in land-use intensity does not further explain the gap. These results indicate that for farmers in the valley zone, culture may influence farmers' biodiversity conservation behavior beyond observed farm structural conditions and management styles, and rather via the inherent cultural dimensions that influence farmers' values, beliefs, and norms (Table 1).

5.3. Discontinuity in farmers' response to policy reform

Table 4 reports estimates of the regression discontinuity design on differenced per-hectare AES payments before and after the 2014 policy reform. While the discontinuities in farmers' response to the policy reform in terms of total payment per hectare are both positive in the mountain and valley zones, the responses differ in action- and result-based payments. Consistent with trends shown in Fig. 2, those in the French-speaking region responded more strongly towards action-based payments after the policy reform in both mountain and valley zones, implying a decrease in the payment gap. Corresponding to the lack of clear pattern in Fig. 2 regarding the change in result-based payment gap in the mountain zones, estimate in Table 4 indicate a statistically insignificant difference in the responses. In the valley zone, French-speaking farmers responded less strongly to the policy reform. These results again indicate that the policy reform reduced farmers' behavioral difference in terms of participating in biodiversity conservation AES between the language regions, particularly for action-based schemes.

5.4. Robustness checks

Alternative specifications We use a local polynomial estimator of second order to re-estimate the baseline estimation (without additional covariates). The overall patterns of the estimates are consistent with the local linear estimation, with shortfalls in both payment types by French-speaking farmers, which decreased after the policy reform (Fig. A4). The local polynomial estimator yields more amplified effects. For the mountain zones, compared to the main analyses, there is a clearer increasing trend in the gap of result-based payment after the policy reform. For the valley zone, the estimated discontinuity in Period 2 is insignificant or (slightly) positive, whereas in the baseline it is insignificant or (slightly) negative.

As we change the bandwidth to 7.5 km and 12.5 km (Fig. A5 and Fig. A6), the estimates again show consistent trends with the baseline estimation as well as similar magnitudes. The estimated discontinuities are relatively larger within a smaller bandwidth with large variances, and vice versa for the larger bandwidth. Estimates from the sharp regression discontinuity design (Fig. A7) show similar patterns as the baseline estimation, with relatively smaller estimated discontinuities.

As we control for natural conditions with tree cover potential, the estimated payment gaps are consistently larger for the mountain zones compared to the main analyses where we separately control for precipitation, slope, and elevation. Thus, for the mountain zones, separate controls of topographical and climate features in our case yielded greater balance in the natural conditions across the language regions. For the valley zone, the estimates are of very similar magnitudes. For

[16] This implies that, increased policy incentives for biodiversity conservation could be especially effective in encouraging farms that obtain higher marginal value of conservation (i.e., monetary incentive minus the costs associated with conservation practices). We acknowledge that such differential response to increased incentives across farms could occur independent of cultural difference. Yet, since culture influences the evolution of farm structure and management, it is possible that prior to the policy reform, a greater proportion of farmers in the French-speaking region faced negative marginal value of conservation, which led to the lack of participation in the AES. The increased monetary incentives could turn the marginal value of conservation positive, which encourages more French-speaking farmers to participate in the AES. This partially explains how increased monetary incentives could counteract culture-driven difference in biodiversity conservation.

Table A2
Changes in payments under biodiversity conservation AES following the 2014 policy reform (in CHF per hectare).

Payment item	Pre-policy reform (2013)	Post-policy reform (2014)	Difference
Action-based[1]			
Extensively used meadow Valley	1,500	1,500	0
Extensively used meadow Hill	1,200	1,200	0
Extensively used meadow Mountain I and II	700	700	0
Extensively used meadow Mountain III and IV	450	550	100
Litter area[3] Valley	1,500	2,000	500
Litter area Hill	1,200	1,700	500
Litter area Mountain I and II	700	1,200	500
Litter area Mountain III and IV	450	950	500
Low intensity meadows[4]	300	450	150
Extensive pastures and wood pastures		450	450
Applicable only to cropland			
Wildflower fallow	2,800	3,800	1,000
Rotational fallow	2,300	3,300	1,000
Field strips	1,300	2,300	1,000
Field margins on arable land	2,300	3,300	1,000
Result-based[2]			
Extensively used meadow Valley	1,000	1,500	500
Extensively used meadow Hill	1,000	1,500	500
Extensively used meadow Mountain I and II	1,000	1,500	500
Extensively used meadow Mountain III and IV	700	1,000	300
Litter area Valley	1,000	1,500	500
Litter area Hill	1,000	1,500	500
Litter area Mountain I and II	1,000	1,500	500
Litter area Mountain III and IV	700	1,500	800
Low intensity meadow Valley Mountain II	1,000	1,200	200
Low intensity Mountain III and IV	700	1,000	300
Extensive pastures and wood pastures Valley-Mountain II	500	700	200
Extensive pastures and wood pastures Mountain II-IV	300	700	400

