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The effect of infrastructure investment on tourism demand: a synthetic control approach for the case of Kuelap, Peru

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Abstract

In this paper we estimate the effect of infrastructure investment on tourism demand. For this purpose, we analyse the case of the Kuelap Archaeological Complex (Peru), which became more attractive and accessible following the construction of Peru's first cable car system and the redevelopment of a nearby airport located in the city of Jaen. In order to estimate the effect of this infrastructure investment package on the number of visitors to Kuelap, we construct a synthetic control using characteristics from several archaeological sites in Peru similar to Kuelap. This synthetic control allows us to estimate the potential number of visits to Kuelap had the infrastructure investment package not been made. Thus, the causal effect is the difference between the actual visits to Kuelap and the ones to the synthetic control. The results show that the number of visits to Kuelap increased by approximately 100% in the wake of the infrastructure investment package.

Keywords Kuelap · Infrastructure investment · Tourism · Synthetic control

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Prior to the COVID-19 pandemic, tourism generated about 10% of the world's GDP and created 1 in 10 jobs worldwide (World Tourism Organization 2019). In Peru, tourism had also been an important economic activity, representing around 4% of GDP. However, since the beginning of the pandemic, tourism has been one of the most affected sectors in the majority of countries due to the closure of international borders and the restriction of non-essential activities. Thus, international tourist arrivals registered a historic contraction of 73% in 2020 and by the end of 2021 it still remains 73% below its prepandemic levels (World Tourism Organization 2022).

Among others, a potential strategy to speed up the recovery of tourism is by improving accessibility to places of interest, which implies building and/or renovating airports and roads, among others. The main purpose of this paper is to estimate the causal effect that such public infrastructure investment may have on tourism demand. For this, we study the case of the Kuelap Archaeological Complex, a tourist site located in the Peruvian Amazon. Kuelap has received more visitors since the opening of the first cable car system in Peru (March 2017) and has benefited from the redevelopment of Jaen airport (one of the closest airports to the archaeological site). This has improved Kuelap's accessibility by increasing the availability of flights to and from Lima, the capital of Peru. The hypothesis of this paper is that this investment package in tourism infrastructure (the construction of the cable car system and redevelopment of the airport of Jaen) has had a significant effect on the number of visits to Kuelap.

To empirically evaluate this hypothesis, we use the infrastructure investment package (IIP) that benefited Kuelap as a case study and build a "synthetic control" unit, which is similar to Kuelap in terms of the number of visits before treatment but has not benefited from the IPP. Thus, the causal effect of the IIP (the treatment) on the number of visitors (variable of interest) to Kuelap (treated unit) is the difference in the number of visitors between Kuelap and the "syntectic control" unit after treatment.

The candidates for the control unit are all tourist sites similar to Kuelap according to the classification of the Ministry of Foreign Trade and Tourism (MINCETUR), namely all those that are classified as "archaeological sites" (type) and "buildings" (subtype). However, given that none of these other tourist sites display a trajectory of visits similar to that of Kuelap, a synthetic control is constructed following the methodology originally proposed by Abadie and Gardeazabal (2003) and Abadie et al. (2010), and taking into account some recent developments and recommendations by Botosaru and Ferman (2019), Ferman and Pinto (2019), Ferman et al. (2020), Chernozhukov et al. (2021), Ferman and Pinto (2021), Chernozhukov et al. (2022), and Kaul et al. (2022). The baseline synthetic control is obtained by weighting the number of visits to each tourist site according to a set of relevant predictors that include only pre-treatment lags of the outcome variables and no covariates. The results show that investment in tourism infrastructure has significantly increased the number of visits to Kuelap since 2017. In particular, it is estimated that this investment package doubled the number of visits to Kuelap. Robustness exercises, related to the elimination of sites that were affected by a weather phenomenon known as El Niño and the inclusion of covariates related to tourism development (such as proportion of domestic tourists and guests per accommodation, among others), do not change the main results.

The literature on tourism as an economic activity has focused on the analysis of its relationship with economic growth. The tourism-led growth hypothesis has been one of the most studied in this literature (for instance, Risso and Brida 2009; Rodríguez et al. 2014; Banerjee et al. 2015, 2016; Faber and Gaubert 2019) and has been empirically assessed using mainly time series econometric techniques (such as cointegration and Granger causality tests). Another branch of the literature has been devoted to the analysis of the relationship between public policies and tourism (Rodríguez et al. 2014; Imikan and Ekpo 2012, among others), and the study of the relationship between public investment in transport infrastructure and tourism (Álvarez-Díaz et al. 2019; Monterrubio et al. 2020; Kanwal et al. 2020, among others). However, there are few empirical studies that estimate the causal effect of public investment on tourism (for example Deng et al. 2019; Doerr et al. 2020; Chow et al. 2021; Albalate et al. 2022; Shu et al. 2022), and none that analyse the causal effect of the construction of a cable car system on tourism.

As far as we know, this is the first paper that estimates the impact of public investment in tourism infrastructure on tourism demand for the Peruvian case. Also, our research contributes to the scarce literature that employs a comparative case study with a synthetic control to study the causal effect of public investment in infrastructure on tourism. Finally, it is the first paper that analyses the causal effect of the construction of a cable car system on tourism.

The rest of this paper is organised into six sections. Section 1 presents a brief review of the economic literature on tourism. Section 2 describes the main stylized facts associated with the investment in tourism infrastructure that has led to an increase in visits to Kuelap. Section 3 presents the empirical methodology used to evaluate the hypothesis of interest. The data are described in Sect. 4. The results are presented and discussed in Sect. 5. Finally, the conclusions are presented in Sect. 6.

1 A brief literature review

The economic literature on tourism has focused on its long-run relationship with economic growth, the so-called tourism-led growth hypothesis. Most of this literature provides evidence of a positive impact of tourism on different economic variables, such as the accumulation of foreign reserves, investment and employment, among others. Empirically, this relationship has been analysed using time series econometric techniques such as cointegration and Granger causality.[1] For instance, Risso and Brida (2009) analyse the contribution of tourism to Chilean economic growth and find that tourism is an important determinant of long-run economic growth; in particular, they estimate that the elasticity of tourism expenditure with respect to real GDP is 0.8 in the long run. Based on the existing literature on tourism and growth using time series, Brida et al. (2013) conclude that tourism Granger causes long-term economic growth; however, they warn that this result should be validated with regional and country-level studies. Along these lines, Faber and Gaubert (2019) study the case of Mexico and show that tourism has a positive economic effect in the long run, both at the local level (municipalities) and at the country level.

[1] See Brida et al. (2013) for a summary.

Another branch of the literature focuses on the analysis of the relationship between public policies and tourism. Rodríguez et al. (2014) provide evidence of a long-run relationship between public investment in advertising and tourism demand in the Andalusia, Spain; furthermore, they show that advertising investment helps to predict tourist demand in the short run. Imikan and Ekpo (2012) study the relationship between investment in different types of infrastructure (water, electricity and transport, among others) and tourism development for the case of River State, Nigeria. Using multiple correlation and stepwise regression analysis, they find that investment in transport infrastructure is highly correlated with tourism development. Gulcan et al. (2009) study the relationship between public investment and value added created by hotels in the Aegean region of Turkey; using a panel data regression model they find that public investment in tourism has a positive effect on hotel activity. More recently, Deng et al. (2019) estimate the causal effect of a regional policy in western China (Western Development Strategy or WDS) on tourism using a quasi-experiment. Specifically, they use a sharp regression discontinuity design where the distance of each city from the geographical boundary of the WDS determines the point of discontinuity. The results of Deng et al. (2019) indicate that the WDS policy, which includes infrastructure projects, has had a positive effect on the development of tourism in China.

The recent literature has shown that investment in tourism infrastructure plays an important role in the development of this sector, promoting sustainable investment policies (Paramati et al. 2018) and cutting through the entire value chain of the tourism sector: transport and communications, hotel industry, restaurants and recreational facilities (Nguyen 2021). One area of this research has focused specifically on the relationship between transport infrastructure and the development of the tourism industry based on investments in different types of transport links including by air (airports and cable cars), land, and rail.

The relationship between air transport and tourism has received considerable attention in the academic literature and among policy makers. Papatheodorou (2021) identifies three types of relevant contributions to the study of tourist air transport: (a) airline business models and regional tourism development, (b) the link between aeropolitics and tourism, and (c) the airline–airport relationship and the development of tourist routes (for example, Benedetti et al. 2012; Jian et al. 2017; Ferníndez et al. 2018; Álvarez-Díaz et al. 2019; Monterrubio et al. 2020, among others). Likewise, land transport infrastructure constitutes an important driver for the dynamism of tourism, generating the development of new tourist sites and motivating the support of local residents towards this activity. For example, Kanwal et al. (2020) demonstrates that the road infrastructure of the China–Pakistan Economic Corridor (CPEC) is positively related to community support for tourism. On the other hand, investment in high-speed rails (HSR) and its relationship with the tourism industry have been extensively studied, demonstrating that improvements in accessibility as a consequence of HSR lead to increased demand for tourism (Yin et al. 2019; Delaplace et al. 2014; Bazin et al. 2011; Kurihara Wu 2016).

Research suggests that investment in transport infrastructure is associated with increased visitor numbers and consequently tourism development. However, there are less empirical studies that estimate the causal effect of investment in infrastructure on tourism. Recent studies have used difference-in-differences, instrumental variable and synthetic control approaches to estimate the effect of airport subsidies and HSR on the number of visitors, the development of national tourism and the efficiency of the tourism industry (Chow et al. 2021; Albalate et al. 2022; Shu et al. 2022). For instance, Doerr et al. (2020) employing a synthetic control approach and using data from Germany conclude that the new airport infrastructure promotes regional tourism development, due to the increase in tourist arrivals and income generated from this activity.

Regarding research on cable car systems and tourism, the literature is scarce. Zhang et al. (2009) reports on visitors' impressions of using a cable car in Wulingyuan (China), but finds that tourists' motivations are focused on landscape aspects and not on the transportation experience. In a paper not directly related to tourism, Martinez et al. (2018) use instrumental variables to identify the causal effect of the cable car in La Paz, Bolivia, on the choice of mode of transport, the use of time, and employment; the results show significant benefits for the users of this type of transportation.

Our study uses a synthetic control approach to estimate the causal effect on tourism demand of the construction of the first cable car system in Peru and the reconstruction of a nearby airport - an investment package on tourism infrastructure. Thus, this paper contributes to the existing literature in three ways. As far as we know, this is the first paper that estimates the impact of public investment in tourism infrastructure on tourism demand for the Peruvian case. Second, our research contributes to the scarce literature that employs a comparative case study with a synthetic control to study the causal effect of public investment in infrastructure on tourism. Finally, it is the first paper that analyses the causal effect of the construction of a cable car system on tourism.

