

Rodríguez, Orlando; Vracholi, Maria; Wüpper, David; Sauer, Johannes

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**ORIGINAL ARTICLE** **OPEN ACCESS**

# World Heritage Status and Farmers' Income: Evidence From a Regression Discontinuity Design in Colombia

 Orlando Rodríguez<sup>1</sup> | Maria Vrachioli<sup>1</sup> | David Wüpper<sup>2</sup> | Johannes Sauer<sup>1</sup>
<sup>1</sup>Technical University of Munich, Munich, Germany | <sup>2</sup>University of Bonn, Bonn, Germany

**Correspondence:** Orlando Rodríguez ([orlando.rodriguez@tum.de](mailto:orlando.rodriguez@tum.de))

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## ABSTRACT

The core of Colombia's coffee growing region was designated as a World Heritage (WH) site in 2011, making a distinction between “the core” of the region and “the periphery.” However, the coffee cultural heritage does not abruptly stop at the WH boundary but it exists inside and outside the boundary. This allows us to use a regression discontinuity design (RDD) to identify the income effect for farmers located just inside the WH site. We find that the WH designation of the region increases coffee farmers' income by up to \$757 per month. The mechanism includes more tourism activities inside the coffee farms by 39%, higher adoption of sustainable farming practices, increasing organic coffee production by 8.38%, and increasing payments for environmental services (PES) by 2.35%.

**JEL Classification:** O13, Q12, Q57

## 1 | Introduction

Coffee prices are volatile, leading to high uncertainty for coffee farmers, and this is exacerbated by increasing climatic and pest problems. Yet, there are still half a million families in Colombia that depend on coffee production for their livelihood. Coffee is one of the leading export products in Colombia, and farmers have developed a cultural identity around coffee production. In 2011, the “Coffee Cultural Landscape of Colombia” (CCL) was inscribed onto the World Heritage (WH) List with the main aim to protect Colombia's unique coffee production culture and traditions and with a secondary goal of improving the living standard of Colombian coffee producers.

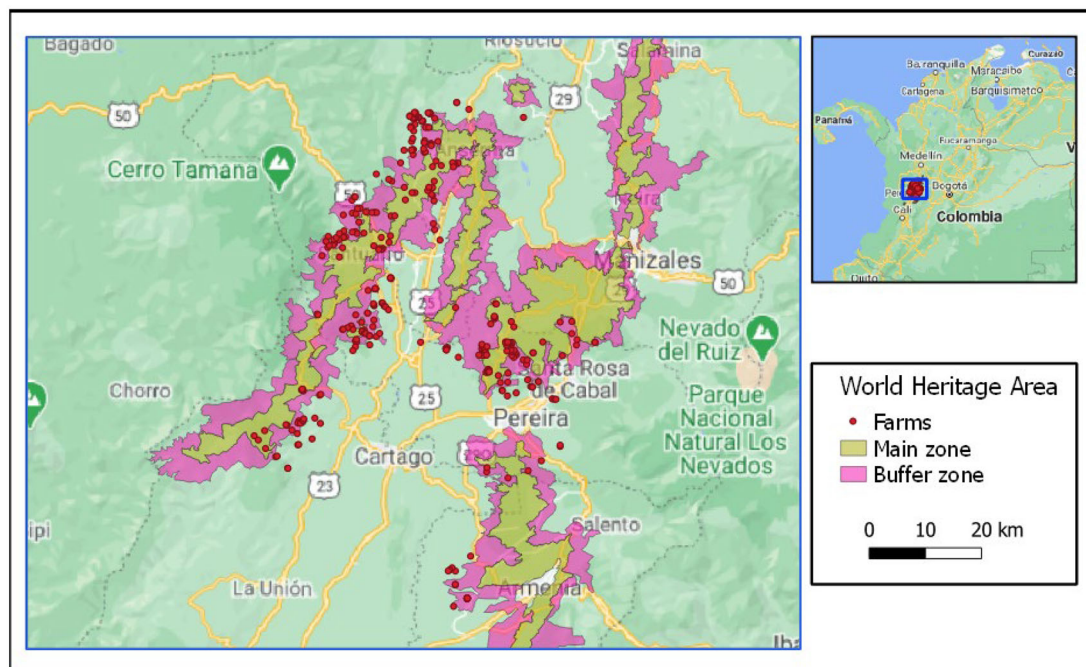
This paper explores whether the WH status, in fact, led to differences in income between coffee farmers across the WH border. We exploit the fact that the WH site was created with

a sharp boundary but aims to protect the cultural heritage of an area that does not otherwise have a sharp boundary. The Coffee Cultural Landscape of Colombia covers a large area with a long and famous coffee tradition. The boundary of the WH site was placed inside this vast area such that close to the boundary, both sides have similar coffee growing conditions—culturally, environmentally—and the only stark difference is that since 2011, one side is inside the WH site and one side is outside. This is an optimal natural experiment to use a spatial regression discontinuity design (RDD) to identify the causal income effect of the WH site.

UNESCO (1972) defines WH as one site of outstanding universal value from a historical, ethnological, aesthetic, or anthropological point of view. The Colombian coffee WH area was delineated according to the combination of 16 cultural and environmental attributes to protect “the core” of the traditional coffee production

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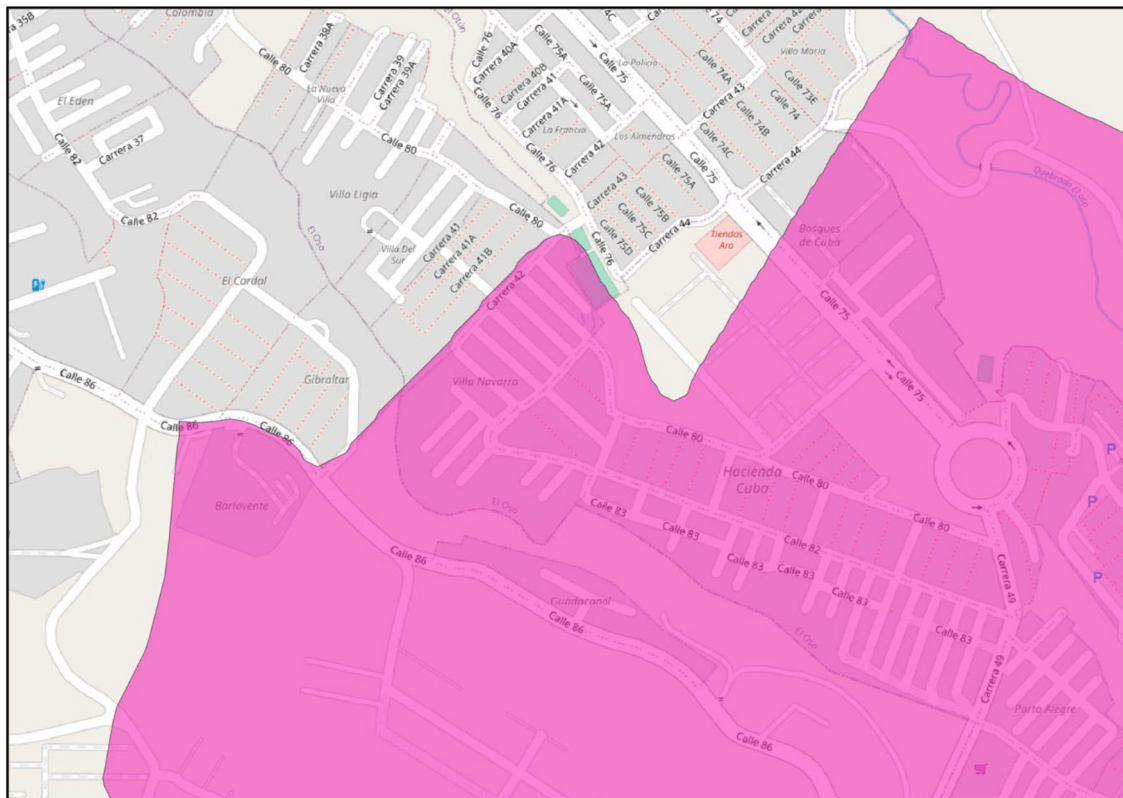
**FIGURE 1** | Location of farms around the coffee WH border.

area with all its cultural significance. By far, not the entire region was included in the WH site, and traditional coffee-growing communities are equally found on both sides of the WH border. Recognizing this, the Colombian government already signed Act 2245 of July 2022 (Congress of Colombia 2022), promoting the recognition of more territories of the Colombian coffee region in the WH status. The government claims that the traditional coffee region is bigger than the frame drawn by UNESCO. Criticism from the Government claims that the Coffee Cultural heritage and the traditional coffee production is not limited by the WH border proposed by UNESCO. Coffee production in Colombia was developed during the 20<sup>th</sup> and 21<sup>st</sup> centuries in the same conditions inside and outside of the WH area. The locations just inside and outside the WH boundary are similar in tradition and culture, coffee growing conditions, and other contextual variables determined before the establishment of the WH site. There is also great continuity in who owns and manages the farms in the region, which is dominated by small family estates that are handed down through the generations.

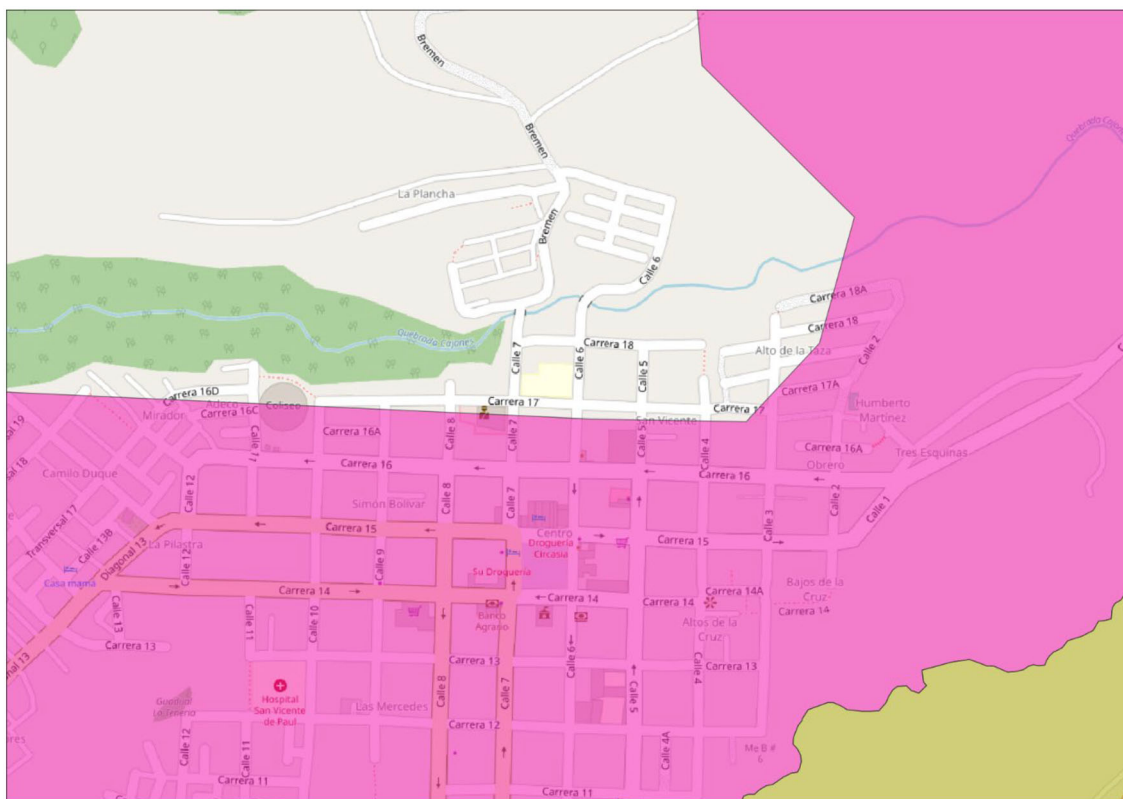
Figure 1 shows the location and extent of the WH site. One characterizing feature of it is that it is not a contiguous area, but it is rather fragmented into six subzones. The reason for this fragmentation was to leave out modern coffee farms with modified infrastructure and settlements with modern urbanization.<sup>1</sup> The WH has 207,000 hectares, distributed in a vertical shape, embedded in the traditional coffee region. The average distance between one WH border to the opposite border is 4.8 km. The highest distance between two segments of the border is 23 km, but 70% of the WH area has less than 6 km of distance b/w borders. We included in our pooled sample the closest coffee farms to the WH border, expecting that we could collect data from coffee farms with similar conditions and the most similar cases. To decide which parts of the coffee growing region should be declared as WH, a list of objective criteria was used:

