Institutional quality, climate change impacts, and regional economic growth Evidence from Peru

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Abstract

We analyze the effects of institutional quality and climate change impacts at the subnational level on regional economic development and the role of geographical externalities in these relationships. We use a panel-dataset for regions in Peru and estimate spatial models of economic growth, augmented by institutional and climate change variables. We found that institutional quality is a key driver of economic performance, particularly in lagging regions, where improved governance facilitates regional economic growth. Climate change impacts also play a crucial role, as rising temperatures negatively impact economic growth beyond a critical threshold, underscoring the need for climate adaptation policies.

Keywords: Regional economic growth, convergence, institutional quality, climate change, spatial models, Peru
JEL codes: R11, R12, Q54, C23

1. Introduction

Regional economic growth is a central topic in economic geography, as scholars seek to understand the factors that drive prosperity and regional disparities (Hansen, 2022). Much research has examined these differences, highlighting the interplay between economic activities, agglomeration processes, human capital, and institutional capacity (Bathelt et al., 2024). Traditional theories emphasize the role of physical capital (Solow, 1956; Swan, 1956), human capital, and innovation (Romer, 1986; Lucas, 1988) as key determinants of growth. However, these explanations have become insufficient to account for persistent regional inequalities (Rodríguez-Pose, 2013; Erfurth, 2024).

Beyond conventional factors, recent studies highlight the importance of institutional, environmental, and geographic conditions in shaping regional economic trajectories. Institutions influence economic performance through multiple channels, including productivity (Rodríguez-Pose & Ganau, 2022), innovation (Zhang & Rodríguez-Pose, 2024; Capello & Lenzi, 2019), entrepreneurship (Nistotskaya et al., 2015), and competitiveness (Annoni & Dijkstra, 2013). Institutional quality also plays a crucial role in environmental governance, affecting how regions manage natural resources and respond to climate-related challenges (Sarpon & Bein, 2020; Halkos et al., 2015). At the same time, climate change has exacerbated regional disparities, with varying economic consequences depending on climate vulnerability and sectoral dependence (Acacha-Acakpo et al., 2024; Warsame et al., 2021; Ahsan et al., 2020). Rising temperatures, extreme weather events, and resource constraints directly impact innovation (Torre, 2023) and human capital performance (Yang & Tang, 2022). These environmental challenges interact with pre-existing institutional weaknesses, further widening regional economic gaps.

New Economic Geography (Fujita et al., 2001; Krugman, 2011) and urban economics (Glaeser, 2011) emphasize the role of agglomeration economies and geographical externalities in shaping regional growth. Geographical externalities are particularly relevant in absorbing investments in physical and human capital (Sanso-Navarro et al., 2020; Benos et al., 2015; Jung & López-Bazo, 2017) and facilitating technological diffusion (Elhorst et al., 2024). From a policy perspective, addressing regional disparities requires recognizing how geography shapes economic opportunities and constraints (Rey, 2025).

This paper contributes to the literature by jointly examining the effects of institutional quality, climate change, and spatial dynamics on regional economic growth in a developing economy, Peru. While previous studies have explored these factors separately (Baarsch et al., 2020; Rodríguez-Pose & Ketterer, 2020; Aristizábal & García, 2021), limited research analyzes their simultaneous influence. This gap is particularly relevant in contexts where institutional weaknesses, environmental vulnerability, and spatial interdependence shape economic performance. By integrating these perspectives, this study provides a more comprehensive understanding of the mechanisms driving regional disparities. Specifically, it assesses how institutional capacity enhances or constrains economic growth, how climate change exacerbates inequalities, and how spatial spillovers influence growth trajectories.

This study focuses on Peru, a developing country where complex geography and territorial diversity create economic opportunities and significant challenges for regional integration (World Bank, 2025). Despite efforts toward regional economic convergence, disparities across Peruvian regions remain significantly higher than the average recorded in OECD countries, indicating persistent economic imbalances (World Bank, 2025). Additionally, Peru's geographical location and topography make it highly vulnerable to natural disasters. The country lies within the Pacific Ring of Fire, one of the most seismically active regions in the world, where more than 80% of global earthquakes occur. It is also periodically exposed to El Niño events, which cause extreme weather fluctuations and severe economic disruptions. These environmental risks compound regional disparities, affecting infrastructure development, economic stability, and long-term growth prospects.

Understanding how the geographical externalities, environmental, and institutional factors interact in the context of a developing country is essential for designing policies that promote sustainable and inclusive growth. Addressing these challenges requires integrated development strategies that mitigate territorial inequalities while enhancing regional resilience to economic and environmental shocks.

After this introduction, Section 2 contains the literature on regional economic performance and its relationship with institutional performance, climate change, and geographical factors. Section 3 describes Peru and its regions. Section 4 presents the empirical analysis data and some descriptive statistics. Section 5 presents the econometric models of regional convergence to be estimated. Section 6 presents empirical findings, and conclusions are drawn in Section 7.

2. Literature review

The study of regional economic growth has evolved significantly in recent decades, with increasing recognition that disparities between regions cannot be explained solely by the accumulation of physical or human capital (Rodríguez-Pose, 2013). Institutional factors (Kouadio & Gakpa, 2021; Aristizábal & García, 2021) and environmental conditions (Baarsch et al., 2020) have gained prominence, particularly in developing economies where regional inequalities remain persistent (Ibourk & Elouaourti, 2023). These disparities are further exacerbated by institutional weaknesses (Iammarino et al., 2019) and climate vulnerability (Paglialunga et al., 2023).

Institutions play a critical role in economic growth, influencing investment stability, resource allocation efficiency, and the ability of governments to provide public goods (Acemoglu & Robinson, 2006). Studies in Europe and North America show that strong and transparent institutions correlate with higher growth rates and lower regional inequalities (Rodríguez-Pose & Di Cataldo, 2015; Charron et al., 2014). However, in developing economies, institutional capacity tends to be weaker and more heterogeneous, resulting in uneven growth trajectories and economic divergence (Bosker & Garretsen, 2009).

At the same time, climate change has emerged as a key determinant of regional economic performance, with its impacts varying across territories. Countries heavily dependent on climate-sensitive sectors, such as agriculture and tourism, face greater economic risks (Burke et al., 2015; Damania et al., 2020). Rising temperatures and extreme weather events reduce labor productivity and deter capital investment, further widening regional economic disparities (Kalkuhl & Wenz, 2020; Khan & Rashid, 2022). While these effects have been well-documented in advanced economies, regional-level evidence for developing countries remains scarce (Baarsch et al., 2020).

Another crucial dimension of regional economic growth is geographical externalities. New Economic Geography highlights how spatial externalities, labor and capital mobility, and agglomeration economies shape regional economic performance (Krugman, 1991; Fujita et al., 2001). Empirical studies indicate that these factors are particularly relevant in developing economies, where infrastructure and market access remain highly uneven (Aristizábal & García, 2021). This spatial concentration of economic activity often results in widening regional inequalities, leaving lagging regions further behind (Rey & Montouri, 1999; Jung & López-Bazo, 2017).

Empirical analyses of regional economic growth in Peru have produced mixed results. Early studies (Odar, 2002; Chirinos, 2008) found that lower-income regions experienced higher economic growth rates, supporting the convergence hypothesis when controlling for regional characteristics. Similarly, Rosales et al. (2008) identified faster growth in lower-income regions. However, more recent research challenges this view. Tello (2020) found no evidence of regional convergence from 2000 to 2020, attributing growth disparities primarily to resource-intensive sectors. These findings suggest that Peru's economic growth remains uneven, with certain regions benefiting more from economic expansion while others stagnate. Despite these contributions, most studies have overlooked spatial effects, which may lead to biased estimates due to omitted variables. Only Gonzales de Olarte and Trelles (2004), and Palomino and Rodríguez (2019) have accounted for geographical externalities. The latter study found significant spatial spillovers influencing regional growth, emphasizing the need to consider spatial interdependencies in regional economic models.

This study addresses this gap by examining how institutional quality and climate change shape regional economic growth in a developing economy. Unlike previous studies that analyze these factors separately, this research integrates institutional capacity, climatic conditions, and spatial dynamics to assess regional economic disparities comprehensively. By addressing these interactions, this study enhances our understanding of the challenges faced by regions with weak institutional capacity and high climate vulnerability. The findings offer valuable insights for policymakers, emphasizing the need for integrated development strategies that account for governance quality, environmental risks, and spatial interdependencies in fostering sustainable and inclusive regional growth.

