EJABM European Journal of Applied Business and Management

European Journal of Applied Business Management, Special Issue Circular Economy, 2022, pp. 31-50 ISSN 2183-5594

Research Paper

Is climate risk affecting private participation in infrastructure projects? Empirical evidence from developing countries

Submitted in 26, July 2022
Accepted in 05, September 2022
Evaluated by a double-blind review system

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ABSTRACT

Purpose: Climate risk emerged as a new source of systematic risk and should be considered in investors' strategies. An empirical analysis is conducted to explore the effects of climate risk on private participation in infrastructure projects developed in low- and middle-income countries (LMIC), using data from 2011 to 2020 obtained from the World Bank's PPI Database.

Methodology: Two different proxies are used to measure private participation: the amount of private investment and the degree (the percentage) of private participation. Appropriate regression techniques are adopted - Tobit and fractional regression models. The independent variables include the climate risk index (CRI) which provides a quantified measure, by country of extreme weather-related economic losses; and, as control variables, factors at the project level and, related to the host country macroeconomic and institutional/political environment.

Findings: The results suggest that higher climate risk is associated with a higher amount of private investments in infrastructure, and it is not considered in the degree of private sector commitment. This should be interpreted with caution, because higher private investment amounts may be a consequence (*ex-post*) of the harmful effects of extreme weather events on each country's infrastructure systems.

Research limitations: This is an exploratory study. With this data, it is not possible to further investigate the eventual ex-post nature of investments. In addition, results may be conditioned by the proxy of climate risk used. Only projects developed in LMIC are recorded in the database.

Originality: This research contributes to the nascent strand of the literature that studies the impact of climate risk on investments. Results may be useful for private investors and public authorities, identifying the key factors that drive the private sector participation.

Keywords: Climate risk, infrastructure projects, private participation.

1. Introduction

The last five years witnessed natural disasters more intense and more frequent than ever (WEF, 2020). The warming of global temperatures increases the likelihood of extreme weather events and related natural disasters, giving rise to a new source of risk – climate

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risk, which deals with the potential adverse effects of climate change on society and the economy (Allen et al., 2018).

Concerns about climate change have rapidly evolved. First, it was only an issue of corporate social responsibility and now this theme has moved to the top of the regulatory agenda. In Europe, regulators are struggling to create policies to establish "climate risk at the heart of firms' investment decisions, governance and risk management processes" (Delloitte, 2021, p. 6).

As emphasized in Buhr and Volz (2018), some developing countries facing higher climate vulnerability have already experienced an increased cost of sovereign debt. Further, in these countries, even for companies the cost of debt has been raising, stressing the interrelation between the capacity of each country to handle climate risk, private investment, and the policy environment.

For infrastructure projects, it is expected that investors will value climate as a new source of systematic risk and as such, that they will take it into account in their investment decisions. Infrastructure assets are characterized by large irreversible investments, with significant sunk costs, a long lifespan and limited alternative uses. These projects, given their long lives and interrelated parties, emphasize complexity, uncertainty and risk. In addition, climate hazards impact infrastructure assets differently depending on the specific sector. A study by McKinsey (2020) highlights the effect of different categories of climate hazards (sea-level rise; hurricanes, storms and typhoons; tornadoes; drought, heat; wildfire) on the main infrastructure sectors - transport, telecom, energy and water, detailing the vulnerabilities associated to different types of assets.

Although a global problem, developing countries are the most affected by the impacts of climate change. They are particularly vulnerable to the damaging effects of an extreme event, have lower capacity to deal with their disastrous consequences and usually need more time to rebuild and recover (Eckstein et al., 2021). Tol (2018) mentioned that these countries are more exposed to weather events, given their location, typically in hotter places and with economic systems mostly based on agricultural activities; lacking technological, financial, and human resources.

Moreover, the infrastructure gap is huge, particularly for developing and emerging countries. Forecasts by the Global Infrastructure Outlook mentions that globally the need for infrastructure investment will reach 94 trillion US dollars by 2040, and a further 3.5 trillion US dollars will be required to meet the United Nations' Sustainable Development Goals (SDGs) for electricity and water, with emerging markets in Asia, Latin America, and the Caribbean requesting the greatest share (Global Infrastructure Outlook, 2017).

The infrastructure gap has been the subject of much attention in recent years, with countries developing efforts to invest more and to attract the private sector, as it is recognized that the private sector may bring fresh capital alongside greater efficiency and innovation to infrastructure projects. Nevertheless, private financing is still a small part of the infrastructure market. Fay et al. (2019) pointed that the public sector dominates infrastructure spending, in all low- and middle income countries (LMIC), accounting for 87–91 percent of infrastructure investments. Nevertheless, these numbers hide a significant variation across regions – South Asia shows the lowest values (53–62 percent), and East Asia, has the highest (98 percent).