natural heritage, water source availability, architectural heritage, archeological heritage, concentrated settlement and fragmented property structure, influence of modernization, urban heritage, coffee production historical tradition, mountain grown coffee, coffee institutions and related networks, coffee predominance, slope of coffee growing, age, smallholding as landownership system, multiple crops, and sustainable production and technologies in the coffee productive chain. These criteria are known as the 16 attributes of the WH site (UNESCO 2011). It was not feasible to include all communities that scored high according to the criteria, but it was tried to include a “representative area.” Importantly, the areas located just within the WH site never had a sharp boundary with the areas located just outside, and where to exactly set the boundary of the WH site was approximately arbitrary. In the end, the pragmatic outcome was to include a representative selection of “veredas”<sup>2</sup> within 51 municipalities among the four mainly relevant coffee producing departments (12 from Risaralda, 18 from Caldas, 11 from Quindio, and 10 from Valle de Cauca) and draw a border between these and their neighboring municipalities. Figures 2 and 3 show how the WH border was drawn across the streets of the municipalities, passing through buildings, houses, and blocks. In some areas, half of the same infrastructure was included in the WH status, and the other half was left out. The WH site has unique conditions highlighted by the UNESCO criteria; however, both the area just within and just outside the WH site exemplify these conditions. Thus, the WH site represents the main facets of the Colombian coffee tradition, but the neighboring municipalities do not have less coffee tradition or differ in other relevant ways from the included ones. Renewal architecture avoided some areas to be included in the WH area. However, the economic activity and the coffee tradition are the same.

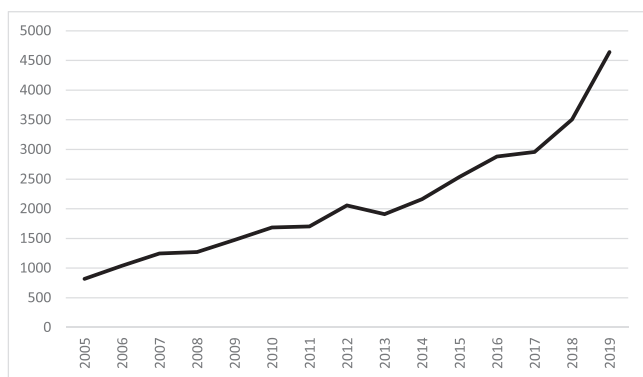
Agricultural WH sites have not yet received much academic attention to date, although in many regions of the world, farmers have low and unstable incomes, and supporting them is regularly



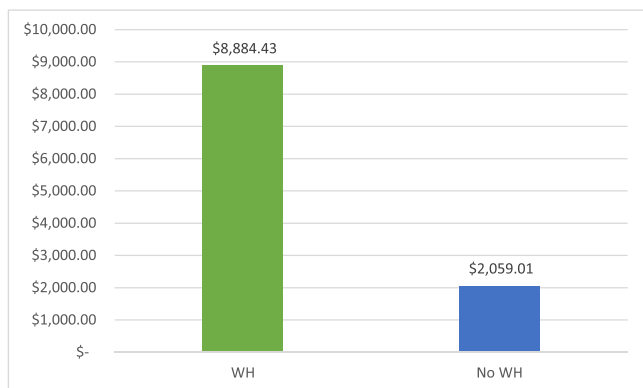
**FIGURE 2** | World Heritage border across the municipality of Pereira (Risaralda).



**FIGURE 3** | World Heritage border across the municipality of Circasia (Quindío).



**FIGURE 4** | Hotels and restaurants in the coffee region.



**FIGURE 5** | Investments in road infrastructure in the coffee region in thousands of US dollars after 2011.

an explicitly stated policy goal when rural WH sites are proposed. Particularly in low-income and middle-income countries, there is often a goal conflict between protecting the environment and raising local livelihoods. Potentially, WH sites can support both, but the literature shows rather mixed results regarding this synergy (Fu et al. 2020; Su et al. 2020).

Our main contribution is the identification of the causal effect of the WH border. The impact of the WH is particularly transparently and robustly estimated here, which is enabled by how the border of the WH site was drawn, not coinciding with any pre-existing discontinuities, (i.e., in geography, culture, politics), and there is no endogenous sorting because the farms in the region are owned and managed by the same families over generations. This is an optimal context for a RDD (Wuepper and Finger 2023). We collected survey data from 337 coffee farmers situated both inside and outside the WH site and we use a spatial RDD to identify the causal effect of the WH listing. Our main finding is that WH status increased the income of the coffee farmers by \$756.97 per month, which was mostly driven by increased activities of coffee growers' involvement in tourism networks (39%). Consistent with this, Figure 4 shows that the number of hotels and restaurants increased in the coffee region since the establishment of the WH status from 819 in 2005 to 4641 in 2019 (Citur 2021). In the same line, Figure 5 shows higher investments in road infrastructure inside the WH area and Figure 6 describes more kilometers built in the WH area after 2011, allowing access to coffee farms and touristic amenities through

the traditional coffee region (Ministry of Transport 2024). Second, higher income among coffee growers inside the WH area was also in part due to increased monthly payments for environmental services (PES) of \$17.77. Finally, WH status changed farming practices, namely there was a shift to more organic coffee production, which increased 8.38%. The main results provide inputs for policy-making process, related to the support of resilience among vulnerable traditional grower's families.

The remainder of the paper is organized as follows. The next section presents the theoretical review, the third section introduces data and methods, the fourth section provides the results, and the final section offers our conclusions.

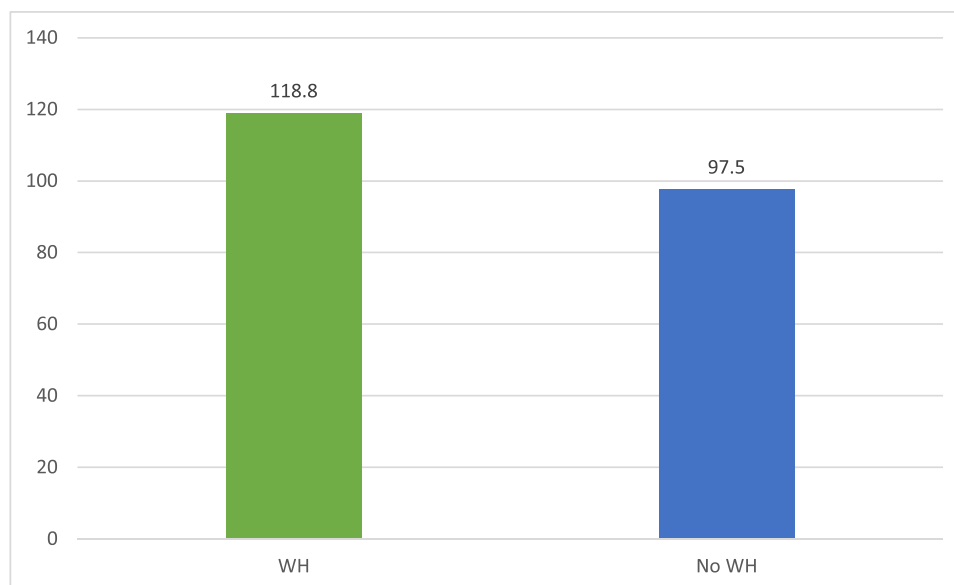
## 2 | Literature Review

Ways of ensuring farmers' income during economic crises have been an active field of research for a long time. Farmers' income can be influenced by fluctuations in prices paid or received, shifts in gross domestic product, technological change, variation in interest and exchange rates, and land prices (Beckman and Schimmelpfennig 2015). Thus, growers face boom-bust cycles leading to economic uncertainty. Greater farm income variability leads to more off-farm activities (Mishra and Goodwin 1997). Therefore, further strategies are needed to complement the income of producers. Particularly, some literature has focused on the effects of WH status on growers' income. Local networks take advantage of higher visibility within the WH list, looking for other economic activities that increase the income of domestic producers (Fauconberg et al. 2017). WH status is used by local governments like city marketing labels to promote social, economic, and environmental goals in a given region among their stakeholders like tourists, investors, and donors.

Farmers' income in WH areas could increase through mechanisms like tourism and PES, which compensate for down-swings during crop price crises. Some evidence shows that the integration of multiple heritage values with tourism is highly important for sustaining agricultural heritage systems and rural communities (Su et al. 2020). However, some authors consider that it still needs to be explored on how to alleviate the contradiction between environmental protection and tourism development faced by WH sites and how to achieve trade-offs and synergies of ecosystem services and compensations (Fu et al. 2020).

There is extensive literature on the economic benefits of WH listing, but the findings are mixed, mainly highlighting the benefits of WH status on promoting tourism. On the one hand, Wuepper (2017) and Su and Lin (2014) found that the economy in and around WH sites can benefit from increased tourism revenues. On the other hand, several studies found that tourism did not increase due to the WH listing, including Gao and Su (2019) and Huang et al. (2012). Particularly striking, Yang and Lin (2014) concluded that cultural WH sites can benefit economically from their listing, whereas Wuepper and Patry (2016) concluded that less famous, more remote, and rural destinations benefit the most from WH status.

The WH status linked to environmental attributes is also managed by local governments as an opportunity for launching PES



**FIGURE 6** | Kilometers of road infrastructure built in the coffee region after 2011.

schemes to protect natural resources and increase the income of local growers. PES schemes offer economic incentives to producers to protect the ecosystems (Wunder 2005). Therefore, PES complements farmers' income by fulfilling environmental policies. Huberman (2009) concludes that the WH list strengthens PES schemes, because the global known WH status promotes the links between foreign donors and local needs. The relevance of PES increases around a WH site to ensure the continuity of specific natural or cultural attributes within the criteria of the WH convention. However, Nuppenau (2002) pointed out that policies with PES schemes are difficult to evaluate because PES agreements represent a principal-agent issue. On the one hand, the farmers' (the agents') interest is to maximize profits, according to their behavior as *homo economicus*. On the other hand, the public (the principal) wants to protect environmental services. Furthermore, Kronenberg and Hubacek (2013) warn that PES schemes could lead to a resource curse because PES programs could centralize revenues on a few activities, leading to dependency on PES in the long term. Therefore, PES schemes should be complemented with further mechanisms to avoid the lack of diversification among regional producers.