3. Peru and its regions

This paper uses data from Peru, a middle-income South American country with a population of around 33 million inhabitants and an area of approximately 1.3 million km2. Table 1 presents economic and social indicators for Peru and other countries. Peru is characterized by positive economic growth coupled with high levels of poverty, inequality, and labor informality: the annual GDP growth rate is 13.3%, but the percentage of people living below the poverty line is 4.5% (i.e., less than USD 2.15 per day), the Gini coefficient is approximately 40 and informal employment is 60%, high values compared to those of neighboring countries. Table 1 also presents government effectiveness scores, where Peru registers a lower value than comparable countries such as Colombia and Ecuador, suggesting weaker perceptions of institutional performance.

[Insert Table 1 around here]

Peru is divided into 24 departments, in addition to Lima as the capital district, 195 provinces, and 1845 districts. The departments are administrative subdivisions with a certain level of autonomy, although economically, resources are always distributed from the state to the departments and then to the provinces and districts. Figure 1 shows the departments and regions defined by the National Institute of Statistics and Informatics (INEI, 2017), which divides Peru into the center, north, south, and east regions. The central part of Peru comprises the departments with the largest populations and highest levels of economic activity: Ancash, Huánuco, Lima, Pasco, Junín, Huancavelica, and Ica. These departments comprise 49.4% of the country's total population for 2021, with around 16 million inhabitants, of which approximately 10 million correspond to the city of Lima (Metropolitan Lima).

[Insert Figure 1 around here]

Other departments with high levels of economic output are located in the southern part of the country, including Apurímac, Arequipa, and Moquegua, which register some of the highest GDP per capita values in Peru. In contrast, several departments in the Amazon region—such as Loreto (Iquitos), Madre de Dios (Puerto Maldonado), Ucayali (Pucallpa), Amazonas (Chachapoyas), and Tumbes (Tumbes)—as well as highland regions like Ayacucho (Huamanga), Huancavelica, Huánuco, and Puno, report lower GDP per capita. These geographic patterns reflect long-standing regional disparities in economic development across the country.

4. Data

This study uses a panel dataset covering 24 departments of Peru over 16 years from 2004 to 2019. The dataset forms a balanced panel with 24 departments observed over 16 years, resulting in 384 observations. The dependent variable, economic growth, is measured using real GDP per capita obtained from the INEI. The analysis includes three main explanatory variables: the time lag of real GDP per capita, which helps identify the convergence parameter, an institutional capacity variable, and climate change indicators.

Measuring institutional capacity presents several challenges (Iammarino et al., 2019; Rodriguez-Pose, 2020). Institutions vary significantly across regions and over time, making it difficult to establish a standardized framework applicable in all contexts. Additionally, the relationship between institutions and other development factors, such as infrastructure investment and human capital, is often nonlinear and dependent on specific development thresholds. Furthermore, contextual factors influencing institutional configurations make obtaining comparable and precise data nearly impossible. As a result, there is no broad consensus on which types of institutions are most relevant for regional economic development (Acemoglu & Robinson, 2006; Rodríguez-Pose & Storper, 2006).

In recent years, research on the quality of government (QoG) has emerged as a multidisciplinary field, encompassing aspects such as corruption, the rule of law, and the impartiality of the public sector (Rodriguez-Pose, 2020). QoG attempts to measure how governments effectively perform their functions and provide public services impartially and uncorruptly. Various studies have examined the impact of government quality on regional economic growth in Colombia (Aristizábal & García, 2021) and the European Union (Rodríguez-Pose & Ketterer, 2020; Charron et al., 2014).

To assess institutional capacity at the departmental level, three indices are used: an index measuring regional efficiency in resource administration, an index capturing the capacity to provide public services and implement policies, and an aggregated index of public administration quality (IQPA), which averages the efficiency and capacity indices. These indices range from 0 to 100, with higher values indicating better institutional performance. The data for these indices comes from the National Registry of Municipalities (RENAMU), an annual survey conducted by INEI. RENAMU collects information from provincial and district municipalities and population centers on infrastructure, administrative processes, personnel, procedures, and public services, aggregating at the departmental level each year. In the regression models, these variables are incorporated into quintiles to account for heterogeneity in institutional capacity across departments.

Climate change variables are represented by the average annual temperature (in degrees Celsius) and total annual precipitation (in millimeters). These indicators are widely used in the literature to assess the impact of climate change on macroeconomic outcomes, as they capture variations in weather effects across different climatic zones. This is particularly relevant for Peru, given its diverse internal geographies (Diffenbaugh & Scherer, 2011; Coumou & Robinson, 2013; Brown et al., 2013; Mendelsohn, 2016; Burke et al., 2015; Baarsch et al., 2020; Damania et al., 2020). The temperature and precipitation data used in this analysis are sourced from the Climate Change Knowledge Portal of the World Bank (CCKP, 2023).

Control variables include key economic growth and convergence indicators identified in the literature (Mankiw et al., 1992; Rey & Janikas, 2005; Aristizábal & García, 2021) and human capital, infrastructure, and population density variables. Human capital is proxied by the percentage of the population with secondary education, using data from INEI. Infrastructure is represented by the percentage of households with fixed internet access, based on the National Household Survey (ENAHO), which reflects the level of digital connectivity in each department. Population density is measured as the number of inhabitants per square kilometer, also sourced from INEI. Table 2 shows the description of the variables used in the analysis.

[Insert Table 2 around here]

5. Descriptive evidence

Table 3 shows that the GDP per capita in Peru between 2004 and 2019 grew by 89%. The coefficient of variation on this variable indicates that the differences in economic performance among regions are important and have decreased during the period analyzed. Regarding the institutional variables, we observe that the quality of public administration in the regions has increased over time, and institutional efficiency has been the primary variable driving institutional performance in the regions.

[Insert Table 3 around here]

For the climate change variables, Table 3 shows that in the period analyzed, the temperature oscillated at 16 °C, with a minimum of 11 °C and a maximum of 22 °C. The descriptive statistics show that, on average, 2019 was a year with high precipitation, while 2012 had less rainfall. Regarding the control variables, there has been an improvement in the accumulation of human capital and infrastructure, and a higher density level in the departments during the period analyzed.

Figures 2 to 5 show the spatial distribution of real GDP per capita, an institutional indicator (IQPA), and climate change variables for 2004 and 2019. For the first variable, Figure 2 evidences significant territorial differences in economic activity, which have become more pronounced over time. We observe that the coastal departments, such as Ancash, Lima, Ica, Arequipa, Moquegua, and Tacna, present higher GDP per capita than those located in the Amazon region (Loreto, Amazonas, Ucayali, Madre de Dios, and Puno).

[Insert Figure 2 around here]

Regarding the institutional capacity indicator, Figure 3 shows that in all regions, there was an increase in the performance of regional institutions: the IQPA increased by approximately 20 points between 2004 and 2019. For 2019, we have that the departments with a higher quality of public administration, therefore, higher institutional efficiency and capacity, are Ucayali, Pasco, Lambayeque, and Madre de Dios, while Apurímac, Amazonas, Arequipa, and Huancavelica are the departments with the lowest institutional performance.

[Insert Figure 3 around here]

Figure 4 displays the spatial distribution of average annual temperatures by department, highlighting apparent geographic clustering. In 2019, the highest average temperatures (above 24°C) were recorded in the Amazonian departments of Loreto, Ucayali, and Madre de Dios. In contrast, the southern highland departments of Huancavelica, Apurímac, Puno, and Moquegua reported significantly lower average annual temperatures, around 9°C.

[Insert Figure 4 around here]

In the case of precipitation (see Figure 5), we observe that the coast departments had the lowest accumulated precipitation per year, while the Amazon region experienced the highest rainfall. We also note that for the year 2019, there was higher precipitation in Loreto (2670.6 mm), Madre de Dios (2637.9 mm), and Ucayali (2308.3 mm). In contrast, the departments of Ica (68.6 mm) and Tacna (113.15 mm) showed periods of lowest precipitation.

[Insert Figure 5 around here]

Before analyzing Beta convergence in the following sections, we tested the existence of sigma-type convergence in real GDP per capita. Figure 6 shows the evolution of the coefficient of variation and Theil index for this variable. The results show evidence of sigma-type convergence between 2008 and 2019 under the estimation of the coefficient of variation and the Theil index. In both cases, the lowest value was observed in 2019 (coefficient of variation: 0.58; Theil index: 0.13). Similarly, in both cases, the highest value was expected in 2008 (0.88 and 0.25, respectively).

[Insert Figure 6 around here]

6. Empirical strategy

We follow the standard framework that Barro and Sala-i-Martin (1991) proposed to analyze the hypothesis of Beta convergence. This framework is based on a convergence equation that relates the economic growth of a region to its initial economic level. If this relationship's negative and significant coefficient is found, poor regions grow more than rich countries, creating a convergence process.