The risk posed by climate change should be taken into account by investors in delineating their investment strategies. But as pointed out by Krueger et al. (2020), this is not an easy task with investment tools and best practices far from being defined and clearly established. Roncoroni et al. (2021) argue that it is very difficult to incorporate climate risk assessments into business and investment decisions, because the former are long-term and the latter are short-term. In the same vein, Stiglitz (2019) mentions that there is an inability of financial markets to internalize externalities, in extended time horizons.

It is in this background that this study attempts to explore the empirical evidence provided by infrastructure projects implemented in LMIC in what concerns private sector involvement, to identify whether climate risk influences private sector participation in these projects.

Our proxy for climate risk is an index compiled and published annually by the non-profit, nongovernmental organization Germanwatch (Eckstein et al., 2021). The climate risk index (CRI) provides a quantified measure by country of extreme weather-related economic losses.

To explore the determinants of private sector' participation we use two proxies: the amount of private investment and the degree (the percentage) of private participation in these projects. We use data from 2011 to 2020, obtained from the World Bank's Private Participation in Infrastructure database (https://ppi.worldbank.org/en/ppi) and appropriate regression techniques, namely Tobit and fractional regression models.

Our results may be useful for private investors and public authorities, identifying the key factors that drive the private sector to enter infrastructure projects and how climate risk may affect that participation.

This paper is structured as follows: Section 2 provides a brief literature review to frame this research, introducing the main hypothesis. Section 3 describes the data, variables and research method. Section 4 details and discusses the results. Finally, Section 5 draws the main conclusions and limitations, highlighting avenues for future research.

2. Literature Review and Research Hypothesis

2.1. Private sector participation in infrastructure and climate risks

The Task Force on Climate-related Financial Disclosures (TCFD, 2017) divided climate-related risks into two major categories: physical risks and transition risks. The first is related to the physical impacts of climate change and includes the financial consequences of the direct damage to assets and the indirect impacts of disruption of supply chains. Physical risks are divided into acute physical risks (those that are event-driven) and chronic physical risks (derived from longer-term shifts in climate patterns). The second includes risks related to the transition to a lower-carbon economy. It includes regulatory, technology, and market changes to address mitigation and adaptation requirements related to climate change and may induce financial or political effects and reputation damage (TCFD, 2017). In this research, the focus is on physical climate risks.

A nascent line of research provides theoretical and empirical evidence that investors should consider climate risks in their investment decisions as pointed in Krueger et al. (2020). For instance, recent asset pricing models emphasize the importance of climate risks as a long-run risk factor (Bansal et al., 2017). Others provide empirical evidence that climate risks may be mispriced in financial markets (Meyer and Schwarze, 2019; Hong et al., 2019; Daniel et al. 2016; Kumar et al., 2019; Alok et al. 2020). At the firm

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level, several authors explore the effects of climate risk on corporate earnings (Huang et al., 2018; Addoum et al., 2019; Ding et al., 2021). Particularly, exploring private participation, Lupton et al. (2021) investigate the impact of climate risk on the success of foreign direct investments in infrastructure projects from 2004 to 2013. Their findings pointed to higher levels of climate risk at the host country being associated with a higher risk of project failure.

However, as pointed in In et al. (2022, p. 4), "Climate risk assessment is challenging because climate risks are on a long-time horizon, their impacts are likely non-linear, they are inherently interconnected in the financial network, and they are uncertain on climate policy introduction." For infrastructure assets, assessing their exposure to climate risks is even more complex. Each asset has a specific nature, therefore cash-flow projections depend on each asset profile, regional situation, and inherent financial contracts.

Despite these limitations, the consequences of an extreme weather event can be substantial and investors should incorporate climate risk considerations when designing their strategies (Oetzel and Oh, 2014; Lupton et al., 2021). Obviously, natural disasters could not be predicted or anticipated. But to deal with the potentially harmful consequences of an extreme weather event, investors should invest additional resources to create safeguards to increase the resilience of the facilities, acquiring insurance and incorporating contingency and recovery plans to mitigate climate disasters (Huang et al., 2018). As a consequence, for projects developed in countries with higher climate risks, the operational and financial complexity of the project will be higher, and more difficulties in lure private investors to these projects will be expected (Lupton et al., 2021).

In the past, the development of infrastructure projects was an exclusivity of governments and other public agencies. More recently there is a growing interest in public-private partnerships and other forms of private sector involvement (Albalate et al. 2014). Several arguments exist, to justify this trend, mixing ideological, political, economic and financial factors. First, the New Public Management (Hood, 1991) paradigm privileges the use of private capital and the State just assuming a regulatory role, instead of direct interventions. In addition, budgetary constraints faced by governments, the globalization of financial markets with the emergence of innovative instruments and new types of investors; and, the development of project finance techniques also have contributed to this shift. Lastly and with more relevance, the recognition that the private sector may offer more efficiency and value for money, due to the capacity to design innovative solutions, as a result of expertise and increased competition.