2 Kuelap and tourism infrastructure investment

The department of Amazonas is part of the tourist circuit of north-eastern Peru,[2] which offers attractive archaeological and natural sites. One of its main tourist attractions is the Kuelap Archaeological Complex or simply Kuelap, located at a distance of approximately 107 kms from Chachapoyas, the capital of Amazonas. Kuelap is the most important archaeological site of the Chachapoyas culture (fifth–sixteenth century). It is located on a limestone mountain at 3000 ms above sea level, on the left bank of the Utcubamba River. The site occupies an area of approximately 6 hectares, surrounded by a perimeter wall of 15 ms height, and is built with heavy but finely edged limestone. Across the plateau there are more than 550 circular structures with different architectural functions (Ministry of Foreign Trade and Tourism 2017). Peru has 23 archaeological sites displaying similar characteristics to Kuelap, including Machu Picchu, Chavin de Huantar and Caral, among others (Ministry of Foreign Trade and Tourism 2019).

[2] This tourist circuit also includes Cajamarca, La Libertad, Lambayeque and San Martin.

Table 1 Milestones of the project "Kuelap cable car system". *Source*: Own elaboration based on Rodríguez et al. (2018)

Date	Event
09-09-2013	Announcement and delivery of the Contest Rules
30-05-2014	Award of the good pro of the project
15-10-2014	Signing of the concession contract
13-08-2015	Beginning of construction
02-03-2017	Opening of the Kuelap cable car system

2.1 The Kuelap cable car system

The project to build a cable car system in Kuelap originated in December 2001, according to Supreme Resolution No. 536-2001-EF, which established the granting of concessions to the private sector for the execution of tourist infrastructure works for the Kuelap Archaeological Complex. On August 26, 2005, the public investment project (PIP) denominated "Implementation of Cable Cars between the town of Tingo Nuevo and the Kuelap-Amazonas Fortress" was registered. Its main goal was to reduce travel time and improve the quality of transport to reach Kuelap. In March 2013, under an inter-institutional collaboration agreement with MINCETUR, The Peruvian Finance Ministry's Investment Agency (ProInversion) was put in charge of undertaking feasibility studies and developing a project proposal as a public–private partnership or PPP (Rodríguez et al. 2018). Table 1 details the main milestones in the process of development and construction of the first cable car system of Peru.

The project was awarded to a French-Peruvian consortium in May 2014. Construction works started in August 2015 and led to a reduction in tourism activity, especially between August and December 2015, because traffic through the site's access road was severely restricted. (During the day the road was open for just three hours.) In addition, maintenance work at the archaeological site meant that visits to some areas of the fortress were restricted. The opening ceremony of Peru's first cable car line was in July 2016 and after a trial period full operations started in March 2017. According to Ministry of Economy and Finance (2017), the final cost of the construction of the cable car system was approximately US$ 27 million (S/ 89.2 millions). The project file projected a 50% increase in tourists during the cable car's first ten years of operation; however, the actual number of visitors has been twice this forecast, increasing from 40,146 in 2014 to 102,905 in 2017. A simple cost-benefit analysis provided by Rodríguez et al. (2018) shows that the this outcome resulted in a reduction of costs of the cable car system of approximately US 370,000 during 2017. Furthermore, 350 workers were hired directly in order to operate the system.

2.2 Airport infrastructure

The average travel time from Lima to Kuelap by bus is approximately 24 h. However, it is possible to significantly reduce travel times by 18 h by taking a 1 h and 30 min flight

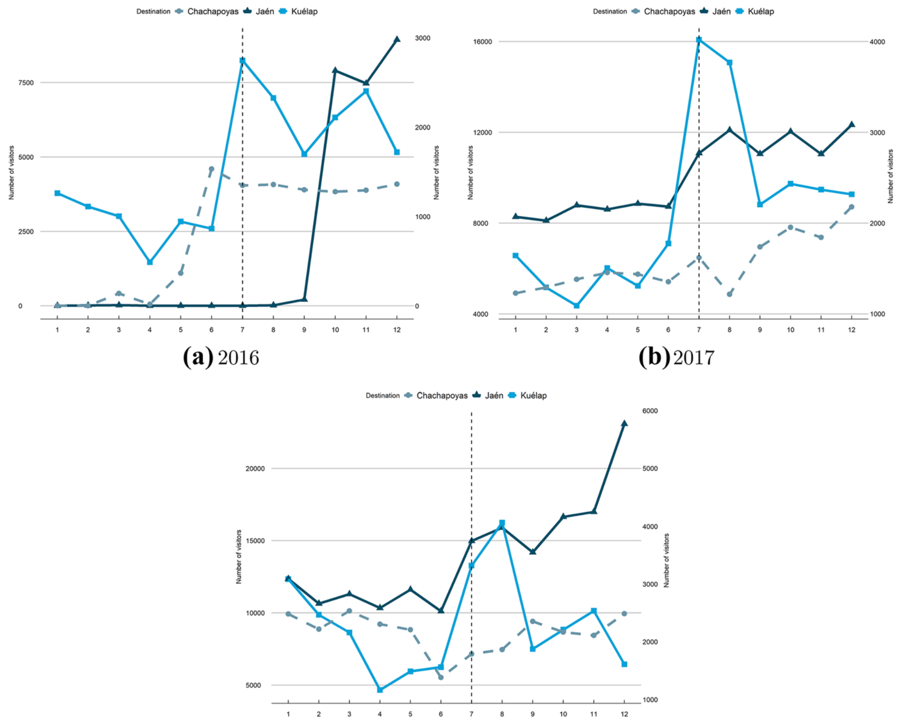
Table 2 Airport investment in Chachapoyas and Jaen. *Source*: Own elaboration based on Private Investment Promotion Agency (2019), Regional Government of Amazonas (2016), Supervisory Board for Investment in Public Transport Infrastructure (2018), Andina (2017), Turismo News (2016), Turismo News (2017a) and Turismo News (2017b)

	Chachapoyas airport	Jaen airport
Description		
Project	Airport modernisation	Airport redevelopment
Investment	US$ 5.77 million (approx.)	US$ 3 million (approx.)
Infrastructure	Remodelling of the passenger terminal	Air terminal improvement
	New gantry construction	Parking lot upgrade
	Parking lot paving	Boarding area improvements
		Installation of basic services
		Operational technical equipment
Distance to Kuélap	3 h approx. (without cable cars)	7 h approx. (without cable cars))
(By road)	2 h approx. (with cable cars)	6 h approx. (with cable cars)
Milestones		
May 2016	Saeta airline started commercial flights	
	between Tarapoto and Chachapoyas	
July 2016		Opening of the airport
September 2016		LATAM airline started daily
		flights between Lima and Jaen
March 2017	Air Majoro airline started direct flights	
	between Lima and Chachapoyas	
July 2017	ATSA Airlines airline started regular direct flights	
	between Lima and Chachapoyas	
Future project	Master Plan for Development of Chachapoyas	Third Group of Airports
	Airport	

to either Chachapoyas or Jaen, the closest cities to Kuelap. Travel times to Kuelap by car from Chachapoyas and Jaen take 3 h and 7 h, respectively. Overall, travel times by land can be an important factor that discourages an average tourist to travel to Kuelap, combined with very limited availability of flights which was the case until 2015. In recent years, investment has been made in these airports, which has allowed an increase in the number of passengers to Chachapoyas and Jaen. The general description of the airport investment programme, as well as the main milestones, is outlined in Table 2.

In 2016, nearly US$ 9 million (30 million Soles) were invested in the redevelopment of the Jaen airport[3] and in the refurbishment of the Chachapoyas airport, which allowed

[3] The reconstruction of this airport has not only benefited Kuelap but also other tourist destinations in the north-east of Peru.



(a) 2016 **(b)** 2017 **(c)** 2018

Fig. 1 Monthly evolution of arrivals at airports and Kuelap.. **Note:** The visits to Kuelap and arrivals at Jaen airport are measured on the left axis. Arrivals at Chachapoyas airport are measured on the right axis. The horizontal axis represents months. *Source:* Own elaboration based on Ministry of Foreign Trade and Tourism (2019)

key airlines to start operating commercial flights to these airports. In the case of Chachapoyas airport, commercial flights from the city of Tarapoto restarted in May 2016 and in 2017 the airlines Air Majoro and ATSA Airlines started direct flights from the city of Lima. Jaen airport started receiving daily direct flights from Lima (LATAM airlines) from September 2016 onwards.

Figure 1 shows the evolution of monthly visits to Kuelap and the arrival of passengers at the airports of Jaen and Chachapoyas between 2016 and 2018. It is evident that the evolution of passenger arrivals at these airports coincides with the evolution of visits to the Kuelap archaeological site. In particular, all three series increased during the high season for tourism to Amazonas (July–August). However, it can be observed that Jaen airport is more important than Chachapoyas in terms of the volume of passengers. For example, in the years 2017 and 2018 Jaen airport received 6.6 times more passengers than Chachapoyas.[4]

[4] In September 2019, the Ministry of Transport and Communications announced that it intends to update the "Master Plan for Development of Chachapoyas Airport" to expand the passenger terminal of the Chachapoyas airport, which could only receive small planes. On the other hand, the airport of Jaen receives

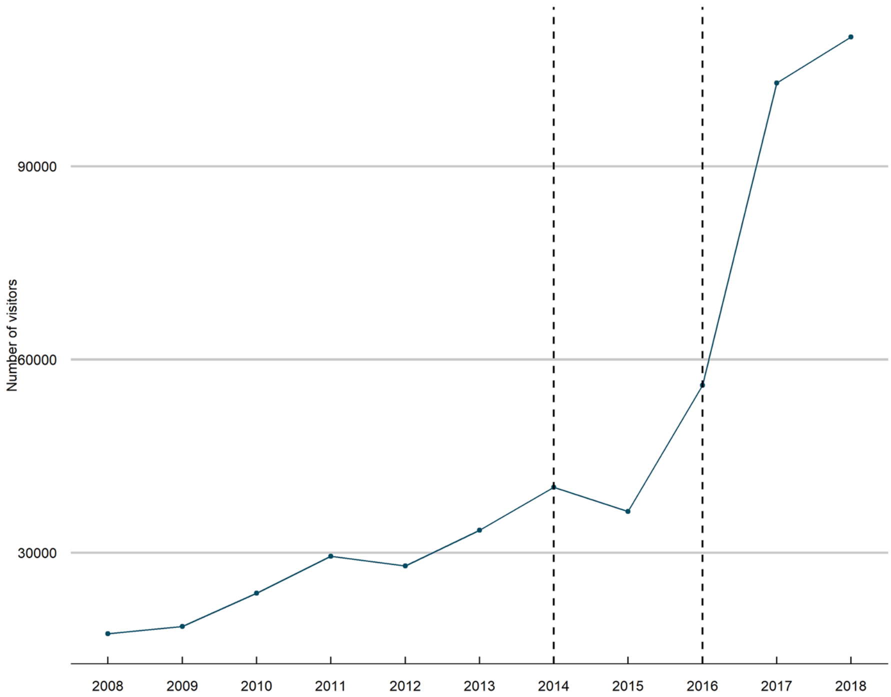


Fig. 2 Evolution of visits to Kuelap: 2008–2018 . *Source*: Own elaboration based on Ministry of Foreign Trade and Tourism (2019)

2.3 Evolution of the number of visits to Kuelap

Figure 2 shows the evolution of the number of visits to the Kuelap Archaeological Complex between 2008 and 2018. A clear upward trend can be seen in the years leading up to 2015 when there is a drop in visitor numbers (from 40,146 to 36,385 visits) due to the construction works on the cable cars. In 2016 the number of visits recovered (56,010 visits), which coincided with the increase of commercial flights to Chachapoyas and Jaen due to the redeveloping and refurbishment of their airports. However, in 2017 a significant jump in the number of visits is observed (102,905 visits) which coincides with the inauguration of the cable car service and the availability of more flights. In addition, the number of visits in 2018 (110,068 visits) has remained well above the levels observed before 2017.