There are two models of Beta convergence: absolute and conditional convergence. The difference between the models is that the conditional Beta convergence model posits that the growth rate depends on the structural characteristics of each region, so it assumes that regions exhibit different steady states. In contrast, the absolute Beta convergence model does not consider different steady states among regions. The functional form of the absolute and conditional Beta convergence models is as follows, respectively:

$$\ln\left(\frac{Y_{iT}}{Y_{i0}}\right) = \alpha + \beta \ln Y_{i0} + u_i \tag{1}$$

$$\ln\left(\frac{Y_{it}}{Y_{it-1}}\right) = \alpha_i + \beta \ln Y_{it-1} + \theta X_{it} + u_{it}, \tag{2}$$

Equation (1) is estimated in the context of cross-sectional data to consider that there are no different steady states among departments. In this equation, the dependent variable represents the GDP per capita growth rate of department *i* between the final period T (in our case, 2021) and the initial period 0 (2012). Y_{i0} is the real GDP per capita in period 0 (2012). α is the constant term to be estimated, β is the convergence term of interest to be estimated, and u_i is the error term.

Equation (2) is estimated using panel data. In this model, the dependent variable is the GDP per capita growth rate for department *i* between period *t* and period *t−1*. Y_{it-1} represents the GDP per capita for department *i* in period *t−1*. β is the convergence coefficient to estimate and is expected to be negative to reflect departments catching up to their steady-state levels. *X* is a matrix of explanatory variables representing different departmental steady states, mentioned in the previous section, and α_i denotes fixed effects for each department and captures unobserved heterogeneity related to the steady state of each department. u_{it} is the error term.

In addition, we estimate the models of economic growth augmented by spatial effects. According to Rey and Montouri (1999) and Abreu et al. (2005), economic growth at the intra-regional level presents a significant spatial dimension. The idea is that the dynamics of economic growth in a region are determined not only by its characteristics but also by those of neighboring regions. In this part of the paper, we use spatial econometric techniques to estimate the models. Table 4 shows the spatial models of convergence to be estimated.

[Insert Table 4 around here]

W is the standardized queen-type first-order spatial contiguity matrix for all the models, and its interaction with the dependent or explanatory variables (SAR, SAC, and SDM) implies spatial lag terms in the model. These terms help determine the existence of spillover effects. They are used to calculate direct, indirect, and total impacts to interpret effects and their statistical significance (LeSage and Pace, 2009). These impacts are supported by the idea that when an explanatory variable for a particular region changes, it changes the dependent variable for the same region and the dependent variables for other regions. The first is called a direct effect, while the second is related to an indirect effect representing spatial spillover effects.

7. Results

The results of the estimations of the spatial panel data models with fixed effects are shown in Table 5.[1] We estimate the models by including the three measures of regional institutional performance. As a general result, we note that in both non-spatial and spatial models, the coefficient on the real GDP per capita in *t-1* is negative and statistically significant, indicating the existence of regional convergence processes in Peru between 2004 and 2019, as it implies that the poorer the region, the faster it grows.

[Insert Table 5 around here]

To assess the presence of spatial dependence in the growth regressions, we rely on the LM and robust LM tests based on the OLS estimates (see bottom of Table 5). These diagnostics provide evidence of spatial dependence, particularly when the IQPA index is used: the robust LM test for the spatial lag is statistically significant, while the error-based test is not. This suggests that spatial autocorrelation primarily affects the dependent variable rather than the error term in that specification. In contrast, when the institutional variables are disaggregated into efficiency and capacity indices, the robust LM statistics are not statistically significant, indicating a more ambiguous spatial structure.

Given this uncertainty, and to fully account for potential spatial interactions, we estimate a comprehensive set of spatial panel models—namely, the SAR, SEM, SAC, and SDM specifications. To capture how institutional quality influences both within-region outcomes and spillovers to neighboring regions, we compute direct, indirect, and total effects across all models, except for the SEM, which does not generate spillover effects by design. This strategy allows for a more nuanced understanding of spatial dynamics, without relying on a single assumed structure of spatial dependence.

Results across all spatial specifications in Table 5 consistently confirm the presence of conditional β-convergence among Peruvian departments. We observe that the lagged GDP per capita coefficient is negative and statistically significant in all models, supporting the notion that poorer

[1] We calculate spatial and non-spatial Hausman tests to select between fixed and random effects, and the tests show that the fixed effects model best fits our data.

regions tend to grow faster than richer ones. On average, the estimated convergence speed is 6.07% per year when institutional quality is proxied by the IQPA index, 6.06% when using the efficiency index, and 6.56% when using the capacity index. These convergence rates translate into half-lives of approximately 11 years. While slightly higher than estimates found in previous studies that did not account for spatial dependence, these values are consistent with the broader literature on regional growth in developing countries that incorporates spatial dynamics (e.g., Arbia et al., 2010; Royuela & García, 2015; Ahmad & Hall, 2017; De Almeida et al., 2018; Aristizábal & García, 2021).

Regarding the explanatory variables of interest, we observe that the coefficient on the institutional variables is positive and statistically significant, and the effects remain when a more complex spatial dependence structure is incorporated (see SAC and SDM models). These results suggest that better public administration performance positively impacts the region's economic performance. Institutional efficiency refers to the ability of regional governments to manage and allocate public resources effectively, while institutional capacity captures their ability to deliver public services and implement policies. We also find that institutional efficiency has a stronger association with economic growth, as its coefficient is larger than that of institutional capacity: 0.059 vs 0.041, respectively (see Columns 5 and 6 in Table 5).

To determine whether institutional performance facilitates regional economic growth and convergence, we include interaction terms between the real GDP per capita in *t-1* and institutional variables. The results show that the parameter estimates of interaction terms are negative and statistically significant, which suggests that good institutional performance through institutional efficiency and capacity helps facilitate regional economic convergence in Peru.

For the explanatory variables of climate change impacts, in particular, on the temperature variable, the results show that the coefficients of these variables are statistically significant, suggesting that the climate change factors are affecting the economic growth in Peru during the period analyzed. Including the quadratic term of the temperature variable allows us to identify the nonlinear relationship between this variable and economic growth. The idea is that it is expected that after a specific temperature, the effects on economic growth begin to be negative (see, for example, Burke et al. (2015), Kalkuhl and Wenz (2020), Baarsch et al. (2020), and Damania et al. (2020)). Using the parameter estimates of the equation in Column 4 of Table 5, it is possible to graph the effect of temperature on economic growth. Figure 7 shows the results, and we note a positive effect of temperature on economic growth, but after 22.75°C, there is an adverse effect on regional economic growth.

[Insert Figure 7 around here]

It is important to note that the point estimates in Table 5 are not directly interpretable, given the existence of indirect effects (LeSage & Pace, 2009). These indirect or spatial spillover effects refer to a change that occurs in the dependent variables of other regions when an explanatory variable for a particular region changes. We calculate the direct, indirect, and total effects following LeSage and Pace (2009), Elhorst (2010), and Halleck Vega and Elhorst (2012). Tables 6, 7, and 8 show these effects and their statistical significance for the SAR, SAC, and SDM.

[Insert Table 6 around here]

[Insert Table 7 around here]

[Insert Table 8 around here]

The results in Tables 6, 7, and 8 consistently show that the indirect effects of lagged GDP per capita are negative and statistically significant. This suggests that, in addition to within-region convergence, there are adverse spillover dynamics: wealthier neighboring regions appear to dampen local economic growth. One possible explanation is that richer neighbors may attract resources, investment, or labor away from adjacent areas, creating competitive pressures that hinder catch-up processes (Aristizábal & García, 2021). These findings reinforce the importance of incorporating spatial interdependencies into regional growth models to avoid underestimating mechanisms of interregional divergence.

In contrast, institutional performance consistently exerts a positive and significant direct effect across all specifications—whether measured via the IQPA composite index, efficiency, or capacity. This result indicates that departments with stronger institutional structures grow faster, highlighting the role of effective governance and policy implementation in fostering development. Notably, both dimensions—efficient public resource management and administrative capacity—contribute to growth at the subnational level. These findings are in line with a robust body of literature emphasizing the foundational role of institutions in shaping regional development, particularly in developing countries (Rodrik et al., 2004; Arbia et al., 2010; Coscia et al., 2017; Ahmad & Hall, 2017; Aristizábal & García, 2021).