WH status creates visibility in delimited agricultural areas. Tourists are attracted to visit the WH sites, recovering domestic economic activities. Further, funders of PES schemes perceive the needs related to environmental and social protection within the WH zone, launching agreements with local farmers. Overall, it is expected that WH status promotes not only tourism and PES programs but can also enhance the income of the local growers.

### 3 | Data and Methods

#### 3.1 | Sources of Data

The WH border was delimited according to georeferenced coordinates, defined by UNESCO (2011) during the inscription of the

Colombian Coffee Cultural Landscape in the WH list in 2011. The coordinates of the main zone and the buffer zone at the WH area for this study were taken from the Colombian Ministry of Culture (2017), which is the national authority in charge of the protection of the WH area. The buffer zone is a protection frame of the main area of the WH. Both the buffer zone and the main zone constitute the WH area. *"The CCLC contains very few contemporary incongruous additions to its traditional architectural and landscape patterns, and no substantial modifications to the small towns located in the property as well as in the buffer zone. Aspects such as traditions, language, and other forms of intangible heritage, have been preserved, mostly by owners and the local community, who have a high sense of social appropriation of their cultural heritage"* (UNESCO 2011).

Data related to the income of farmers, their participation in tourist networks, the amount of PES, and the number of PES recipients were collected by conducting on-site surveys with 337 coffee farmers in the Western and Central Mountain ranges of the Andes in 2017. The sample covered the departments of Risaralda, Quindio, Caldas, and Valle del Cauca, which represent the most traditional coffee production regions in Colombia. The dataset contains detailed information on coffee production, household characteristics, socioeconomic information, and environmental variables (Table 1).

The sample selection was focused on farms located closer to the WH border in a frame of 5 km to both sides of the WH frontier, seeking that the observations were consistent in the variable "Distance." The sampling frame is representative of the area and consistent with a simple random sampling of coffee farms along the WH border. Figure 1 shows the spatial distribution of the main zone and the buffer zone of the WH area around the coffee region. The population of coffee farms in the traditional coffee region was 93,500 (Dane 2016). Following the classic Cochran formula (1977) in Equation (1), the sample size should be higher than 336.8 observations, where  $e$  is a margin of error of 5.34%,  $p$  is the estimated population that confirms the attribute (50%),  $q$  is the

**TABLE 1** | Definition of variables.

Variable	Unit	Definition
Total income	US \$	Monthly total income of coffee growers
Involvement in tourism networks	Dummy	1 if coffee grower is involved in tourism network, otherwise 0
Monthly payment for ES	US \$	Monthly monetary compensation received per coffee grower from PES
Participation in PES schemes	Dummy	1 if coffee farmer is involved in PES schemes; otherwise 0
Organic coffee production	Percentage	Share of organic coffee out of total coffee production
Age	Years	The time someone has been alive
Education	Level	Education level is classified according to the following categories: 1 = None; 2 = Some primary; 3 = Primary completed; 4 = Some secondary; 5 = Secondary completed; 6 = Technical training after secondary; 7 = University
Natural tree cover potential	Score	Predicted percentage of tree cover without human impact, based on 10 summarized variables: annual mean temperature, annual precipitation, precipitation seasonality, mean temperature of the wettest quarter, precipitation of the driest quarter, organic carbon stock from zero to 15 cm, The data on the natural tree cover potential are from Bastin et al. (2019) depth to bedrock, sand content from zero to 15 cm, elevation, and hill-shade
Altitude	Meters	Location of farm above the sea level
Temperature	Celsius	Degrees of hotness or coldness
Location	Coordinates	Geographic coordinates of each farm according to longitude and latitude
Distance to the border	Kilometers	The length of space between the WH border and the farm
Boundary fixed effects	Yes/Not	Set of boundary segment to know which border is the closest to the farm
Membership	Years	Time affiliated to the National Federation of coffee growers
Farm ownership	Dummy	1 if coffee farmer is owner of the farm, or 0 if farmer is not the owner
Alternative cut-off	Km	Distance of new placebo border to the WH border
Political borders	Departments	Frontier between two departments
Land per farm	Hectares	Total area within the farm system
Coffee land	Hectares	Area orientated to coffee production within the farm
Coffee crops in 2007	Hectares	Area per municipality in the coffee region
Coffee crops before 2011	Hectares	Area of coffee fields
Volume of coffee before 2011	Tons	Weight of coffee production

estimated population rejecting the attribute (50%), and z value is 1.96, which is calculated according to a confidence level of 95%.

$$\text{Sample} = \frac{z^2 * p * q}{e^2} \quad (1)$$

We matched satellite images with the georeferenced location of each farm in our database through GIS analysis. The Ministry of Culture that oversees protecting the attributes of the Colombian Coffee Cultural Landscape within the WH provided us with the official georeferenced coordinates of the WH area. Figure 1 shows the approximate distribution of farms within the main zone and the buffer zone of the WH and outside of the WH, protecting the identity and personal information of farmers. GPS coordinates

allowed us to classify the farms in the control group outside the WH and the treatment group inside the WH area (Table 2). Furthermore, we calculated the distance in kilometers from each farm to the closest border of the WH area.

We augmented the dataset with environmental variables, such as the predicted natural tree cover from Bastin et al. (2019), which provides a convenient summary index for natural conditions across Colombia's coffee-growing region. The authors provide a high-resolution, global map of potential tree cover without human impact. For this, Bastin et al. (2019) used a random forest machine-learning algorithm, trained on protected areas all around the world, to predict—based on over 200 environmental and natural variables—the natural tree cover consistently glob-

TABLE 2 | Summary statistics.

Variable	Mean			Std. Dev			Min			Max		
	Pooled	Inside	Outside	Pooled	Inside	Outside	Pooled	Inside	Outside	Pooled	Inside	Outside
<b>A. Coffee farms after WH status</b>												
Total income	902.80	980.37	783.81	989.03	1.111.834	751.83	125	125	125	8000	8000	5100
Involvement in tourism networks	0.26	0.26	0.25	0.44	0.44	0.44	0	0	0	1	1	1
Monthly payment for PES	19.05	21.57	16.44	36.77	40.76	33.47	0	0	0	250	250	201
Participation in PES schemes	0.5	0.52	0.46	0.50	0.50	0.50	0	0	0	1	1	1
Organic coffee production	5.34	5.88	4.51	22.51	23.58	20.83	0	0	0	100	100	100
Age	54.41	55.97	52.05	12.25	11.50	13.02	20	20	20	86	86	79
Education	3.45	3.46	3.44	1.73	1.73	1.73	1	1	1	7	7	7
Natural tree cover potential	82.37	82.50	82.18	11.678	11.53	11.91	38.05	52.55	38.05	100	100	100
Altitude	1493.41	1475	1521	270.49	249.90	298.14	811	811	989	2391	2391	2262
Temperature	19.83	19.6	20.19	1.94	1.60	2.33	17	17	17	28	27	28
Membership	4.05	4.01	4.02	2.64	2.59	2.74	0	1	0	10	10	10
Farm ownership	0.96	0.99	0.92	0.19	0.09	0.28	0	0	0	1	1	1
Distance to border	0.23	1.01	2.14	1.82	0.96	1.02	0	0	0	4.15	4.15	4.13
Location (latitude)	4.98	4.98	4.99	0.19	0.17	0.21	4.50	4.51	4.50	5.31	5.29	5.31
Location (longitude)	−75.87	−75.85	−75.88	0.12	0.12	0.12	−76.13	−76.13	−76.10	−75.59	−75.59	−75.62
Boundary fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Land area per farm	9.89	10.17	9.46	12.39	12.96	11.50	1	1	1	90	90	80
Coffee land	5.62	5.47	5.85	6.65	5.93	7.65	0.07	0.07	0.07	56	33.75	56
N	337	204	133									
<b>B. Coffee production before WH</b>												
Coffee crops in 2007 (per municipality)	61			2264			2778			9268		
N	90											
Coffee crops before 2011	1.9	1.8	2.0	4.90	4.06	5.38	0.01	0.01	0.01	261	100	261
Volume of coffee before 2011	2.1	2.0	2.2	5.46	4.67	5.91	0.01	0.01	0.01	281	126	281
N	75077	29552	45525									

Note: A. Data based on survey to 337 coffee farmers in the Western and Central mountain ranges of The Andes in Colombia. B. Data from the National Agricultural Evaluation (Ministry of Agriculture 2022) and the Third National Agricultural Census (Dane 2016).

ally without human impact (with a spatial resolution of 30 arc sec). The predictive variables were then summarized in factor variables local, capturing annual mean temperature, annual precipitation, precipitation seasonality, mean temperature of the wettest quarter, precipitation of the driest quarter, organic carbon stock from 0 to 15 cm, depth to bedrock, sand content from 0 to 15 cm, elevation, and hill-shade. The random forest machine-learning algorithm linked these 10 variables to predict the natural tree cover potential in percentage. We matched this data to our farm-level dataset to test whether we would find any discontinuity in the natural vegetation across the WH border. We added to the global map of tree cover potential a layer in GIS software with the GPS location of each farm. The machine-learning algorithm of Bastian et al. (2019) provided the score of tree cover potential to the geographical coordinates of each farm. The smooth transition in this pre-existing outcome confirms the environmental homogeneity in the WH border region.

Data related to coffee crops before the WH status is based on two sources. First, we used the database from the Ministry of Agriculture (2022) that includes the annual report of national agricultural production between 2007 and 2018 for each municipality in Colombia. We matched the data of coffee production in 2007 with the GPS location of coffee farms from our sample and the coordinates of the WH border through GIS software. The analysis allows us to illustrate the homogeneity of coffee production around the traditional coffee region before the WH status. Second, the Third National Agricultural Census provided data on both hectares of coffee crops and coffee production in tons (Dane 2016). Furthermore, from the same Census, we extracted data related to the year of the coffee plantation and the village where each coffee plantation was located. Dane (2016) reported 93,500 coffee fields in the traditional coffee region among the departments of Caldas, Quindio, Risaralda, and Valle del Cauca. According to Dane (2016), 80% of coffee crops in the traditional coffee region were planted before the WH status. We used this sample of 75,000 coffee crops to test homogeneity in coffee production inside and outside of the WH area before the WH status.

Finally, we imported the satellite image and data of night-time lights in 2009, processed by the National Oceanic and Atmospheric Administration from the Department of Commerce of USA Government, and collected by US Air Force Weather Agency (NOOA 2014). We designed a GIS map to illustrate the distribution of modern urban settlements, which helps to explain the fragmentation among the six discontinuous WH subzones within the bigger area of the traditional coffee region.<sup>3</sup>

### 3.2 | Empirical Strategy

As the WH status establishes a spatial boundary, we estimate its causal effect on income using a RDD<sup>4</sup>; for details, see Wuepper and Finger (2023). RDD allows us to assess the treatment effect of WH status on coffee growers' income in the traditional Colombian coffee region. The cutoff is the WH border between similar coffee farms. We examine whether the WH border leads to discontinuity in the income of coffee growers, according to their location and the known covariates, latitude, and longitude, from the georeference of each coffee farm. We included farms less than 5 km from the WH border, evaluating the treatment effect

on a homogenous group close to the WH boundaries. The control group includes farms up to 5 km to the border outside of the WH, while the treatment group included farms up to 5 km to the border inside the WH, located in the coffee region in the Andes. RDD reduces the bias by choosing the sample with observations closer to the border and dismissing observations located far away from the cutoff. The sample of observations closer to the border allows us to analyze farms in similar geographical and environmental conditions.

