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Planning in Project Management: Human vs Artificial Intelligence-driven

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ARTICLE INFO	ABSTRACT
Article History Received 07 February 2026 Accepted 28 May 2026 <i>JEL Classifications</i> M11, O22 Keywords: project management, ai-driven, human-centric, project planning.	Purpose: This paper presents a comparative case study on project planning using two distinct approaches: the traditional human-driven method and an AI-assisted method. The study utilizes a publicly shared requirements for a software project, with the scope limited to the planning phase of the project. In the first scenario, the planning was performed by an experienced PMP-Certified Project Manager, with over seven years of practice, applying industry best practices, Project Management Body of Knowledge guidelines and professional judgement to create a structured plan. In the second scenario, the same requirements were processed through an AI-driven approach, using ChatGPT as a conversational tool, with results obtained through multiple prompt iterations. The outputs were analyzed comparatively, focusing on differences in structure, completeness, and adaptability of the proposed plans. A SWOT analysis was then conducted to evaluate strengths, weaknesses, opportunities, and threats of both approaches. Findings suggest that while the human-driven approach offers a context-aware prioritization, tailored approach and comprehensive stakeholder integration, the AI-generated plan demonstrates rapid structuring and access to vast knowledge base. This work highlights the complementary potential of combining human expertise with AI support in project planning and accelerate the process, providing a broader perspective. While AI might lack contextual sensitivity and domain-specific prioritization that experienced project managers provide, the human expertise can ensure adaptability and creativity, but may be limited by personal experience or oversight. The study concludes that future project management practices can benefit from hybrid approaches, where AI augments human decision-making that could lead to successful completion of the projects. Design/methodology/approach: In this article it will be presented a proposed study case that will compare a phase in project management created by two different entities: a human professional in the field and in comparison, an AI generative tool (ChatGPT-5 model). The study case was applied on a random search for a public official requirement, and selected the first result returned when searching after Software Requirements Specification. The proposed protocol for the analysis follows Yin R. (2003) recommendations. Based on the explanation from his book, the study case starts with formulating the research question, then selection criteria of the study case, study case questions, delimitation of the study case, collection of the data and the results of the analysis of the data. Findings: The proposed study case question is: “How it is different the planning done by a human compared with an artificial intelligence, in terms of structure, sequencing, logic, time, completeness of the documents proposed, compared with project management best practices?”. The results differ in output size (10 pages and 17 annexes vs 20 pages), tool utilization (different tool vs no tool), time invested (3 days vs 1 hour), proposed deliverables, context relevance (tailored vs general information) and completeness (attached annexes vs enumerated). The findings were provided considering the same input and comparing the output received from both actors, emphasising the idea that the utilization of a generative AI tool enhance and complements the role of the human project manager. Although the project manager human is constrained to his experience, the help of the AI tool can be effective by leveraging extensive knowledge. Research limitations/implications:

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The sample size is small and includes only one human project manager, who is also one of the co-authors. Future research could involve multiple AI tools and a larger number of project managers working with the same requirements, allowing comparison across professionals. In addition, future studies could incorporate external expert reviews to validate plans generated by the human professional. Another proposal to extend this study could also be expanded to include multiple project documents rather than a single case. It can be considered as another limitation that the planning activity was created by a project manager and not by multiple participants with different roles. In companies, the planning typically involves contributions from various roles, such as business analysts for requirement breakdown or development teams for effort estimation. Further limitation concerns are related to the quality of the plan generated by the AI that depends heavily on the prompts provided. Since prompting skills vary with the user's experience, the outputs may differ across individuals. Considering the experience of the person that introduces the prompting, the quality of the result can be different.

Originality/value:

The planification phase can be the most time-consuming and needs extensive project management knowledge. At the same time, there is growing discussion nowadays about AI and its impact on the workplace of project management field. In this study the aim was to search for empirical evidence on whether artificial intelligence can truly replicate expert human reasoning in project management planning. The results were presented between the two actors using narrative analysis, comparative analysis, benchmark analysis and SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis, considering the PMBOK guide as a framework. There were also presented responses to the proposed questions. This case study would likely present different results in six months or in one to two years and it will be interesting to document how the impact of AI is evolving and it is integrated into real life projects.

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1. Introduction

Nowadays, planning a software development project as a project manager, can be approached in the traditional way, incorporating agile, using Artificial Intelligence (AI) tools, or a mixture of methods. Using traditional method usually means that a professional project manager reviews the specifications, split them into milestones employing a work breakdown structure and prepare the big picture for the requirements, typically together with a business analyst. A timed box meeting with the development team is scheduled, where the requirements are analysed and each item is estimated. It is not mandatory that the team involved in the estimation process is the one that will do the actual implementation of the project. Commonly, for a more accurate assessment, the team that perform the evaluation should be formed by both senior and junior software developers. In this meeting, it is also covered the discussion regarding the dependency, in order to identify which item will be blocked by another product backlog entry. Typically, the people involved are splitting the requirements into details and discuss the steps that should be done to accomplish specific functionalities. They estimate based on their experience with the past similar projects. After this meeting, the project manager can create a planification, allocate resources and propose the Gant chart.

This entire process takes time, and the quality of deliverables depends, to a large extend, on the project manager expertise. With the technical advancements, project managers, can use artificial intelligence tools to increase the quality of the planification, to better have a view on the Work Breakdown Structure (WBS) and to accomplish it in a shorter time.

2. Background and related work

According to Rita Mulcahy (2020) project management is a methodical approach to manage the work that needs to be accomplish in order to successfully obtain the proposed goal and to do it in an organized manner.

Over time, there were different ways of working that project managers adopted, including traditional, iterative, adaptive, or a hybrid approaches, according to PMBOK (2017), and nowadays integrated with artificial intelligence. While waterfall is referring to going from a phase to another only after finalizing the previous one and the requirements are well defined in advance (Layton et al., 2020), agile propose a shift in mindset and based on a manifesto created in 2001, the delivery is adaptive and is focusing on providing value and a functional product, accepting changes and clarifications even late in development (Perkin, 2020).

Because the methodology chosen is very important for the success of the project, it is also highlighted in the literature, as there are numerous studies that examine the project management approaches and studies about which approaches work best and are recommended. For instance, Maier and Emmerich (2022) conducted their analysis and conclude that agile methodology helps save time. However, it is mentioned that practitioners in domain should train

with both traditional and adaptive methods and be able to use a hybrid of the two. Moreover, Mishra and Ganesh (2026) compared the same two methods and based on a survey of 100 developers found that agile methodology has less delays in the schedule and a lower cost. In addition, more in-depth, Ly et al. (2025) studied the differences in written communication, with the findings suggesting that agile teams present more collaborative exchanges using unofficial channels. Other study highlights the benefits of transition from waterfall and agile, showing better bug trends, more frequent releases and an increase in automation (Natarajan & Shanmugavadivu, 2024). Another study conducted by Leong et al. (2023) analysed the advantages and disadvantages of combining agile and traditional methodologies, while Mishra and Alzoubi (2023) ending with the idea that there is no methodology that can best fit for all type of projects.