An examination of the spillover effects reported in Tables 6, 7, and 8 reveals that the indirect effects of institutional performance on regional growth are not uniform across models. While the direct effects of institutional quality are consistently positive and statistically significant, the indirect effects vary in sign and magnitude, depending on the specific institutional dimension and the spatial specification (SAR, SAC, or SDM). For instance, the indirect effect of the capacity index is positive in the SAR model, but turns negative in the SAC and SDM models. Similarly, the spillover effect associated with institutional efficiency is significant and positive in the SAR and SDM models, yet becomes statistically insignificant—or even negative—under the SAC specification. These findings suggest that, although improvements in institutional quality promote a region's own economic performance, the extent and direction of cross-regional effects are sensitive to both the type of institutional variable and the spatial structure imposed. Hence, institutional spillovers are neither necessarily unidirectional nor uniformly beneficial, underscoring the complexity of spatial interactions in development processes. These results are consistent with previous studies highlighting the importance of institutional quality in neighboring regions for shaping local economic outcomes (Ades & Chua, 1997; Bosker & Garretsen, 2009; Arbia et al., 2010).

In the case of climate change variables, the results show that the indirect effect of temperature variables is positive and statistically significant on economic growth, which indicates that the temperature conditions in a department affect the economic activity of neighboring regions.

However, the indirect effect of the quadratic term of temperature is not statistically significant, suggesting that nonlinear relationships between temperature and economic growth in neighboring regions are unimportant.

Relative to our findings, Kalkuhl and Wenz (2020) and Khan and Rashid (2022) showed that in the short run, the effects of climate change damages on economic growth are very low, but in the long run, these effects are significant in hurting economic performance. These authors state that extreme climate events do not seem to have had an impact until now due to the human capacity to adapt to new realities (e.g., higher temperatures, higher precipitation, and severe climate phenomena), but the effects will be seen in the future. However, more studies are needed to measure the impact of climate change on economic growth and convergence, in particular, at the intra-regional level, where it is possible to take local climate action that more effectively mitigates the impacts of climate change.

8. Conclusions

This paper analyzes the effects of institutional quality and climate change on economic growth at the intra-regional level in the context of a developing Latin American country, Peru. We used balanced panel data for 24 departments for the 16 years from 2004 to 2019. We estimated spatially augmented growth models, which incorporate institutional and climate change variables while accounting for different forms of spatial dependence, thereby capturing geographical externalities and intra-regional convergence in Peru. This study makes a novel contribution in its simultaneous incorporation of institutional and climate risk variables and spatial dependence into a panel model of intra-regional growth, which has been little explored in the literature on regional growth in developing countries.

We found various interesting results. First, the findings highlight the critical role of local institutional quality in fostering economic growth, particularly in less developed regions. The results indicate that institutional quality is more significant for economically lagging regions, facilitating regional convergence. Specifically, a quantile shift in the institutional quality performance index is associated with a 4.7% increase in economic growth for the average lagging region, 4.2% for the average transition region, and 3.5% for the average leading region.

Second, this study shows that climate change also has a complex relationship with regional economic growth. The results confirm that temperature changes significantly impact Peru's economic growth over the analyzed period. Including a quadratic term for temperature allows for identifying a nonlinear relationship consistent with economic theory, suggesting that rising temperatures harm growth beyond a certain threshold.

Third, the analysis provides evidence of the importance of geographical externalities in regional development. Spatial dependence is observed, implying that the changing characteristics of neighboring regions influence a region's growth. For instance, a higher proportion of individuals with secondary education in surrounding regions positively correlates with regional economic growth. Similarly, improvements in institutional quality in one region contribute to the economic development of adjacent regions. The findings highlight key policy implications for fostering regional economic growth and reducing disparities in Peru. Institutional quality should be a priority, particularly in lagging regions, as effective governance enhances economic performance and facilitates regional convergence. Targeted policies to increase transparency, reduce corruption, and improve local government efficiency can generate significant economic benefits.

All in all, climate change poses a serious challenge to regional growth. Addressing its adverse effects requires adaptive strategies, such as investments in climate-resilient infrastructure and sustainable agricultural practices, to mitigate temperature-related economic losses. Additionally, we note that the presence of spatial externalities underscores the importance of regional coordination in policy design. Investing in education and institutional capacity fosters local development and generates positive spillover effects in neighboring regions. A comprehensive regional development strategy should integrate institutional reforms, climate adaptation policies, and spatially coordinated investments to promote inclusive and sustainable economic growth.

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Tables

Table 1. Economic and social indicators in Peru and other countries

	Perú	Colombia	Ecuador	Brazil	Chile	Argentina	México	US	UK
GDP per capita (2017 PPP $)[a]	12,514	14,648	10,668	14,592	25,449	21,527	19,086	63,669	44,978
GDP growth (annual, %)[a]	13.3	10.7	4.2	4.6	11.7	10.4	4.7	5.9	7.5
Population (thousand)[a]	33,715	55,516	17,797	214,326	19,493	45808	126,705	331,893	67,326
Gini coefficient[b]	40.2	51.5	45.8	52.9	44.9	42	45.4	39.7	32.6
Population living below US$1.90 PPP per day (%)[c]	4.5	10.8	6.5	1.9	0.7	1.1	3.1	1	0.3
Unemployment rate (%)[d]	3.7	10.7	4.0	9.5	7.8	6.5	3.3	3.6	3.6
Informal employment (% of total non-agricultural employment) (%)[e]	60.5	57.5	65.9	38.3	27.9	49.4	60.7	-	-
Government effectiveness[f]	-0.26	-0.01	-0.21	-0.46	0.63	-0.36	-0.31	1.34	1.28

Notes: PPP: purchasing power parity. [a] Data refer to 2021 (World Bank data); [b] Data refer to the most recent year available 2020-2021 (World Bank data); [c] Data refer to the most recent year available 2017-2020 (Human Development Data (1967–2020)); [d] Data refer to 2022 (Word Bank data); [e] Data refer to the most recent year available during the period 2014–2019 (ILOSTAT). [f] It captures perceptions on the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies, data refer to 2021 (World Bank data).

Table 2. Variable description

Variable	Description	Dimension
Real GDP per capita	Gross domestic product per capita in thousands of Peruvian Soles at constant 2007	Production
Quality of public administration index (IQPA)	The average of the efficiency and capacity indexes	Institutional and fiscal factors
Efficiency index	Index of regional efficiency in the administration of the resources	
Capacity index	Index of regional capacity to provide public services and execute the policies	
Temperature	Mean of annual temperature in °C	Climate change variables
Precipitation	Total annual precipitation in millimeters (mm)	
School performance in secondary	Percentage of the population with secondary education	Human capital endowments
Access to fixed internet	Percentage of households with internet access	Infrastructure variable
Population density	Number of people per square km (in thousand)	Location endowment

Table 3. Descriptive statistics

Variable	Year	Mean	SD	P25	Median	P75	Min	Max	CV	Theil
Real GDP per capita	2004	7.68	5.53	4.54	6.10	9.41	2.50	28.73	0.72	0.19
	2012	12.37	8.44	7.32	9.12	16.14	4.96	45.26	0.68	0.17
	2019	14.27	8.34	8.71	11.39	17.51	6.88	44.35	0.58	0.13
IQPA	2004	41.46	5.32	37.27	39.16	45.66	34.10	51.30	0.13	0.008
	2012	49.98	6.08	45.27	49.15	53.87	38.54	60.91	0.12	0.007
	2019	58.89	5.37	55.17	58.28	62.63	50.09	70.39	0.09	0.004
Efficiency index	2004	33.19	7.41	27.20	31.61	37.41	22.77	47.44	0.22	0.023
	2012	49.50	7.63	43.79	48.07	54.12	39.86	65.10	0.15	0.011
	2019	61.47	4.04	59.51	62.03	64.72	53.38	69.54	0.07	0.002
Capacity index	2004	49.73	5.26	45.99	47.62	53.39	43.20	61.63	0.11	0.005
	2012	50.46	9.07	44.85	48.82	56.34	34.14	70.08	0.18	0.015
	2019	56.30	9.41	47.97	55.89	63.03	40.22	75.48	0.17	0.013
Temperature (°C)	2004	16.62	5.94	11.55	16.19	22.18	8.24	26.75	0.36	0.062
	2012	16.62	5.93	11.29	16.19	22.18	8.37	26.57	0.36	0.062
	2019	16.72	6.06	11.36	16.44	22.65	8.15	27.01	0.36	0.064
Precipitation (mm)	2004	961.11	885.74	266.48	649.46	1549.0	30.39	3120.84	0.92	0.38
	2012	891.87	707.78	329.92	654.06	1366.2	40.75	2407.81	0.79	0.30
	2019	1007.0	812.58	337.69	753.45	1590.8	68.64	2670.58	0.81	0.31
Secondary education (%)	2004	13.62	4.76	9.98	13.05	16.67	6.30	24.21	0.35	0.059
	2012	16.03	4.20	12.79	15.84	18.61	9.20	25.09	0.26	0.033
	2019	17.43	4.01	14.41	17.11	19.75	11.34	25.68	0.23	0.025
Fixed internet (%)	2004	0.43	0.75	0.07	0.24	0.43	0.00	3.62	1.74	0.62
	2012	9.89	7.27	3.96	7.14	13.87	1.32	27.72	0.74	0.24
	2019	23.34	11.72	14.35	21.97	26.95	4.68	46.29	0.50	0.12
Density (in thousand)	2004	161.31	644.82	13.81	21.39	38.79	0.29	3186.50	4.00	2.21
	2012	179.38	719.76	15.44	23.19	41.67	0.35	3556.21	4.01	2.23
	2019	196.58	796.22	16.37	23.65	43.20	0.42	3932.32	4.05	2.26

