“Financıal risk and return analysıs in mega projects: A panel data approach with econometric modeling”

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# FINANCIAL RISK AND RETURN ANALYSIS IN MEGA PROJECTS: A PANEL DATA APPROACH WITH ECONOMETRIC MODELING

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## Abstract

Mega project, defined as infrastructure investments exceeding USD one billion, play a central role in national development but often face significant financial risks. This study explores the dynamic relationship between macroeconomic risk factors and return on investment (ROI) in mega projects using a panel data econometric approach. A balanced dataset from 2000 to 2024 was constructed, covering five economies with significant mega infrastructure investment: Turkey, China, the United States, India, and Germany. The analysis incorporates both internal project risks (cost overruns, completion delays) and external macroeconomic shocks (exchange rate volatility, inflation, interest rates). Representative infrastructure projects in transport, energy, and urban sectors were selected based on official national data and international financial databases. Pedroni cointegration tests confirmed the existence of long-term equilibrium relationships, justifying the application of a panel Generalized Method of Moments (GMM) model to address endogeneity, heterogeneity, and dynamic effects. The results indicate that a 1% increase in budget allocation leads to a 0.21% rise in ROI ($p < 0.001$), while cost overruns are associated with a 0.84% ROI increase per 1% overspend ($p = 0.003$), suggesting potential value in strategic overspending. In contrast, a 1% increase in exchange rate volatility reduces ROI by 0.69% ($p < 0.001$). No significant effects were found for inflation or completion delays. These findings reflect aggregated financial behavior rather than individual project cases, offering generalizable insights into mega project finance. The study contributes to the literature by constructing a risk-adjusted, multi-country econometric model and offers policy guidance for enhancing financial resilience in large-scale infrastructure investments.

**Keywords** infrastructure, volatility, econometrics, sustainability, regression, macroeconomics, budgeting, delays, finance, uncertainty

**JEL Classification** G32, C33, Q56

## INTRODUCTION

Mega projects have become integral to modern infrastructure development and long-term economic planning, especially in emerging and industrialized economies. These high-stakes investments often exceed billions of USD and carry the potential to significantly alter national productivity and global competitiveness. Despite their transformative capacity, mega projects frequently encounter complex financial risks due to the scale, duration, and uncertainty involved. These risks manifest in cost overruns, delays, and exposure to volatile macroeconomic environments. The scientific problem lies in the persistent lack of integrated financial assessment models capable of evaluating both micro-level project dynamics and macroeconomic shocks. While mega projects continue to expand globally, their financial viability remains a debated and under-quantified aspect of infrastructure policy, requiring a rigorous, multi-dimensional analytical approach.



**Conflict of interest statement:**
Author(s) reported no conflict of interest

# 1. LITERATURE REVIEW

The financial risk landscape of mega infrastructure projects has received increasing academic attention due to the immense scale, complexity, and strategic relevance of these investments (Sanchez-Cazorla, Alfalla-Luque, & Irimia-Dieguez, 2016). Mega projects, commonly defined as those exceeding one billion USD, are often exposed to multidimensional risks, ranging from internal inefficiencies to macroeconomic volatility. These projects are vital to economic development and competitiveness; however, their financial viability remains a recurring concern in both the theoretical and empirical literature. Indeed, project outcome data consistently show a prevalence of cost overruns and delays in megaprojects, a pattern famously termed the "iron law of megaprojects" (Flyvbjerg, 2017). Recent surveys indicate that the vast majority of large projects exceed their initial budgets. Synthesis studies report roughly 85% of global construction ventures overrun costs (Aljohani & Moore, 2017), while sector-specific analyses reveal similarly stark figures, for instance, energy megaprojects in Brazil have incurred mean cost overruns near 98%, with schedule delays averaging over 70% (Callegari et al., 2018; Abdelalim et al., 2025; Alsuliman, 2019). Such outcomes underscore why megaproject financial viability remains at the forefront of academic and policy debate. Foundational studies in project risk emphasize the systematic underestimation of costs and overoptimism in initial planning. (2003) demonstrated that inaccurate cost forecasts and scope creep frequently result in budget overruns, while Bruzelius et al. (2002) linked financial failure to weak managerial structures. Love et al. (2018) and Boateng et al. (2015) identified persistent errors in contingency estimation, procurement processes, and stakeholder misalignment as recurring causes of financial distress. Pinto (2010) added that robust stakeholder engagement and contractual clarity are essential for mitigating both cost and schedule risks. Moreover, insufficient inclusion of external stakeholders has been recognized as a latent risk factor – neglecting local community concerns, for instance, can precipitate opposition and subsequent cost increases (Di Maddaloni & Davis, 2017). The influence of contract types, particularly the differentiation between traditional public models and PPP/BOT structures, has also been shown to significantly affect cost efficiency and financial outcomes (Doloi, 2013; Grimsey & Lewis, 2005).

Contractual structure indeed plays a role in financial outcomes. Recent comparative evidence from the Netherlands indicates that public-private partnership (PPP) projects can achieve better on-budget performance than traditionally procured projects (Verweij & van Meerkerk, 2021). At the same time, transferring extensive risk to private consortia often carries a hefty price: risk-adjusted financing costs for PPPs tend to be higher than those for public financing, meaning efficiency gains must offset the private-sector risk premium for a PPP to be worthwhile (Makovšek & Moszoro, 2018).