This paper is also supported by other strands in the literature, namely on the grounds of the Transaction-Cost Theory (Williamson, 1979). Projects with high asset specificity, low competitiveness, long lives, high complexity and uncertainty, and low government contract management skills (as it is the case of infrastructure projects) have higher contracting costs. Each project relies "strongly" on contracts and long-term complete contracts are impossible to define, due to unforeseen contingencies. In this situation and as a consequence of the opportunistic behavior of the parties, problems of adverse selection and moral hazard may appear. Relationship-specific investments imply higher transaction costs (Parker & Hartley, 2003; Williamson, 1981). Therefore, the degree of risk taken by the private agent will depend on the expected benefits. And in turn, risks will depend on the characteristics of the transaction and of the environment where it takes place (Wang et al., 2018; Fleta-Asín & Muñoz, 2020).

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Principal-agent problems are typically mitigated through contracts, regulation, and more demanding requirements concerning transparency and disclosure, but for undefined and unallocated risks, such as climate risks, these problems become more pronounced (PPIAF, 2016).

The empirical literature exploring private sector participation in infrastructure projects include Banerjee et al. 2006; Kirkpatrick, et al. 2006; Tewodaj, 2013; Moszoro, et al. 2014; Jiménez et al., 2017; Basílio, 2017; Wang et al. 2019; Ragosa & Warren, 2019; and Fleta-Asín & Muñoz, 2021; among others. Typically, project-specific characteristics and macroeconomic, institutional / political factors related to the environment of the host country are explored as key drivers of private sector involvement.

In this paper, our main focus is to explore if private sector participation in infrastructure projects is being affected by climate risk. Although an exploratory study, this analysis is important to highlight if private agents explicitly considers this new type of risk and may contribute to spur future research. The next section presents the main hypothesis to be tested and several control variables used to account for potential relevant effects on private sector participation.

2.2. Research hypotheses

The main goal is to assess if private participation in infrastructure projects developed in LMIC, is being affected by climate risk. We measure private participation using two different proxies, the volume of investment and the degree of private participation. Our main hypotheses are as follows:

Hypothesis 1: Private sector' investment levels are higher for infrastructure projects developed in countries with lower climate risk.

Hypothesis 2: The degree of private sector participation in infrastructure projects is higher for projects developed in countries with lower climate risk.

Several control variables were included that may have a relevant effect. First, project-specific characteristics, such as government or Multilateral Development Banks' (MDBs) support. The government participation, providing direct financing or indirect guarantees, will make estimates of the repercussions of climate events easier and, will provide assistance in the recovery efforts. (Lupton et al., 2021). The same beneficial effect in mitigating climate risks may be expected concerning MDBs, given their development mandates and technical expertise.

- ✓ Government Support, either Direct or Indirect to the infrastructure project, was measured by a Gov dummy variable (1 if the project has Government support, 0 otherwise). Governments can facilitate and foster private investments in infrastructure in several ways. Using financial leveraging tools such as guarantees, insurance policies, and credit enhancements or through grants, tax exemptions and other fiscal incentives, among other possibilities (World Bank, 2015). Private sector involvement will be higher if some form of Government' support is in place. Wang et al. (2019) showed that this is particularly true for direct support schemes, while indirect supports through government guarantees policies do not have an expressive effect on private investment.
- ✓ MDBs' participation in the infrastructure project, measured by a MDB dummy variable (1 if the project has MDBs' participation, 0 otherwise). First and foremost, MDBs and similar agencies are critical sources of financial funds for

infrastructure projects. In addition, their participation also reduces the perception of risk to other participants and reinforces the social aspects of the project. MDBs can play an important role as catalysts for private investments in various ways (policy advice, project design, co-investor, insurance, etc.). The ‘protective umbrella’ provided by MDBs is a sign of creditworthiness. However, the literature is not consensual about the MDBs’ effects, oscillating between crowding in and crowding out effects, e.g., emphasizing a catalytic effect or a substitution effect of private flows (Basílio, 2014; Bird & Rowlands, 2007). Here, we expect a crowding-in (positive) effect in private sector engagement.

Second, variables to account for the macroeconomic and institutional/political environment of the host country were considered.

- *Macroeconomic conditions*

Capital flows to emerging markets are affected by macroeconomic conditions. Typically, the following variables are considered important determinants (e.g., Jandhyala, 2016):

Real GDP per capita and economic growth – as measures of a country’s wealth.

Inflation – a high rate of inflation points to structural problems. Therefore, a controlled inflation is a sign of macroeconomic stability and a factor of attractiveness to investors.

Population – to proxy for the dimension of the market, particularly if the project is to be financed also with user charges.

- *Political / institutional framework*

Countries that enjoy political stability and a democratic regime should attract more private money (Kosack 2003; García-Canal & Guillén, 2008; Morrissey & Udomkerdmongkol, 2012; Wang et al. 2019). The development of infrastructure projects with high complexity, high asset specificity, uncertainty, and low competitiveness are based on contracts (naturally incomplete and prone to opportunistic behavior). Therefore, private investors must ensure that they have their legal rights recognized and that local law enforcement is efficient. Countries with stronger property rights recognizable to investors are able to raise more long-term private capital to develop infrastructure projects, and higher private sector participation is expected in countries with ‘good’ legal practices, political stability, and sound institutions. As already noted, the quality of the institutional framework affects the performance of all forms of financial flows (Lindbaek, 1998). For instance, Banerjee et al. (2006) show that property rights guarantee, bureaucratic quality, and the strength of political systems play a significant role in promoting private infrastructure investment. The next two indexes were chosen from the World Governance Indicators:

Political stability – To measure the probability of political instability and/or violence related to political factors and acts of terrorism.