The key question is to what extent the increase in visitor numbers to Kuelap from 2017 has been due to the infrastructure investments made. Our hypothesis posits that most of this increase is basically due to the construction of the cable car and the redevelopment of the Jaen airport. We assess this hypothesis in a comparative case study using a synthetic control.

planes with a capacity of 70 passengers or more and is part of the concession process of the "Third Group of Airports".

3 Empirical methodology: a synthetic control approach

A comparative case study is an empirical approach used to measure the causal effect of an event, treatment or intervention (e.g. the enforcement of a policy or law) on a variable of interest when it is not possible to apply an experimental design. To implement a comparative case study, "units" (cities, regions, locations, etc.) exposed to an event (treatment, shock, etc.) and others not exposed to the event are required, and all units must be similar before treatment.[5]

We employ a comparative case study where Kuelap is the "treated" unit, investment in tourism infrastructure is the "treatment" and the number of visits to Kuelap is the variable of interest or the outcome variable. Let $Y_t^{\mathcal{T}}$ represent the number of visitors to Kuelap in period t, for $t = 1, 2, \ldots, T, T+1, \ldots, T^*$, and assume that the treatment occurs in period $t = T + 1$, so there are T preintervention or pre-treatment periods. To estimate the effect of the treatment on the treated unit, we need a control unit that replicates its counterfactual, Y_t^C, i.e. the evolution of visits to Kuelap had the treatment not occurred. Then, the causal effect of the treatment is the difference between the number of visitor numbers to the treated unit, $Y_t^{\mathcal{T}}$, and its counterfactual, Y_t^C, after treatment, i.e. $Y_t^{\mathcal{T}} - Y_t^C$ for all $t > T$.

Natural candidates for a single control unit are any of the tourist sites that have the same Mincetur classification as Kuelap: archaeological sites/buildings. However, it is possible that none of those sites provides a close enough match to be a valid control.[6] In this case, Abadie and Gardeazabal (2003) and Abadie et al. (2010) proposed the use of a "synthetic control" to approximate Y_t^C, which is a weighted average of all J potential control units or donor pool. In order to be a valid estimate of the counterfactual, the synthetic control must satisfy two conditions. First, the synthetic control unit and Kuelap should display a similar number of visits before the intervention (for all $t < T+1$). Second, the synthetic control unit and Kuelap should be similar in terms of the preintervention values of the "predictors" of the number of visits. The predictors may include L lagged values of the visits to Kuelap (or linear combination of those values) and other M variables that can help predicting those visits, which are referred to as "covariates", so that the total number of predictors is $K = L + M$.

Estimation

A synthetic control for Kuelap can be constructed by "optimally" weighting all the available sites. Formally, for each archaeological site $j = 1, 2 \ldots, J$ that is part of the donor pool, we define a vector y_j of dimension $T \times 1$ that contains the number of visits to archaeological site j along the preintervention periods (T periods). The synthetic control of Kuelap, y^*, is defined as the vector of visits that results from "optimally" weighting each y_j using weights $w_1^*, w_2^*, \ldots, w_J^*$:

[5] If all units were exposed to the event, the level of exposure is required to be very different between the treated and the control group.

[6] Our analysis showed that none of the other sites in Peru were a close enough match to use as a control.

$$
\begin{aligned}
y^* &= y_1 \cdot w_1^* + \ldots + y_j \cdot w_j^* + \ldots + y_J \cdot w_J^* \\
&= Y_0 w^*
\end{aligned} \tag{1}
$$

where w_j^* represents the optimal weight of the archaeological site j in the synthetic control of Kuelap, Y_0 is a matrix of order $T \times J$ whose columns are $y_1, y_2, \ldots, y_J$, and $w^* = [w_1^*, w_2^*, \ldots, w_J^*]'$ is a vector of order $J \times 1$ whose elements are weights that add up to one, $w_1^* + w_2^* + \ldots + w_J^* = 1$.

The choice of optimal weights is made such that the resulting synthetic control replicates as close as possible the preintervention values of all the K predictors of visits to Kuelap. Kaul et al. (2022) call this procedure the "inner optimization" process and can be formalised as follows. Let x be a vector of order $(K \times 1)$ containing the pre-treatment values of the K predictors and x_j the corresponding vector for each archaeological site j, for $j = 1, 2, 3, \ldots, J$; let X_0 be a $(K \times J)$ matrix whose columns are the vectors $x_1, x_2, \ldots, x_J$. In addition, let V be a matrix whose values reflect the relative importance of each predictor (i.e. the weights of the predictors), which will be determined by a second procedure that Kaul et al. (2022) refer to as the "outer optimization". Then, for a given V matrix, the vector of optimal weights w^* is chosen to minimize the weighted distance between x and $X_0 w$, subject to the fact that the weights are nonnegative and they sum up to 1:

$$
\begin{aligned}
\underset{w}{\text{Min}} \quad & (x - X_0 w)' V (x - X_0 w) \\
\text{s.t. } & w_j \geq 0 \ , j = 1, 2, \ldots, J \\
& w_1 + w_2 + \cdots + w_J = 1
\end{aligned} \tag{2}
$$

The solution to this problem is the vector $w^*(V) = [w_1^*, w_2^*, \ldots, w_J^*]'$, which defines the synthetic control unit for Kuelap $y^* = y_1 \cdot w_1^* + \ldots + y_j \cdot w_j^* + \ldots + y_J \cdot w_J^*$, for a given matrix V. The next step consists of obtaining the optimal predictor weights, V^*, which is achieved by the so-called "outer optimization". Abadie and Gardeazabal (2003) and Abadie et al. (2010) proposed to choose a positive definite and diagonal matrix V such that the synthetic control optimally replicates the trajectory of visits to Kuelap before treatment. Specifically, V^* is the matrix that solves the following minimisation problem:

$$
\underset{V}{\text{Min}} \ (z - Z_0 w^*(V))'(z - Z_0 w^*(V)) \tag{3}
$$

where z is a $(m \times 1)$ vector containing all the preintervention values of the visits to Kuelap, Z_0 is a $(m \times J)$ matrix with columns $z_1, z_2, \ldots, z_J$, and z_j is a $(m \times 1)$ vector containing all the preintervention values of the visits to site j for $j = 1, 2, \ldots, J$. An alternative way to obtain the predictor weights contained in V a regression-based method as in Bohn et al. (2014).

Abadie et al. (2010) justify the use of the synthetic control method in a comparative case study under certain conditions. First, the intervention has no effect on the outcome variable before it is implemented; however, the anticipation of the intervention may affect preintervention outcomes, in which case the treatment period can be redefined and include the affected periods. Second, the outcomes of the untreated units are not affected by the intervention. However, if the pre-treatment fit of the synthetic control is poor (compared to the actual pre-treatment outcome variable), then Abadie et al. (2010) do not recommend the use of a synthetic control.

A synthetic control allows the presence of unobserved confounders that vary over time. To see this formally, Abadie et al. (2010) assume that the outcome that would be observed for site i in period t in the absence of the treatment, Y_{it}^N is described by the following factor model:

$$Y_{it}^N = \delta_t + \theta_t C_i + \lambda_t \mu_i + \varepsilon_{it} \tag{4}$$

where δ_t is an unknown common factor that varies with constant factor loadings across units, C_i is a $(K \times 1)$ vector of observed covariates (not affected by the intervention), θ_t is a $(1 \times K)$ vector of unknown parameters, λ_t is a $(1 \times F)$ vector of unobserved common factors that varies over time, μ_i is an $(F \times 1)$ vector of unknown factor loadings, and ε_{it} represents unobserved idiosyncratic, transitory shocks with mean zero.

Equation (4) is a generalization of the difference-in differences (DID) model with fixed effects: If λ_t is constant for all t, then Eq. (4) reduces to the DID fixed-effects model. Thus, the DID model allows for the presence of unobserved confounders μ_i but restrict their effect to be constant over time if $\lambda_t = \lambda$; thus, the confounders can be eliminated using the first difference transformation. In contrast, the synthetic control allows the effect of confounding unobserved characteristics to vary over time and, when the pre-treatment fit is very good, it provides an unbiased estimator of Y_{it}^N for the treated unit i.

However, in many applications, the pre-treatment fit is imperfect. Ferman and Pinto (2021) study the properties of the synthetic control, a demeaned version of the synthetic control, and the DID estimator when the pre-treatment fit is imperfect and provide some conditions under which those estimators can used with confidence. For instance, if the synthetic control unit recovers the levels of the treated unit and the preintervention fit is imperfect, then the synthetic control would be reliable if there is no important unobserved confounders that vary over time. In this case, if the DID and synthetic control provide similar results, then Ferman and Pinto (2021) suggest that the synthetic control is a good choice.

As discussed by Ferman et al. (2020), there is lack of consensus about which predictors should be used in synthetic control applications. The standard practice is to use pre-treatment outcomes and covariates and to construct the synthetic control trying to balance at least on a long set of pre-treatment outcomes (Botosaru and Ferman 2019). Usually, linear combinations of preintervention outcomes are used as predictors, but there is no formal recommendation about it. If there are no good reasons to include covariates in the application, Ferman et al. (2020) recommend the use of the specification including all pre-treatment periods, given that it minimizes the root mean squared error (RMSE) in the pre-treatment period, and it is not subject to the choice of arbitrary pre-treatment outcome lags as predictors. On the other hand, the only reason not to use all pre-treatment periods is when there are good reasons to include covariates. In this case, it is recommended to use a specification that does not include all pre-treatment lags, otherwise all covariates would be irrelevant in the estimation of weights, as documented by Kaul et al. (2022): even though the inner optimization takes into account the covariates, the synthetic control obtained from the outer optimization will ignore all the covariates when all the pre-intervention values of the outcome variable are used as predictors.