Table 4. Spatial panel data models

Spatial autoregressive model (SAR)	$\ln\left(\frac{Y_{it}}{Y_{it-1}}\right) = \alpha_i + \beta\ln(Y_{it-1}) + \rho W \ln\left(\frac{Y_{it}}{Y_{it-1}}\right) + \theta X_{it} + \varepsilon_{it}$
Spatial error model (SEM)	$\ln\left(\frac{Y_{it}}{Y_{it-1}}\right) = \alpha_i + \beta\ln(Y_{it-1}) + \theta X_{it} + \varepsilon_{it}$ $\varepsilon_{it} = \lambda W \varepsilon_{it} + u_{it}$
SAC model	$\ln\left(\frac{Y_{it}}{Y_{it-1}}\right) = \alpha_i + \beta\ln(Y_{it-1}) + \rho W \ln\left(\frac{Y_{it}}{Y_{it-1}}\right) + \theta X_{it} + \varepsilon_{it}$ $\varepsilon_{it} = \lambda W \varepsilon_{it} + u_{it}$
Spatial Durbin model (SDM)	$\ln\left(\frac{Y_{it}}{Y_{it-1}}\right) = \alpha_i + \beta\ln(Y_{it-1}) + \rho W \ln\left(\frac{Y_{it}}{Y_{it-1}}\right) + \theta X_{it} + \gamma W X_{it} + \varepsilon_{it}$

Table 5. Estimates of spatial panel data models of growth

Y = GDP per capita growth rate

	No spatial effects			SAR			SEM			SAC			SDM		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
ln GDP per capita (t-1)	-0.103*** (0.0294)	-0.098*** (0.0295)	-0.118*** (0.0289)	-0.093*** (0.0277)	-0.088*** (0.0278)	-0.107*** (0.0273)	-0.097*** (0.0279)	-0.091*** (0.0280)	-0.112*** (0.0272)	-0.099*** (0.0283)	-0.093*** (0.0285)	-1.160*** (0.0272)	-0.134*** (0.0306)	-0.127*** (0.0308)	-0.153*** (0.0300)
IQPA	0.061*** (0.0170)			0.063*** (0.0160)			0.061*** (0.0159)			0.060*** (0.0162)			0.059*** (0.0162)		
Efficiency		0.059*** (0.0149)			0.059*** (0.0140)			0.060*** (0.0142)			0.060*** (0.0144)			0.059*** (0.0144)	
Capacity			0.0383** (0.0182)			0.041** (0.0172)			0.044*** (0.0169)			0.045*** (0.0166)			0.046*** (0.0173)
ln GDP per capita (t-1)*IQPA	-0.027*** (0.0067)			-0.028*** (0.0063)			-0.028*** (0.0063)			-0.028*** (0.0063)			-0.028*** (0.0064)		
ln GDP per capita (t-1)*Efficiency		-0.026*** (0.0061)			-0.026*** (0.0057)			-0.027*** (0.0058)			-0.027*** (0.0058)			-0.027*** (0.0058)	
ln GDP per capita (t-1)*Capacity			-0.021*** (0.0077)			-0.022** (0.0072)			-0.024*** (0.0070)			-0.024*** (0.0069)			-0.025*** (0.0073)
Precipitation	0.004 (0.0005)	0.0003 (0.0004)	0.005 (0.0004)	0.001 (0.0609)	0.001 (0.001)	0.001 (0.0001)	0.001 (0.0001)	0.001 (0.001)	0.001 (0.0001)	0.005 (0.0005)	0.005 (0.0005)	0.004 (0.0005)	0.006 (0.0005)	0.005 (0.0006)	0.006 (0.0004)
Precipitation^2	-0.008 (0.0009)	-0.0007 (0.0008)	-0.0007 (0.0008)	-0.001 (0.0001)	-0.001 (0.001)	-0.001 (0.0001)	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.0001)	-0.001 (0.0002)	-0.001 (0.0003)	-0.001 (0.0002)	-0.009 (0.0001)	-0.008 (0.0001)	-0.009 (0.0001)
Temperature	0.0958** (0.0383)	0.084** (0.0382)	0.116*** (0.0397)	0.091** (0.0361)	0.080** (0.0361)	0.112*** (0.0376)	0.102** (0.0415)	0.089** (0.0414)	0.125*** (0.0429)	0.105** (0.0442)	0.093** (0.0406)	0.130** (0.0466)	0.116 (0.1011)	0.120 (0.1003)	0.141 (0.1018)
Temperature^2	-0.002** (0.0010)	-0.001* (0.1186)	-0.002** (0.0010)	-0.002** (0.0010)	-0.001* (0.0010)	-0.002** (0.010)	-0.002* (0.0011)	-0.001 (0.0011)	-0.002** (0.0011)	-0.002* (0.0011)	.001 (0.0011)	-0.002* (0.0012)	-0.004 (0.0017)	-0.003 (0.0016)	-0.006 (0.0017)
Ln secondary rate	0.147*** (0.0550)	0.141** (0.0549)	0.180*** (0.0531)	0.144*** (0.0518)	0.139*** (0.0518)	0.178*** (0.0505)	0.119** (0.0279)	0.0112** (0.0512)	0.149*** (0.0494)	0.108** (0.0518)	0.102** (0.0523)	0.129** (0.0501)	0.143 (0.0544)	0.135** (0.0551)	0.155*** (0.0542)
Ln internet rate	0.005 (0.0027)	0.003 (0.0027)	0.001 (0.0027)	0.001 (0.0025)	0.001 (0.0025)	0.001 (0.0026)	0.001 (0.0025)	0.004 (0.0025)	0.001 (0.0025)	0.005 (0.0025)	0.003 (0.0025)	0.001 (0.0025)	-0.004 (0.0027)	-0.004 (0.0027)	-0.001 (0.0027)
Ln population density	-0.127 (0.1302)	-0.181 (0.1186)	-0.096 (0.1306)	-0.072 (0.1230)	-0.127 (0.1125)	-0.042 (0.1239)	-0.099 (0.1224)	-0.163 (0.1137)	-0.087 (0.1216)	-0.117 (0.1310)	-0.185 (0.1241)	-0.140 (0.1317)	-0.005** (0.1769)	-0.534 (0.1686)	-0.569** (0.1879)
(w)ln GDP per capita (t-1)													-0.065 (0.0728)	-0.081 (0.0739)	-0.062 (0.0741)
(w) IQPA													-0.027 (0.0324)		
(w) Efficiency														-0.044 (0.0290)	
(w) Capacity															-0.0576 (0.0373)
(w) ln GDP per capita (t-1)*IQPA													0.019 (0.0130)		
(w) ln GDP per capita (t-1)*Efficiency														0.024** (0.0121)	
(w) ln GDP per capita (t-1)*Capacity															0.030* (0.0156)
(w) Precipitation													0.002 (0.0009)	0.001 (0.0009)	-0.002 (0.0003)
(w) Precipitation^2													-0.002 (0.0003)	-0.002 (0.0003)	-0.002 (0.0003)
(w) Temperature													-0.042 (0.1248)	-0.005 (0.1234)	-0.070 (0.1261)
(w) Temperature^2													-0.001 (0.0002)	-0.009 (0.0024)	-0.009 (0.0024)
(w) ln secondary rate													0.365*** (0.1310)	0.379*** (0.1310)	0.349*** (0.1329)
(w) ln internet rate													0.017 (0.0122)	0.017 (0.0125)	0.018 (0.0124)
(w) Ln population density													-0.376 (0.2446)	-0.307 (0.2250)	-0.249 (0.2356)
λ				0.198*** (0.0628)	0.194*** (0.0627)	0.194*** (0.0633)				-0.086 (0.2114)	-0.090 (0.2045)	-0.168 (0.1908)	0.223*** (0.0633)	0.221 (0.0634)	0.225*** (0.0634)
ρ							0.238*** (0.0637)	0.238*** (0.0637)	0.246*** (0.0634)	0.313* (0.1839)	0.315* (0.1785)	0.384** (0.1545)			
Speed of convergence (%)	6.08	6.62	6.62	5.69	5.51	6.23	5.85	5.61	6.41	5.57	5.69	5.57	7.15	6.93	7.73