Rule of Law - To measure the quality of contract enforcement, property rights, confidence in the police and courts, as well as the likelihood of crime and violence.

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- *Sector*

The intrinsic characteristics of the infrastructure project also explain the interest of private investors, as reported in Albalate et al. (2015). Projects that have network characteristics, for instance water distribution, affect negatively private sector participation due to higher transaction costs and more complex institutional arrangements. In the current research given the lack of more detailed information, only differences among sectors will be explored. For that, dummies for sectors were used - energy, information and communications technology (ICT), water / sewerage, municipal solid waste (MSW), and transport, as the base sector.

Finally, to capture potential time-specific effects, time-dummies are included.

3. Research Method

3.1. Data and variables

A sample of 3536 infrastructure projects from 88 countries was drawn from the PPI database using projects developed in LMIC that reached financial closure from 2011 to 2020. Two dependent variables were tested to measure private sector participation: the degree of participation in the infrastructure project (the database records the percentage of private participation in each project); and considering only the projects exclusively undertaken by the private sector (with the percentage of private participation equal to 100%), the amount of the investment.

The explanatory variables were chosen based on the literature review and were already described in the previous section. The climate risk index (CRI) was taken from Germanwatch. CRI is a country-level index that measures the level of influence of climate-related extreme events (storms, floods, forest fires, droughts, etc.) in various countries. The index is published annually and captures the severity of losses that a country incurs due to climate change (Eckstein et al., 2021). CRI is computed as an average of the next four indicators: (1) total number of deaths, (2) number of deaths per 100,000 inhabitants, (3) total losses at purchasing power parity (PPP) in U.S. dollars, and (4) losses per unit of gross domestic product (GDP). A lower CRI corresponds to higher physical climate risk.

Additionally, as control variables, we consider factors at the project level and, related to the host country macroeconomic and institutional/political environment.

All the projects' information was obtained in the Private Participation in Infrastructure (PPI) Database (https://ppi.worldbank.org/en/ppidata). This database records information about private investment in infrastructure, covering several sectors – telecommunications, transportation, municipal solid waste, water/sanitation and energy – developed in low- and middle-income countries. Macroeconomic data are from the World Bank's World Development Indicators. Real GDP per capita and population are set in logarithms to avoid scaling issues.

Finally, institutional/political indicators are drawn from the World Governance Indicators (WGI) available at https://info.worldbank.org/governance/wgi/.

Matching the different data sources, we obtain a database of infrastructure projects with 3536 observations. To study the degree of private sector participation (with a dependent

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variable that is a fractional response variable, ranging from 0%-100%) we use this full sample. When the dependent variable is the dollar amount of investments, we only consider projects developed with 100% of private participation, with 3042 observations (corresponding to 86% of the full sample). Table 1 summarizes the information on the variables and data sources.

Table 1. Summary of variables

Dimension	Variable Definition	Source
Project	**lnINV** (DEPENDENT VARIABLE 1): The logarithm of the total project investment in millions of US dollars	PPI database
	Degree (DEPENDENT VARIABLE 2): The degree of private participation in the infrastructure project, which varies between $0 \leq y \leq 1$;	
	Gov: A dummy variable adopting the value of 1 when the project has direct or indirect Government support and 0 otherwise.	
	MDB: A dummy variable adopting the value of 1 when one or several multilateral development banks support the infrastructure project and 0 otherwise.	
	Sector: Dummies for sectors: energy, ICT, MSW, water, and transport as the base sector	
Climate Risk	**CRI:** country-level index published annually - captures the severity of losses that a country incurs due to climate change. A lower CRI corresponds to higher climate risk.	Germanwatch (Eckstein et al., 2021).
Macroeconomic	**LnRealGDPpc:** The log of GDP per capita (constant 2010 US$).	World Bank's World Development Indicators
	Growth: GDP growth (annual %).	
	Inflation: Consumer prices (annual %).	
	lnPOP: The log of total Population.	
Political/institutional	**PolStab: Political Stability** – An index to measure the likelihood of political instability and/or violence due to political motives. It ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance.	World Governance Indicators (WGI)
	Rlaw: Rule of Law – An index to measure the quality of contract enforcement, property rights, and confidence in the police and courts operation. It varies from -2.5 (weak) to 2.5 (strong) governance performance.	

Summary statistics for all the variables, except time-dummies, are presented in Table 2. Private investment in infrastructure projects (INV) presents a high variability (std. dev.> mean) with a mean value of 219.94 million USD. We opt to use this variable in log form (lnINV) rather than levels, given that the methods used rely on the normal distribution of the data. The percentage of private participation has some observations below 1, but the bulk of the projects have 100% private participation, exhibiting a mean value very close to 1. The climate risk index (CRI) varies between 2.17 (the highest risk of the Philippines) and 126.17 (corresponding to the lowest risk of Ghana and Jordan).