In the latest years, it appeared a growing numbers of studies focused on project management and artificial intelligence. For instance, a search in Web of Science database by “project management” and “artificial intelligence” in topics, filtering by open-access articles in English, shows an increase in the numbers of published articles (in 2025, more than twice as many as in 2024), which highlight the interest in exploring the way how these two fields interact and can create a positive impact.

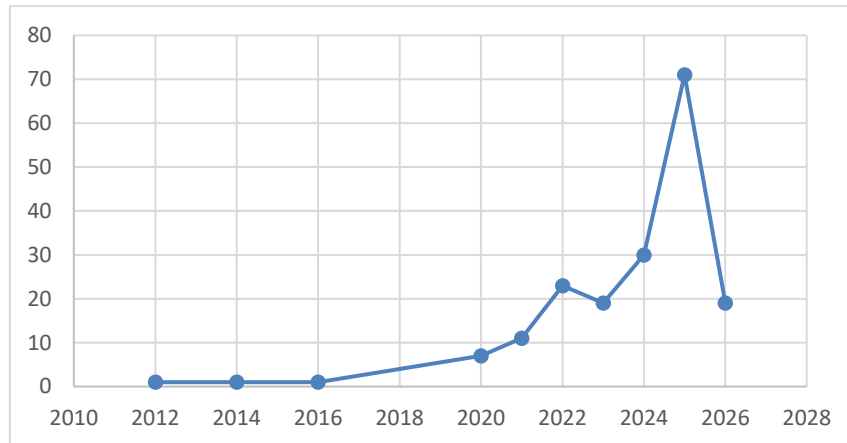


Figure 1: Distribution of articles published by year
(Source: Web of Science)

Some authors studied the impact of artificial intelligence, for instance specific related to costs, risk and scheduling (Fridgeirsson et al. 2023), others discussed about the job’s transformation for practitioners (Mariani & Mancini, 2025) and also the analysis of the gap between junior and senior that can be covered with AI gen tool (Hettrich et al , 2025). Furthermore into the future, Hughes et al. (2025) proposed in their study a framework regarding the ethics and a model for AI adoption for a structured transition to the year 2030. Using specific selected experts from academia and industry, the authors proposed the models based on challenges and possible solution.

Considering the increased interest in using artificial intelligence in management of projects, in the following sections is presented the study case that dive into this topic in more depth and compare how the project planning is done by a generative AI and, and by a human professional in the field.

3. Study case and methodology

In this article it will be presented a proposed study case that will compare a phase in project management (planning phase) created by two different entities: a human professional in the field and in comparison, an AI generative tool (ChatGPT-5 model). Using a qualitative methodology, the analysis is performed on the same set of requirements by both actors involved.

This study specifically aims to identify the main differences between a planification done by a person with more than 7 years’ experience in the project management field and one done automatically by a generative artificial intelligence tool. To narrow the scope, the coverage is only for the planification phase, which is the step that comes after the initiation of the project, and before the execution. The aim is to compare how planning looks like when it is performed in a traditional way and how it looks like when it is done by the machines.

The project was selected random based on initial accessibility and relevance. It was identified through a Google search, after Software Requirements Specifications, where the first result led to an official requirement document. Additional related documents were then collected from official sources, including the Ministry of Finance website and Electronic Public Procurement System (SEAP) platform, to ensure consistency and completeness of information. Regarding project size, it can be considered medium to large in scale, with the value established at 344,448 EURO (1722240 without TVA considering 1 EURO= 5 RON) and an estimated completion time of 18 months. This was a real project where the participation announce was published in April 2022 and the attribution decision was made in January 2024, according to the data available in the SEAP (Electronic Public Procurement System) announcements (SEAP, 2024). Furthermore, on this site was presented amongst the selection criteria, the experience of the project manager that was valuing 5% and the proposed methodology and documentation accounted for 25%, representing in total 30% reference to the value on the project manager’s contribution.

The project involves the development of a software system, more specific, for redesigning, improving and migration of current system already in place. It is a software project in the public sector with a moderate complexity considering involvement of multiple institutional stakeholders and compliance with specific requirements, regarding availability and security. The project was chosen because it was easy to access, public, related to software development and relevant to real-world situations, since it was requested to an existing company and with all the information that come from official sources.

In the presented case study, the recommendations proposed by Yin R. (2003) contain the objectives, field procedures, questions and the report. Following the explanation from his book, this analysis starts with formulating the research question: How it is different the planning done by a human compared with an artificial intelligence, in terms of structure, sequencing, logic, time, completeness of the documents proposed, compared with project management best practices?

Withing this research, the approach was to take a formal public requirement for a software development project and act as a project manager to create the planning part. This was accomplished using two approaches, meaning the human and the artificial ways. This perspectives intends to respond to the research question and as suggested by Yin R. (2003) is a contemporary phenomenon as the release of the artificial intelligence tool (ChatGPT-5 model) was done in November 2022 to the wide public (Marr, 2023) and according to Gartner 80% of the work of the project managers will be replaced by artificial intelligence (Gartner, 2019).

Following Yin R (2003) recommendations, this article follows a set of guiding questions to be addressed. For this specific comparative study, the following four questions were proposed:

1. How is the overall structure of the two proposals?
2. What level of details are proposed by the two parts?
3. Do both actors propose the same documents and deliverables?
4. Does any of the actors have wrong or incomplete information?

This study is limited to a comparative study between two actors: a human professional in the field and artificial intelligence chat tool for an official requirement of a software development project.

Following Yin's protocol, the collection of the data are represented by the open-access documents from the existing requirements, the documentation provided by the project manager professional in the field with over 7 years of experience, and a document provided by prompting with ChatGPT as an artificial intelligence model, based on the same tender. Both documents have identical input conditions, to ensure a better comparability. In both cases, were used the PMBOK (Project Management Body of Knowledge) sixth edition, as benchmark for best practices. The data is shared in this study case in a systematic way and contain documents provided by both human and generated by artificial intelligence, narrative analysis, comparative analysis, benchmark analysis and SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis.

The plan for creating the database is to follow the next steps in this specific order:

1. The human-based approach based on the public tender requirements and documentation of all outputs
2. The prompting with an artificial intelligence tool (chat GPT) and saving the results obtained
3. Narrative analysis conducted based on the two results
4. Comparative analysis performed and gathered in a table for a better overview
5. Benchmark analysis carried out following the best practices provided by the PMBOK
6. SWOT analysis with result shared in a comparative tool

In the analysis of the data within this study case, following Yin's approach, the results are presented, compared and explained where needed. The data is categorized, and each proposal, along with its corresponding outcome, is compared against the PMBOK framework to ensure alignment with established project management standards.

The discussion section presents a synthesis of the findings along with their practical and theoretical implications. In the next imagine, (Figure 2) is presented a visualization of the protocol considering adaptation of Yin, R., K., (2003) books and Moss S. adaptation that was edited in Miro tool.