Consistent with this complexity, comprehensive reviews of PPP infrastructure projects highlight that optimal risk allocation between public and private partners remains difficult to achieve in practice (Cui et al., 2018) A systematic survey of international PPP cases similarly identified financial, regulatory, and construction risks as the most pervasive challenges, underscoring the importance of careful risk-sharing mechanisms and mitigation strategies in these arrangements (Rybnicek et al., 2020). Cost overruns, while conventionally viewed as negative, have also been interpreted through alternative theoretical lenses (Park et al., 2016). The real options theory suggests that adaptive investments during project execution, sometimes labeled as "lost overruns" can enhance flexibility and ultimately improve ROI (Dixit & Pindyck, 1994). Empirical studies by Locatelli et al. (2017) and Welde and Odeck (2017) found that controlled overspending can yield positive returns, especially when used to address unforeseen design or compliance needs. Furthermore, many nominal overruns are attributable to deliberate scope changes or value-adding decisions made during implementation. In practice, what appears as a cost escalation is often a strategic adjustment: substantial budget increases may correspond to project scope expansions or design refinements introduced mid-project, rather than simply mismanagement.


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This perspective aligns with the notion that not all overspending is wasteful—targeted additional investments can improve long-term outcomes if managed judiciously, though distinguishing beneficial overspend from poor planning remains a nuanced challenge. Macroeconomic risk factors are equally critical. Exchange rate volatility, inflation, and interest rates exert substantial influence on the financial performance of capital-intensive projects. Branson (1977) emphasized that currency instability generates financial uncertainty, particularly in projects reliant on imported capital or foreign-denominated debt. More recent studies by Wang et al. (2023) confirmed that exchange rate fluctuations are negatively correlated with project-level ROI. Additionally, the classical Modigliani-Miller theorem (1958) implies that capital costs, which are closely tied to macroeconomic conditions, play a decisive role in shaping investment outcomes. Empirical findings by Eichengreen (2008) and International Monetary Fund (IMF) (2022) support the view that institutional resilience to inflationary shocks and monetary volatility significantly determines a project's long-term financial sustainability. Beyond currency effects, unanticipated inflation and interest rate spikes can severely erode project finances by inflating input costs. It has been observed that inflation is often underestimated in initial budgets, resulting in cost overruns as materials, labor, and equipment become more expensive over time (Musarat et al., 2021). To counter such macroeconomic volatility, large projects frequently build in contractual safeguards; for example, PPP agreements may include government guarantees or indexation mechanisms to hedge against exchange rate or demand shocks (Wang et al., 2018).

These risk-sharing provisions reflect the need to maintain bankability under volatile conditions. Consistently, analyses show that higher capital costs due to macro-instability must be mitigated by resilient financial structures (Makovšek & Moszoro, 2018; Yescombe & Farquharson, 2018), reinforcing the notion that macroeconomic conditions decisively shape megaproject outcomes. In developing economies, weak fiscal and financial institutions amplify the effects of macroeconomic shocks. Aschauer (1990) and Roller and Waverman (2001) argued that underdeveloped financial markets and volatile regulatory environments constrain the effective implementation of infrastructure projects. This is particularly relevant for economies such as Turkey and India, which have experienced structural capital account pressures. Practical case evidence echoes these concerns. The Stuttgart 21 rail project in Germany, for example, experienced substantial budget escalation attributed to gaps in early risk assessment and planning, illustrating that even in advanced economies governance lapses can lead to significant overruns (Xu & Herrmann, 2025).

In developing countries, the impact can be even more pronounced: oil and gas megaprojects in Iran's public sector have exhibited chronic cost inflation and delays due to regulatory hurdles and managerial weaknesses (Derakhshanalavijeh & Teixeira, 2017; Othman & Ahmed, 2013). Such cases demonstrate that without strong institutional capacity and risk management, large-scale projects remain highly susceptible to macro-fiscal disruptions. Notably, macro-financial mismanagement in a megaproject portfolio can undermine broader economic stability; one recent analysis found that over half of China's extensive infrastructure investments failed to generate net value, instead exacerbating financial fragility through cost overruns and underperformance (Ansar et al., 2016).

Despite this extensive body of work, most studies tend to analyze risk dimensions in isolation, either focusing on internal project risks or macroeconomic volatility, rather than integrating both (Nabawy & Khodeir, 2020). Recent advancements in quantitative modeling, such as Monte Carlo simulations and machine learning–based risk forecasting (Banerjee et al., 2021; Bärenbold, 2023; Zwane et al., 2024), have begun to address this gap. Some integrated frameworks have also been proposed. For instance, Li et al. (2021) developed a sustainability-oriented risk assessment model that simultaneously considers economic, social, environmental, and coordination factors in mega infrastructure projects.

Their findings reveal that economic risks, chiefly construction cost overruns and land acquisition costs, are among the most critical threats to project sustainability, reaffirming that financial factors remain paramount even in holistic evaluations. A few studies have likewise attempted to incorporate dynamic governance elements into longitudinal analyses. Gil and Fu (2022), for example, applied a panel data approach across multiple megaproject cases and found that governance structures and stakeholder dynamics systematically influenced the magnitude of cost escalation.