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Table 2. Descriptive statistics of the variables

Variable	Obs	Mean	Std. Dev.	Min	Max
lnINV (ln)	3042	4.3661	1.4254	-0.2231	10.47972
INV (million USD)	3042	219.94	771.14	0.80	35586.5
Degree	3536	0.9660	0.1189	0	1
CRI	3536	46.7237	27.2656	2.17	126.17
Gov dummy	3536	0.3999	0.4899	0	1
MDB dummy	3536	0.1326	0.3392	0	1
lnRealGDPpc (ln)	3536	8.4425	0.8276	5.337897	9.758156
Growth (%)	3536	5.2345	2.9667	-3.80528	17.29078
lnPOP (ln)	3536	19.2152	1.7818	10.87491	21.05811
Inflation (%)	3536	5.2320	3.5810	-4.29848	63.29251
PolStab (index)	3536	-0.6467	0.5556	-2.81	1.2
Rlaw (index)	3536	-0.2808	0.3102	-1.67	0.95
Sector:					
Energy	3536	0.5922	0.4915	0	1
MSW	3536	0.0970	0.2960	0	1
ICT	3536	0.0054	0.0731	0	1
Water	3536	0.1015	0.3021	0	1
Transport	3536	0.2039	0.4030	0	1

Additionally, near 40% of the projects considered in the sample benefitted from Government support, and 13% have the participation of one or more MDBs. The lion share of the infrastructure projects are being developed in China (#879), India (#593) and Brazil (#506), corresponding to approximately 56% of our sample. By sector, energy is the prevalent sector with 2094 projects. The distribution by year is balanced, with almost all years exhibiting values above 300 projects, with a peak in 2012 with 519 projects and the lowest value in 2020, with 232 (see Table A.1 in the Appendix). Although it remains too early to fully measure the negative impacts of COVID-19, a possible explanation for the lower number of projects in 2020 may be attributed to the adverse impacts of the pandemic, when governments channeled financial resources to the immediate needs of health care and supply chains and stopped to prioritize investments in infrastructure (World Bank, 2020).

To check for collinearity problems, a correlation matrix was computed (results in Appendix A.2), with no particular high values of pairwise correlation. In addition, a statistical test was performed using the variance inflation factor (VIF) confirming the absence of any problems. Mean VIF is 1.44, being the highest value related to the lnPOP variable (1.99)[2].

3.2. Empirical approach

We approached private participation in infrastructure projects using two different dependent variables. First, the dependent variable is the amount of investment in each project: a nonnegative, partly continuous and assuming the value zero with positive

[2] VIF is an indicator of how much the variance (or standard error) is inflated due to collinearity. Values above 10 should be a cause for concern and must be corrected, but ideally, VIF values should be below 5.

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probability. Tobit models are usually adopted to estimate this kind of variable. Tobit has a censoring value at zero, and the latent variable is linear in regressors with an additive error term, normally distributed and homoscedastic. Thus:

$$y^* = \beta_0 + \mathbf{x}'\beta + \epsilon, \qquad where\ \ \epsilon|\mathbf{x} \sim Normal(0, \sigma^2)$$

Second, the degree of private participation is a fractional response variable, ranging from 0–1. Generalized linear models (GLM) and quasi-maximum likelihood estimation are used to deal with these variables. Several functional forms for the conditional mean of y that enforce the conceptual requirement that E(y|x) is in the unit interval are possible. The degree of private participation is on the interval 0≤y≤1, with a large proportion of observations with y=1, and as such, the Complementary Loglog (cloglog) is more appropriate to fit our data. While the logistic and standard normal specifications for G(.) are symmetric about the point 0.5 and therefore approach 0 and 1 at the same rate, the cloglog model is not symmetric and increases sharply when G(.) is near 1 (Ramalho et al. 2011). The extreme minimum distribution function underlying the model is given by:

$$G(z) = 1 - exp(-exp(z))$$

It should be noted that classical fractional response models (Logit, Probit, Cloglog) do not predict y = 1 but in practice, one can consider that if the fitted values are very close to one, that corresponds to entirely private participation. As a robustness check, we also test a two-limit Tobit model, following a similar approach as Fleta-Asín and Muñoz (2021), and Wang et al. (2019).

In addition, to allow for intragroup correlation, clustered robust standard errors are used, relaxing the usual requirement that the observations are independent. With country data, it is more reasonable to assume that observations are independent across countries (clusters) but not within each country (Cameron & Trivedi, 2010).