A central assumption of the RDD is that there is no treatment confounding. The only difference is the threshold of the WH border. We explicitly tested the RDD assumption, evaluating discontinuity in different confounding variables, following the best practices suggested by Alix-Garcia et al. (2018) and Wuepper and Finger (2023). We tested environmental variables like the natural tree cover potential, altitude, and temperature. In addition, we tested discontinuity in social variables like age, education, and farm ownership. We tested homogeneity in coffee crops (hectares) and volume in coffee production (tons) before the WH status. Further, we evaluated discontinuity according to political borders between departments. Finally, we tested the RDD assumption by estimating "placebo" borders.

The WH border forms a deterministic and discontinuous function of covariates (longitude and latitude) (Cattaneo, Idrobo, and Titiunik 2019). The two-dimensional spatial identification of longitude and latitude allowed us to perform a more robust interpretation across the boundary (Keele and Titiunik 2015). The threshold is the border drawn by the geographical coordinates of the WH status, which divides two similar groups of coffee farms. Every coffee farm received a score according to its geographic location (Dell 2010). The distance score at the cutoff is zero. Distance to the right of zero refers to farms inside the WH area, and distance to the left of zero refers to farms outside of the WH. The score of the distance of farms inside the WH area to the WH border receives a positive sign, and the distance of farms located outside of the WH area are marked with a score with a negative sign for the representation in the figures. RDD analyzes discontinuity between observations with the minimum score eligible by the WH status and observations with deficient scores to be included in the WH area. Therefore, RDD estimates causal treatment effects of farms near the border. Finally, "Distance" should be continuously distributed near the cutoff, ensuring the presence of observations closer to the border (Calonico et al. 2014).

The RDD identifies causal treatment effects close to the threshold that determines treatment assignment (given the validity of all identifying assumptions, such as that the border is exogenous, etc.). RDD is needed in our analysis as a transparent method to reflect the causal treatment effect of the WH status, rather than using the simple comparison of mean incomes inside and outside the WH border. Comparing means inside and outside the WH border would give a highly biased estimate for the causal income effect. The estimation of RDD does not intend to estimate differences within each subsample, but between both groups. The jump at the threshold between the control group and the treatment group is a transparent validation of RDD.

First, we used the haversine formula (Aldieri and Cincera 2007) in Equation (2) to calculate the distance from the geographic coor-

dinates  $(\delta_1, \varphi_1)$  of each coffee farm to the coordinates  $(\delta_2, \varphi_2)$  of the closest point in the WH border.  $Distance_i$  represents the kilometers of each observation  $i$  to the border, according to the geographical coordinates of longitude  $\delta$  and latitude  $\varphi$ . Finally,  $r$  is the Earth's radius (6371 km).

$$Distance_i = 2r \sin^{-1}$$

$$\left( \sqrt{\sin^2 \left( \frac{\varphi_1 - \varphi_2}{2} \right) + \cos(\varphi_1) \cos(\varphi_2) \sin^2 \left( \frac{\delta_1 - \delta_2}{2} \right)} \right) \quad (2)$$

Second, we used  $Distance_i$  from Equation (2) to estimate regressions in the following form in Equation (3):

$$Y_i = \alpha + \beta D_i + \gamma X'_i + Distance_i + \Phi_i + \varepsilon_i \quad (3)$$

where  $Y_i$  is the income of farm  $i$ ; indicator  $D_i$  takes the value of 1 if the farm is located inside of the WH, and 0 otherwise. The covariates age, farm ownership, years of membership in the National Federation of Coffee Growers, and Education are denoted as  $X'_i$ .  $Distance_i$  from Equation (2) is the RD running variable.  $\Phi_i$  is a set of boundary segment fixed effects and the error term,  $\varepsilon_i$ . We estimate the model using the robust local polynomial framework of Calonico et al. (2014), and as a sensitivity check, we report the results for using linear, quadratic, and cubic polynomials. The optimal bandwidth is computed by minimizing the mean squared error (MSE), according to Calonico et al. (2020), following the best practices and statistical selection of an optimal bandwidth for the RDD (Calonico et al. 2014). The optimal bandwidth is 1126 km on each side of the WH border.

We controlled the municipality fixed effect with Equation (4), where:  $\gamma$  is total income;  $\chi$  is the distance to the WH border;  $\beta$  is the coefficient for  $\chi$ ;  $\alpha$  is the municipality fixed effect;  $\varepsilon$  is the error term; and  $i$  is the coffee farm.

$$\gamma = \chi_i \beta + \alpha_i + \varepsilon_i \quad (4)$$

Finally, standard errors are clustered spatially across the 100 nearest neighbors to account for the spatial dependence of observations. Observations are binned, such that the sample estimator is delimited according to the confidence intervals (CI), where each bin represents a smaller interval of data to reduce the effect of minor observation errors (Calonico et al. 2015). The number of bins is defined by using the mimicking variance evenly-spaced method based on spacing estimators.

## 4 | Results

The results section is organized into four parts. First, we estimated the discontinuity of total income at the WH border. Second, we tested the external validity through the Treatment Effect Derivative (TED). Finally, we consider the mechanisms underlying the income effect due to the involvement of farmers in tourism networks and their participation in PES schemes.

Figures 5–17 include the fitted regression lines and show the different effects of the WH site that we confirm econometrically

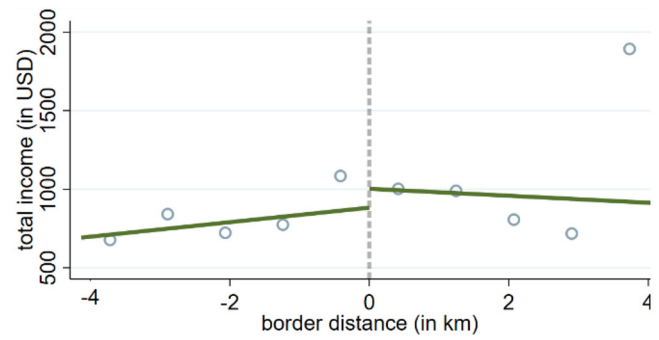


FIGURE 7 | RD effect of WH on total income—first polynomial order.

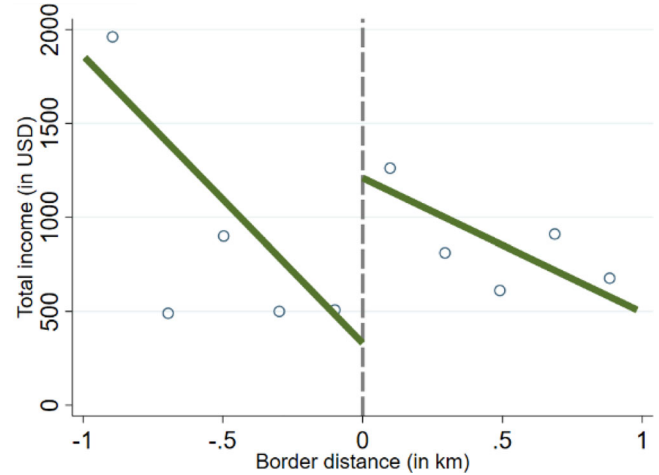


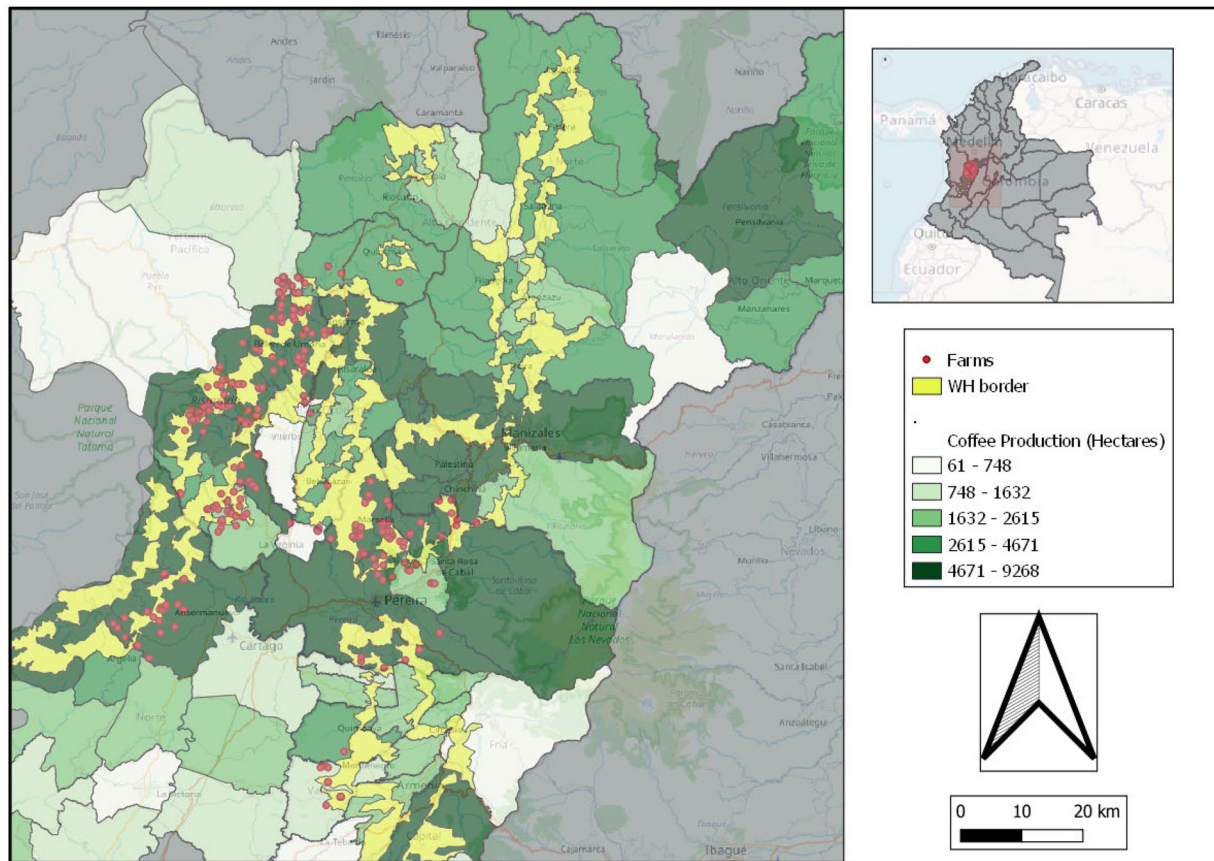
FIGURE 8 | RD effect of WH on total income—with all covariates (optimal bandwidth ~1 km).

below. The left side in the figures represents the area outside of the WH status, and the right side represents the area included in the WH. The dots are bins of local averages of the outcome variable, focusing on total farm income, income from tourism, and income from payments for ecosystem services. In our analysis, we use the local polynomial regression of Calonico et al. (2014), however, Gelman and Imbens (2019) suggest using a linear polynomial as baseline, and quadratic and other polynomial versions for sensitivity checks.