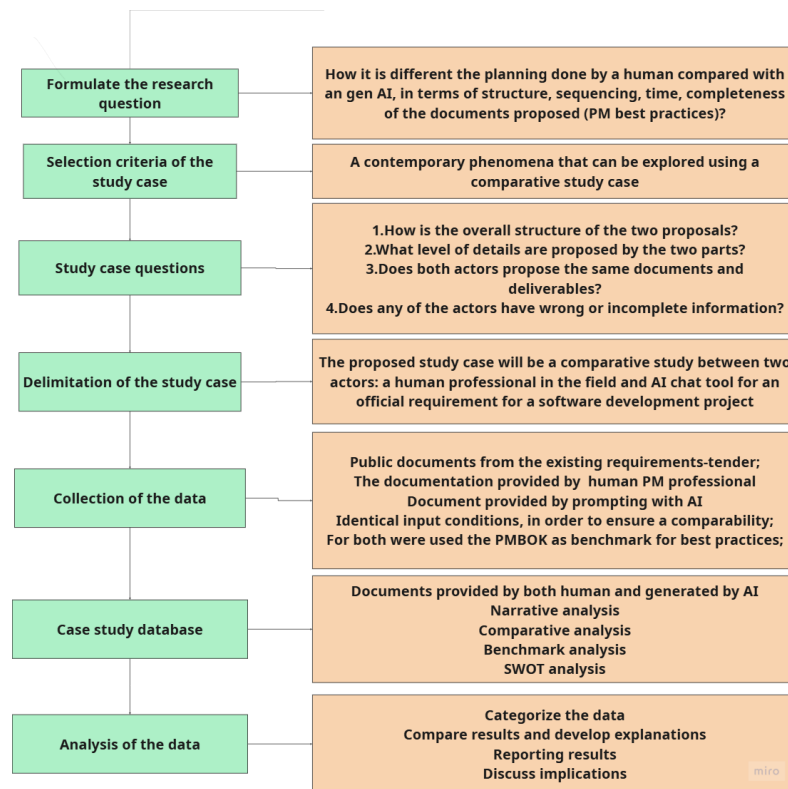


Figure 2: Visualization of the protocol
(Source: Yin, R., K., 2003 book and Moss S. adaptation)

The human approach implies the traditional way of doing the planification for a project, respecting the international standards, specifically following the international guidelines recommended in Project Management Body of Knowledge sixth edition. With a knowledge of over 7 years of experience in project management field, the project manager took the public requirement of the chosen study case and created the plan based on the experience and classical methodology.

The second part of this study consist in the use of an artificial intelligence tool, one of the most popular tools, according to Westfall (2023) from Forbes, chatGPT. The plan was developed by entering a prompt in the chat, that instructed the AI tool to act as a project manager, outline the requirements, and do the planification, same as the human project manager did, enabling a comparison of the results.

In order to evaluate the results of both planification provided by the human and the AI, it was applied a proposed framework based on project planning principles described in PMBOK guide (sixth edition) and Rita Mulchly's work. The evaluation criteria are structured according to the PMBOK knowledge areas. The list of criteria proposed in this framework for evaluation are as follows:

- Scope: level of planning, working methodology, completeness of the list of activities and deliverables, assumptions, constraints, exclusions, acceptance criteria and also the clarity of the breakdown for the proposed tasks in the project
- Schedule: the logical sequencing of activities and the Gantt chart level of detail
- Resources: resource requirements proposals, definition of roles and responsibilities and the breakdown structure
- Risks: identifications and analysis
- Quality: alignment with the proposed standard
- Stakeholders: identification and analysis
- Communication: plan structure and clarity
- Cost: budget details
- Integration: overall level of the integration that was mentioned by the two sided
- Procurement: plan for the procurement, if needed

This framework was applied to both human and artificial intelligence (GenAI) approach and a proposed score was mentioned based on the level of explanation presented by each side, considering the structure and completeness of the task. A scale from 1 to 5 was used for these criteria and are presented in the results section. The lower scale is 1, meaning that it was not addressed or very poorly addressed, then 2 means that it was presented in the proposal, but limited, 3 means that it was detailed but not structured or detailed and 4 means that it was very detailed and presented in a structured manner. The highest point in the scale 5, is meant for the most detailed and complete detail presented.

The scope is to compare both results and see what strengths and weakness has each approach and what can be done to improve for the future project managers.

3.1 Study case phase 1: Human approach

According to Rita Mulcahy (2020) description in her book at processes and domains, there are five phases that a professional project manager needs to go through to complete a project. It starts with initiating phase, continue with the planning process, which has a set order of 25 actions to follow, then it continues with the execution of the project monitoring and controlling, and in the end the closing part of the project. The actions described for the planning part, starts with the decision of the approach considering the development and life cycle of the project, the defining of the requirements, developing the schedule, budget, communication engagement, risk plan and conclude with obtaining the final approval for the planned project. The planning components that were split into smaller backlog items, can be incorporated in a management tool, such as Jira for instance. In the next image (Figure 3.) are illustrated the steps proposed and description for each of them.