Furthermore, because our data may suffer from endogeneity problems, we assume that private sector participation is affected by the macroeconomic and institutional situation of a country on the previous year, following a similar approach as Moszoro et al. (2014) and Basílio (2017). Concerning the CRI score, it is also reasonable to assume a lag of one year. The cross-sectional regression models are the following:

Model 1

$$\begin{aligned} \boldsymbol{lnINV_{i,t}} = {} & \boldsymbol{\beta_0 + \beta_1 CRI_{t-1} + \beta_2 Gov_{i,t} + \beta_3 MDB_{i,t} + \beta_4 lnRealGDPpc_{t-1} + \beta_5 Growth_{t-1}} \\ & \boldsymbol{+ \beta_6 Inflation_{t-1} + \beta_7 lnPOP_{t-1} + \beta_8 PolStab_{t-1} + \beta_9 RLaw_{t-1}} \\ & \boldsymbol{+ \beta_{10} sectordummies + \beta_{11} yeardummies + \mu_{i,t}} \end{aligned}$$

Model 2

$$\begin{aligned} \boldsymbol{degree_{i,t}} = {} & \boldsymbol{\beta_0 + \beta_1 CRI_{t-1} + \beta_2 Gov_{i,t} + \beta_3 MDB_{i,t} + \beta_4 lnRealGDPpc_{t-1} + \beta_5 Growth_{t-1}} \\ & \boldsymbol{+ \beta_6 Inflation_{t-1} + \beta_7 lnPOP_{t-1} + \beta_8 PolStab_{t-1} + \beta_9 RLaw_{t-1}} \\ & \boldsymbol{+ \beta_{10} sectordummies + \beta_{11} yeardummies + \mu_{i,t}} \end{aligned}$$

Where *i* stands for the project and *t* for the year.

4. Main Results and Discussion

Table 3. reports the estimation results of model 1 and 2. Concerning model specification, the models seem to be appropriate to deal with our data, the linktest performed show no evidence of misspecification problems[3]. As a measure of goodness of fit, the Pseudo R^2 is presented, but it should be interpreted with caution given its limitations with non-linear models.

Table 3: Results - Private participation in infrastructure projects

	Model 1	***Model 2***
	y = lnINV	***y=degree***
	TOBIT	***FRACGLM (cloglog)***
CRI	-0.0031**	-0.0014
	(0.0016)	(0.0014)
Gov *dummy*	-0.1364	0.0397
	(0.0866)	(0.052)
MDB *dummy*	0.4318***	-0.1336*
	(0.1204)	(0.0727)
lnRealGDPpc	0.2508***	-0.0454
	(0.0714)	(0.0646)
Growth	-0.0316	0.0103
	(0.0199)	(0.012)
lnPOP	-0.0034	-0.0555**
	(0.0478)	(0.0246)
Inflation	-0.0138	-0.014
	(0.0118)	(0.0096)
PolStab	-0.2006	-0.3805***
	(0.1255)	(0.1013)
Rlaw	0.1655	0.3697***
	(0.1801)	(0.1254)
Energy	-0.9036***	0.1868
	(0.1151)	(0.1446)
MSW	-1.7291***	0.2685
	(0.371)	(0.1913)
ICT	-0.1576	-0.1028
	(0.3489)	(0.2511)
Water	-1.6672***	0.1452
	(0.2011)	(0.096)
Year dummies	yes	yes
Constant	3.4951***	2.4229***
	(1.2427)	(0.5658)
# Observations	3042	3536
Log likelihood	-5123.53	-491.31
Pseudo R2	5.07%	6.40%

Note: Cluster-robust standard errors in parentheses
*, ** and *** indicate significance at a 10%, 5% and 1% level, respectively.

[3] The prediction squared has no explanatory power (p-value hatsquared = 0.391 for model 1, and 0.938 for model 2).

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Focusing on model 1, let us begin by discussing the findings for our main variable, CRI, presenting a coefficient which is negative and statistically significant. This suggests that countries with higher values of CRI (meaning, facing less climate risk) have lesser private investment in infrastructure projects what is an unexpected result and contrary to our hypothesis H1. On the other hand, and recalling that we are using CRI with a lag of one year, countries that have experienced extreme weather events will need more investment in infrastructure to recover from their adverse effects, and this may be the explanation for the negative sign on the CRI coefficient. However, because more detailed information about the projects is unavailable, it is not possible to draw definitive conclusions. In addition, some studies have already emphasized that investors are not adequately pricing climate risk (IMF, 2020). For instance, Hong et al., (2019) concluded that global stock markets' are underpricing the drought risk in the food sector.

Examining the control variables, we find as expected, that projects with MDBs involvement to benefit with greater financial commitments from the private sector. As mentioned, MDBs' participation in infrastructure projects provides a protective umbrella, and may overcome countries' fragilities in the institutional environment, enhancing projects viability. Marcelo and House (2016) and Jandhyala (2016) already noted that projects with support from MDBs benefitted with lower rates of cancellation and distress. Government support does not appear significant, and this result may be explained by the fact that in model 1, we are only using projects with fully private participation, resting less on the direct/indirect support of the host governments.

Our results show that richer countries (measured by GDP per capita) tend to have projects with higher amounts of private investment. The private sector prefers to invest in wealthier countries, particularly if projects rely on user charges to recover investments. It should be recalled that the majority of the projects in the dataset are energy projects. Although still a regulated industry, exhibiting significant differences across countries, usually user charges are also used to partially recoup investments. Other macroeconomic variables, like population, inflation, or GDP growth, do not exhibit statistical significance.