Half-life (years)	11.38	10.45	10.45	12.16	12.56	11.11	11.83	12.34	10.80	12.43	12.16	12.43	9.68	9.99	8.95
	Test LM of spatial dependence														
LM Lag	7.155***	6.888***	6.765***												
LM Error	0.102	8.310***	8.800***												
Robust LM Lag	8.238***	0.240	1.127												
Robust LM Error	1.186	1.662	3.163*												
N	384	384	384	384	384	384	384	384	384	384	384	384	384	384	384

Notes: Standard errors in parenthesis. Speed of convergence = $\ln(1 - T\beta)/T$, Half-life = $\ln(2)/speed\ of\ convergence$ ***p<0.01, **p<0.05, *p<

Table 6. SAR models: direct and indirect spillovers effects

	(1)			(2)			(3)		
	DE	IE	TE	DE	IE	TE	DE	IE	TE
ln GDP per capita (t-1)	-0.093*** (0.0230)	-0.023*** (0.010)	-0.116*** (0.0309)	-0.108*** (0.0260)	-0.026** (0.0122)	-0.134*** (0.0339)	-0.088** (0.0281)	-0.021* (0.0113)	-0.110** (0.0362)
IQPA	0.063*** (0.0193)	0.015*** (0.0079)	0.078*** (0.0244)						
Capacity				0.041** (0.0168)	0.010* (0.0065)	0.051** (0.0220)			
Efficiency							0.060*** (0.0134)	0.014** (0.0071)	0.074*** (0.0178)
ln GDP per capita (t-1)*IQPA	-0.028*** (0.0061)	-0.006* (0.0029)	-0.003*** (0.0078)						
ln GDP per capita (t-1)*IQPA				-0.022*** (0.0070)	-0.005** (0.0031)	-0.027*** (0.0095)			
ln GDP per capita (t-1)*IQPA							-0.026*** (0.0055)	-0.006** (0.0030)	-0.033*** (0.0178)
Precipitation	0.003 (0.0004)	-0.009 (0.0001)	-0.035 (0.0005)	0.003 (0.0004)	0.008 (0.0001)	0.004 (0.0005)	0.003 (0.0004)	0.001 (0.0001)	0.004 (0.0005)
Precipitation^2	-0.009 (0.0001)	-0.002 (0.0003)	-0.001 (0.001)	-0.009 (0.0006)	-0.002 (0.0003)	-0.001 (0.0001)	-0.009 (0.0001)	-0.002 (0.0003)	-0.001 (0.0008)
Temperature	0.091* (0.0349)	0.022* (0.0135)	0.014* (0.0012)	0.126*** (0.0377)	0.027** (0.0168)	0.139*** (0.0510)	0.083* (0.0365)	0.019* (0.0113)	0.099* (0.0449)
Temperature^2	-0.002* (0.0009)	-0.005 (0.0003)	-0.002* (0.0012)	-0.002 (0.0014)	-0.001 (0.0004)	-0.003 (0.0013)	-0.001* (0.0009)	-0.001 (0.0001)	-0.002* (0.0012)

Note: DE: Direct effects; IE: Indirect effects; TE: Total effects. Standard errors in parenthesis. ***p<0.01, **p<0.05, *p<0.1

Table 7. SAC models: direct and indirect spillovers effects

	(1)			(2)			(3)		
	DE	IE	TE	DE	IE	TE	DE	IE	TE
ln GDP per capita (t-1)	-0.099*** (0.0301)	-0.007 (0.0184)	-0.091*** (0.0329)	-0.116*** (0.0259)	-0.016** (0.0191)	-0.099*** (0.0303)	-0.093*** (0.0294)	-0.077 (0.0239)	-0.085*** (0.0393)
IQPA	0.060*** (0.0193)	0.060 (0.0130)	0.055*** (0.0216)						
Capacity				0.045** (0.0159)	-0.006* (0.0074)	0.038** (0.0220)			
Efficiency							0.060*** (0.0156)	-0.004 (0.0151)	0.055*** (0.0205)
ln GDP per capita (t-1)*IQPA	-0.028*** (0.0061)	-0.028 (0.0075)	-0.026*** (0.0094)						
ln GDP per capita (t-1)*IQPA				-0.024*** (0.0067)	0.003** (0.0039)	-0.020*** (0.0065)			
ln GDP per capita (t-1)*IQPA							-0.027*** (0.0061)	-0.002 (0.0069)	-0.025*** (0.0089)
Precipitation	0.005 (0.0005)	0.005 (0.0005)	0.005 (0.0005)	0.004 (0.0005)	-0.006 (0.0001)	0.004 (0.0005)	0.005 (0.0004)	-0.004 (0.0001)	0.005 (0.0004)
Precipitation^2	-0.001 (0.0001)	-0.001 (0.0001)	-0.001 (0.0001)	-0.001 (0.0001)	0.002 (0.0003)	-0.001 (0.0001)	-0.001 (0.0001)	0.009 (0.0003)	-0.008 (0.0001)
Temperature	0.105** (0.0504)	0.010 (0.0504)	0.097* (0.0525)	0.131*** (0.0454)	-0.018** (0.0220)	0.112*** (0.0479)	0.093*** (0.0456)	-0.007 (0.0223)	0.085** (0.0479)
Temperature^2	-0.002 (0.0012)	-0.002 (0.0012)	-0.002* (0.0012)	-0.002 (0.0011)	0.003 (0.0004)	-0.002 (0.0011)	-0.001 (0.0012)	-0.001 (0.0004)	-0.001 (0.0012)

Note: DE: Direct effects; IE: Indirect effects; TE: Total effects. Standard errors in parenthesis. ***p<0.01, **p<0.05, *p<0.1

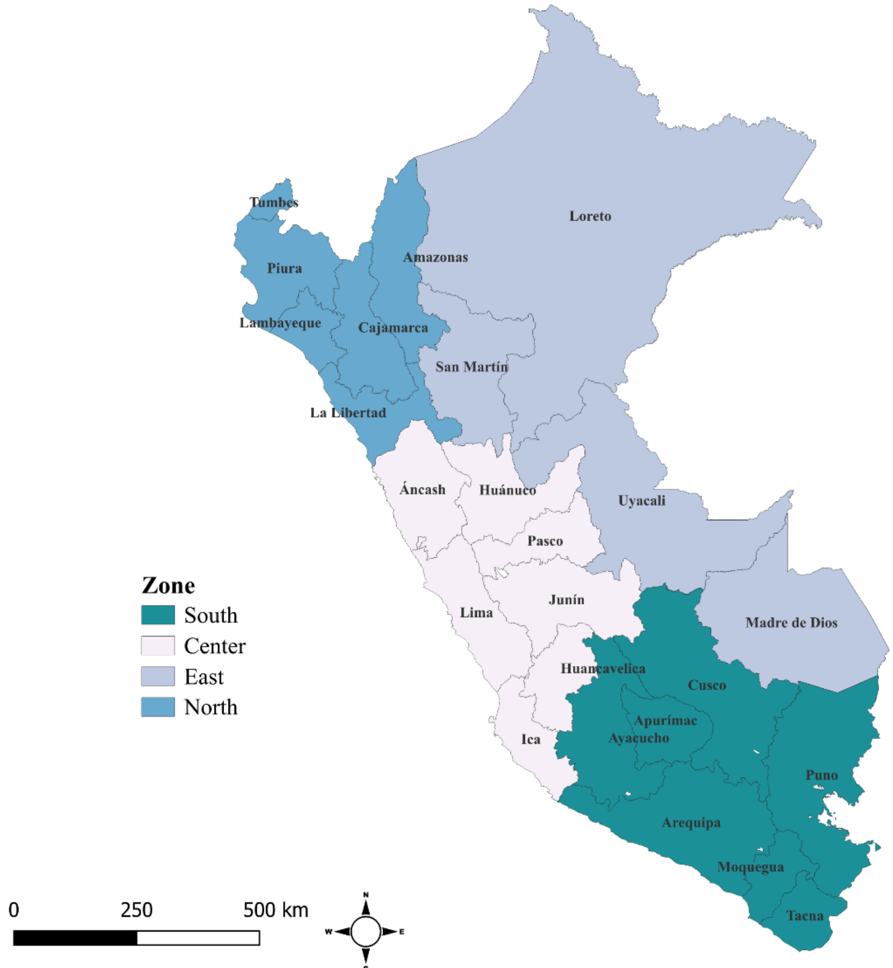
Table 8. SDM models: direct and indirect spillovers effects