1: Action-based payments are given to farmers for certain farming practices, such as extensive management of grasslands. The exact payments are determined by both the farming practice and the agricultural zones (e.g., in the valley, the hills, or one of the mountain zones).
2: Result-based payments are added on top of action-based payments, if certain quality indicators are present, such as a minimum amount of rare indicator species that differ regionally and by habitat. For example, the (action-based) payment for extensively used meadows in the valley remained 1500 CHF per hectare from before to after the policy reform, but the (result-based) bonus payment for the detection of rare indicator plants was increased from 1000 CHF in 2013 to 1500 CHF per hectare in.
2014.
3: Litter areas are meadows mowed for animal bedding. No fertilization or pesticides are allowed on these areas.
4: "Low intensity" refers to reduced intensity levels that are still higher than "extensive".

both agricultural zones, the patterns of the payment gaps before and after the policy reform remain consistent with the main analyses (Fig. A8).

Adding population density to the baseline specification, the estimated discontinuities are highly close to those in the baseline analyses (Fig. A9). The French-speaking region has a slightly higher population density within the 10 km bandwidth, yet the overall population density is higher in the German-speaking region. Furthermore, including the areas omitted from the study area, there is no statistical significance in the mean difference in population density across language regions. In all cases, we do not find discontinuity in this variable at the language border. Thus, it is unlikely that population density difference, reflecting difference in demand for agricultural products, drives the discontinuities in biodiversity conservation across language regions.

Placebo tests Figs. A11 and A12 show results from the placebo test for which we select four arbitrary areas with continuous natural conditions, with one in each agricultural zone and each language region. For all four areas, the estimated payment differences near the artificial border are much smaller in magnitude compared to the main analyses, with many close to zero, and are mostly statistically insignificant. These results provide evidence that the estimated differences in farmers' participation in biodiversity conservation are not driven by spurious effects, but rather reflect cultural differences.

6. Discussion

Effective agri-environmental policymaking demands matching policy incentives for environmental services with farmers' preferences, which are often shaped by their cultural background. From the perspective of cost-effective design of AES, understanding the cultural dimensions that influence farmers' values, beliefs, and thus preferences inform policymakers about farmers' heterogeneous willingness to accept AES payments. Such knowledge contributes to tailored policies towards farmers' heterogeneous preferences and spatial targeting of policy interventions. In this study, we first find that for any given time period, there exist systematically different participation behaviors in biodiversity-promoting AES between farmers from different cultures. For both agricultural zones (mountain and valley), French-speaking farmers lag their German-speaking counterparts in participating biodiversity conservation AES, even with identical AES design, comparable institutional framework, economic opportunities, natural conditions, and farming activities. This provides evidence that culture plays a role in farmers' preference in conserving biodiversity, which we contend via shaping farmers' intrinsic motivation for conservation and their perception of monetary incentives. The culture-driven behavioral difference in biodiversity conservation also indicates culture as a determinant of heterogeneous conservation costs among farmers, and spatial patterns in agricultural conservation practices. In the context of our study, for farmers in the French-speaking mountain region, response to increased payments under AES may be partially limited by farm structural conditions. Tailored policies targeting large and intensively managed farms in this region may contribute to increasing biodiversity provision, especially since these farms have relatively more room to implement extensive measures to conserve biodiversity. For the valley zone, a comprehensive understanding of the relevant inherent cultural dimensions (e.g., attitudes towards work, money, the environment, and individual vs. state responsibilities) that lead to heterogeneity in farmers' preferences could facilitate tailored policymaking towards different cultures.[17]

Furthermore, policy incentives could help level off cultural-driven behavioral differences and thus reach more balanced policy goals across cultures. In our study, the multiple-period setting allows us to examine responses across cultural groups to changing monetary incentives for biodiversity conservation over time. Our second set of findings highlight heterogeneous responses towards the same policy change across cultures, which decreased behavioral differences in biodiversity conservation. For mountain zones, French-speaking farmers responded relatively more strongly to the policy reform than German-speaking farmers, such that the two groups of farmers behaved similarly post-reform when their farm structural conditions are comparable. For the valley zone, the differences in AES participation and response to the policy reform between the language groups rather reflect farmers' preference beyond the structural conditions of farms. The decreased relative economic significance of payments received by different cultural groups post-reform indicates that increased monetary incentives can counteract culture-driven behavioral difference in biodiversity conservation. These findings are consistent with our hypothesis that monetary incentives could reduce culture-driven behavioral difference that reflect values, beliefs, and norms. In the context of our study, farmers in the French-speaking region responded more strongly towards payment increase under action-based AES, reducing the importance of culture in behavioral differences of action-based biodiversity conservation. Since action-based AES are prerequisites for farmers to further participate in result-based AES, these findings suggest the increased monetary incentives introduced by the policy reform were effective in motivating farmers to participate more extensively in biodiversity

Table A3
Tests on covariate balance.