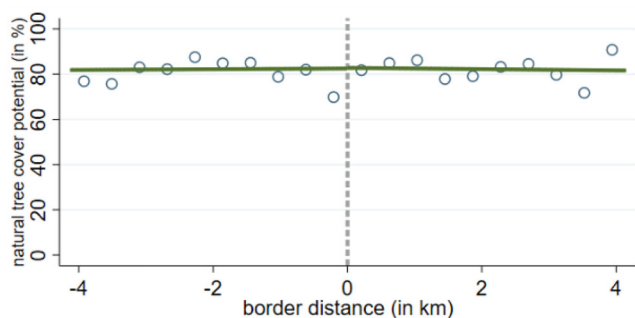
### 4.1 | WH Effect on Income

Farms located inside the WH receive higher income than farms outside of the WH, as presented in Figures 5 and 6. The regression discontinuity effect of the WH status on farmers' income is 756.97 USD, which is significant at the 5% level (Table 3). Farms close to the cut-off embody similar characteristics with the main difference being the causal effect illustrated by the gap in the linear regression.

The mean income inside the WH site is \$980, and outside is \$783. However, the causal income effect identified by the RDD is \$757 – much larger than the mean-difference of \$197. The reason is that away from the WH border, the farms lose comparability. Using the RDD, we avoid selection bias, in contrast to a comparison of



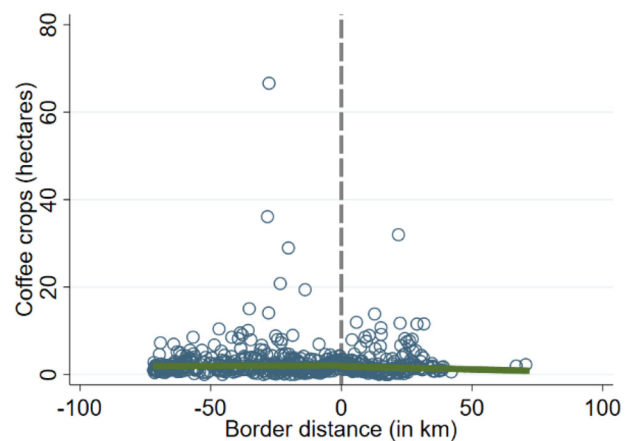
**FIGURE 9** | Coffee production (hectares) in the traditional coffee region in 2007.



**FIGURE 10** | No discontinuity in the natural tree cover potential at the WH border.

means, which might be affected by selection bias. We estimate that the statistically optimal bandwidth is about 1 km on each side of the border, and there, the fitted regressions lead to a much larger causal estimate than suggested by comparing simple means. We identify these causal effects right at the border. Figure 7 shows the data of our full sample, which indicates small income differences, while Figure 8, in contrast, shows the raw data from our statistically optimal sample (within 1 km away from the border), which indicates a large income difference.

We controlled further covariates, considering that some farmers' features could lead to higher income to prove the robustness of the WH effect on farmers' income (Calonico et al. 2019). For instance, age, farm ownership, or the membership years



**FIGURE 11** | No discontinuity in coffee crops before the WH status.

within the National Federation of Coffee Growers (FNC) could change farmers' decision-making process. The FNC provides technical support services to the coffee growers, and the structure of cooperatives and agricultural associations offers knowledge transfer to coffee producers. These features are related to the experience of coffee production; therefore, these covariates could affect the management in handling production features. Table 3 shows that the regression discontinuity effect of the WH border on total income is significant, including some control variables. The effect of WH on farmers' income is still significant at 1%

**TABLE 3** | RD effect of WH status on Total Income.

Variable	RD estimator	Bandwidth	Left sample	Right sample
<b>A. Polynomial order</b>				
Linear	881.21*** (315.52)	1.052	133	204
Quadratic	985.73*** (337.73)	1.724	133	204
Cubic	974.23** (359.95)	1.499	133	204
<b>B. Additional covariates</b>				
Age	809.44*** (306.52)	1.163	133	204
Farm ownership	856.03*** (315.45)	1.081	133	204
Membership years	639.62** (341.28)	1.135	133	204
Education	544.81** (315.19)	1.455	133	204
Temperature	828.53** (306.47)	1.015	133	204
Natural tree cover	796.52** (347.64)	1.320	133	204
Altitude	880.05** (306.22)	1.078	133	204
Age, farm ownership, membership years, education	756.97** (354.96)	1.126	133	204
Municipality fixed effects	Yes			
<b>C. Adjustments in kernel</b>				
All covariates with Epanechnikov	805.48* (358.08)	0.935	17	113
All covariates with uniform	920.23* (379.65)	0.901	15	111

*Note:* A. Polynomial order refers to the degree of a polynomial in RD effect of WH status on total income. B. Additional covariates reports the RD effect of WH on total income: first, one by one covariate, and finally the covariates together. Kernel: triangular for panels A and B. Optimal bandwidth choice: minimum square error for RD (mserd). Coefficients significant different from zero are denoted with the following system: \*10%, \*\*5%, \*\*\*1%.

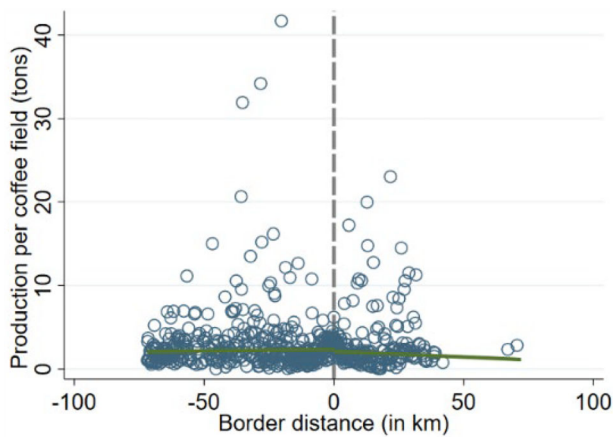
after controlling age and farm ownership, and the RD estimators provide similar results.

If we control the FNC membership of coffee producers measured in years, the RD estimator reduces to \$639.62. Farmers in both treatment and control groups have similar social features such as age, FNC membership, or farm properties. Therefore, the difference in income is related to the distance from the WH border. Still, the effect of WH on total income is significant at 5% after controlling membership in the FNC. The treatment effect of WH status does not result in a huge change with the control variables. Overall, the discontinuity effect of WH status on coffee growers' income remains even with the covariate analysis,

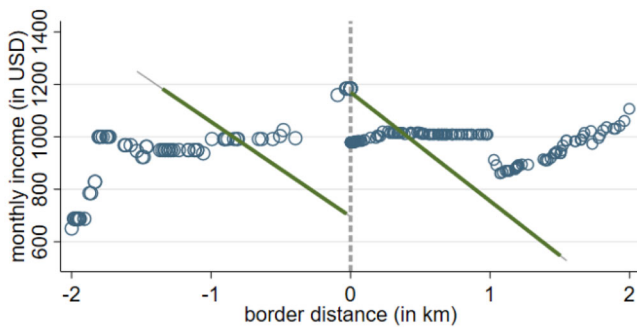
and the causal effect of WH status on farmers' income is still confirmed.

## 4.2 | Testing the Discontinuity of the WH Status

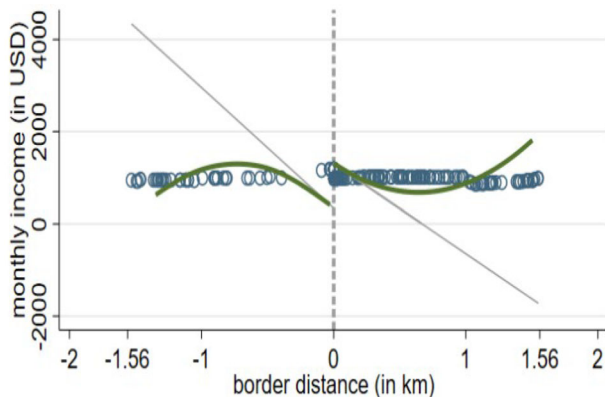
The assumption in our RDD application is the absence of discontinuity in potential confounding variables. First, we tested discontinuity in environmental variables, social variables, and coffee crops before the WH status. Second, we tested the effect on income according to political borders and placebo cut-offs to see whether there could be discontinuity due to other borders and not just because of the WH frontier. Results of non-



**FIGURE 12** | No discontinuity in the volume of coffee production before the WH status.

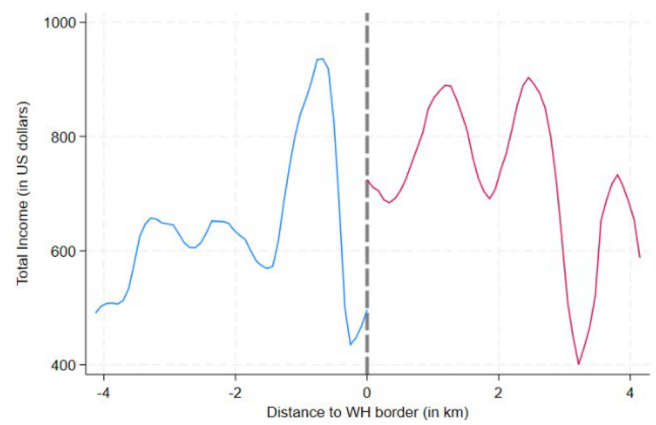


**FIGURE 13** | Test of stability TED of linear polynomial order.

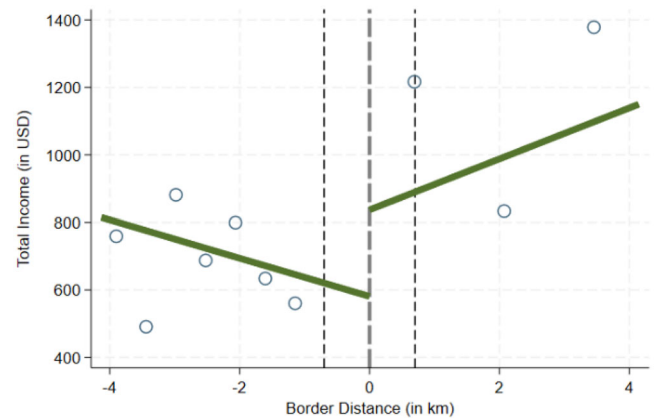


**FIGURE 14** | Test of stability TED of quadratic polynomial order.

significance in discontinuity are reported in Table 4. A density test does not apply like a robust test in this case because it could mislead the findings about the sorting of coffee farmers (McCrary 2008). We collected data by surveys through random sampling, and a density test would estimate the density of our sampling rather than the density of coffee farms around the border. Panel C in Table 4 shows a negative marginal difference in coffee production before the WH status. Even though the result is not significant. The coffee region was bigger than the zone included in the WH status. This lack of discontinuity supports the opportunity for RDD analysis, where there are two groups



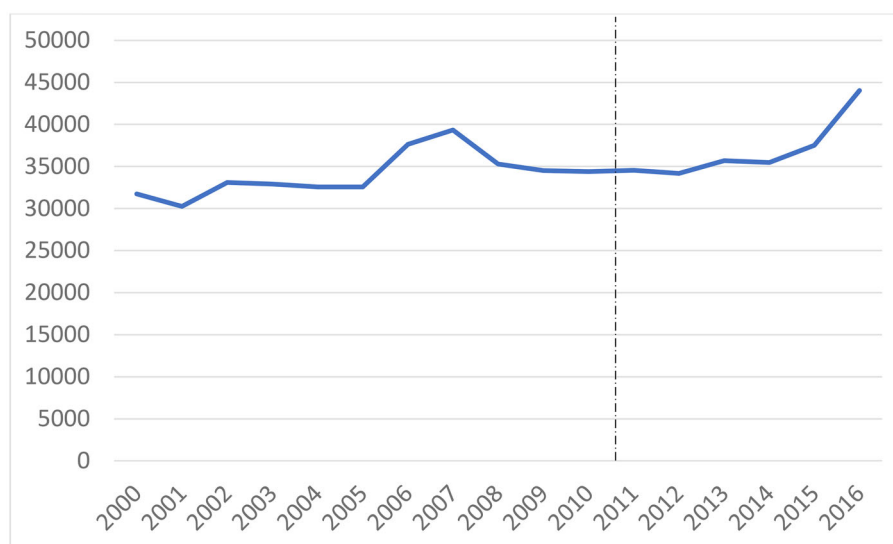
**FIGURE 15** | Kernel-weighted local polynomial.