Based on the above discussion about the synthetic control method, our baseline synthetic control will be constructed using as predictors all the pre-treatment lags and no covariates, given we have limited economic information for each specific site. Then, the robustness of the results will be analysed by including covariates and taking into account the effect of the El Niño phenomenon in the donor pool and in the synthetic control unit.

Inference

One way to evaluate the significance and robustness of these estimates is to analyse whether the results could have been obtained by chance. In other words, how often would we have obtained an effect on visits of the estimated magnitude had we chosen an archaeological control site at random. To address these questions, Abadie and Gardeazabal (2003) and Abadie et al. (2010) proposed the use of "placebo tests". It consists of applying the same methodology to tourist sites that did not experience any treatment (investment package) similar to Kuelap and analysing the resulting gap for each site, where the gap is defined as the difference between the actual number of visits and its synthetic counterpart. If any of the "placebos" create gaps of similar magnitude to those estimated for Kuelap, then we would conclude that there is no significant evidence of a positive effect of Kuelap's infrastructure investment package. However, if none of the placebos show a positive gap as significant as the one associated with Kuelap, we can conclude that there is a positive and statistically significant effect of the infrastructure investment package.

In order to evaluate Kuelap's gap relative to the gaps obtained from the placebos obtained for each site, we follow Abadie et al. (2010) and analyse the distribution of the ratios of post/pre-intervention mean squared prediction errors (MSPE). The MSPE of site j is defined as the average of the squared difference between the number of visits to site j and its synthetic counterpart. If the synthetic control for Kuelap is such that the pre-treatment MSPE is zero and the post-treatment MSPE is large in magnitude, then the estimated gap reflects the effect of the investment package on the number of visitors to Kuelap. In particular, if the ratio "post-treatment MSPE / pre-treatment MSPE" (RMSPE) for Kuelap is the highest compared to the rest of sites, then the estimated effect is statistically significant: if a site was chosen at random, then the chances of obtaining a RMSPE as high as Kuelap's would be approximately $1/J$, which represents the p-value to test the null hypothesis of no significant effect of the treatment. Recently, some alternative inference methods for synthetic control analysis have been proposed, such as conformal inference (Chernozhukov et al. 2021) and t-test (Chernozhukov et al. 2022). In this paper our inference results of will be based on the approach proposed by Abadie et al. (2010).

Table 3 Tourist sites: category "cultural manifestations", type "archaeological sites" and subtype "buildings". *Source*: Own elaboration based on Ministry of Foreign Trade and Tourism (2019)

Department	Tourist site	Number
Amazonas	Kuélap, Revash y Karajía.	3
Áncash	Chavín.	1
Apurímac	Saywite.	1
Ayacucho	Intihuatana y Wari.	2
Cajamarca	Otuzco y Cumbemayo.	2
Cusco	Machu Picchu, Moray, Tipon, Choquequirao, Pikillaqta y Raqchi.	6
Huánuco	Kotosh.	1
La Libertad	Huaca Arco Iris, Huaca Sol, Huaca Bruja y Nikán.	4
Lima	Caral.	1
Piura	Narihualá.	1
Puno	Sillustani.	1
Total		23

4 Data

The information used has been obtained from MINCETUR and the National Institute of Statistics and Informatics (INEI). The data are annual and cover the period 2008–2018. Additionally, we collected monthly data on the number of visits from different tourist sites. MINCETUR has a database of the arrival of visitor numbers to 118 tourist sites in the country. It also maps and classifies tourist attractions by category, type and subtype, geographical location and other characteristics. Based on this classification, sites that are categorised as "cultural manifestations", of the type "archaeological sites" and subtype "buildings" are considered as possible candidates for our control. Table 3 presents the list of tourist sites that fall into this classification by geographical location (department).[7]

To build the synthetic control, we use as predictors the pre-treatment number of visits. Additionally, we also include variables related to key characteristics of tourism activity by region, such as average length of stay in accommodation facilities (length of stay), number of domestic tourists as a percentage of total number of tourists (domestic visitors), number of guests per accommodation facility (guests per accommodation), participation of tourism in GDP (tourism development), average level of education achieved by people over 15 years old (educational attainment), average annual temperature (regional temperature) and pre-treatment visits. The information is annual and corresponds to the period 2008–2018, where the sub-sample 2008–2014 is the pre-treatment period and the sub-sample 2015–2018 is the post-treatment period. Table 4 describes the variables and the sources. The descriptive statistics per region are detailed in "Section A of the appendix".

[7] More details can be found in "Table B of the Appendix".

Table 4 Predictor variables employed to build the synthetic control . *Source*: Own elaboration based on Ministry of Foreign Trade and Tourism (2019) and National Institute of Statistics and Informatics (2019)

Source	Variable	Definition
MINCETUR	Length of stay	Average stay in accommodation facilities (in days)
MINCETUR	Domestic visitors	Number of domestic tourists (% of total number of tourists)
MINCETUR	Guests per accommodation	Number of guest arrivals per accommodation facility
INEI	Tourism development	Gross value added at 2007 prices (% of GDP)
INEI	Educational attainment	Average years of study achieved by the population over age 15.
SENAMHI	Regional temperature	Average annual temperature, expressed in degree Celsius.
MINCETUR	Pre-treatment visits	Total number of visits for each year between 2008 and 2014

5 Results

Figures 3 and 4 show the evolution of the number of visits to Kuelap compared to the tourist sites located in Cusco (Peru's main tourist destination) and to the rest of tourist sites outside Cusco, respectively, between 2008 and 2018.

At first glance, none of the tourist sites display a trajectory of visits similar to Kuelap's and thus would not qualify as a control unit. Therefore, a synthetic control was constructed following the methodology described in Sect. 3. The baseline synthetic control unit (SCA) is obtained using the pre-treatment values of the number of visits as the only predictors (no covariates included), and all the sites of the type "archaeological sites" and subtype "buildings" as the donor pool.

As a robustness exercise, we present alternative specifications to estimate the synthetic control unit. First, given that in 2018 some of the tourist sites included in the donor pool were adversely affected by the "El Niño" weather phenomenon, we re-estimate the synthetic controls excluding those sites. Second, we estimate the synthetic control unit using two sets of potential covariates. As shown below, the results confirm the positive causal effect of the investment package on the number of visits to Kuelap.

5.1 Baseline results

The baseline synthetic control (Synthetic control A or SCA) is constructed using as predictors all the preintervention number of visits and no covariates. The donor pool consisted of all sites listed in Table 3 with the exception of "Revash" and "Karajia", because the number of visitors to these sites has only been recorded since 2016; additionally, both sites are affected by the demand for Kuelap, since they are also located in the department of Amazonas. The weights of each site in the baseline

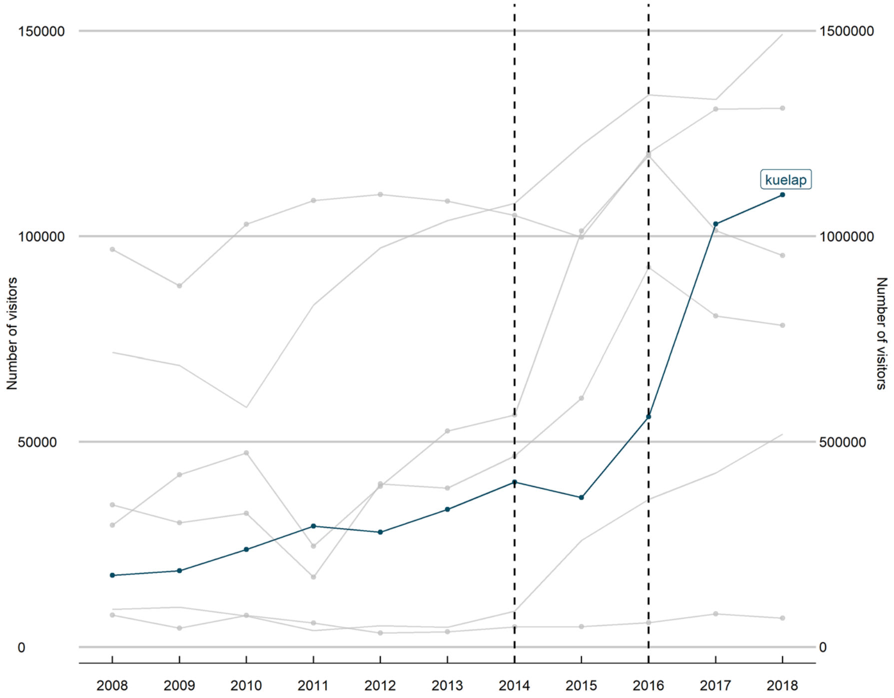


Fig. 3 Visits to Kuélap and other archaeological sites located in Cusco: 2008–2018 . *Source*: Own elaboration based on Ministry of Foreign Trade and Tourism (2019)

synthetic Kuelap are displayed in the second column of Table 5. The synthetic Kuelap is a weighted average of six sites: Cumbemayo (weight of 0.17), Kotosh (weight of 0.20), Intihuatana (weight of 0.18), Huaca Brujo (weight of 0.31), Choquequirao (weight of 0.12), and Wari (weight of 0.31); the rest of the sites have zero weights in the synthetic control.

Columns (2), (3) and (4) of Table 6 display the pre-treatment visits to Kuelap, Cumbemayo (the site with the individual highest weight) and the baseline SCA, respectively. A simple comparison indicates that the SCA's pre-treatment visits are more similar to Kuelap's than Cumbemayo's. Thus, the SCA replicates well the trajectory of preintervention visits.

Figure 5 shows the trajectory of visits to Kuelap and its synthetic control for the period 2008–2018. It is clear that the SCA replicates almost perfectly the preintervention visits to Kuelap, which makes the SCA a good counterfactual in order to estimate the causal effect of the investment package on the number of visits to Kuelap. Given that the difference between the visits to Kuelap and the synthetic control is positive in 2017 (when the cable car system started to operate) and 2018, we can conclude that the investment package had a positive effect on the number of visits to Kuelap.