	(1)			(2)			(3)		
	DE	IE	TE	DE	IE	TE	DE	IE	TE
ln GDP per capita (t-1)	-0.135*** (0.0320)	-0.038*** (0.0185)	-0.173*** (0.0456)	-0.153*** (0.0289)	-0.044** (0.0209)	-0.198*** (0.0431)	-0.127*** (0.0277)	-0.036*** (0.0156)	-0.163*** (0.0385)
IQPA	0.059*** (0.0150)	0.017*** (0.0084)	0.076*** (0.0206)						
Capacity				0.046** (0.0177)	-0.013* (0.0086)	0.060** (0.0245)			
Efficiency							0.059*** (0.0143)	0.016** (0.0074)	0.075*** (0.0194)
ln GDP per capita (t-1)*IQPA	-0.028*** (0.0060)	-0.008*** (0.0036)	-0.036*** (0.0082)						
ln GDP per capita (t-1)*IQPA				-0.025*** (0.0073)	-0.007** (0.0040)	-0.032*** (0.0103)			
ln GDP per capita (t-1)*IQPA							-0.027*** (0.0057)	-0.007** (0.0032)	-0.035*** (0.0079)
Precipitation	0.006 (0.0009)	0.001 (0.0003)	0.007 (0.0001)	0.006 (0.0005)	0.001 (0.0003)	0.008 (0.0005)	0.005 (0.0007)	0.001 (0.0002)	0.007 (0.0009)
Precipitation^2	-0.001 (0.0001)	-0.001 (0.0005)	-0.001 (0.0002)	-0.001 (0.0001)	0.002 (0.0003)	-0.001 (0.0001)	-0.008 (0.0001)	-0.002 (0.0003)	-0.001 (0.0001)
Temperature	0.116 (0.1091)	0.033 (0.0373)	0.149 (0.1442)	0.141 (0.0914)	0.041 (0.0334)	0.183 (0.1196)	0.120 (0.1003)	0.034 (0.0312)	0.155 (0.1285)
Temperature^2	-0.001 (0.0015)	-0.001 (0.0005)	-0.001 (0.0020)	-0.001 (0.0017)	-0.002 (0.0005)	-0.002 (0.0022)	-0.003 (0.0017)	-0.001 (0.0005)	-0.004 (0.0023)

Note: DE: Direct effects; IE: Indirect effects; TE: Total effects. Standard errors in parenthesis. ***p<0.01, **p<0.05, *p<0.1

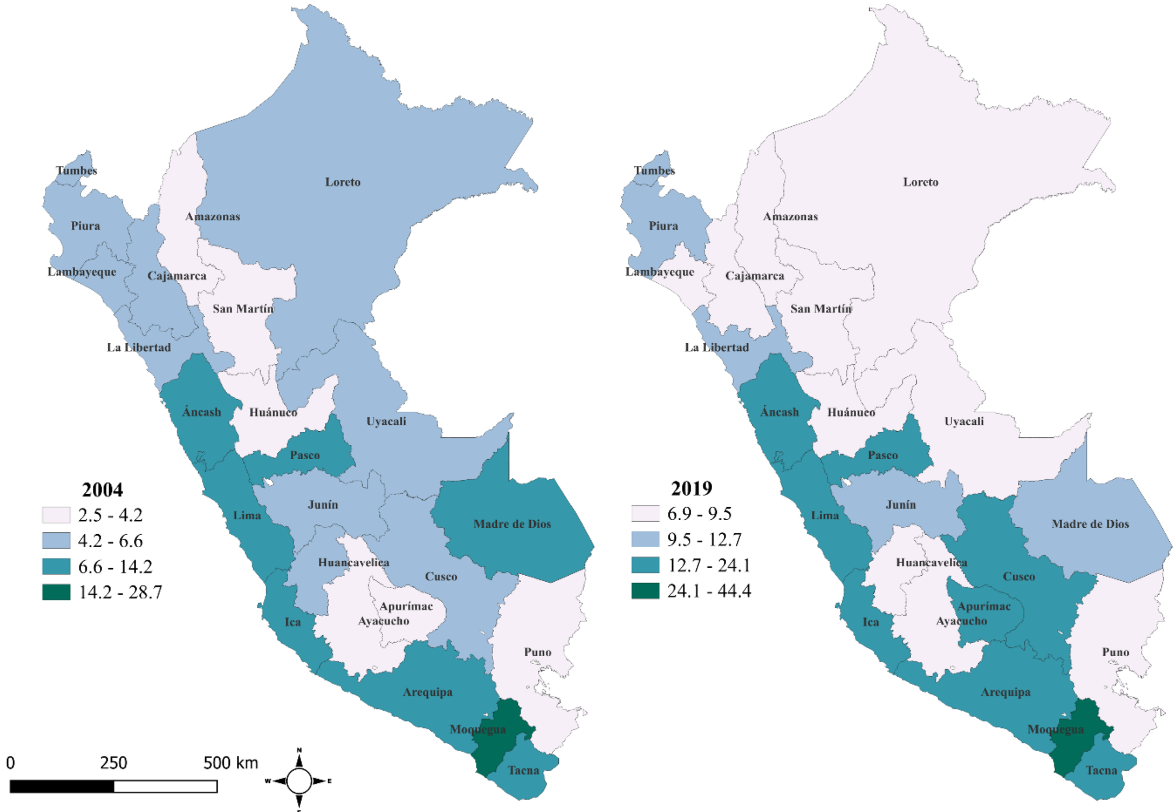
Figures

Figure 1. Departments and regions of Peru



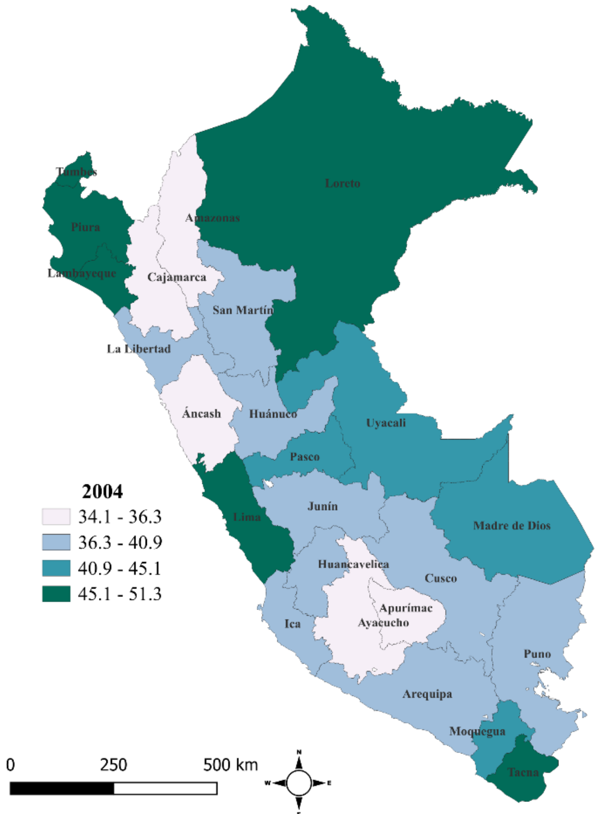
Fuente: INEI.