Surprisingly, the political and institutional dimensions, measured here with the variables of political stability (PolStab) and rule of law (Rlaw), do not have a statistically significant effect on private sector investments.

Dummies for sectors, energy, MSW and water, report a significant and negative coefficient compared to the reference category (transport). In addition, year-dummies do not show any significant time effect concerning private sector investments in infrastructure.

In model 2, the degree of private sector involvement in infrastructure projects are explored. The coefficient of the climate risk score (CRI) does not appear with significance, leading to the rejection of H2.

The MDBs involvement in the project influences negatively the degree of private participation. This variable presents a coefficient with the opposite sign if we consider

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model 1 (private investment) and model 2 (degree of private participation). Nevertheless, as pointed by Jandhyala (2016), MDBs provide political assistance by leveraging their influence to resolve disputes that arise between firms and host governments during the course of an infrastructure project, and these disputes may be higher when the private sector has a degree of participation under 100%. Therefore, projects with a lower degree of private participation will benefit more with MDB's involvement.

The market dimension is an important determinant of investment as shown by Neumayer (2003). The coefficient on Population is negative, suggesting that there is a bias favoring small countries in what concerns the degree of private sector involvement.

The estimated coefficient on Political Stability is negative and statistically significant, meaning that the degree of private sector participation is lower for projects developed in more stable countries, what is an unexpected result. As argued by García-Canal and Guillén (2008, p. 1109), firms operating in regulated industries[4], seek to avoid countries with high levels of macroeconomic uncertainty, "but they displayed a preference to enter countries with discretionary governments, most likely because they place more value on the advantages that can be obtained at entry than on the possibility that the government changes the rules of the game subsequent to committing the investment".

In addition, the variable Rule of Law presents a positive and statistically significant coefficient, as expected. Countries with more stable policies and sound institutions should attract higher degrees of commitments from private investors.

Although these opposite findings on political stability and rule of law are striking, the same results have been already reported by Fleta-Asín and Muñoz (2021).

Differences among sectors are not statistically significant concerning the degree of private sector involvement.

To conclude, some robustness checks were conducted. First, in order to check the robustness of the analysis, we re-estimate model 2 adopting a two-limit Tobit, although its limitations. We defined a censored lower limit at 0 and an upper limit at 1. The same results were obtained for all the variables (coefficients and statistical significance).

Second, because projects developed in China, India, and Brazil represent 24.9%, 16.8%, and 14.3%, respectively, of the observations dominating our sample, we ran model 1 and model 2, excluding the projects in each of these three host countries by turn, to check for possible divergences in the results. The results obtained for model 1 (Tobit: y=lnINV) are consistent with those of the base model presented in Table 3, the coefficients maintain the signs and statistical significance for all the variables already mentioned. For ease of presentation, detailed results are not showed here.

Only the results for model 2 present some differences, particularly if we exclude observations from India. See Table 4.

[4] Regulated industries include, for instance, telecommunications, electricity, water, oil, gas, and banking.

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European Journal of Applied Business Management, Special Issue Circular Economy, 2022, pp. 31-50 ISSN 2183-5594

Table 4. Results – Degree of Private participation in infrastructure projects

Model 2 *y=degree*	No Brazil Coef. (β)	No China Coef. (β)	No India Coef. (β)
CRI	-0.0024	-0.0012	-0.0021
Gov *dummy*	0.0439	0.1414**	0.0548
MDB *dummy*	-0.1621**	-0.1504**	-0.1317*
lnRealGDPpc	0.0047	-0.0359	0.1101
Growth	0.0032	0.0188	0.0235*
lnPOP	-0.0437	-0.0268	-0.1051***
Inflation	-0.0083	-0.0193*	-0.0171
PolStab	-0.3276***	-0.3243***	-0.3258***
Rlaw	0.4335***	0.3274**	0.0841
Energy	0.2884**	0.0104	0.2934*
MSW	0.2329	0.0270	0.4284***
ICT	-0.0595	-0.2185	-0.0352
Water	0.0526	0.5203**	0.2650***
Year-dummies	yes	yes	yes
Constant	1.9153***	1.9293**	1.7484**
# Observations	3030	2657	2943
Log likelihood	-371.241	-323.232	-460.489
Pseudo R^2	7.81%	9.65%	6.36%

Note: For simplicity, just coefficients are presented. Cluster-robust standard errors were used.
*, ** and *** indicate significance at a 10%, 5% and 1% level, respectively

From Table 4, the results concerning CRI, on average, are the same. In addition, we have a higher degree of private sector commitment if the project has government support, as expected, if observations from China are excluded. However, more noticeable differences exist, if observations from India are excluded: the coefficient on GDP growth shows a positive effect, as expected, on the degree of private sector involvement and the coefficient on population maintains its sign but reinforces statistical significance. Rule of law loses significance and sector-dummies have positive and statistically significant coefficients (except for ICT) compared with the base sector (transport). A positive time-trend was evidenced by year-dummies coefficients.