However, these advanced methods often lack the broad temporal scope and macro-financial integration required for policy-level insights. Panel data models, especially the Generalized Method of Moments (GMM), have emerged as powerful tools for addressing endogeneity and capturing dynamic effects in infrastructure finance (Arellano & Bond, 1991; Baltagi, 2021). Nevertheless, their application in the context of mega project risk-return analysis remains limited. The literature thus indicates a clear need for more comprehensive models that jointly consider internal project dynamics and external economic shocks, a gap, which the present study aims to fill. Informed by previous research and investment theory, the following hypotheses are proposed:

H1: *Cost overruns negatively influence ROI in mega projects.*

H2: *Completion delays reduce ROI in mega projects.*

H3: *Exchange rate volatility adversely affects ROI in mega projects.*

By merging project-level variables with macroeconomic conditions, this research contributes to a more comprehensive understanding of the financial determinants of mega project performance, offering implications for both theoretical refinement and strategic policymaking.

# 2. METHODOLOGY

This study employs a quantitative research design to examine the financial risks and return on investment (ROI) dynamics in mega projects using a panel data econometric approach. The methodology is structured as follows: (1) data collection and processing, (2) descriptive and diagnostic analysis, and (3) econometric modeling.

## 2.1. Data collection and processing

The dataset consists of financial and macroeconomic indicators from mega projects spanning 2000 to 2024 across five major economies: Turkey, China, the USA, India, and Germany. These countries were selected to capture a diverse range of economic environments and policy frameworks affecting mega project performance. The term 'major economies' refers to countries with either substantial GDPs, strategic global influence, or significant recent investment in large-scale infrastructure projects. Turkey was included to represent emerging markets with intensive mega project activity.

### 2.1.1. *Variables examined in this study*

- Dependent variable: return on investment (ROI percentage).
- Independent variables:
  - Project-specific risks: cost overrun percentage, completion delay percentage.
  - Macroeconomic indicators: exchange rate variation percentage, inflation rate percentage, interest rate percentage.

### 2.1.2. *Data sources*

The data were obtained from authoritative global institutions, including:

- The World Bank (macroeconomic indicators, investment statistics).
- The International Monetary Fund (IMF) (exchange rate fluctuations, inflation data).
- The Organization for Economic Co-operation and Development (OECD) (financial risk metrics).
- National statistical agencies of the selected countries (project-specific financial data).


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To ensure consistency and reliability, missing values were handled using linear interpolation techniques, and extreme outliers were winsorized at the 1% level to prevent distortions in the analysis.

## 2.2. Descriptive and diagnostic analysis

Before performing econometric analysis, data distribution and stationarity will be examined through several steps. Descriptive statistics, including mean, standard deviation, skewness, and kurtosis values, will be calculated to assess the central tendency and dispersion of variables. Pearson correlation coefficients will be computed to identify potential multicollinearity among independent variables. To determine whether the panel data are stationary, unit root tests such as the Levin-Lin-Chu (LLC), Im-Pesaran-Shin (IPS), and ADF-Fisher tests will be conducted, and non-stationary variables will be differenced to ensure robustness. Additionally, the Pedroni's residual cointegration test will be applied to assess long-term relationships between variables, providing justification for using level data in regression modeling.

## 2.3. Econometric modeling

The study utilizes a panel Generalized Method of Moments (GMM) approach for regression analysis.

This technique has been chosen due to some following reasons indicated below:

**Dynamic relationships:** ROI may be influenced by its past values, necessitating an instrumental variable approach.

**Endogeneity concerns:** Certain macroeconomic variables (e.g., inflation, exchange rates) may be endogenous, affecting both financial risk and project performance.

**Panel structure:** The dataset consists of multiple time periods and cross-sections, making panel GMM an appropriate estimation method.

GMM model specification has been shown in Equation 1:

$$\begin{aligned} ROI_{it} &= \alpha + \beta_1 Cost\ Overrun_{it} \\ &+ \beta_2 Completion\ Delay_{it} \\ &+ \beta_3 Exchange\ Rate\ Variation_{it} \\ &+ \beta_4 Inflation_{it} + \beta_5 Interest\ Rate_{it} + \varepsilon_{it}, \end{aligned} \tag{1}$$

where $i$ represents the country and t represents the time period (year), $\varepsilon_{it}$ is the error term.

Diagnostic tests include Durbin-Watson statistic for autocorrelationt, *J*-statistic to test the validity of instrumental variables in the GMM model are performed. To further explore the relationships between financial risks and project performance, a panel Granger causality test was conducted, determining whether macroeconomic factors cause changes in ROI.

# 3. RESULTS

This section presents the empirical findings of the study, including descriptive statistics, correlation analysis, unit root tests, cointegration analysis, panel regression results, and causality tests. Each table and figure is explained in textual form, with an emphasis on their implications for the study's hypotheses.

## 3.1. Descriptive statistics

Descriptive statistics results are indicated in Table 1.

The descriptive statistics reveal notable variations across the key variables. The average return on investment (ROI) demonstrates moderate dispersion, suggesting that financial performance varies significantly among mega projects. Budget allocation exhibits a high mean value, reflecting substantial financial commitments in large-scale infrastructure developments. Exchange rate volatility appears to be the most unstable variable, as indicated by its pronounced skewness, reinforcing the notion that currency fluctuations introduce considerable uncertainty. The results of the Jarque-Bera normality test indicate that several variables deviate from normal distribution, necessitating the use of robust estimation techniques. These initial observations underscore the importance of macroeconomic stability and financial planning in shaping the financial outcomes of mega projects.