The top part of Table 7 displays the number of visits to Kuelap, Cumbemayo and SCA during the treatment period from which the causal effect of the infrastructure investment package can be calculated. It can be observed that the investment package

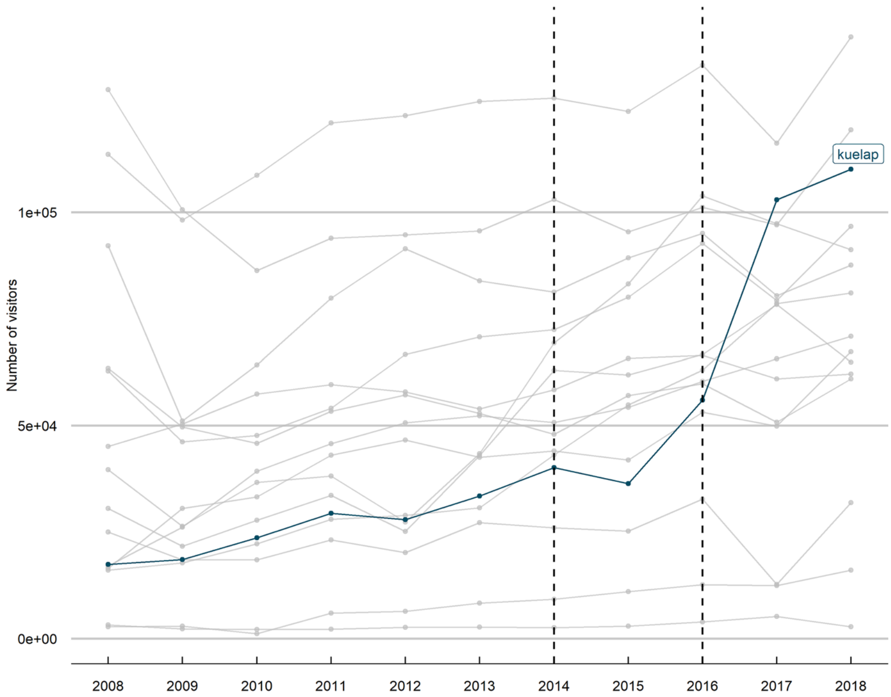


Fig. 4 Visits to Kuélap and other archaeological sites: 2008–2018 . *Source*: Own elaboration based on Ministry of Foreign Trade and Tourism (2019)

had a negative impact during the first year of construction of the cable car system, due to the restriction in access to the Archaeological Complex related to the construction works; this is reflected by a gap (difference between actual and synthetic control visits) of -4668 visitors in 2015. However, the gap became positive in 2016 by 10,160 visitors and then was more than double in 2017 and 2018 (105% and 117%, respectively). Specifically, the estimated causal effect of the investment package on the number of visits to Kuelap is 52,610 visitors in 2017 and 59,612 visitors in 2018. On average, the estimated causal effect is 55,935 which is statistically significant at the 5% level (p-value = 0.048).

For comparison purposes, the bottom part of Table 7 displays the estimated causal effect using the difference-in-differences (DID) estimator and robust standard errors as suggested by Ferman and Pinto (2019) when there is only one treated group. The DID estimator is positive (43,931 visitors) and statistically significant at the 10% level (p-value = 0.052). This effect is smaller than the estimated effect obtained with the synthetic control (A) but greater than the one obtained with Cumbemayo (34,889 visitors). However, the DID control unit does not replicate well the preintervention number of visits, as it is evident from Fig. 5.

Figure 6 illustrates the statistical significance of the causal effect using the “placebo tests” proposed by Abadie and Gardeazabal (2003) and Abadie et al. (2010) and discussed in Sect. 3. The figure displays the estimated gap for Kuelap and placebo

Table 5 Synthetic control: Weights for each archaeological site

Archaeological site	Preintervention visits	
	Synthetic control A	Synthetic control B
Choquequirao	0.12	0.08
Cumbemayo	0.31	0.23
Intihuatana	0.18	0.23
Kotosh	0.20	0.27
Machu Picchu	0.00	0.00
Moray	0.00	0.00
Otuzco	0.00	0.00
Pikillaqta	0.00	0.00
Raqchi	0.00	0.02
Saywite	0.00	0.00
Sillustani	0.00	0.00
Tipon	0.00	0.00
Wari	0.01	0.17
Caral*	0.00	
Chavin*	0.00	
Huaca Arco Iris*	0.00	
Huaca Brujo*	0.17	
Huaca Sol y Luna*	0.00	
Narihuala*	0.00	
Nikan*	0.00	

Sites with (*) were affected by El Niño phenomenonn

Table 6 Synthetic control units using all preintervention outcomes . *Source*: Ministry of Foreign Trade and Tourism (2019) and authors' estimates

Predictors	Kuelap	Cumbemayo	Synthetic control A	Synthetic control B
Visits in 2008	17,396	30,580	17,448	17,698
Visits in 2009	18,542	21,701	18,618	18,080
Visits in 2010	23,696	27,810	23,723	23,855
Visits in 2011	29,431	33,636	29,246	28,832
Visits in 2012	27,960	25,155	28,022	28,396
Visits in 2013	33,495	42,965	33,555	33,584
Visits in 2014	40,146	62,961	40,136	40,196

gaps for other archaeological sites that did not experience a similar investment package in tourism infrastructure as Kuelap did during the period of analysis.[8] It is clear that the positive gap for Kuelap is highly unusual and that its magnitude is the largest compared to the rest of the other sites. This is confirmed by the ratio of mean squared

[8] Moray and Nikan are excluded as they have the largest predictive errors in the placebo studies.

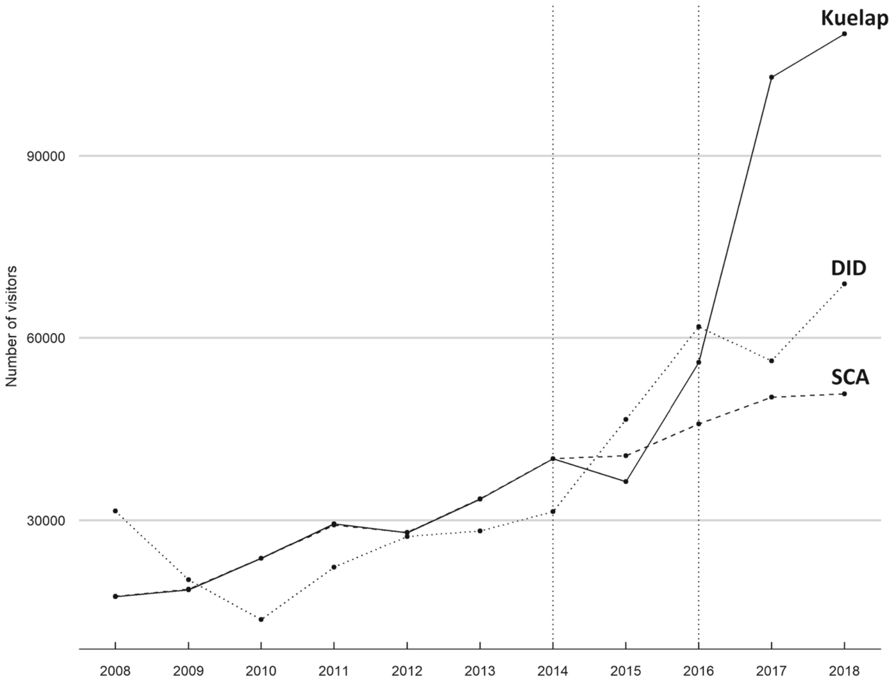


Fig. 5 Total visits: Kuelap, baseline synthetic control (SCA), and difference-in-differences (DID), 2008–2018 . *Source*: Own elaboration

Table 7 Synthetic control and estimated treatment effects

	Kuelap	Cumbemayo	Synthetic control A	Synthetic control B
Visits during treatment period				
2015	36,385	61,837	40,637	43,873
2016	56,010	66,611	45,850	49,225
2017	102,905	78,316	50,295	56,538
2018	110,068	64,879	50,807	56,425
Difference between Kuelap and controls				
2017		24,589	52,610	46,367
2018		45,189	59,261	53,643
Average (2017–2018)		34,889	55,935	50,005
p-value			0.048	0.071
Difference-in-differences				
Effect			43,931	38,173
p-value			0.052	0.070

Using the t-test proposed by Chernozhukov et al. (2022), SCA is 53,880 with a $t = 13.26$, and SCB is 49,423 with $t = 15.03$; these results confirm that the causal effect is statistically significant. Own elaboration

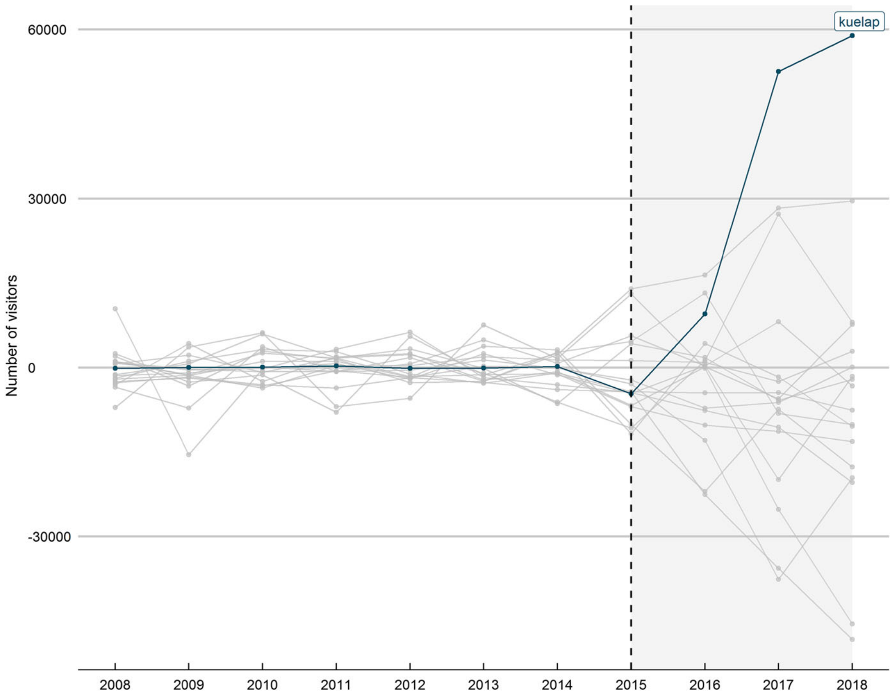


Fig. 6 Visit gaps for Kuelap and "placebo" gaps for other archaeological sites: 2008–2018 . *Source*: Own elaboration

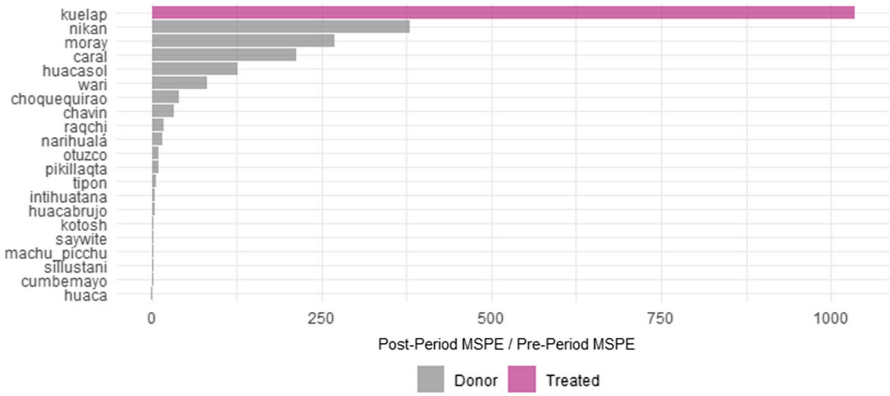


Fig. 7 Ratio of post-treatment MSPE and pre-treatment MSPE: Kuelap and control sites . *Source*: Own elaboration

prediction error (MSPE) between post-treatment and pre-treatment for Kuelap and the sites that are part of the donor pool, which are displayed in Fig. 7. As can be observed, Kuelap's ratio is larger than the rest, which means that if a site were chosen at random, then the chances of obtaining a ratio as high as Kuelap's would be $1/21 \approx 0.0476$.