All in all, the climate risk index (CRI) maintains the results of the base models (Table 3). The empirical evidence suggests that higher climate risk is associated with a higher amount of private investments in infrastructure and is not an influential factor in the degree of private sector commitment.

5. Conclusion

Infrastructure investments are essential to achieve economic growth, prosperity, and improving well-being. Any infrastructure project requires substantial financial resources and involves numerous stakeholders with different interests and objectives for long time spans. Given the specific nature of the assets, uncertainty and risks are emphasized and particularly if projects are being developed in LMIC, where the macroeconomic and political/institutional conditions may be weaker and less predictable.

In recent years, extreme weather events have highlighted infrastructure vulnerabilities and a new source of systematic risk appeared: climate risk. As such, private sector participation in infrastructure projects will be dependent on the assessment of the different risk factors, project-specific but also related to the country environment where the project will be developed, including physical climate risk perceptions.

Our work contributes to the nascent strand of the literature that studies the impact of climate risk on investments. We use two proxies for private sector participation, namely, investment levels and the degree of private commitment. The results lead to the rejection of H1 and H2, we find that higher climate risk is associated with higher private investments in infrastructure and, climate risk is not relevant for the percentage of private participation in the project. However, countries that are classified as riskier in climate terms will need more funds invested into infrastructure to deal with the harmful and devastating consequences of tornados, storms, floods, wildfires, etc. on sectors like transport (roads, ports, and airports), energy, and telecommunications.

Furthermore, recent research suggests that the risk of climatic disasters is not reflected in financial assets around the world. As already mentioned, translating the impact of future climate adverse events into asset prices is very complex and difficult, because it requires an understanding of the future behavior of climatic and non-climatic variables, which are uncertain and not possible to predict (IMF, 2020).

The current research has limitations that constitute opportunities for further investigation. First, at the moment, with the level of detail available for the infrastructure projects is not possible to further investigate the eventual ex-post nature of investments. Second, our results may be conditioned by the proxy of climate risk used. As such, alternative measures of climate risk should be tested. One possibility is to use data from the Global Climate Report from the National Oceanic and Atmospheric Administration. Third, the PPI database includes only projects developed in low- and middle-income countries and it will be interesting to extend this analysis to include more developed countries.

As a final note, this paper should be considered an exploratory study and besides the aforementioned limitations, important insights have been obtained. It contributes to the growing field of literature relating to the impact of climate risk on investments. It adds to the scarce literature and is a starting point to stimulate research about the effects of climate risk on infrastructure investors' strategies. Our results may be useful for private investors and public authorities, identifying the key factors that drive private sector participation.

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European Journal of Applied Business Management, Special Issue Circular Economy, 2022, pp. 31-50 ISSN 2183-5594

APPENDIX A

Table A.1 – Breakdown by sector / year

Sector	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**Total**
Energy	299	359	232	185	207	172	196	162	146	136	2 094
ICT	3	1	2	0	3	0	3	4	2	1	19
MSW	15	22	16	39	35	52	50	54	43	17	343
Transport	85	97	70	53	42	58	65	108	105	38	721
Water	36	40	29	36	51	33	29	28	37	40	359
Total	438	519	349	313	338	315	343	356	333	232	3 536

Table A.2 – Correlation Matrix

	CRI	Gov *dummy*	MDB *dummy*	lnRealGDPpc	Growth	lnPOP	Inflation	PolStab	Rlaw	Energy	MSW	ICT	Water
CRI	1												
Gov *dummy*	-0.109	1											
MDB *dummy*	0.1842	-0.0197	1										
lnRealGDPpc	0.2449	-0.0929	-0.1508	1									
Growth	-0.3303	0.1953	-0.0965	-0.3225	1								
lnPOP	-0.5214	0.1299	-0.3082	-0.0716	0.4374	1							
Inflation	0.0556	0.0834	0.0684	-0.3007	-0.1074	-0.0203	1						
PolStab	0.1266	-0.041	-0.0954	0.452	-0.1626	-0.2238	-0.3826	1					
Rlaw	0.0071	0.0201	-0.1323	0.1904	-0.0118	0.1092	0.0526	0.2426	1				
Energy	0.1514	0.0054	0.1599	-0.0387	-0.1395	-0.308	0.1374	-0.0262	-0.0292	1			
MSW	-0.0356	-0.1681	-0.0915	0.0953	0.0611	0.1234	-0.1289	0.0983	0.013	-0.395	1		
ICT	0.0752	-0.0363	0.0283	-0.0371	-0.017	-0.104	-0.0168	0.0353	-0.063	-0.0886	-0.0241	1	
Water	-0.1052	0.0926	-0.0845	0.1466	0.097	0.2006	-0.1656	0.1151	-0.0418	-0.4051	-0.1102	-0.0247	1
VIF	1.51	1.1	1.17	1.66	1.51	1.99	1.37	1.63	1.18	1.7	1.43	1.05	1.47