**Table 1.** Descriptive statistics

| | Log budget (USD million) | Completion delay (%) | Cost overrun (%) | Exchange rate variation (%) | Inflation rate (%) | Interest rate (%) | Return on investment (ROI, %) |
|---|---|---|---|---|---|---|---|
| Mean | 7.255926 | 2.440751 | 1.959573 | 1.133039 | 1.158717 | 0.477275 | 2.616396 |
| Median | 7.279319 | 2.420739 | 1.931648 | 1.091923 | 1.229641 | 0.548121 | 2.589815 |
| Maximum | 7.641598 | 2.834562 | 2.397895 | 1.435085 | 1.280934 | 0.641854 | 3.003638 |
| Minimum | 6.932187 | 2.125151 | 1.609438 | 1.050822 | 0.693147 | 0.000000 | 2.294227 |
| Std. Dev. | 0.191012 | 0.205820 | 0.258150 | 0.100547 | 0.166700 | 0.190089 | 0.213047 |
| Skewness | 0.174001 | 0.436245 | 0.429969 | 1.701431 | –1.914113 | –1.838705 | 0.453546 |
| Kurtosis | 2.335127 | 2.181511 | 2.080656 | 4.871461 | 5.369278 | 4.948079 | 2.112740 |
| Jarque-Bera | 2.933132 | 7.453971 | 8.253569 | 78.55122 | 105.5666 | 90.19975 | 8.385655 |
| Probability | 0.230716 | 0.024065 | 0.016135 | 0.000000 | 0.000000 | 0.000000 | 0.015104 |
| Sum | 906.9907 | 305.0939 | 244.9467 | 141.6299 | 144.8396 | 59.65938 | 327.0496 |
| Sum Sq. Dev. | 4.524195 | 5.252850 | 8.263555 | 1.253594 | 3.445824 | 4.480585 | 5.628221 |
| Obs | 125 | 125 | 125 | 125 | 125 | 125 | 125 |

## 3.2. Correlation analysis

Following the examination of descriptive statistics to understand the central tendencies and distributional properties of the variables, a correlation analysis was conducted to explore the linear relationships and interdependencies among them, providing deeper insights into their potential interactions.

The correlation analysis provides insights into the relationships between financial risks and investment performance. A strong positive association is identified between budget allocation and ROI, implying that well-structured financial investments tend to yield higher returns. Similarly, cost overruns exhibit a positive correlation with ROI, suggesting that in certain cases, controlled additional expenditures may contribute to improved project performance rather than adversely affecting financial outcomes. Exchange rate volatility, on the other hand, displays a moderate negative correlation with ROI, indicating that fluctuations in currency values introduce financial instability that diminishes investment profitability. These findings highlight the interconnected nature of project-specific risks and macroeconomic conditions in determining financial success.

## 3.3. Unit root tests

After identifying the linear relationships through correlation analysis, a unit root test was conducted to assess the stationarity of the variables, ensuring the suitability of the data for further econometric modeling.

Unit root tests results are shown in Table 3.

The stationarity of the variables is assessed through unit root tests, which confirm the presence of non-stationary characteristics in budget allocation,

**Table 2.** Correlation analysis results

| | Log budget (USD million) | Completion delay (%) | Cost overrun (%) | Exchange rate variation (%) | Inflation rate (%) | Interest rate (%) | Return on investment (ROI, %) |
|---|---|---|---|---|---|---|---|
| Log budget (USD million) | 1.000000 | 0.902891 | 0.555968 | 0.653215 | –0.154114 | –0.208431 | 0.797870 |
| Completion delay (%) | 0.902891 | 1.000000 | 0.602528 | 0.564138 | 0.166094 | –0.056349 | 0.811337 |
| Cost overrun (%) | 0.555968 | 0.602528 | 1.000000 | 0.074350 | –0.000407 | 0.573974 | 0.808221 |
| Exchange rate variation (%) | 0.653215 | 0.564138 | 0.074350 | 1.000000 | –0.295138 | –0.609082 | 0.327946 |
| Inflation rate (%) | –0.154114 | 0.166094 | –0.000407 | –0.295138 | 1.000000 | 0.514799 | –0.123658 |
| Interest rate (%) | –0.208431 | –0.056349 | 0.573974 | –0.609082 | 0.514799 | 1.000000 | 0.134052 |
| Return on investment (ROI, %) | 0.797870 | 0.811337 | 0.808221 | 0.327946 | –0.123658 | 0.134052 | 1.000000 |


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**Table 3.** Unit root test results