5.2 The effect of El Niño phenomenon on visits

In 2017, several regions of the country were adversely affected by the El Niño phenomenon. According to the National Emergency Operations Center (COEN), Piura, Lambayeque, La Libertad, Ancash and Lima were the departments that registered the greatest damage (Radio Programas del Perú (2017)). This event caused a decrease in visits to tourist sites within these regions which could reduce the number of visits to the synthetic control, especially if they have an important weight (for example, Huaca Brujo), and thus lead to a larger difference between actual visits and synthetic control and thus to an upward bias in the estimated causal effect. In order to avoid this potential bias, we re-estimated the synthetic control excluding the archaeological sites located in departments affected by the El Niño phenomenon in 2017. Figure 8, which displays monthly visits to these places between 2015 and 2017, shows a drop in visits during March, April and May 2017 compared to the same period in previous years.

The last column of Table 5 displays the weights of each site used to construct the alternative synthetic Kuelap excluding those site affected by El Niño phenomenon, which we call synthetic control (B) or SCB. The SCB is a weighted average of six sites: Kotosh (weight of 0.27), Cumbemayo (weight of 0.23), Intihuatana (weight of 0.23), Wari (weight of 0.17), Choquequirao (weight of 0.08) and Raqchi (weight of 0.02); the rest of the sites have zero weight in the synthetic control. It is worth noting that all sites not affected by El Niño that contribute to SCA remain in the SCB.

The last column of Table 6 displays the pre-treatment visits to the SCB. A simple comparison indicates that the SCA's pre-treatment visits are very similar to SCB's. Figure 9 shows the trajectory of visits to Kuelap and the synthetic controls (A) and (B), for the period 2008–2018. It is clear that the SCB replicates almost perfectly the preintervention visits to Kuelap as SCA does. However, as expected, the SCB's gap is positive but smaller than the SCA's gap because we are excluding sites adversely affected by El Niño. Again, it is evident that the investment package had a positive effect on the number of visits to Kuelap.

The last column of the top part of Table 7 displays the number of visits to SCB during the treatment period. Similar to the case of SCA, it can be observed that the investment package had a negative impact during the first year of construction of the cable car system, which is reflected by a gap of -7488 visitors in 2015. However, the gap became positive in 2016 by 6785 visitors and then almost double in 2017 and 2018. Specifically, the estimated causal effect of the investment package on the number of visits to Kuelap is 46,367 visitors in 2017 and 53,643 visitors in 2018. On average, the estimated causal effect is 50,005 which is statistically significant at the 10% level (p-value = 0.071). As expected, in 2017 and 2018 the SCB's gap is smaller than SCA's gap because we are excluding sites adversely affected by El Niño. Again, the results indicate that the investment package in tourism infrastructure has had a positive and significant effect on the number of visitors to Kuelap.

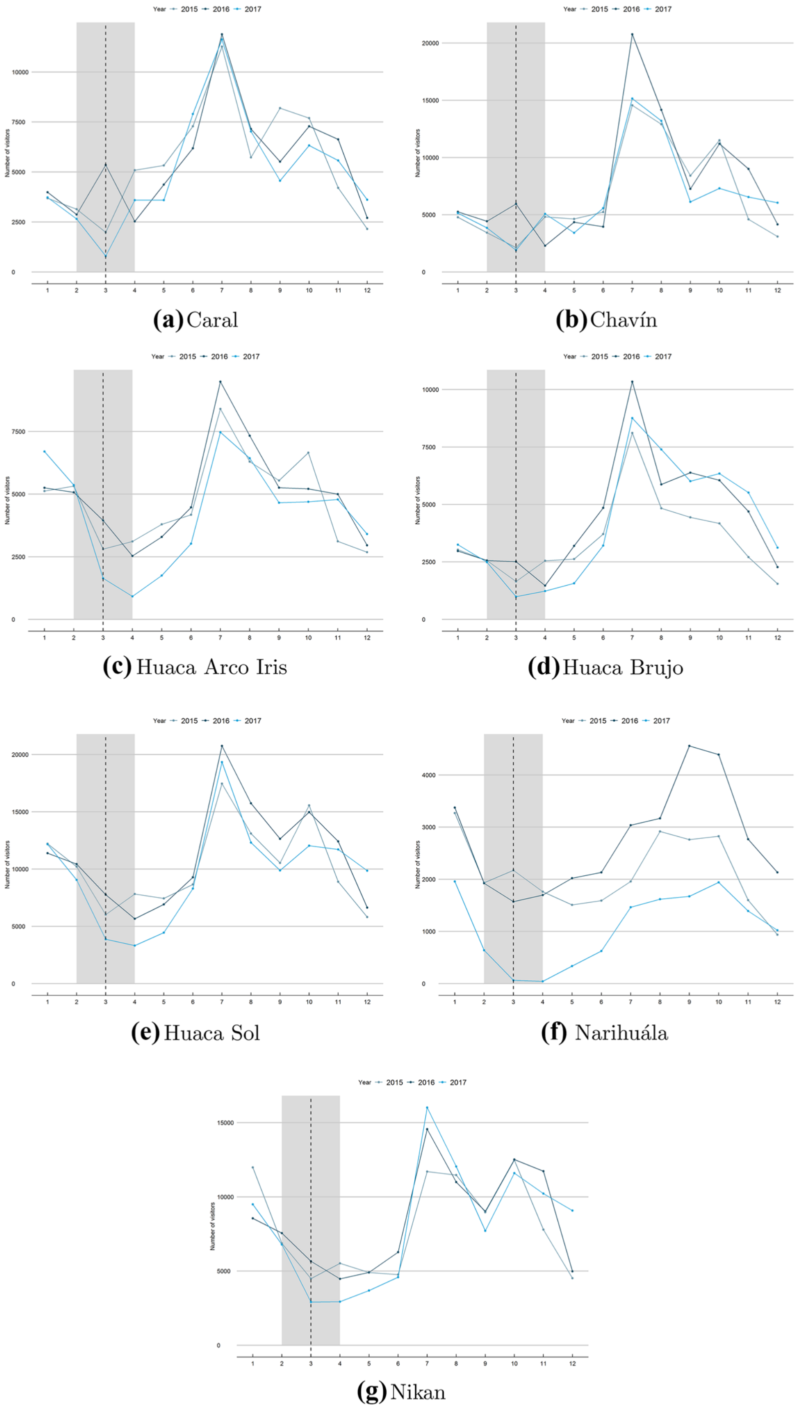


Fig. 8 Monthly visits to archaeological sites affected by the El Niño phenomenon: 2015, 2016 and 2017 . *Source*: Own elaboration based on Ministry of Foreign Trade and Tourism (2019)

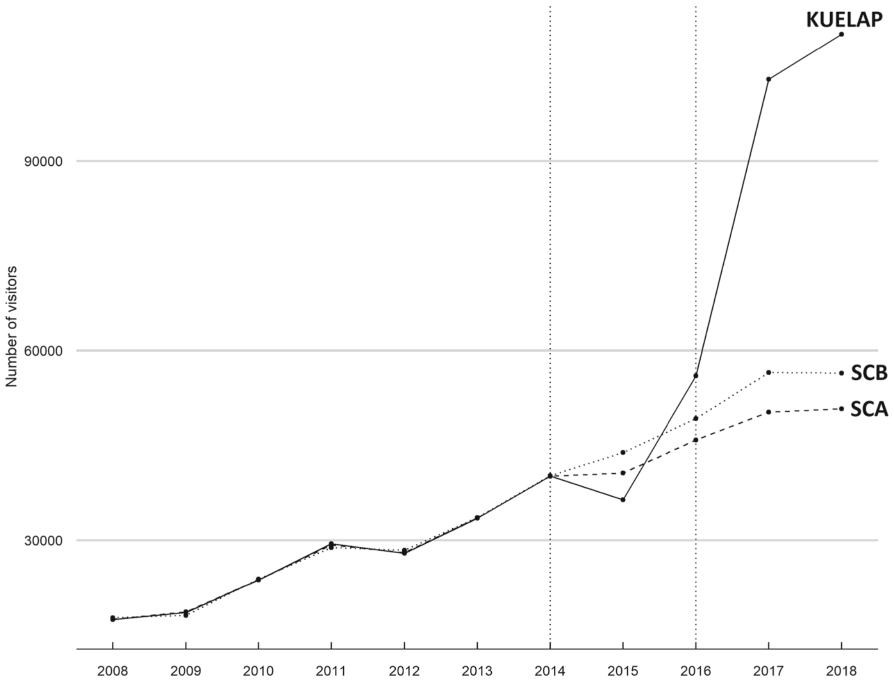


Fig. 9 Total visits: Kuelap, "Synthetic control", and El Niño: 2008–2018 . *Source*: Own elaboration

5.3 The effect of adding covariates

The second robustness analysis we undertake is the estimation of the synthetic control using covariates. The results are displayed in Tables 8 and 9.

As discussed in Sect. 3, when there exists uncertainty as to which covariates to include, then it is advisable to construct the synthetic control using the preintervention visits as the only predictors (Ferman et al. 2020; Kaul et al. 2022). In our case, the lack of reliable site-level data for potential predictors is the main limitation for not adding covariates in the baseline synthetic control.

However, we estimate alternative synthetic controls in order to check if the results remain stable. First, we estimate a synthetic control adding as a covariate the number of domestic tourists as percentage of the total number of tourists (domestic visitors), which is the only covariate with information specific to each site. The second specification includes more covariates: average length of stay in accommodation facilities (length of stay), number of guests per accommodation facility (guests per accommodation), participation of tourism in GDP (tourism development), average level of education achieved by people above the age of 15 (educational attainment) and average annual temperature (regional temperature). We add covariates to both SCA and SCB.