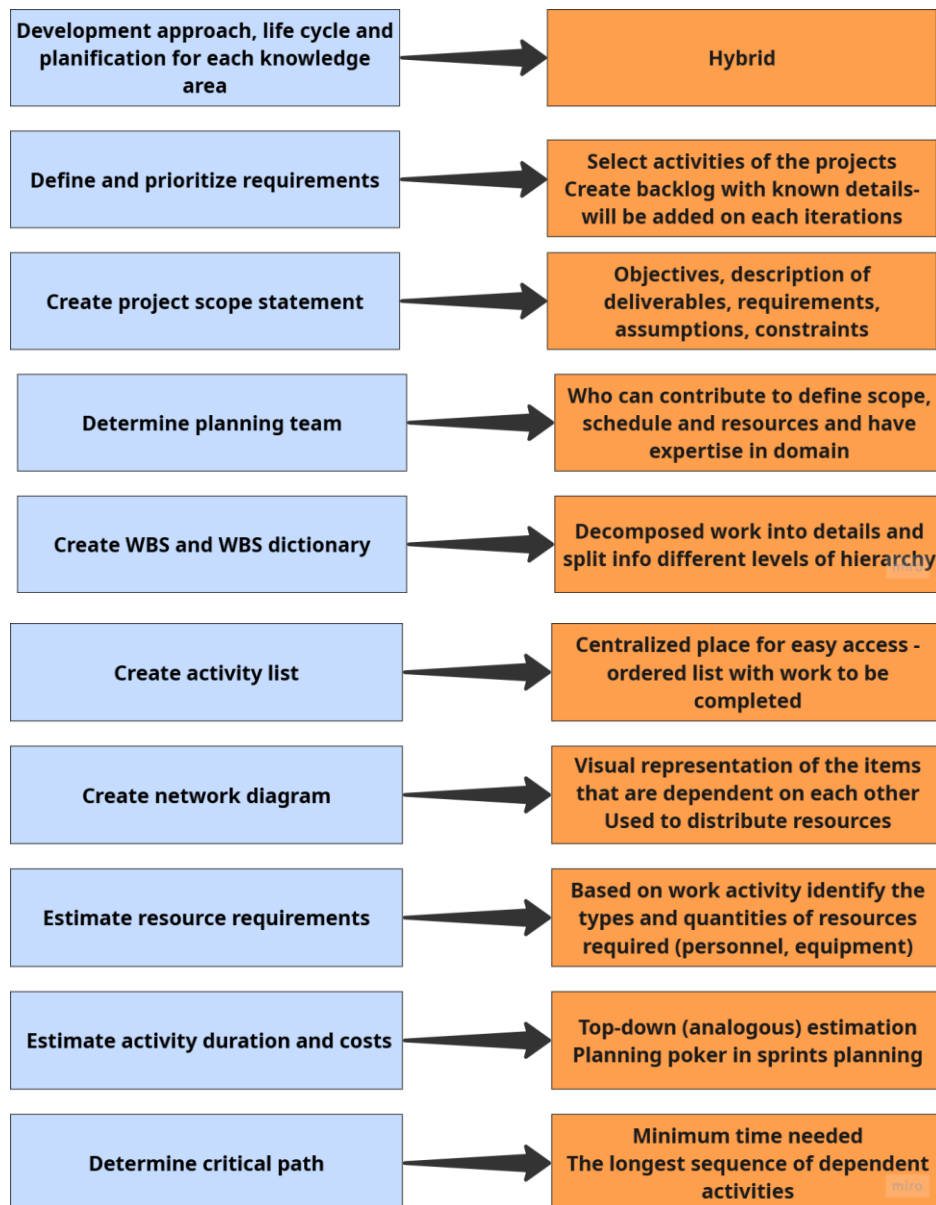




Figure 3: Planning steps adapted for this study case proposed by the human project manager
(Source: Rita Mulcahy, 2020)

Backlog requirements

In this phase of the planning process, project manager centralizes written requirements. These were completed according to the initial request available online.

In the subsequent steps of the traditional execution of the planification for the proposed project, the actions described by Rita Mulcahy (2020) in her book were followed.

Establish the approach: hybrid

A project can be approached using different methodologies: waterfall, agile, or hybrid, as mentioned by project management institute in the PMJ Practitioner Insights (2022). Typically, it depends on each company and on their rules and procedure, however the project manager will decide or will be involved in the decision process for determining the approach of the project.

In this study case, because in the public requirement there is a contract with fix budget, limited in time, and containing multiples objectives requested, the waterfall model alone could be used. Nevertheless, a hybrid approach is proposed, that include both waterfall and agile, because in the Software Requirements Specification was not outline a fix scope, however, was mentioned several times that new requirement which could be discovered during the execution phase must be accommodated, such as changes in the legislations or clarifications during the development that were not specified in detail at the beginning.

With the proposed framework, there will be a fix timeline, a fix budget, and development will be performed in iterations. Moreover, using the agile mindset, the development team will work together with the business and will show regularly the work that was implemented in the previous iteration, in order to receive feedback or confirmation that it is working as expected. Following this approach, the team can be able to accommodate all corner cases that were not included in the initial requirement document.

The proposed phases of the projects will be analysis, design, document proposal, present proposal, approve proposal, update proposal, implementation, migration, optimization, test and adjustment, which are related to the waterfall approach. The development part, migration, optimization, test and adjustment will be done in iterations, which are related to the agile approach. In the next imagine (Figure 4) are illustrated the stages proposed by the human project manager for this project considering the hybrid approach.

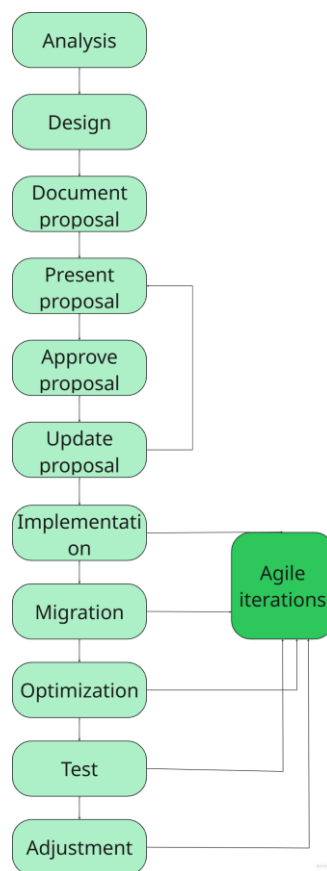


Figure 4: Adapted stages proposed for this study case
(Source: adapted from Microsoft, What is the software development life cycle?)

Considering the details related to the contract, with a fix time and a clear objective, the project manager will plan, monitor and control the project, according to the approved plan. Since a hybrid method was chosen, the proposal of the human approach is that at the beginning, to have a high view of the planification and as progressing in time, when it is known more about detail to elaborate and update the plan, as the team meets regularly with the business side and check to validate that it is within the scope.

Ordering for required activities

The next step done for the planification of this study case is to define requirements and to make a prioritization in a logical way in order to accomplishing the actions. The professional project manager detailed all activities of the project that need to be completed and included, not only items related to development of the code, but also activities expected to be done by other actors involved. Usually, the backlog that contain all requirements is updated and completed after the analysis phase of the project. At the same time, the chosen approach in our study was the hybrid one, that also assume not all details are known upfront and are expected to be explained as the project advance, in iterations. In addition, part of the documentation of the initial requirement list prioritized, is the assumption log, that contains hypothesis proposed for unpredictable elements.

In the analysis phase, the proposed plan will be to obtain information and collect all details for the implementation, using different methods, such as interviews, observation, facilitation and mind maps, following the PMBOK guidelines. To be sure that all use cases are covered, and considering the hybrid methodology chosen, there will be clarifications discussed that will use the same approaches (interviews, facilitations and mind map). At the same time, these new details in requirements, or possible new addition, will be checked and confirmed by the project manager, if they are within the scope. If yes, then the project manager will also check the impact in time, cost, resource and risks.

The project prioritization plan will first focus to do the update and migration phases, to check and ensure that all system functionalities are working flowless. The next action will involve the implementation of the new requirements module, followed by optimization and automation, while also ensuring security and confidentiality. Additionally, the plan includes provisions for disaster recovery procedures and ongoing maintenance. The proposed idea for prioritization is to have first what we call an MVP (minimum viable product) which in this case is to work with the new update and old functionalities, and then to add new functionalities and improvements.

According to Scrum Guide, the backlog is an ordered list of what needs to be implemented for a specific product or project. All these requirements and all actions performed by the development team will be documented in a dedicated tool where they can be tracked and monitored (such as a shared excel or Jira tool). In this way, all the stakeholders can visualize at any time, the entire backlog with requirements, their order of the implementation and their status. Each item will be added in the product backlog by the business analyst only after it was analysed and confirmed that it is in scope. Every element added in the centralized system, is proposed to have a standard shape, in the format of a user story. The Agile Alliance points out that a frequently suggested format, is the "As a... I want to... So that..." template. This approach is widely used to help teams and product owners when they are first learning to work with user stories and product backlog items. All product backlog items are proposed to have detailed requirements, acceptance criteria and use cases for tests. Following this way, the business analyst has a clear understanding on exactly what it will be implemented and what falls in scope of each item, which then will be confirmed with the beneficiary. At the same time, the developer will gain a clear view of the impact, use cases covered, and acceptance criteria, while the tester will have all use cases needed to be confirmed for validation. For this study case, the human project manager used for the project backlog item the standard format and acceptance criteria.