**FIGURE 16** | Donut test of total income without observations within 1 km.

of coffee farms with similar characteristics divided by a policy intervention.

The WH border was drawn within the traditional coffee region, disrupting the homogenous zone of coffee production. The map in Figure 9 shows us that coffee production was not limited to the areas included in the WH status. The map was designed on GIS software, based on data of 2007 from the Ministry of Agriculture (2022), matched with the WH coordinates provided by the Ministry of Culture, and the location of farms collected in our sample. The map shows that some municipalities were excluded from the WH status, while they had more hectares of coffee fields than other municipalities that were included in the WH area. Therefore, the WH border does not represent a sharp division between areas with coffee farms and areas without coffee production, neither the WH border was focused just on municipalities with the biggest coffee production. The reason is that the criteria for the WH border was not just coffee production but also the protection of traditional architecture. Coffee farmers were divided by the invisible WH border into two areas. The closer to the WH border, the more similar the coffee farms located at both sides of the frontier along the coffee region. The sample focused on observations close to the border reduces the influence of confounding factors, allowing the comparison across the threshold. Traditional coffee production is developed across the border in the same natural conditions.



**FIGURE 17** | Farm Sales in the WH area 2000–2016.

Environmental conditions should be the same inside and outside the WH area. We analyzed the natural tree cover potential through the photo-interpreted map of Bastin et al. (2019). The effect of the WH border on natural tree cover potential is not significant in Table 4. The zone outside of the WH has similar environmental conditions as those inside the WH area in Figure 10. Both groups represent the most similar case for comparison through regression discontinuity analysis. Similar environmental conditions around the sample of farms confirm that the WH border is the only difference between the control group and the treatment group.

We tested homogeneity among coffee crops across the WH border before the WH status based on data from the Third National Agricultural Census (Dane 2016). Figure 11 shows us that hectares of coffee crops planted before the WH status were homogenous inside and outside of the WH area. In addition, Figure 12 shows the absence of discontinuity across the WH border, based on the volume of coffee production (tons) among coffee fields planted before the WH status. The coffee region is bigger than the WH area, and coffee production was homogenous around the WH border.

We tested whether the effect on farmers' income is not found in "placebo" specifications based on artificial cut-offs away from the actual border (Cattaneo et al. 2019). It is expected that the discontinuity is present right at the WH border but not elsewhere. There should be no statistically significant discontinuities in random places where the border is not actually located. The placebo test in Table 4 proves the RDD model in artificial borders, moving the cut-off one (–1) or two (–2) kilometers to the left and one (1) or two (2) kilometers to the right of the WH border. Panel D in Table 4 shows us that there is no discontinuity in total income if we consider alternative points like the threshold for the RDD estimations. The continuity-based analysis of alternative cut-offs proved that there is not another variable around the WH border leading to discontinuity in the total income of coffee growers other than the WH borders.

We also considered whether differences in the total income of coffee growers are due to political borders rather than the WH frontier. Each Department has a local government with their policy packages. It is expected that the difference in the political territory could lead to discontinuity in the total income of coffee growers across the political border. We conducted an RDD analysis using like threshold the political frontiers of the departments in three different estimations: RDD of total income among coffee farms located in the departments of Valle del Cauca and Quindio, and the distance to the political border like the running variable. We estimated the same analysis among coffee farms across the border of Valle del Cauca and Risaralda, and Quindio and Risaralda, finding again no discontinuity in income of coffee growers. Our results on political borders are reported in Table 4.

We analyzed additional pre-treatment variables, such as temperature and altitude, and no discontinuity was detected. Further, we tested if the WH border was correlated to differences in social variables, like age, education level, or farm ownership, between both groups of coffee farmers, inside and outside of the WH area. Table 4 shows that there was no discontinuity at the WH border driven by social or environmental variables.

### 4.3 | Test of Stability

RDD models were used to identify the local treatment effect; therefore, some results could be unstable and lack external validity. We checked the external validity of the regression discontinuity model through a test of stability on Table 5, which evaluated whether changes in covariates would change the discontinuity effect (Dong and Lewbel 2015). If discontinuity at the border is consistent, even with changes in other variables, this would confirm that the discontinuity is because of the border and not because of other factors. In that case, the results of RDD would be robust in explaining the causal effect.

**TABLE 4** | Test for discontinuity of the WH status.

Variable	RD estimator	Bandwidth	Left sample	Right sample
<b>A. Environmental variables</b>				
Natural tree cover potential	12.14 (−9.068)	1.791	39	151
Altitude	11.985 (−64.323)	1.535	19	122
Temperature	0.704 (0.480)	2.206	37	145
<b>B. Social variables</b>				
Age	−5.447 (−5.561)	1.977	43	159
Education	−0.084 (0.836)	1.973	46	161
Farm ownership	0.232 (0.154)	2.656	81	181
<b>C. Coffee production before WH status</b>				
Coffee crops (hectares) before WH	−0.063 (0.051)	0.162	37562	29418
Volume of production of coffee crops before WH (tons)	−0.066 (0.058)	0.105	175	87
<b>D. Alternative cut-off</b>				
−2 km	133.49 (347.33)	1.339	64	69
−1 km	2490.6 (1860.6)	0.438	115	18
+1 km	658.55 (368.18)	0.756	117	87
+2 km	121.42 (462.86)	0.774	170	34
<b>E. Political borders</b>				
Quindio/Risaralda	3410.3	60	19	235
Valle/Risaralda	664.62	70	32	19
Valle / Quindio	10891	37	32	274

Note: A, B, and C report pre-treatment environmental, social and coffee production variables like outcome variables. D refers to tests for discontinuities at alternatives thresholds to  $\pm$  km to the WH border. E evaluates discontinuity according to the borders of Departments. Kernel: triangular. Optimal bandwidth choice: minimum square error for RD (mserd). None of the results were statistically significant.

The test in Table 5 shows how the TED estimates the local average treatment effect change if the regression discontinuity threshold changes (Cerulli et al. 2017). TED proves the model stability in the RDD around the WH border as well as its external validity. The significance of this test is assessed with the  $p$  value of the estimated coefficient. If, ceteris paribus, a small change in the independent variable leads to a significant change in the average treatment effect, the RDD model would be unstable and lack external validity. In contrast, if a change in the treatment effect

is small and non-significant, RDD at the original cut-off point could be more reliable. The parallel tangent lines in Figures 13 and 14 suggest model stability in the TED test. Therefore, a change in the average treatment effect is non-significant, and the RDD based on the causal effect of the WH border is robust. Results reported in Table 5 show that changes due to model instability are not significant for total income, confirming stability and external validity. We tested the model in linear, quadratic, and cubic polynomial orders.

**TABLE 5** | Test of stability—treatment effect derivative (TED) for total income.

Polynomial order	Coefficient	S.E	p value
Linear	−52.82	377.92	0.889
Quadratic	656.84	1547.87	0.671
Cubic	−2932.39	3241.25	0.366

Note: This table reports test of stability TED for total income. The significance of this test is assessed with the *p* value of the estimated coefficient. Kernel: triangular. Optimal bandwidth choice: minimum square error for RD (mserd). None of the results are significant, according to *p* value.

#### 4.4 | Kernel-Weighted Local Polynomial

We tested discontinuity by estimation of kernel-weighted local polynomial at the WH border in Figure 15. The non-parametric estimator has parameters that control the local weights and the size of the neighborhood used for estimation. The method combines multiple regression models in k-nearest-neighbor-based model. We confirmed a jump in total income across the WH border.

#### 4.5 | Endogenous Sorting

We tested endogenous sorting by a donut test in Figure 16 (Barreca et al. 2016), where we ignored the observations located within 1 km of the border, whether inside or outside of the WH border. The donut test solves concerns about the systematic sorting of coffee farms around the WH area, which could distort the estimations of the RD effect of the WH border.

We complemented the analysis of potential endogenous sorting, inquiring about the migration of coffee growers toward the WH area and rising income in coffee farms. We examined farm sales records as empirical evidence of changes in the owners of the land. However, we did not find adjustments in the patterns of land sales. The WH border does not follow a specific territorial division between native population groups, and the whole area is known as the coffee region. Coffee growers do not migrate their coffee production to another place, even if the economic conditions change over time. Unlike coffee growers, harvesters<sup>5</sup> used to migrate to the coffee region during the harvesting period. Temporal migration of harvesters satisfies the need for seasonal labor to collect the beans from the coffee trees (Carriazo et al. 2002). Rather, families of coffee growers do not move coffee production from one location to another. The permanence of coffee grower families in the zone helped to build the coffee cultural landscape, which is embodied by the roots of strong family traditions. Figures 17 and 18 show us that property sales inside the WH area followed the business cycle as usual without increasing extensively. There was not a wave of migration and investments into the zone after the WH status; rather, local coffee growers turned their own farms into touristic destinations. Figure 18 shows farm sales without the main cities in the region: Pereira, Armenia, and Manizales, considering that traditional coffee farms are located mainly in rural areas. The flat farm sales figures show that coffee farms have been owned by the same families before and after the WH status without endogenous sorting

around 2011. The WH border made the difference between both sides.