As seen in Table 9, the weights of the synthetic control (A) do not change when one or more covariates are added, as is formally shown by Kaul et al. (2022). This

Table 8 Synthetic control: Weights for each archaeological site . *Source*: Own elaboration

Archaeological site	One control		More controls	
	Synthetic control A	Synthetic control B	Synthetic control A	Synthetic control B
Choquequirao	0.12	0.08	0.12	0.08
Cumbemayo	0.31	0.22	0.30	0.23
Intihuatana	0.18	0.22	0.19	0.23
Kotosh	0.20	0.27	0.20	0.27
Machu Picchu	0.00	0.00	0.00	0.00
Moray	0.00	0.00	0.00	0.00
Otuzco	0.00	0.00	0.00	0.00
Pikillaqta	0.00	0.00	0.00	0.00
Raqchi	0.00	0.02	0.00	0.02
Saywite	0.00	0.00	0.00	0.00
Sillustani	0.00	0.00	0.00	0.00
Tipon	0.00	0.00	0.00	0.00
Wari	0.01	0.17	0.01	0.17
Sites affected by the El Niño phenomenon				
Caral	0.00		0.00	
Chavin	0.00		0.00	
Huaca Arco Iris	0.00		0.00	
Huaca Brujo	0.17		0.17	
Huaca Sol y Luna	0.00		0.00	
Narihuala	0.00		0.00	
Nikan	0.00		0.00	

is also the case for SCB and the corresponding synthetic controls with one and more covariates. Also, the values of Kuelap's covariates are very similar to those of the alternative synthetic controls, as displayed in Table 9. Finally, the estimated causal effects are very similar to those of the baseline SCA and SCB. Overall, the results show strong evidence that the investment package in tourism infrastructure has had a positive causal effect on the number of visitors to Kuelap.

6 Conclusions

This paper estimates the effect of public investment in tourism infrastructure on tourism demand for the Peruvian case. We analysed the case of the Kuelap Archaeological Complex, which has become more attractive and accessible after the construction of the first cable car system in Peru and the redevelopment of Jaen airport. For this purpose, we applied a comparative case study with a "synthetic control", which was built using information from other similar archaeological sites in Peru. The results show that investment in tourism infrastructure generated an increase of approximately 100% in the number of visits to Kuelap, twice the initial forecast.

Table 9 Synthetic control units . *Source*: Own elaboration

Predictors	Kuelap	One convariates		More covariates	
		Synthetic control A	Synthetic control B	Synthetic control A	Synthetic control B
Preintervention outcomes					
Visits in 2008	17,396	17,447	17,692	17,445	17,699
Visits in 2009	18,542	18,613	18,081	18,623	18,080
Visits in 2010	23,696	23,723	23,858	23,709	23,858
Visits in 2011	29,431	29,241	28,830	29,251	28,830
Visits in 2012	27,960	28,019	28,397	28,031	28,391
Visits in 2013	33,495	33,551	33,574	33,567	33,583
Visits in 2014	40,146	40,136	40,191	40,137	40,175
Controls					
Domestic visitors	76.52	85.5	88.3	85.7	88.3
Length of stay	1.14			1.39	1.42
Guests per accommodation	1380			1354	1255
Tourism development	1.34			2.23	2.09
Educational attainment	8.20			8.73	8.65
Regional temperature	14.58			17.1	17.3
Visits during treatment					
2015	36,385	40,635	43,883	40,637	43,830
2016	56,010	45,827	49,238	45,873	49,172
2017	102,905	50,326	56,574	50,243	56,469
2018	110,068	50,818	56,468	50,795	56,351
Estimated effect					
2017		52,579	46,331	52,662	46,436
2018		59,250	53,600	59,273	53,717
Average 2017–2018		55,914	49,966	55,967	50,077
p-value		0.048	0.071	0.048	0.071

Our findings provide evidence that promoting investment in infrastructure to facilitate access to archaeological sites with high tourism potential can be a useful tool to stimulate both tourism and by extension economic activity. Thus, investment in tourism infrastructure could contribute to overcoming the negative economic consequences of the Covid-19 pandemic. Choquequirao, located in the Cusco region and long considered the second Machu Picchu, is an archaeological site that has been attracting more tourists in recent years; however, the lack of accessibility to this place limits its potential for development and a significant increase in visitor numbers. An investment package similar to Kuelap's could make it more accessible and attractive.[9]

[9] Non-official estimates indicate that with a system of cable cars providing access to Choquequirao from the nearest road could reduce travel times from a 2-day walk to less than 30 min.

Finally, this paper provides an example of how investment under a public–private partnership (PPP) scheme can be a useful tool to foster tourism.

Appendix

A: Descriptive statistics of the predictor variables

Site	Variable	Mean	SD	Min.	25th p.	75th p.	Max.
Kuelap	Pre-treatment visits	45,094.00	32,228.44	17,396.00	25,828.00	48,078.00	110,068.00
	Length of stay	1.17	0.10	1.10	1.10	1.20	1.40
	Domestic visits	78.43	4.67	69.00	76.18	81.75	83.28
	Hotel demand	1365.69	111.87	1208.99	1286.64	1448.04	1534.82
	Tourism development	1.37	0.05	1.29	1.35	1.41	1.46
	Education	8.36	0.26	7.90	8.20	8.50	8.80
	Regional temperature	14.88	0.53	14.00	14.75	15.18	15.60
Caral	Pre-treatment visits	57,984.91	6335.22	45,095.00	55,650.50	61,534.00	66,425.00
	Length of stay	1.35	0.05	1.30	1.30	1.40	1.40
	Domestic visitors	93.17	2.10	90.49	91.11	95.04	96.00
	Guests per accommodation	4637.93	712.35	3417.26	4344.45	5150.44	5392.01
	Tourism development	4.57	0.19	4.28	4.40	4.74	4.76
	Educational attainment	11.08	0.14	10.90	10.95	11.20	11.30
	Regional temperature	19.51	0.71	18.70	19.00	20.03	20.80
Chavin	Pre-treatment visits	69,929.73	16,738.07	46,156.00	58,453.00	79,672.00	96,642.00
	Length of stay	1.25	0.05	1.20	1.20	1.30	1.30
	Domestic visitors	87.77	3.50	82.58	84.96	90.71	91.85
	Guests per accommodation	437.36	61.52	382.33	393.83	478.77	555.51
	Tourism development	2.34	0.31	1.86	2.17	2.58	2.79
	Educational attainment	9.46	0.19	9.10	9.40	9.55	9.70
	Regional temperature	12.45	0.35	12.00	12.23	12.65	13.10
Choquequirao	Pre-treatment visits	5768.82	1657.62	3334.00	4718.50	7341.50	8023.00
	Length of stay	1.63	0.07	1.50	1.60	1.70	1.70
	Domestic visitors	34.52	12.63	21.06	24.79	43.01	56.77
	Guests per accommodation	686.00	107.15	551.40	569.74	767.04	829.57
	Tourism development	4.05	0.29	3.77	3.81	4.12	4.73
	Educational attainment	9.55	0.20	9.20	9.40	9.70	9.80
	Regional temperature	12.47	0.43	12.00	12.15	12.60	13.30

Site	Variable	Mean	SD	Min.	25th p.	75th p.	Max.
Cumbemayo	Pre-treatment visits	46,950.09	20,272.64	21,701.00	29,195.00	63,920.00	78,316.00
	Length of stay	1.34	0.09	1.20	1.30	1.40	1.50
	Domestic visitors	93.07	2.80	88.35	91.39	95.05	97.74
	Guests per accommodation	1250.72	107.53	1096.11	1147.06	1337.54	1397.42
	Tourism development	1.94	0.24	1.60	1.73	2.13	2.26
	Educational attainment	8.16	0.17	7.80	8.15	8.30	8.30
	Regional temperature	14.78	0.54	14.00	14.45	15.00	15.60
Huaca	Pre-treatment visits	54,433.00	5674.30	45,833.00	50,224.00	58,497.50	63,405.00
	Length of stay	1.25	0.05	1.20	1.20	1.30	1.30
	Domestic visitors	78.04	1.57	75.06	76.94	78.92	80.62
	Guests per accommodation	1780.69	174.56	1563.03	1662.68	1903.17	2127.01
	Tourism development	2.28	0.16	2.07	2.13	2.44	2.48
	Educational attainment	9.59	0.19	9.30	9.50	9.70	9.90
	Regional temperature	20.55	0.89	19.30	19.93	21.15	22.20
Huaca Brujo	Pre-treatment visits	42,607.73	13,056.07	16,474.00	37,579.00	48,212.50	67,262.00
	Length of stay	1.25	0.05	1.20	1.20	1.30	1.30
	Domestic visitors	82.83	3.05	78.28	81.18	84.53	87.75
	Guests per accommodation	1780.69	174.56	1563.03	1662.68	1903.17	2127.01
	Tourism development	2.28	0.16	2.07	2.13	2.44	2.48
	Educational attainment	9.59	0.19	9.30	9.50	9.70	9.90
	Regional temperature	20.55	0.89	19.30	19.93	21.15	22.20
Huaca Sol	Pre-treatment visits	121,109.90	11,867.18	98,143.00	114,909.50	126,377.00	141,123.00
	Length of stay	1.25	0.05	1.20	1.20	1.30	1.30
	Domestic visitors	75.26	1.99	71.34	74.44	76.82	77.62
	Guests per accommodation	1780.69	174.56	1563.03	1662.68	1903.17	2127.01
	Tourism development	2.28	0.16	2.07	2.13	2.44	2.48
	Educational attainment	9.59	0.19	9.30	9.50	9.70	9.90
	Regional temperature	20.55	0.89	19.30	19.93	21.15	22.20