According to Marone (2000), there can be used a control tool, requirement traceability matrix, so that all the items that are developed to relate to the beneficiary request. In this way, there is a higher chance of acceptance from the client side, and it is also improving the overall quality while will help the tester during the check and validation phase.

For this study case, the PMI (Project Management Institute) template was used by the human project manager to create the requirement traceability matrix, published by Nyantakyi T. The purpose of these actions is to confirm that the scope is well detailed and explicitly write what items are needed to be implemented so that all deliverables are created and the project is considered completed.

Project scope statement

According to Mulcahy (2020), project scope refers to the set of tasks and activities the team undertakes to produce the project's deliverable. Also, according to PMBOK Guide sixth edition (2017), Institute Project management (2020) and Mulcahy (2020), it is important in the planification phase for the project manager to define correctly and completely the scope of the project. In this action is included the creation of the project scope statement, so that it can be used as a guide during the project. The elements added in this document, include the objectives, description of the deliverables, requirements, assumptions and constraints, as described by Institute Project Management (2022).

In this study case, for the creation of project scope statement, was used the example defined by the Institute Project Management (2022) to ensure the team remains focused on the project's objectives and to align the stakeholders.

Project managers also use project roadmap order to have a better visual overview of the progress indicators. According to Atlassian, the roadmap is a strategic tool that can be used to understand high level activities and to have a fast and clear view over the current status comparing to the goals.

This study case has a unique project scope that is tailored based on the specifications and needs described.

Work Breakdown Structure of the project work

According to Berg and Colenso (2000), the project manager should decompose the work into details and split into different levels and hierarchy for a better understanding and managing of the project. As indicated also PMBOK Guide sixth edition, the Work Breakdown Structure (WBS) contains the major elements that need to be implemented in a hierarchical display. This is a tool that was initiated in 1998 according to Berg and Colenso (2000) and has the purpose to be a visual organization of the scope that needs to be accomplished in the project.

According to Mulcahy (2020) the WBS is an essential instrument for the project managers in which the deliverables are identified without dependencies between activities. Together with the WBS diagram, there is also the dictionary, where is the description of the work associated with each element so that it can serve as clarifications for stakeholders.

In this study case, it was created an initial WBS, based on the requirements received and the next step would be for the WBS to be updated after the analysis phases, when different clarifications will be agreed on. As a template for the WBS was used the ones provided by Miro tool.

Prioritized activity list

All activities described in the requirements and composed in the WBS are kept in a centralized place so that both the stakeholders and the development team can have access easily. The project backlog, as described also by Gaona-

Cuevas et al. (2024) is an ordered list with all items needed to complete the request. In this way, the team is working all the time at the most important items that need to be implemented next.

According to Mulcahy (2020), defining and ordering activities means breaking down the WBS into the individual tasks required to achieve the deliverables of each work package. In this specific use case, there are some unknown details that are aimed to be discovered during the analysis phases and some that might appear during the development. To cover unforeseen items that can appear in the project, project manager can plan to use rolling wave planning. According to Microsoft (2024), this tool means to be able to adjust and refine while the work is done and it can be split into two waves: initial planning and as project evolve the more detailed plan.

Network diagram

For a better planification, according to Mulcahy (2020), project managers can create network diagrams in order to see the sequence of the items that needs to be implemented and the relation between activities. According to Sangkon and Shvetsova (2019) using this diagram, a project manager can have a visual representation of the items that are dependent on each other. Based on the network diagram, the project manager can determine which task needs to be accomplished first, in order for another to begin, and also is able to identify other constraints. The network diagram is used to determine the critical path, predict potential bottlenecks according to Mulcahy (2020). It can be used to distribute the resources effectively and better plan the overload. In this study case, the network diagram and critical path were not created, since it required more details than the ones provided in the specifications and could be discovered later, in the analysis phase.

Activities and resources estimate

In this study case, the budget is already publicly available and the company that implements the software is accepting it. Nevertheless, the project manager will do the estimation of the activities together with the development team, so that the project can be split into smaller items, to display it into a timeline and be able to allocate resources. As a best practice, Rita (2020) recommends in her book for a more realistic estimation, not only the list of items to be implemented, but also the assumption log, resources profile and availability and risk registry. In the current study case, the approached established in the plan for the estimation is the top-down type and as the project advance and the agile methodology will be executed, from sprint to sprint, the planning poker could be used.

According to Heldman et al (2018) the top-down technique, is also called analogous estimating and it uses actual costs of a similar activity completed on a different previous project to determine the cost estimate of the current activity. This will be used at the beginning, since not all the details are known before the analyse phase. At the same time, this is a lower technique in accuracy compared to alternative methods.

As the project progress under agile methodology, the team is planned to meet at a regular basis to estimate the items from the backlog. In order for the work to be better planned and accurate, the team will use the estimation poker techniques. Layton et al. (2020) describe this tool as a collaboratively game designed to size each item and build consensus among development team members. Each participant selects a card to represent their estimate for a given item, and the results are then discussed until the team reaches an agreement on the final estimate.

Critical path

Creating a project schedule requires information from past similar projects, including lessons learned, along with key elements of the project management plan as Mulcahy (2020) emphasis in her book. These elements consist in the list of defined activities, project milestones, documented assumptions, the activity network diagram, estimation data, activity duration forecasts, and resources needed. Additional inputs include the resource calendar, the resource breakdown structure, the organizational calendar of working and non-working days, records of resources already allocated by management or agreement, and the risk register.

As described by Abdel-Basset et al. (2022), the critical path constitutes the longest chain of dependent items in the network. It establishes the minimum completion timeframe required to deliver the project, even if though finalization may take longer if delays occur, the critical path represents the fastest possible route. This tool helps the project managers to maintain control and manage deadlines, by focusing on the critical items to be implemented.

In this study case, the critical path was out of scope because more details that should be discovered in the analysis phase were needed.

Project schedule

In the planning phase, the project manager is creating a version of the schedule with start and end date and resource assignments, as also described by Heldman et al. (2018) in their book. In this case study, the human project manager selected the Gantt chart to present the project schedule. This visual tool allows the project manager to view activity sequences and durations alongside the assigned resources.

According to Moylan (2002), the project schedule serves as a roadmap of planned activities, integrating scope requirements with work packages. It functions as both a guide for the project journey and a reference point for measuring progress, enabling the team to track achievements and management to assess performance. The schedule acts as a milestone indicator and a benchmark, and it is providing the structure for organizing project outcomes.

Cost management plan

According to Georgas and Vallance (1987), cost management is a function applied by project managers that integrates the processes required to maintain financial control of a project. It typically includes activities such as evaluation, estimation, budgeting, monitoring, analysis, forecasting, and the reporting of cost information. According to PMBOK Guide sixth edition, the cost management plan includes historical information, existing cost estimating guidelines, and different financial controls procedures.