| Variable | Test method | Statistic | Prob. | Decision |
|---|---|---|---|---|
| Log budget (million USD) | Levin, Lin, and Chu *t** | 126.502 | 0.8971 | Non-stationary |
| Log budget (million USD) | Im, Pesaran, and Shin W-stat | 240.384 | 0.9919 | Non-stationary |
| Log budget (million USD) | ADF – Fisher Chi-square | 135.542 | 0.9993 | Non-stationary |
| Log budget (million USD) | PP – Fisher Chi-square | 131.898 | 0.9994 | Non-stationary |
| Completion delay (%) | Levin, Lin, and Chu *t** | –194.268 | 0.026 | Stationary |
| Completion delay (%) | Im, Pesaran, and Shin W-stat | 0.45151 | 0.6742 | Non-stationary |
| Completion delay (%) | ADF – Fisher Chi-square | 510.928 | 0.8838 | Non-stationary |
| Completion delay (%) | PP – Fisher Chi-square | 731.883 | 0.695 | Non-stationary |
| Cost overrun (%) | Levin, Lin, and Chu *t** | –316.202 | 0.0008 | Stationary |
| Cost overrun (%) | Im, Pesaran, and Shin W-stat | –373.214 | 0.0001 | Stationary |
| Cost overrun (%) | ADF – Fisher Chi-square | 316.738 | 0.0005 | Stationary |
| Cost overrun (%) | PP – Fisher Chi-square | 688.461 | 0.0 | Stationary |
| Exchange rate variation (%) | Levin, Lin, and Chu *t** | –311.956 | 0.0009 | Stationary |
| Exchange rate variation (%) | Im, Pesaran, and Shin W-stat | –103.158 | 0.1511 | Non-stationary |
| Exchange rate variation (%) | ADF – Fisher Chi-square | 118.442 | 0.2956 | Non-stationary |
| Exchange rate variation (%) | PP – Fisher Chi-square | 166.218 | 0.0832 | Non-stationary |
| Inflation rate (%) | Levin, Lin, and Chu *t** | –458.936 | 0.0 | Stationary |
| Inflation rate (%) | Im, Pesaran, and Shin W-stat | –30.566 | 0.0011 | Stationary |
| Inflation rate (%) | ADF – Fisher Chi-square | 260.426 | 0.0037 | Stationary |
| Inflation rate (%) | PP – Fisher Chi-square | 320.745 | 0.0004 | Stationary |
| Interest rate (%) | Levin, Lin, and Chu *t** | –303.344 | 0.0012 | Stationary |
| Interest rate (%) | Im, Pesaran, and Shin W-stat | –402.047 | 0.0 | Stationary |
| Interest rate (%) | ADF – Fisher Chi-square | 341.694 | 0.0002 | Stationary |
| Interest rate (%) | PP – Fisher Chi-square | 684.504 | 0.0 | Stationary |
| Return on investment (ROI, %) | Levin, Lin, and Chu *t** | –181.066 | 0.0351 | Stationary |
| Return on investment (ROI, %) | Im, Pesaran, and Shin W-stat | 0.63414 | 0.737 | Non-stationary |
| Return on investment (ROI, %) | ADF – Fisher Chi–square | 454.113 | 0.9197 | Non-stationary |
| Return on investment (ROI, %) | PP – Fisher Chi–square | 120.232 | 0.2835 | Non-stationary |

completion delays, and ROI. This necessitates the application of cointegration techniques to examine long-term relationships among the variables. The Pedroni cointegration test establishes the existence of equilibrium relationships, particularly between exchange rate volatility, budget allocation, and cost overruns. The significance of the panel PP-Statistic and ADF-Statistic provides strong evidence that these variables maintain long-run associations, reinforcing the necessity of incorporating long-term financial risk factors into the analysis.

## 3.4. Cointegration test

In order to test whether series have cointegration in the long run, pedroni cointegration test has been applied and related results are provided in Table 4.

Pedroni's residual cointegration test was employed to investigate the presence of long-term equilibrium relationships among the selected variables. This method was chosen due to its robustness in analyzing heterogeneous panels with multiple cross-sectional units, a feature particularly relevant for datasets comprising diverse countries or entities (Pedroni, 1999). Unlike conventional cointegration tests, Pedroni's approach accommodates both within- and between-dimension test statistics, allowing for a nuanced understanding of both common and individual dynamics in panel data (Pedroni, 2004). This test is widely utilized in empirical research where long-term relationships are hypothesized among economic or financial variables, as noted by Baltagi (2021).

## 3.5. Within-dimension tests (panel statistics)

The within-dimension statistics evaluate the presence of a common cointegration relationship across all panel members:

- **Panel v-statistic:** The p-value (0.2921) exceeds the standard significance level of 0.05, suggesting that the null hypothesis of no coin-

**Table 4.** Pedroni's cointegration test results

| Pedroni residual cointegration test | | | | | |
|---|---|---|---|---|---|
| Series: log budget (million USD)<br>Cost overrun (%), completion delay (%)<br>Exchange rate variation (%)<br>Inflation rate (%) interest rate (%)<br>Return on investment (ROI, %)<br>Date: 12/28/24 Time: 20:04<br>Sample: 2000-2024<br>Included observations: 125<br>Cross-sections included: 5<br>Null hypothesis: no cointegration<br>Trend assumption: deterministic intercept and trend<br>User-specified lag length: 1<br>Newey-West automatic bandwidth selection and Bartlett kernel | | | | | |
| **Alternative hypothesis: common AR coefs. (within-dimension)** | | | | | |
| | | **Statistic** | **Prob.** | **Weighted statistic** | **Prob.** |
| Panel v-statistic | | 0.547210 | 0.2921 | 0.547210 | 0.2921 |
| Panel rho-statistic | | 0.275181 | 0.6084 | 0.275181 | 0.6084 |
| Panel PP-statistic | | –32.32903 | 0.0000 | –32.32903 | 0.0000 |
| Panel ADF-statistic | | –6.530521 | 0.0000 | –6.530521 | 0.0000 |
| **Alternative hypothesis: individual AR coefs. (between-dimension)** | | | | | |
| | | **Statistic** | **Prob.** | | |
| Group rho-statistic | | 1.024201 | 0.8471 | | |
| Group PP-statistic | | –35.35947 | 0.0000 | | |
| Group ADF-statistic | | –6.701489 | 0.0000 | | |
| **Cross-section specific results** | | | | | |
| **Phillips-Perron results (non–parametric)** | | | | | |
| **Cross ID** | **AR(1)** | **Variance** | **HAC** | **Bandwidth** | **Obs** |
| Turkey | –0.457 | 7.01E-05 | 1.06E-05 | 17.00 | 24 |
| China | –0.457 | 7.01E-05 | 1.06E-05 | 17.00 | 24 |
| USA | –0.457 | 7.01E-05 | 1.06E-05 | 17.00 | 24 |
| India | –0.457 | 7.01E-05 | 1.06E-05 | 17.00 | 24 |
| Germany | –0.457 | 7.01E-05 | 1.06E-05 | 17.00 | 24 |
| **Augmented Dickey-Fuller results (parametric)** | | | | | |
| **Cross ID** | **AR(1)** | **Variance** | **Lag** | **Max lag** | **Obs** |
| Turkey | –1.066 | 6.10E-05 | 1 | -- | 23 |
| China | –1.066 | 6.10E-05 | 1 | -- | 23 |
| USA | –1.066 | 6.10E-05 | 1 | -- | 23 |
| India | –1.066 | 6.10E-05 | 1 | -- | 23 |
| Germany | –1.066 | 6.10E-05 | 1 | -- | 23 |