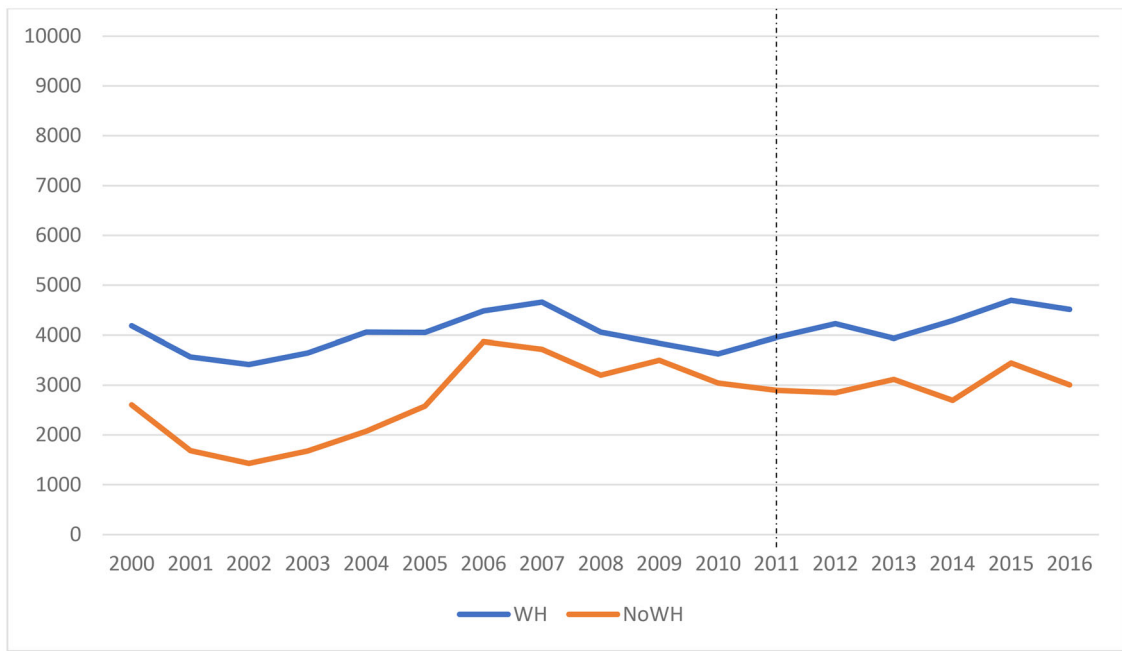
There was no migration of coffee farmers from outside of the WH area to inside after the UNESCO designation. Coffee growers remained in their original farms inside or outside of the WH area within the coffee region, which is bigger than the WH zone. The migration of coffee growers between rural areas is unusual, according to the FNC (2021).

The tradition of staying in the same place to produce coffee is one of the characteristics highlighted by UNESCO to include the traditional coffee region in the WH list. Two socio-economic characteristics helped to build their cultural landscape. First, coffee farmers inherited a long coffee tradition within the farms of their families. The study from the Economics Research Department of FNC applied a survey to the directors of local committees of coffee growers, reporting that 76% of survey respondents consider that coffee growers remain in the coffee activity because coffee production is a familiar tradition (FNC 2021). The cultural heritage of coffee growers affects their willingness to change, even during the downswing of coffee prices. The strong roots of coffee families called the attention of UNESCO, which remarked the Authenticity of the Colombian Coffee Cultural Landscape for its designation like WH: “Aspects such as traditions, language and other forms of intangible heritage, have been preserved, mostly by owners and the local community, who have a high sense of social appropriation of their cultural heritage” (UNESCO 2011). The current coffee farm owners in the whole region are predominantly families who have owned these farms for generations. The second characteristic is that coffee families are small producers. The average of coffee crops inside the WH is 2.6 hectares (Ministry of Culture 2017). Permanent labor is represented by the coffee family itself, and therefore, the WH in Colombia is a lived landscape. Coffee families do not receive large-scale outside investments. Rather, one of the main criteria of PES programs is to offer benefits to small coffee growers, leading to a higher impact from the economic incentive for the environmental service provision.

#### 4.6 | Mechanisms Increasing Income of Farmers

In this part, we explain the relationship between the WH status and the higher income of coffee growers. The regression discontinuity effect of WH status on involvement in tourism networks is highly significant, as presented in Table 6.

The tourism plan in the document for the nomination of the CCL to the WH list pursued to avoid mass tourism by promoting sustainable tourism within the productive vocation of the coffee land (Ministry of Culture 2010). Coffee farms inside the WH zone already had the architectural heritage for the coffee cultural experience. However, tourists used to go to just 16 out of the 47 municipalities with “veredas” located inside the WH area before the WH status (Ministry of Culture 2009). By contrast, after the inscription of the Colombian Coffee Cultural Landscape in the WH List in 2011, 84% of tourists who arrived by flight to the coffee region stayed at the municipalities with “veredas” included in the WH status (SITUR 2018). Coffee growers have adapted their farms after the WH status into restaurants with



**FIGURE 18** | Farm Sales in the coffee region 2000–2016 without urban centers.

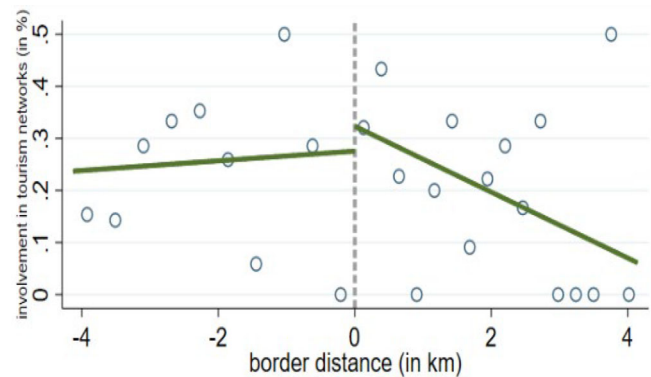
**TABLE 6** | RD effect of WH status on mechanisms increasing income.

Variable	RD estimator	Bandwidth	Left sample	Right sample
Involvement in tourism networks	0.39*** (0.075)	0.925	133	204
Monthly payment for ES	17.77* (9.245)	1.085	133	204
Participation in PES schemes	0.39* (0.223)	1.405	133	204
Organic coffee production	0.08** (0.035)	1.485	133	204
Coffee Revenue	340.67** (115.64)	1.138	133	204

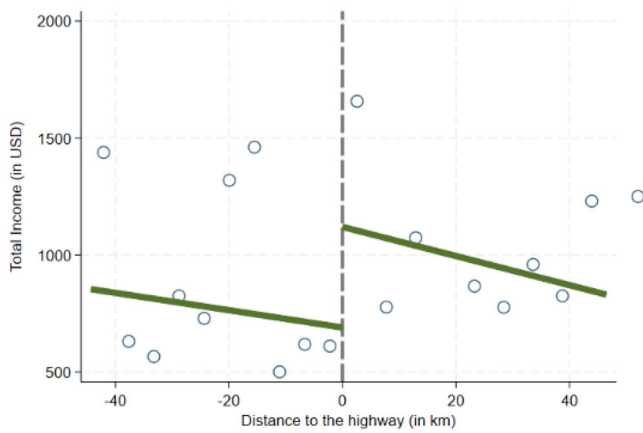
*Note:* This table reports RD effect of WH status on mechanisms increasing income: Involvement in tourism networks, Monthly payment for ES, Participation in PES schemes and organic coffee production. Kernel: triangular. Optimal bandwidth choice: minimum square error for RD (mserd). Coefficients significant different from zero are denoted with the following system: \*10%, \*\*5%, \*\*\*1%.

traditional gastronomy, spa centers, hotels, or handicraft shops, where tourists can feel immersed in traditional coffee culture.

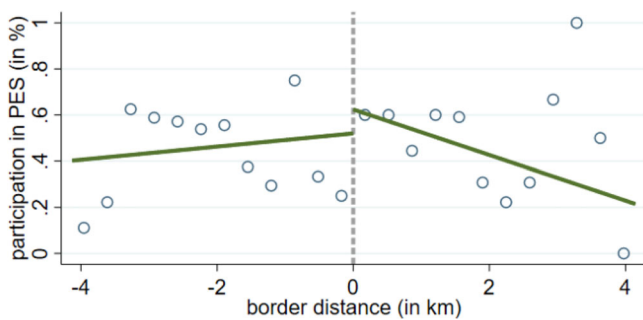
Farmers inside the WH zone include tourism supply and participation in tourism committees in their agricultural activities at a higher level than growers outside of the WH. The WH status allowed the diversification of traditional coffee producers' income through tourism networks around the Colombian coffee culture (Figure 19). Tourism around coffee culture ensures the continuity of coffee production. Tourism networks were complemented by easier access to the WH areas by increasing investments in road infrastructure after the WH status in 2011. Figure 20 reports the RD effect of the distance from each coffee farm to the closest frame of the highway network built or adjusted after 2011. The distance represents the kilometers from coffee farms to



**FIGURE 19** | RD effect of WH on involvement in tourism networks.



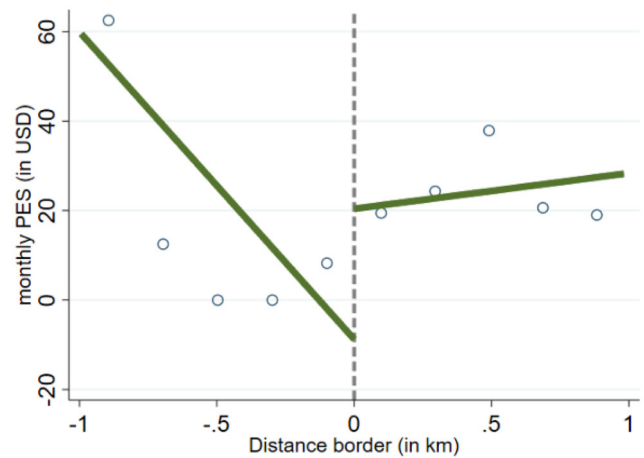
**FIGURE 20** | RD effect of road network on total income in coffee farms.



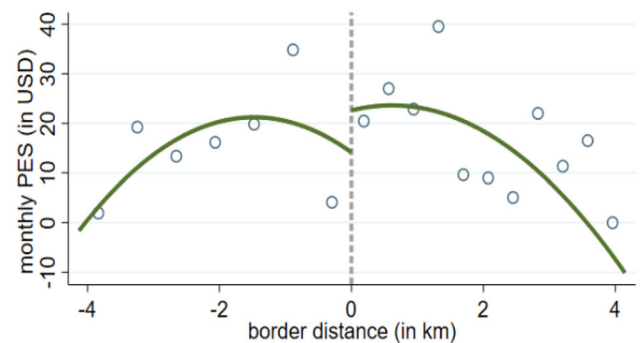
**FIGURE 21** | RD effect of WH on participation of farmers in PES.

the highway network. The sign represents the location of coffee farms, being outside (negative) or inside (positive) of the WH area. Results are consistent with Su and Lin (2014), which indicate a positive relationship between having WH sites and tourism activity. The economic opportunities found by coffee farmers within the WH area confirm the conclusion of Wuepper (2017) about more likely benefit from WH branding in rural settlements through conservation and economic incentives.

One of the attractions for tourists is the coffee landscape. The biodiversity in the Western and Central Mountain ranges of the Andes around coffee production offers environmental services for visitors. Coffee farmers receive economic incentives from the government, NGOs, and private firms if they actively protect forests, watersheds, biodiversity, or the cultural landscape. The PESs contribute as a mechanism to ensure the income of coffee families through formal agreements. PES represents both additional income for coffee growers and the protection of the environment. The regression discontinuity effect of WH status on the participation of coffee growers in PES is significant at 10% in Table 6. There is a jump across the border of the WH area according to participation in PES schemes (Figure 21). PES can offer an additional source of income for coffee growers facing uncertainty of price volatility in the coffee market. The regression discontinuity effect of the WH border on monthly PES is significant at 10% in Table 6. The RDD estimator of the monthly PES amount is 17.7 USD, which represents 2.35% of the share in monthly income increase of 756.97 USD across the WH border.