In this study case, the budget is defined from the beginning, and the project manager is responsible to keep it under control. For a better oversight, the project manager can break down the budget into activities and phases. In

this specific analysis, the main costs included are related to the team involved in the project directly. This can be calculated by having a rate per persons and the estimation for each activity. Overheads are also included in the rates.

Quality standards, process, and metrics

According to PMBOK, the quality management outlines the activities and resources needed for the team to fulfil the project's defined quality objectives. Pribadi et al. (2020) describe quality as the extent to which inherent characteristics satisfy requirements, while project quality refers to the process of achieving business objectives as outlined in the project charter. As Mulcahy (2020) describe in her book, quality is the degree to which requirements are fulfilled, nothing less, nothing more. The requirements are planned to be described in this use case, as user stories and acceptance criteria for each item, to ensure the quality of each functionality developed.

The PMBOK Guide sixth edition defines a quality metric as a specific description of a project attribute that will confirm its compliance. Examples of such metrics include the percentage of tasks completed on schedule, defect rates, the number of errors detected daily, total monthly downtime, errors per line of code, customer satisfaction ratings, and the percentage of requirements addressed by the test plan as an indicator of test coverage. Specific for this study case, there are some quality measures requested to be fulfilled specifically, such as services available 24x7x365.

Roles and responsibilities

The PMBOK identifies the RACI (Responsible, Accountable, Consulted, Informed) chart as a widely used assignment matrix that categorizes stakeholder involvement in project activities by labelling them. As a form of responsibility assignment matrix, RACI is described as being a list with all stakeholders known and roles assigned to each of them.

According to Miranda et al. (2025) this type of chart is popularly used in project management, and it helps with the communication flow across the participants. The project manager designates the personnel responsible for each activity, and this document allows all participants to review their roles and responsibilities, ensuring transparency, preventing misunderstandings, managing expectations, and confirming that every task is assigned to the appropriate person, who understands what is required of them.

As outlines by Mulchay (2020), the project manager designates the individuals and stakeholders responsible for providing updates and reports, determines reporting lines, assigns participation in meetings, and identifies who will support risk management, collaborate with the quality department, and contribute to other project activities.

The resource breakdown structure (RBS) is a valuable tool that can be used by the project managers as a list of the resources allocated with their costs and recommended to be used in organizations as detailed by Rad and Cioffi (2004). Atlassian emphasis on the fact that resource breakdown structure demonstrates how the tool evolves throughout each phase of its life cycle, capturing changes in resource availability, project scope, and organizational priorities. In this study case, the resource breakdown structure, was made following the model proposed by Bika (2024) where can be seen the visual representation of the members categorized.

Communication and stakeholder plan

Ganis and Waszkiewicz (2018) highlight that projects rely heavily on communication because of the high level of interdisciplinarity within teams and the possible different location of their members. Choosing the right tool that can be used by the team will help improving the success rate of the project.

According to Minois (2023) there are different categories in this field, including stakeholder engagement and team collaboration. There is also a formula provided by the PMBOK Guide and described also by Rajkumar (2010) which refers to the range of possible communications routes. This calculation is presented as $n(n-1)/2$, with n used to signify the numbers of individuals on the team. As an example, for five people in a team, there will be calculated ten possible channels for communication. This means that the project manager will make sure that every team member involved will be informed and aligned with the requirements, status and details of the project.

To ensure that everyone involved in the project receives clear and consistent information, provided just in time and align with the objective of the project, a communication plan is recommended as a tool for the project manager, as detailed by Atlassian. In this study case, the communication plan was designed considering the proposed way of working, meaning hybrid. In the agile section of the methodology used, the team will meet on the daily basis to align on the project, in the daily meeting. Because the team is proposed in the plan to use a two-week sprint, there will also be a bi-monthly meetings, as described in scrum guide, such as planning meeting, review meeting and retrospective. At the same time, the project manager will meet weekly with the project manager from the beneficiary side to discuss on status and progress, as requested in the initial documents of the project.

According to PMBOK all stakeholders impacted by the project should be identified and their expectation, interest, level of influence and level of authority should be established to be effectively managed and engaged throughout the project lifecycle. According to Mulcahy (2020), the project manager should plan for stakeholders to be engaged, and define a communication approach, manage their expectations and continuously monitor both communication and stakeholder engagement.

According to Miller and Oliver (2015) the project manager should engage stakeholder in a consistent and organized manner. A stakeholder management plan is recommended. In this study case, the human project manager created the stakeholder management plan following the template provided by Snyder (2013) from project management institute. In the plan are detailed all the people identifies and their current level of engagement.

In addition, there can be a gap caused by unclear feedback, also known as gulf of evaluation. As described by Project Management Research Institute, this describes the disconnect between the actual state of a system and the user perception. If there is a mismatch and it is not checked and confirmed for a longer period, it could lead to rework, additional costs and negative impact on the entire project.

PMI is also recommending the use of the stakeholder engagement assessment matrix. As Vogwell (2003) describes, the project manager should do a classification for all stakeholders according to their interest and impact that they can have on the project. In this study case, the professional project manager detailed all stakeholders identified and categorised them in a matrix from low to high power and interest.

Risk management

According to Mulcahy (2020), there are risk factors when trying to determine the likelihood of a risk event happening, the potential consequences or scale of impact, the point in the project life cycle when it might occur, and how frequently such an event could arise from that source. This means the analysis of the probability, magnitude, timing and frequency. PMBOK edition sixth outlines the steps project managers should follow in order to manage risks that may arise during a project. Pym (1987) argues that when it comes to risks, one can never be too prepared. In his article, a project manager should identify the risk, create a response system, made an analysis of the impact and a plan for response.

According to Mulcahy (2020) the project manager can use different tools to identify risks that might arise in the project, for instance data gathering and data analysis. In these categories, can be included brainstorming, conducting interviews, reviewing documentation, performing root cause analysis, examining assumptions and constraints, SWOT analysis, and utilizing checklists for analysis.

In the PMBOK, the risk register is detailed as a document prepared at project beginning and continuously updated during execution. In this study case, the human project manager created the project risk register, following the template format provided by Masood, provided by PMI. In the matrix there are outlined the entire list of risks identified, date, the details and consequences, what can trigger it, who is the owner of it, an assessment, and response details.

According to Mulcahy (2020), a project manager should perform a qualitative and quantitative risk analysis in order to have a clear view of the probability, impact, and to determine the overall project risk exposure. There are also described different strategies to respond to risks, such as avoid, mitigate or transfer.

Formal approval and kick off

Depending on the company and its internal policies, the management plan may need to be a formal document approved by senior management, or in some cases, it might even require official client approval. In this study case, the plan proposed by the project manager is set to be presented and approved by the beneficiary.

The following step involves the project manager initiating the plan's execution with the assigned team. One of the suggestions of Mulcahy (2020) book is to do the kick off meeting with all the stakeholders involved in order to set up the expectation and to obtain commitment.

Next steps

In this study case, the project management integrate all the proposed documents and can start the execution. As also recommended by the PMBOK, all these documents should be iterated and updated later in the project, as project evolve and more details are known and could have different impact. This may involve adding new items to the product backlog, updating the stakeholder list or identifying additional risks.