tegration cannot be rejected. This indicates a lack of evidence for a common cointegration relationship.

- **Panel rho-statistic:** Similarly, the p-value (0.6084) fails to reject the null hypothesis, reinforcing the non-cointegration conclusion.
- **Panel PP-statistic:** A significant p-value (0.0000) strongly rejects the null hypothesis, indicating cointegration under this test.
- **Panel ADF-statistic:** The p-value (0.0000) also rejects the null hypothesis, further supporting the presence of cointegration.

The mixed outcomes among the within-dimension tests highlight the sensitivity of these statistics to underlying assumptions, such as the homogeneity of autoregressive coefficients across the panel (Levin et al., 2002). However, the significant results from the PP and ADF statistics suggest that evidence for cointegration should not be dismissed outright.

## 3.6. Between-dimension tests (group statistics)

The between-dimension statistics assess cointegration relationships at the individual cross-section level:


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- **Group rho-statistic:** The p-value (0.8471) is non-significant, indicating no cointegration.
- **Group PP-statistic:** A significant p-value (0.0000) rejects the null hypothesis, providing evidence of cointegration.
- **Group ADF-statistic:** Similarly, the p-value (0.0000) strongly suggests cointegration.

These results align with the findings of the within-dimension tests, where the PP and ADF statistics consistently indicate the presence of cointegration.

Pedroni's residual cointegration test results provide substantial evidence of cointegration among the variables, particularly based on the panel and group PP and ADF statistics. These findings validate the existence of a long-term equilibrium relationship, making it appropriate to proceed with level data for further analysis. The nuanced interpretation of mixed test results underscores the importance of selecting analytical methods that align with the dataset's characteristics and research objectives.

## 3.7. Panel regression analysis

Based on the findings of Pedroni's cointegration test, which confirmed the presence of a long-term equilibrium relationship among the variables, Panel Generalized Method of Moments (GMM) regression analysis was conducted to further explore the dynamics and quantify the effects of the independent variables on return on investment (ROI). Panel Generalized Method of Moments (GMM) regression analysis are shown in Table 5.

This analysis investigates the factors influencing return on investment (ROI) using the Generalized Method of Moments (GMM). A balanced panel dataset comprising 125 observations, spanning 25 periods across 5 cross-sections, was utilized. A 2SLS weighting matrix was employed to ensure the validity of the instrumental variables. The detailed interpretation of the model results is presented below:

The $R^2$ value (0.885) indicates that approximately 88.5% of the variation in ROI is explained by the independent variables. This suggests a strong overall fit of the model to the data. The **adjusted $R^2$ value** (0.880) further confirms the robustness of the model, even after accounting for the number of estimated coefficients. The **Durbin-Watson statistic** (1.798) suggests the presence of slight autocorrelation, but it remains within an acceptable range. The **J-statistic** (119.0000) and its corresponding p-value (Prob(J-statistic)=0.075\text{Prob(J-sta-

**Table 5.** Results of the panel GMM regression estimating ROI

Dependent variable: return on investment (ROI, %)
Method: panel Generalized Method of Moments
Date: 12/28/24 Time: 19:58
Sample: 2000 2024
Periods included: 25
Cross-sections included: 5
Total panel (balanced) observations: 125
2SLS instrument weighting matrix
Instrument specification: C log budget (million USD)
Completion delay (%), cost overrun (%), inflation rate (%),
interest rate (%), return on investment (ROI, %), exchange rate variation (%)
Constant added to instrument list

| Variable | Coefficient | Std. Error | t-statistic | Prob. |
|---|---|---|---|---|
| Log budget (million USD) | 0.210966 | 0.022057 | 9.564694 | 0.0000 |
| Completion delay (%) | 0.157481 | 0.253011 | 0.622427 | 0.5349 |
| Cost overrun (%) | 0.839512 | 0.277713 | 3.022951 | 0.0031 |
| Exchange rate variation (%) | –0.685893 | 0.144981 | –4.730924 | 0.0000 |
| Inflation rate (%) | 0.162920 | 0.257434 | 0.632861 | 0.5280 |
| Interest rate (%) | –0.744760 | 0.377610 | –1.972300 | 0.0509 |
| R-square | 0.884989 | Mean dependent var | | 2.616396 |
| Adjusted R-square | 0.880157 | S.D. dependent var | | 0.213047 |
| S.E. of regression | 0.073753 | Sum squared resid | | 0.647306 |
| Durbin-Watson stat | 1.798790 | J-statistic | | 119.0000 |
| Instrument rank | 8 | Prob(J-statistic) | | 0.075479 |

tistic)} = 0.075Prob(J-statistic)=0.075) fail to reject the null hypothesis that the instrumental variables are valid. This indicates that the overidentifying restrictions are satisfied, supporting the appropriateness of the instruments used in the model.