**FIGURE 22** | RD effect of WH on the monthly payments for ES (linear polynomial order).

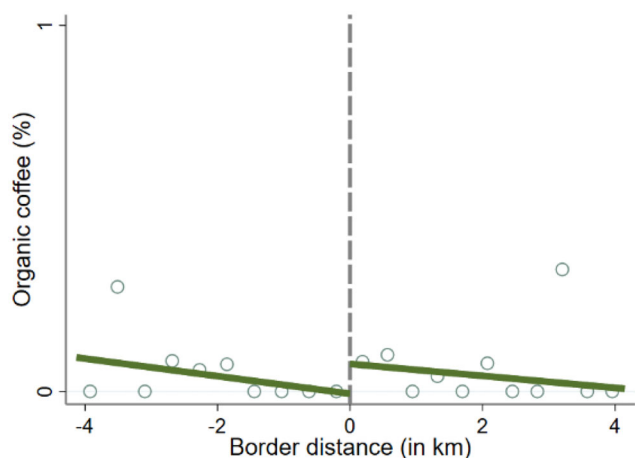


**FIGURE 23** | RD effect of WH on the monthly payments for ES (quadratic polynomial order).

PES has become a mechanism to complement the income of coffee growers inside the WH area (Figures 22 and 23).

Finally, PES schemes promoted cleaner practices around coffee crops inside the WH, leading to the specific attributes of organic coffee. Higher quality is represented by higher prices for customers. Discontinuity for organic coffee production is significant inside the WH area at 5% (Table 6). Higher production of quality coffee (8.38%) is an additional mechanism to increase the income of farmers inside of the WH (Figure 24). The WH status promoted sustainable production and environmental protection of the WH area, increasing organic coffee production in response to coffee producers to the WH status. We tested the RD effect of the WH border on coffee production itself. Table 6 reports discontinuity at the border in coffee revenue. Discontinuity shows that WH status not just increases tourism and environmental protection, but WH also helps to preserve coffee production.

The economic incentives to promote the balance between coffee production, environmental protection, and social stability are articulated to the suggestions from UNESCO. The Management Plan for the Coffee Cultural Landscape of Colombia by UNESCO (2009) mentions the legal tools to defend the recognition of “Café de Colombia” as Protected Geographic Indication (PGI). These guidelines call for the intervention of governments to defend the unique social and environmental conditions of the



**FIGURE 24** | RD effect of WH on organic coffee production.

WH. PES answer to this initiative, drawing green corridors within the WH borders and next to the river basins. Most PES programs target coffee farms inside the WH area. PES programs include communication platforms that connect coffee farmers with donors, like Banco2 (2024) <https://banco2.com/>. Donors could choose the location of the coffee farm, and they could read a brief review of the coffee families.

Colombia is well known for the associative model among coffee producers by the National Federation of Coffee Growers (NFC), which has a long tradition since 1927. NFC is one of the main actors that promote the WH. PES programs like Banco2 and Reforestation of Magdalena River used to provide the economic incentive through the NFC such as intermediary, because of NFC has the governance structure to ensure the channels for communication and financial allocation with local coffee growers.

WH status called the attention of government, private sector, tourists and NGOs over the WH area. Government and private firms designed instruments like PES schemes for environmental protection of coffee cultural landscape increasing monthly income in 2.35%. Cleaner practices around coffee crops inside the WH increased organic coffee production (8.38%). Tourism activities in coffee farms increased 39%. WH status led to PES schemes and touristic networks around coffee farms, which became mechanisms to increase income of coffee growers.

## 5 | Policy Implications

Our findings have implications for policy making. It is much debated whether WH status is actually impacting local livelihoods. For rural communities, there is usually high hope that WH inscription of a site will bring economic benefits, but the empirical evidence is mixed so far (Wuepper 2017; Gao and Su 2019). Particularly for Colombia's coffee farmers, incomes are volatile, both because of market fluctuations and because of environmental shocks that are exacerbated by climate change. Our finding that WH status makes them financially better is encouraging. Results can provide input to policy makers to take advantage of WH status, leading to resilience of the traditional agricultural sector in developing countries. The main findings

promote research opportunities about the allocation of PES and their characteristics.

The case of the Colombian Coffee Cultural Landscape can encourage policymakers in other developing countries to take advantage of traditional agricultural production. Coffee production represents a cultural identity in Colombia. Coffee farmers continue producing coffee because they are entrenched in the identity of being coffee producers as an idiosyncratic feature. The traditional Colombian coffee region confirms that policymakers should consider developing and celebrating local cultural cosmogonies to handle economic crises. In addition, WH status and PES schemes are examples of how local coffee growers could benefit from global initiatives from international organizations like UNESCO or foreign donors. This is an opportunity to strengthen traditional agricultural practices. Coffee growers need additional policies to protect traditional coffee production from land use change. Environmental services are threatened by alternative economic activities, thereby affecting the ecosystem equilibrium. The WH status promoted policies for environmental protection and cultural recognition, which became sources of complementary economic activities and reduced the negative effect of the price crisis on coffee grower income. Furthermore, policymakers should be aware of the risk of providing unfair distribution of PES. Otherwise, environmental protection of the WH area could lead to negative economic consequences for farmers outside of the WH status because tourism and other economic sources focus on a particular area.

The balance between environmental protection and higher income is not perfect in the Colombian Coffee Cultural Landscape. The disruption of the WH border within a municipality, leaving out some coffee farms, makes it more difficult to control the land use by policymakers. Therefore, allowed economic activities in the zone of the municipality outside of the WH permeate the invisible WH borders, threatening the protected areas by the WH status and PES schemes.<sup>6</sup>

## 6 | Conclusion

WH status promotes alternative sources of income for traditional coffee producers. Coffee farms inside the WH border received higher income than farms located outside the WH border. The increased income of coffee growers is supported through three main mechanisms. First, coffee farmers in the WH area became highly involved in tourism networks because the WH status promoted rural tourism in the region. The interest of tourists in emerging local coffee production traditions enabled coffee farmers to complement their income. The government and the universities launched strategies to take advantage of traditional coffee production as a landmark. Local networks of coffee growers adapted their farms to receive tourists who are attracted by the coffee culture; therefore, such tourism operates within the coffee production activities. The daily routine of growers includes exotic practices, which attract the interest of the tourist community. Nonetheless, governments and private firms still have a long way to go to fully take advantage of this label.

Second, the coffee region has become a recipient of PES programs to protect the equilibrium of ecosystems from land use change

after the coffee price crisis. PES supplemented the lack of income after the coffee crisis and provided incentives to protect the Coffee Cultural Landscape highlighted by UNESCO through WH status. Finally, promoting rural tourism and environmental protection propitiated a context for organic coffee production inside the WH area. The different specifications of RDD methods show a jump in total income at the WH border. The jump coincides with discontinuity at the border in the involvement of coffee producers in tourism networks and their participation in PES and organic coffee production. Thus, WH status could be considered an effective incentive to increase total income in rural areas.

Moreover, there is no evidence of endogenous sorting in the coffee region, as most coffee farms are handed down the generations and not sold and bought on a market. Figures 17 and 18 show the lack of changes in the owners of the land like empirical evidence of the patterns of land sales. The discontinuities we estimate reflect that WH status made a difference in the income of coffee farmers inside of the WH area, which is quite sizable and important for the farmers.

Because this study relies on a cross-sectional dataset, a few limitations are implied and shall be discussed. First, the main mechanism of how WH designation increases the farmers' income is increased tourism revenues. This raises the concern of spillovers, either positive ones (like the WH attracting tourists and this could also generate income opportunities nearby, but outside the WH) or negative ones (like the WH attracting tourists who would otherwise spend their money in the places nearby, but outside the WH). These spillovers are unlikely to be substantial, as the increase in tourism income is likely a mix of new visitors who are Only aware of / interested in the region because of the "WH promotion" (Wuepper and Patry 2016) and because these visitors are likely spending more money because they themselves have higher incomes. This suggests little interaction with the regions outside the WH site, either positive or negative. Another limitation is external validity. Our research design, the spatial RDD, arguably achieves high internal validity but in a very local fashion (right at the boundary). It is unclear how much this can be extrapolated spatially, for example, all the way to the center of the WH site. However, we also have no evidence suggesting that the effect at the boundary is a special case or that the context is vastly different from other parts of the region.

Our findings lead to further research questions. For instance, is the higher income of coffee producers in addition to the regular allocation of resources, or is this a zero-sum game, where other producers are losing economic benefits? Are there up-and-down swings in income resilience in the long term after the WH status? Are there other cases of income resilience among agricultural producers within WH sites? Does the adaptation of farms to tourism affect coffee productivity? Overall, the case of the Colombian Coffee Cultural Landscape shows us that the international relevance of the WH status, linked to other mechanisms, such as tourism networks and PES, is effective for promoting higher income among coffee growers after the coffee price crisis.

The environmental conditions close to the WH boundaries are quite similar. Natural tree cover potential percentage describes the same levels both inside and outside of the WH border; therefore, there are no notable differences in the natural environment

across the border. This feature confirms that the farms in the control group and the treatment group have the same environmental opportunities in coffee production. The only major difference between them is their location inside or outside of the WH border.

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## Conflicts of Interest

The authors declare no conflicts of interest.

## Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

## Endnotes

<sup>1</sup> The nightlights map in Figure A3 in the Supporting Appendix illustrates the disruption of some modern infrastructure, leading to discontinuity in the WH area. However, coffee farms are located inside and outside of the WH area.

<sup>2</sup> The "veredas" are the minimum territorial structure in the rural area in Colombia, and they are compared to the neighborhoods of urban settlements. The municipality is integrated by a group of veredas.

<sup>3</sup> The resulted nightlights map in the coffee region is available in the Supporting Appendix in Figure A3.

<sup>4</sup> The spatial regression discontinuity design is based on cross-sectional data and the assumption that there is a continuously distributed variable with a sharp threshold value that is exogenous to the outcomes of interest and that determines treatment assignment (e.g. distance to the WH border and the border is the threshold). RDD is not similar to other methods like difference in differences (diff-in-diff), which is based on the availability of panel data and the assumption that there is a treatment and a control group that were on parallel paths before treatment, such that the diff-in-diff between treatment and control group before and after treatment identifies the causal treatment effect. For an overview of such research designs, see Abadie and Cattaneo (2018).

<sup>5</sup> Labor in coffee production is divided in two categories: permanent labor and seasonal labor. Harvesters represent seasonal labor during the harvesting period to collect the beans from the coffee trees. Coffee production has two harvesting periods: the small one is called 'mitaca' between April and May, which represents 30% of annual coffee production. The main harvesting period is between October and November with 70% of annual coffee production. Coffee growers are farmers, who manage the whole process of coffee production since the planting process of coffee trees until the post-harvesting process. Permanent labor use to be represented by the families of coffee growers. Coffee cultural landscape is mainly embodied by coffee growers. Harvesters come to coffee region from different regions and cultures, even from other countries and stay in the zone just for the harvesting period.

<sup>6</sup> Official data from tourism activity before the WH status was reported at the level of municipality rather than vereda level. There are some municipalities with veredas inside the WH area, and another veredas outside of the WH zone. Therefore, data from tourism authorities is not clear about which share of this municipality data belongs to the WH area.

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### Supporting Information

Additional supporting information can be found online in the Supporting Information section.