3.2 Study case phase 2: Artificial intelligence approach

The tool used for this second approach, AI-driven is ChatGPT Plus (OpenAI), utilizing a GPT-5 model available at the time of the analysis. The initial prompt given was the following: "Act as a professional project manager with over 7 years of experience in project management for software development. The project manager has won a new project and attached are the official specifications document, which contains the detailed requirements. Develop the complete planification of this project in details. Structure everything in a professional, clear, and well-organized document that can be presented directly to the client. Write the response in English".

The initial response was to present a big picture plan, aligned with international best practices, such as PMBOK and Prince2. The response starts with an executive summary, objectives, general and specific, scope and deliverables, a description of the project organization and a WBS and schedule proposed. It was also mentioned the risk and quality management, communication and reporting, logistic and reporting and acceptance and closure.

In the Figure 5 can be visualized the steps proposed by the generative artificial intelligence created in Miro tool.



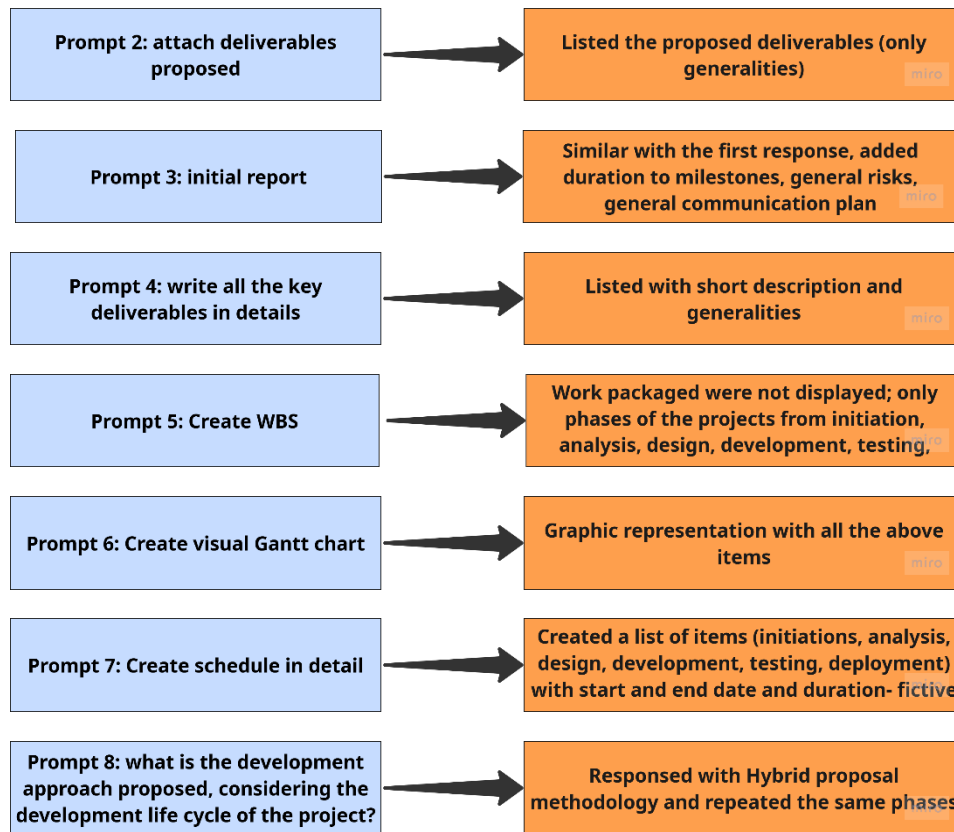


Figure 5: Planning steps proposed by ChatGPT
(Source: ChatGPT)

As it can be seen in the figure above, the prompt continued with the second iteration, where it was proposed to “Attach all deliverables proposed”. The response was a list of deliverables mentioned for each phase considered, starting with the initiation, continuing with the analysis and closing with maintenance, change request and project closure, as a response from the AI tools side. The third iteration input was to “Write the initial report” and the response displayed was an overview of the scope, details about governance and organization, a high-level Work Breakdown Structure description, details regarding phases and milestones with duration proposed, an initial version for the risk register, short details regarding quality assurance, communication, next steps and approval. On the fourth iteration, the prompt added was to “write all these key deliverable in details”, that were referring to the deliverables mentioned by Gen AI tool in the previous prompt. For each line it was received high-level input. The fifth iteration was to “create the WBS”, but the response was split in phases, such as initiation, analysis, design and closure, similar with the previous responses already given. At the end of this response of the fifth iteration, the AI asked if it is needed a visual Gantt chart. The sixth iteration was with the response “yes” and then ChatGPT presented the visualization of the proposed Gantt chart.

Furthermore, the seventh iteration was with the following instruction “create the schedule in detail” and a document split in tasks and grouped by phases, with proposed start date, end date and durations was displayed. The last iteration, the eighth one, was “what is the development approach proposed, considering the development life cycle of the project?” and it responded with details regarding split on proposed phases, but also the hybrid proposal.

The entire conversation with the questions asked and the responses received from ChatGPT is available in appendices.

4. Results

The result suggests two project planning proposals considering identical input conditions. The plan created by the human project manager relies on contextual understanding, industry practices, and various tools like Jira, Miro, and Atlassian templates. The proposed plan reflects practical experience, iterative reasoning and methodological justifications.

The AI-generated plan follows a structure based on PRINCE2 and PMBOK terms (version not mentioned). The results received are different in size, while the AI produced 20 pages, the human project manager approach had 10 pages and 17 Annexes. The human plan covers PMBOK areas and details for the planning processed, as described by Mulcahy (2020), whereas the AI plan addresses them conceptually but lacks documentation details specific for the requirements received.

Below in Table 1, is summarised the comparison between the two approaches, using the following proposed criteria. The AI generated plan is fast, however it can be at risk to provide insufficient information and not tailored on

the project. The human plan is more time consuming, however it has a higher fidelity to industry standards and domain specific of the requirements provided.

Table 1: Comparison between the two approached based on proposed criteria

Criteria	Human Approach	AI approach	Comments
Time spent to produce the plan	3 working days	1 hour (considering the checking, reading responses)	Artificial intelligence gives an almost instant response; however, it requires human supervision and input and knowledge to observe the wrong information received
Proposed documents and deliverables	17 annexes part of the planning and 39 deliverables mentioned	19 mentioned at the first iteration and 34 only listed at the second iteration	AI did not provide some documents that are mentioned in best practices (e.g. Project Scope Statement, WBS Dictionary, Responsibility Assignment Matrix (RAM), RBS, Stakeholder engagement assessment matrix)
Context relevance	High (tailored on the specific tender and annexes likely cannot be used as it is for another project)	Lower (focused on general information) Inaccurate details (such as initiation, closure mentioned in planning phase)	Human professional relied on the contact and specific requirements provided, AI lacks specificity
Output	10 pages and 17 annexes	20 pages	The human approaches have tables and figures created in different tools
Tool utilization	Jira, Miro, Atlassian	No tool proposed	Human approach used different templates
Best practice guide	Mulcahy, PMBOK	PMBOK, PRINCE2	

(Source: Authors analysis comparing the response following best practices PMBOK)

Regarding the response time, the planification done by the human project manager is approximatively 24 times bigger than the one done by AI. ChatGPT gives almost instant responses, however the mention 1 hour from the above table include the entire conversation, reading the details received and decide how to proceed with the next prompting integration.