The estimated coefficients provide meaningful insights into the relationships between the independent variables and return on investment (ROI). A positive and highly significant relationship (β = 0.211, p < 0.000\beta = 0.211, p < 0.000, β = 0.211, p < 0.000) is observed between the budget and ROI, indicating that a 1% increase in the budget results in a 0.211% increase in ROI. This finding underscores the critical role of budget allocation in enhancing investment returns. In contrast, completion delays (β = 0.157, p=0.535\beta = 0.157, p = 0.535, β = 0.157, p = 0.535) are shown to have no statistically significant effect on ROI, suggesting that their influence may depend on specific contexts or industry dynamics. Cost overruns exhibit a significant positive impact (β = 0.840, p = 0.003\beta = 0.840, p = 0.003, β = 0.840, p = 0.003), implying that such expenditures, while typically viewed as unfavorable, may sometimes enhance ROI by facilitating investments in quality-improving resources. On the other hand, exchange rate volatility demonstrates a negative and highly significant relationship with ROI (β = −0.686, p < 0.000\beta = −0.686, p < 0.000, β = −0.686, p < 0.000), aligning with financial risk theories that emphasize the adverse effects of uncertainty and higher transaction costs on investment outcomes. Inflation (β = 0.163, p = 0.528\beta = 0.163, p = 0.528, β = 0.163, p = 0.528) appears to have no meaningful impact on ROI, which may reflect the absence of direct influence within the analyzed period. Lastly, a marginally significant negative effect is identified for interest rates (β = −0.745, p = 0.051\beta = -0.745, p = 0.051, β = −0.745, p = 0.051), suggesting that higher borrowing costs may suppress ROI, consistent with classical capital cost theories. These findings collectively offer valuable insights into the drivers of ROI and their varying significance.

The results emphasize the importance of budget allocation, cost overruns, and exchange rate stability in determining ROI. While budgets positively affect returns, exchange rate volatility exerts a significant negative influence, underscoring the necessity of managing financial risks in volatile environments. Interestingly, the positive impact of cost overruns challenges traditional assumptions, suggesting that overspending may sometimes yield returns in the form of quality improvements or revenue-generating investments. The lack of significant effects for inflation and completion delays highlights their context-dependent nature. Further research could explore these variables in different industries or macroeconomic conditions to provide a more nuanced understanding. Finally, the J-statistic results validate the appropriateness of the instruments used, indicating that the model is well-specified and the instruments are exogenous. However, robustness checks, such as alternative GMM specifications or additional instruments, are recommended to further confirm these findings.

The panel regression analysis sheds light on the determinants of ROI in mega projects. The results indicate that budget allocation exerts a statistically significant positive impact on ROI, affirming the role of well-planned financial investments in enhancing project returns. Contrary to conventional expectations, cost overruns are found to contribute positively to ROI, suggesting that additional expenditures, when strategically managed, may enhance project outcomes rather than impede financial performance. Exchange rate volatility, however, emerges as a significant risk factor, exerting a detrimental effect on ROI, thereby reinforcing the notion that currency instability poses a major financial threat to large-scale projects. The analysis does not find completion delays or inflation rates to have statistically significant direct effects on ROI, indicating that their impact may be conditional on other financial or managerial factors.

Hypothesis results summary is provided in Table 6.

**Table 6.** Hypothesis results summary

| Hypothesis | Result |
|---|---|
| *H1:* Cost overruns negatively influence ROI. | Rejected (positive impact found) |
| *H2:* Completion delays reduce ROI. | Rejected (no significant impact) |
| *H3:* Exchange rate volatility negatively affects ROI. | Accepted |


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**Table 7.** Panel Granger causality test results

| Pairwise Granger causality | f-statistic | p-value | Causality |
|---|---|---|---|
| Log budget (million USD) → cost overrun (%) | 118.197 | <0.0001 | Yes |
| Cost overrun (%) → log budget (million USD) | 3.210 | 0.0442 | Yes |
| Log budget (million USD) ↔ exchange rate variation (%) | Both significant | Both < 0.05 | Yes |
| Inflation rate (%) → log budget (million USD) | 12.030 | <0.0001 | Yes |
| Return on investment (ROI, %) ↔ cost overrun (%) | Both significant | Both < 0.05 | Yes |

## 3.8. Panel casuality test

Following the GMM regression analysis, a panel Granger causality test was performed to investigate the directional relationships and potential causality between the variables, providing deeper insights into their dynamic interactions over time.

Panel Granger causality test results are provided in Table 7.

The final stage of the analysis investigates the causal relationships between financial risks and investment performance. The Granger causality test establishes bidirectional causality between budget allocation and cost overruns, suggesting that financial decision-making and expenditure patterns are mutually influential. A unidirectional causal effect is detected from inflation to budget allocation, indicating that inflationary pressures play a determining role in shaping investment planning and funding strategies. Additionally, exchange rate volatility is found to Granger-cause changes in ROI, reinforcing the idea that currency fluctuations significantly impact financial outcomes. These results further illustrate the dynamic interplay between macroeconomic factors and project-specific financial decisions, underscoring the need for adaptive financial risk management strategies in mega projects.

# 4. DISCUSSION

The findings of this study offer important insights into the financial dynamics of mega projects, shedding light on the relationships between budget allocation, financial risks, and return on investment (ROI). The role of financial planning and macroeconomic stability has been strongly reaffirmed, emphasizing the necessity of strategic risk management in large-scale infrastructure investments.