Figure 2. Real GDP per capita by departments



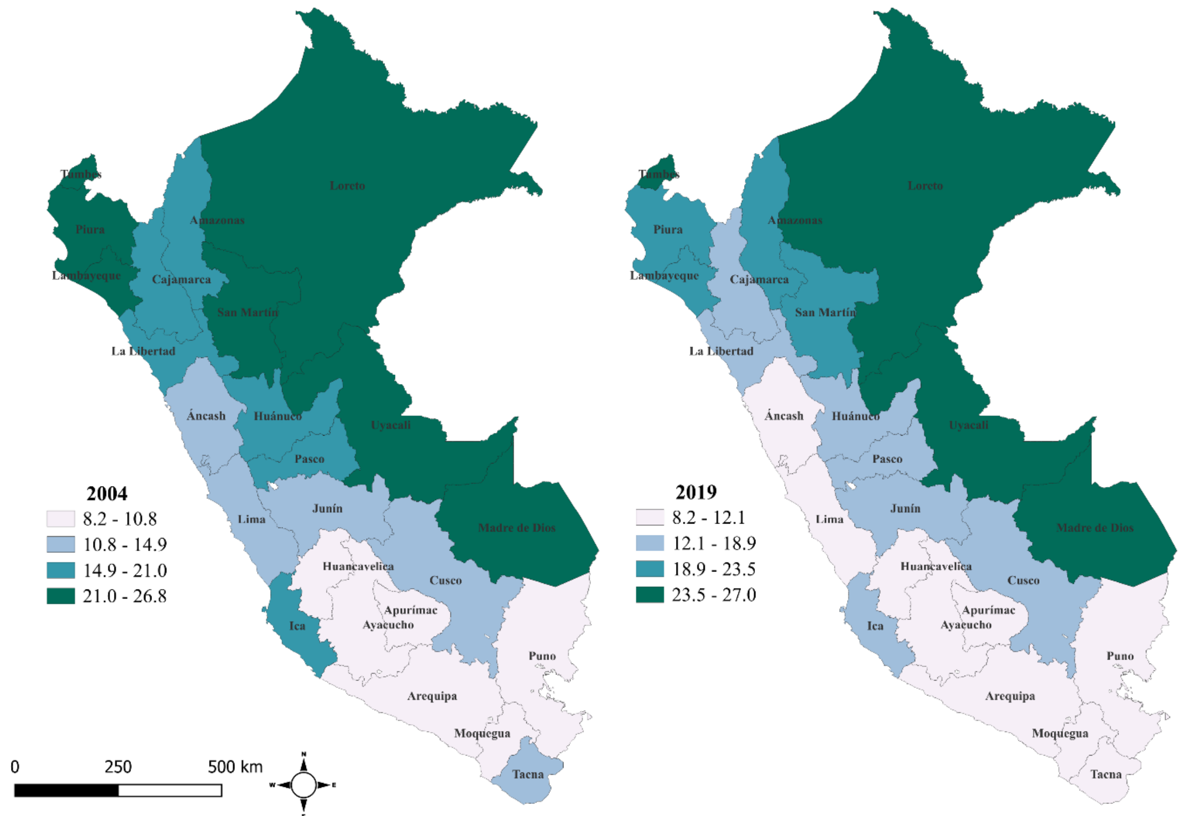
Notes: Real GDP per capita in millions of Peruvian Soles of 2007. Source: INEI.

Figure 3. Index of the quality of public administration (IQPA) by departments



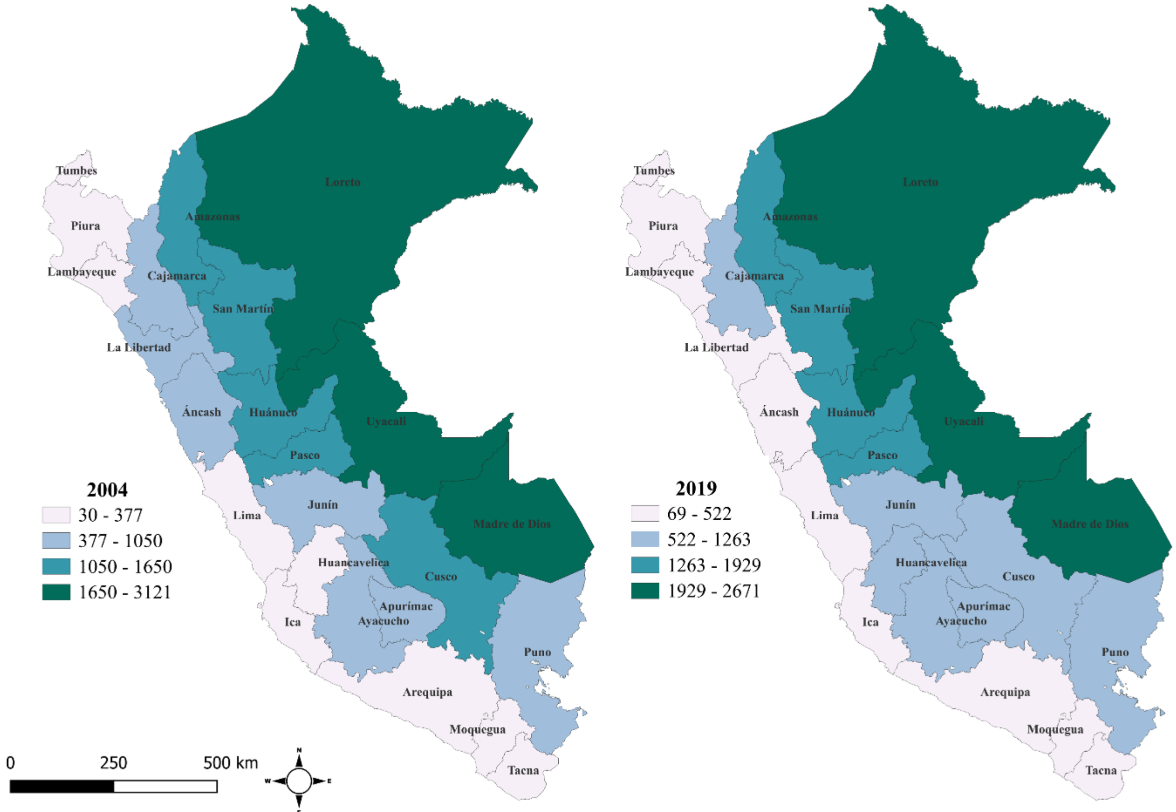
Source: ENAHO.

Figure 4. Average annual temperature by departments (in °C)



Source: Climate Change Knowledge Portal - World Bank.

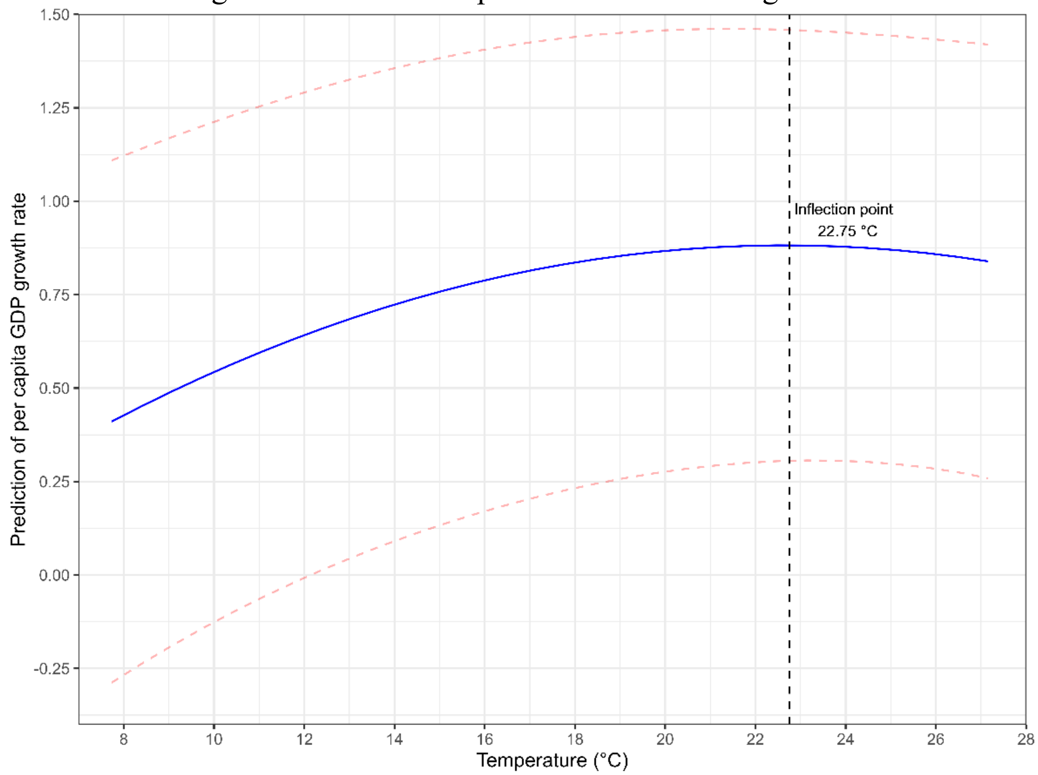
Figure 5. Total annual precipitation in Peru by departments (in millimeters, mm)



Source: Climate Change Knowledge Portal - World Bank.

Figure 6. Coefficient of variation and Theil index of the real GDP per capita

Figure 7. Effect of temperature on economic growth



Notes: Prediction of per capita GDP growth rate with variables in its means for different temperature levels (blue line) with 90% confidence interval (red lines). Vertical line represents the inflection point calculated as $\frac{-\hat{\beta}_{Temperature}}{2\hat{\beta}_{Temperature^2}}$, which results from deriving the economic growth equation with respect to temperature and equals zero and isolating the temperature.