Site	Variable	Mean	SD	Min.	25th p.	75th p.	Max.
Intihuatana	Pre-treatment visits	8099.91	4725.68	1129.00	4457.00	11,738.50	16,044.00
	Length of stay	1.46	0.13	1.20	1.50	1.50	1.60
	Domestic visitors	97.13	2.55	92.47	96.12	98.96	100.00
	Guests per accommodation	1111.23	135.53	934.06	1024.77	1190.79	1343.56
	Tourism development	1.26	0.04	1.20	1.23	1.28	1.32
	Educational attainment	9.00	0.21	8.50	8.95	9.10	9.30
	Regional temperature	18.36	0.38	18.00	18.03	18.70	19.00
Kotosh	Pre-treatment visits	48,469.64	16,030.58	17,092.00	42,548.50	57,309.50	70,854.00
	Length of stay	1.23	0.08	1.10	1.20	1.25	1.40
	Domestic visitors	97.76	2.61	90.63	97.59	99.22	99.68
	Guests per accommodation	1613.04	56.27	1531.91	1582.12	1636.85	1720.52
	Tourism development	2.77	0.08	2.57	2.76	2.81	2.88
	Educational attainment	8.44	0.22	8.10	8.30	8.60	8.70
	Regional temperature	20.58	0.45	20.00	20.23	20.88	21.40
Machu Picchu	Pre-treatment visits	1,026,919.00	300,337.60	583,480.00	774,216.00	1,277,352.00	1,491,840.00
	Length of stay	1.63	0.07	1.50	1.60	1.70	1.70
	Domestic visitors	26.87	2.82	22.79	24.44	28.28	31.29
	Guests per accommodation	686.00	107.15	551.40	569.74	767.04	829.57
	Tourism development	4.05	0.29	3.77	3.81	4.12	4.73
	Educational attainment	9.55	0.20	9.20	9.40	9.70	9.80
	Regional temperature	12.47	0.43	12.00	12.15	12.60	13.30
Moray	Pre-treatment visits	186,340.60	173,026.30	39,957.00	63,487.00	309,383.00	517,909.00
	Length of stay	1.63	0.07	1.50	1.60	1.70	1.70
	Domestic visitors	36.94	4.35	29.85	34.11	39.64	44.06
	Guests per accommodation	686.00	107.15	551.40	569.74	767.04	829.57
	Tourism development	4.05	0.29	3.77	3.81	4.12	4.73
	Educational attainment	9.55	0.20	9.20	9.40	9.70	9.80
	Regional temperature	12.47	0.43	12.00	12.15	12.60	13.30
Narihuala	Pre-treatment visits	23,746.09	5986.69	12,760.00	19,336.00	26,635.00	32,754.00
	Length of stay	1.49	0.05	1.40	1.50	1.50	1.60

Site	Variable	Mean	SD	Min.	25th p.	75th p.	Max.
	Domestic visitors	97.63	0.60	96.52	97.46	97.94	98.36
	Guests per accommodation	1440.59	140.98	1189.95	1341.15	1546.53	1630.59
	Tourism development	2.21	0.14	2.04	2.09	2.28	2.46
	Educational attainment	9.26	0.10	9.10	9.20	9.30	9.40
	Regional temperature	24.83	0.82	23.90	24.05	25.28	26.10
Nikan	Pre-treatment visits	101,410.30	12,208.17	86,284.00	95,034.00	102,066.00	128,732.00
	Length of stay	1.25	0.05	1.20	1.20	1.30	1.30
	Domestic visitors	76.96	2.88	72.30	74.75	79.15	81.10
	Guests per accommodation	1780.69	174.56	1563.03	1662.68	1903.17	2127.01
	Tourism development	2.28	0.16	2.07	2.13	2.44	2.48
	Educational attainment	9.59	0.19	9.30	9.50	9.70	9.90
	Regional temperature	20.55	0.89	19.30	19.93	21.15	22.20
Otuzco	Pre-treatment visits	59,680.91	29,702.54	26,361.00	37,409.00	87,188.00	103,872.00
	Length of stay	1.34	0.09	1.20	1.30	1.40	1.50
	Domestic visitors	95.58	2.16	92.22	94.19	97.42	98.19
	Guests per accommodation	1250.72	107.53	1096.11	1147.06	1337.54	1397.42
	Tourism development	1.94	0.24	1.60	1.73	2.13	2.26
	Educational attainment	8.16	0.17	7.80	8.15	8.30	8.30
	Regional temperature	14.78	0.54	14.00	14.45	15.00	15.60
Pikillaqta	Pre-treatment visits	50,073.54	24,303.07	17,009.00	33,568.00	69,382.50	92,383.00
	Length of stay	1.63	0.07	1.50	1.60	1.70	1.70
	Domestic visitors	65.54	2.22	61.78	64.42	66.32	70.18
	Guests per accommodation	686.00	107.15	551.40	569.74	767.04	829.57
	Tourism development	4.05	0.29	3.77	3.81	4.12	4.73
	Educational attainment	9.55	0.20	9.20	9.40	9.70	9.80
	Regional temperature	12.47	0.43	12.00	12.15	12.60	13.30
Raqchi	Pre-treatment visits	109,231.10	13,533.33	87,877.00	101,256.00	115,177.50	131,089.00
	Length of stay	1.63	0.07	1.50	1.60	1.70	1.70
	Domestic visitors	14.61	4.48	5.86	12.63	16.20	23.24
	Guests per accommodation	686.00	107.15	551.40	569.74	767.04	829.57
	Tourism development	4.05	0.29	3.77	3.81	4.12	4.73
	Educational attainment	9.55	0.20	9.20	9.40	9.70	9.80
	Regional temperature	12.47	0.43	12.00	12.15	12.60	13.30

Site	Variable	Mean	SD	Min.	25th p.	75th p.	Max.
Saywite	Pre-treatment visits	2958.27	900.67	2131.00	2418.00	3046.50	5213.00
	Length of stay	1.28	0.08	1.10	1.30	1.30	1.40
	Domestic visitors	87.33	11.73	62.51	82.46	96.12	100.00
	Guests per accommodation	1217.74	330.96	766.37	946.01	1446.66	1749.41
	Tourism development	2.17	0.67	0.84	2.32	2.55	2.64
	Educational attainment	9.02	0.24	8.70	8.80	9.20	9.40
	Regional temperature	14.88	0.83	14.00	14.15	15.53	16.20
Sillustani	Pre-treatment visits	81,472.46	13,132.82	51,068.00	80,149.50	90,344.00	95,008.00
	Length of stay	1.29	0.07	1.20	1.25	1.30	1.40
	Domestic visitors	29.11	8.37	13.23	25.17	34.59	40.01
	Guests per accommodation	1438.97	80.31	1298.62	1402.60	1470.95	1612.51
	Tourism development	2.11	0.09	1.96	2.06	2.17	2.23
	Educational attainment	9.60	0.20	9.30	9.50	9.70	9.90
	Regional temperature	10.43	0.65	9.00	10.23	10.75	11.50
Tipon	Pre-treatment visits	64,434.64	33,410.48	24,497.00	40,522.50	98,256.50	119,598.00
	Length of stay	1.63	0.07	1.50	1.60	1.70	1.70
	Domestic visitors	65.92	5.48	53.24	64.58	67.19	76.50
	Guests per accommodation	686.00	107.15	551.40	569.74	767.04	829.57
	Tourism development	4.05	0.29	3.77	3.81	4.12	4.73
	Educational attainment	9.55	0.20	9.20	9.40	9.70	9.80
	Regional temperature	12.47	0.43	12.00	12.15	12.60	13.30
Wari	Pre-treatment visits	42,216.00	23,683.14	16,105.00	25,125.50	58,922.00	81,033.00
	Length of stay	1.46	0.13	1.20	1.50	1.50	1.60
	Domestic visitors	94.21	3.03	90.08	92.01	96.84	98.96
	Guests per accommodation	1111.23	135.53	934.06	1024.77	1190.79	1343.56
	Tourism development	1.26	0.04	1.20	1.23	1.28	1.32
	Educational attainment	9.00	0.21	8.50	8.95	9.10	9.30
	Regional temperature	18.36	0.38	18.00	18.03	18.70	19.00

B: Archaeological sites

	Short name	Full name	Department	Province	District
1	Kulap	Complejo Arqueológico de Kúelap	Amazonas	Luya	Tingo
2	Revash	Sitio Arqueológico Revash	Amazonas	Luya	Santo Tomás
3	Karajia	Sitio Arqueológico karagía	Amazonas	Luya	Trita
4	Chavin	Monumento Arqueológico Chavín de Huantar	Áncash	Huari	Chavín De Huántar
5	Saywite	Conjunto Arqueológico de Saywite	Apúrimac	Abancay	Curahuasi
6	Intihuatana	Centro Arqueológico Intihuatana	Ayacucho	Vilcashuaman	Vischongo
7	Wari	Complejo Arqueológico de Wari	Ayacucho	Huamanga	Quinua
8	Otuzco	Centro Arqueológico Ventanillas de Otuzco	Cajamarca	Cajamarca	Los Baños Del Inca
9	Cumbemayo	Monumento Arqueológico Cumbemayo	Cajamarca	Cajamarca	Cajamarca
10	Machu Picchu	Ciudad Inka de Machu Picchu	Cusco	Urubamba	Machu Picchu
11	Moray	Complejo Arqueológico de Moray	Cusco	Urubamba	Maras
12	Tipón	Complejo Arqueológico de Tipón	Cusco	Quispicanchi	Oropesa
13	Choquequirao	Parque Arqueológico de Choquequirao	Cusco	La Convención	Vilcabamba
14	Pikillaqta	Parque Arqueológico de Pikillaqta	Cusco	Quispicanchi	Lucre
15	Raqchi	Parque Arqueológico de Raqchi	Cusco	Canchis	San Pedro

	Short name	Full name	Department	Province	District
16	Kotosh	Complejo Arqueológico Kotosh	Huánuco	Huánuco	Huánuco
17	Huaca Arco Iris	Complejo Arqueológico Huaca Arco Iris	La Libertad	Trujillo	La Esperanza
18	Huaca Sol	Complejo Arqueológico Huaca del Sol y de la Luna	La Libertad	Trujillo	Moche
19	Huaca Brujo	Complejo Arqueológico Huaca el Brujo	La Libertad	Ascope	Ascope
20	Nikan	Palacio Nikán casa del centro	La Libertad	Trujillo	Huanchaco
21	Caral	Ciudad Sagrada de Caral	Lima	Barranca	Supe
22	Narihualá	Zona Arqueológica y Museo de Sitio Narihualá	Piura	Piura	Catacaos
23	Sillustani	Complejo Arqueológico de Sillustani	Puno	Puno	Puno

Source: Ministry of Foreign Trade and Tourism (2019)

C: Variables

	Institution	Source	Indicator	Variable	Measure
1	MINCETUR	Monthly Survey of lodging establishments	Average length of stay in lodging establishments	Length of stay	Average number of days
2	MINCETUR	Tourism Statistical Reports	Number of domestic tourists (% of total number of tourists)	Domestic visitors	Percentage

	Institution	Source	Indicator	Variable	Measure
3	MINCETUR	Monthly Survey of lodging establishments	Guests arrivals per accommodation facility	Guests per accommodation	Number of guests per accommodation
4	INEI	INEI	Gross value added at 2007 prices (% of GDP)	Tourism development	Percentage
5	INEI	National Household Survey	Average years of schooling attained by the population over age 15	Educational attainment	Years
6	SENAMHI	SENAMHI	Average annual temperature	Regional temperature	Degrees Celsius
7	MINCETUR	Tourism Statistical Reports	Total visits (2008 - 2014)	pre-treatment	number of visitors

Source: Ministry of Foreign Trade and Tourism (2019), National Institute of Statistics and Informatics (2019)

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