The results confirm that budget allocation positively influences ROI, a finding consistent with Flyvbjerg (2003) who highlighted the importance of adequate financial planning in mitigating risks and enhancing project viability. This alignment with prior research suggests that well-structured investment strategies contribute significantly to financial success. However, the study also finds that cost overruns do not necessarily reduce ROI, contradicting traditional assumptions in project finance literature. While previous studies (e.g., Love et al., 2018) emphasized the detrimental effects of cost overruns, the present analysis suggests that controlled additional expenditures may, in some cases, enhance project quality and financial performance. This finding aligns with Boateng et al. (2015), who argued that unexpected cost adjustments, when strategically managed, can lead to improved long-term outcomes.

Another key finding is that exchange rate volatility exerts a significant negative impact on ROI, corroborating the work of Branson (1977), who demonstrated that currency fluctuations introduce uncertainty in project financing. This result reinforces the argument that international infrastructure investments require robust foreign exchange risk management strategies to mitigate potential financial instability (Blanchard & Johnson, 2013). The observed lack of significant effects for completion delays and inflation presents an interesting contrast to previous studies. While Love et al. (2018) emphasized that delays negatively affect financial returns, the present study suggests that their impact may depend on additional factors such as contract structures, penalty mechanisms, and project-specific financial resilience strategies. Similarly, the insignificant effect of inflation on ROI diverges from earlier macroeconomic analyses (e.g., Modigliani & Miller, 1958), suggesting that inflation-related costs may already be factored into long-term investment planning.

The panel Granger causality results provide additional depth to the analysis, demonstrating bidirectional relationships between budget allocation and cost overruns. These findings highlight the dynamic nature of financial decision-making in mega projects, where changes in budget structures directly influence expenditure patterns and vice versa. This aligns with Hansen's (1982) framework on dynamic interactions in financial modeling, emphasizing that financial management in mega projects must account for feedback loops between cost allocation and risk exposure.

The results of this study contribute to the literature by offering empirical evidence on the interdependence between macroeconomic stability, project-specific financial risks, and ROI in mega projects. Unlike previous studies that primarily examined individual risk factors, this research integrates a panel econometric approach to uncover long-term financial risk dynamics. The methodological contribution lies in the application of panel GMM and cointegration analysis, allowing for a more robust examination of financial risks across multiple economic contexts.

From a practical perspective, these findings underscore the importance of proactive risk management strategies for mega project stakeholders, including governments, private investors, and financial institutions. Policies aimed at stabilizing exchange rates and improving budget forecasting accuracy can enhance project sustainability. Additionally, the results suggest that not all cost overruns are detrimental, highlighting the need for flexible financial planning mechanisms that can accommodate necessary expenditures without undermining project feasibility.

Several avenues for future research emerge from these findings. First, sector-specific variations in financial risks should be explored, as mega projects in transportation, energy, and telecommunications may exhibit different risk-return dynamics. Second, the role of technological advancements, such as artificial intelligence and blockchain-based financial tracking systems, in mitigating financial risks warrants further investigation. Third, expanding the geographical scope of analysis to emerging markets and developing economies could provide a more comprehensive understanding of how macroeconomic volatility interacts with financial risks in infrastructure projects. Lastly, the inclusion of social and environmental impact factors in mega project financial models could offer valuable insights for policymakers seeking to align large-scale investments with sustainability goals.

## CONCLUSION

The purpose of this study was to analyze the financial risks associated with mega projects and to evaluate their impact on return on investment (ROI). By integrating macroeconomic factors with project-specific risks, an empirical framework was developed to better understand the financial performance of large-scale investments. A panel data econometric approach was applied to a dataset spanning from 2000 to 2024, covering five economies to ensure a diverse and robust analysis.

The findings indicate that budget allocation plays a crucial role in determining financial outcomes, with well-structured investments leading to higher returns. Surprisingly, cost overruns were found to contribute positively to ROI in certain cases, suggesting that additional expenditures, when strategically managed, can enhance long-term project value. In contrast, exchange rate volatility emerged as a significant risk factor, exerting a negative impact on financial performance and reinforcing the importance of currency risk management in large-scale investments. However, inflation and completion delays did not exhibit statistically significant effects on ROI, implying that their influence may be moderated by external financial and operational factors.

These results highlight the necessity of adaptive financial strategies that account for both internal project risks and external economic fluctuations. The complexity of mega projects requires a dynamic risk assessment approach, where financial planning is continuously refined in response to evolving macro-


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economic conditions. A structured investment framework that incorporates risk mitigation strategies can enhance project resilience and improve overall financial sustainability.

Unlike previous studies that primarily focus on individual risk factors, this research employs a comprehensive panel data analysis to uncover long-term financial risk dynamics in mega projects.

Moving forward, further research could explore sector-specific variations in financial risk dynamics, as different industries may exhibit unique risk-return profiles. Additionally, the integration of emerging financial technologies, such as artificial intelligence and blockchain-based risk assessment tools, could offer innovative solutions for managing investment uncertainties. By expanding the scope of analysis to include developing economies and additional macroeconomic variables, future studies can contribute to a more comprehensive understanding of financial risk management in mega projects.

Ultimately, the insights gained from this study provide valuable guidance for policymakers, investors, and project managers seeking to optimize financial decision-making in capital-intensive investments. A more holistic approach to financial planning, informed by both empirical analysis and strategic foresight, is essential for ensuring the long-term success and sustainability of mega projects.

## AUTHOR CONTRIBUTIONS

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