Covariate	Coefficient estimate	p-value	Bandwidth
Elevation (m)	−57.3	0.5	10 km
Slope (degree)	−2.5	0.21	10 km
Annual precipitation (mm)	−21.7	0.68	10 km
Vegetation	2.0	0.49	10 km
Population density 1	2.4	0.27	10 km
Population density 2	1.3	0.33	10 km

Population density 1 is based on study area; population density 2 includes omitted areas (Fig. 1). No discontinuities found in the covariates within the 10 km bandwidth.

Table A4
Summary of estimated discontinuities in biodiversity conservation payment (payment gaps).

Agricultural zone	Additional covariates	Payment gap (Period 1)	Payment gap (Period 2)
Mountain	None	51 – 70	57 – 73
	Farm size, labor intensity, land use intensity	42–59	37 – 51
Valley	None	86 – 122	75 – 121
	Farm size, labor intensity, land use intensity	83 – 121	72–117

Estimated payment gaps correspond to coefficient estimates in Fig. 2 and Fig. 4. Payment gap narrowed after additional covariates are included for the mountain zones, but not for the valley zone.

[17] Our discussion focuses on cost-effectiveness of fixed-rate payment schemes. Although more common in contexts outside of Europe, our results also speak to conservation auction mechanisms aimed at revealing the private conservation cost of farmers not observed by policymakers (e.g., Latacz-Lohmann & van der Hamsvoort, 1997; Arnold et al., 2013; Polasky et al., 2014). Sorting farmers based on culture-driven preference could reduce information asymmetry and improve the efficiency of an auction.

conservation, which potentially paves the way for more substantial land use adjustment to conserve biodiversity in the future (i.e., via participating in result-based AES). On the contrary, it is also possible that the policy reform was only effective in inducing biodiversity conservation at the action level. Whether increased incentives could achieve measurable outcomes in enhancing biodiversity could depend on the cost to adjust farming practices for biodiversity conservation in the short run versus the long run. Higher conservation cost could be particularly relevant to result-based AES in the short run. Future research on the long-run implications of incentive changes under AES is thus warranted.

7. Conclusion

Cultural backgrounds often shape farmers' environmental, economic, and political preferences, which affects their preferences for policy incentives for pro-environmental practices. To understand how the interplay between culture and policy affects farmer behavior, we investigate a natural experiment where a national level agricultural policy reform increased the monetary incentives for biodiversity conservation for farmers from different cultural backgrounds. Using farm census panel data, we analyze cultural differences along the inner-Swiss French and German language border in both farmers' level of participation in biodiversity conservation AES, and their response to a policy reform. Our findings indicate that while farmers from different cultural backgrounds behave differently in conserving biodiversity, monetary incentives offered by AES could potentially counteract and shrink the behavioral difference. We show that the 2014 agricultural policy reform in Switzerland was effective in terms of motivating French-speaking farmers who previously lagged in biodiversity conservation to take additional steps (i.e., via a stronger response towards action-based AES).

Our study advances the understanding of the interaction between culture and economic policy in shaping individual environmental behaviors and economic decision-making. Culture-driven behavioral differences within farming populations bear important implications for agri-environmental policymaking. For policymakers, our results indicate that first, culture plays a role in shaping farmers' pro-environmental behavior such as biodiversity conservation. Our analyses quantify this cultural effect and show that it is far from trivial. Second, increased economic policy incentives could counteract culture-driven behavioral difference. We show that with increased payments for biodiversity conservation, the effect of behavioral factors such as culture-driven preferences become relatively less important. These findings also warrant future research towards a deeper understanding of specific cultural dimensions that lead to differences in farmers' preference for sustainable agricultural practices, which would inform tailored policies that enhance the outcome and cost-effectiveness of an incentive scheme. Our study generates broad implications for a wide range of policy scenarios where policy instruments with monetary incentives for pro-environmental behaviors are applied to individuals with diverse cultural backgrounds. Understanding how culture drives heterogeneous preference and willingness to accept the incentives informs the design of cost-effective incentive schemes. This is relevant within countries but also across countries, e.g., in the Common Agricultural Policy of the European Union, under which increasing monetary incentives are being offered for environmental services (e.g., Pe'er et al., 2022). Accounting for cultural differences would improve the design of policy instruments and the evaluation of policy effects.

CRediT authorship contribution statement

Yanbing Wang: Conceptualization, Methodology, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. **Sergei Schaub:** Conceptualization, Methodology, Visualization, Writing – review & editing. **David Wuepper:** Conceptualization, Methodology, Writing – review & editing. **Robert Finger:** Conceptualization, Methodology, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

See Figs. A1-A12 and Tables A1-A4.

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