The professional project manager, considered the planification based on the best practices from PMBOK guide and created the list of deliverables, as follows: backlog requirements, list of activities of the project, traceability matrix, project scope statement, work breakdown structure, document assumptions, resource requirements, risk register, Gantt Chart, RACI Matrix, resource breakdown structure, communication plan, stakeholder management plan and stakeholder matrix. The AI generated response provided description on the project management plan, mentioned risk, quality, communication management, work breakdown structure, Gantt chart visualization based on the phases of the project (not based on activities) and a schedule.

4.1 Narrative analysis

Using Yin's (2003) case study methodology, both documents were analysed narratively, considering qualitative insight and analytical reasoning. Human approach follows a logical sequence, link the process to best practice and explain why the proposed steps were chosen (for instance, how the hybrid model was chosen due to fix cost from the contract, but evolving requirements). While the artificial intelligence approach listed all the proposed elements in high level details, it does not explain the details proposed or context specificity.

The traditional approach made by a human project manager was based on the experience of one of the authors and best practice from the industry from PMBOK and described in Mulcahy's book. In the next imagine (Figure 6) can be visualised the proposed steps for planification done by the human project manager, while the imagine below (Figure 7) can be visualised the steps proposed by ChatGPT.

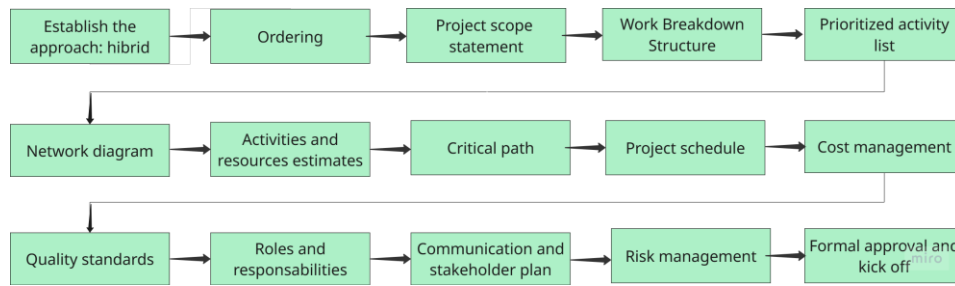


Figure 6: Proposed steps for planification by the human project manager
(Sources: adapted after Mulcahy, 2020)

In contrast, the artificial intelligence approach provided a slightly different proposal for the structure in the first iteration of the prompting request, as can be seen in the next image.

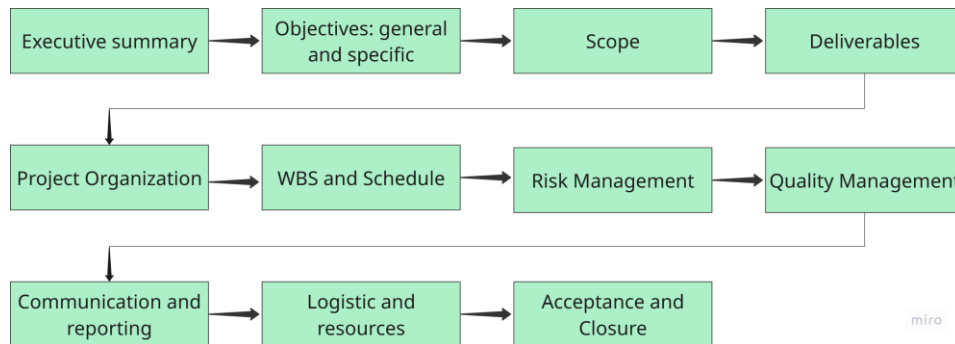


Figure 7: Proposed steps for planification by artificial intelligence on first prompt
(Source: ChatGPT)

The steps proposed for the description of the plan are slightly different between human and artificial intelligence. While both have the Project scope, WBS, Schedule, Communications, Quality and Risk management, there are also some differences in approaches. The artificial intelligence proposed the start with an executive summary and description of the objectives and deliverables, while in the human approach, the objectives and deliverables were included in the “Project scope statement”. Artificial intelligence proposed in the planification, details regarding project organization, while the human approach included these details in Roles and Responsibilities and Communication and Stakeholder plan. Artificial intelligence mentions logistics and resources in a separate section, while in the human approach the logistics are not mentioned, based on relevance.

In the artificial intelligence response, the last proposal is related to acceptance and closure, and it is referring to the completion of the project (a different phase than the planning phase), the human approach was related to the end of the planning phase, obtaining approval for it and start the execution with a kick-off meeting.

The human approach contains some elements that were not included in the initial proposal from artificial intelligence, such as prioritized activity list and kick-off. Prioritization and critical path appeared in the AI generated, however only in the fourth iteration of the prompting, when explicitly required more details.

Both the AI system and the human project manager suggested adopting a hybrid development life cycle, using the waterfall model for overall contractual requirements and deliverables, while carrying out the software implementation through iterative cycles. Both the human and the AI had the same idea to build on the predictive methodology all the details from the contract, and in Agile iterations to start building it, in order to be able to obtain early feedback from the beneficiary.

On the human perspective, the proposed phases were analysis, design, document proposal, present proposal, approve proposal, update proposal, implementation, migration, optimization, test, adjustment. In contrast, on the first iteration of the prompting in ChatGPT, the response was project initiation (a different phase than planning phase), analysis, design, development and migration, testing and validation, deployment, training and documentation, maintenance, change requests. While both approaches contain analysis, design, development, migration and testing, there are also slightly different responses. The human perspective presented some iteration on the document proposal and approval, as requested in the specifications, while were also included a part for optimization and adjustment, as requested in the document. The AI tool started with the project initiation phase, which is a phase that should happen, according to PMBOK, before the planning phase. It mentions specific the deployment, training and documentation, maintenance and change requests.

Regarding the prioritization of the required activities, the human approach was to have a backlog that is refined periodically with the team, and it is in the order of the priority, so that the developers will work on the most important item at a certain point. In real life projects, this prioritized work is performed because, in case the project stops at a certain point (for instance because of lack of funds) is better to have something implemented with the most

important features, even if it is not completed, and does not have ‘nice to have’ functionalities. The artificial intelligence mentioned prioritization as a recommendation in the fourth iteration on the prompting.

The project scope statement was added in the human planification phase, following the best practices in the industry, but not in the AI generated response. However, details about the scope, description, and deliverables were mentioned in the AI proposal, nonetheless not specific mentioned on the scope statement. Work Break down Structure was proposed as an important topic in both human and AI approaches, while network diagram is only found mentioned in the human approach proposal, but not developed.

4.2 Comparative analysis

Below is a description of the comparison (Table 2) between the two approaches, considering the proposed criteria and the results for each side.

Table 2: Comparative analysis

Criteria	Human Approach	AI approach
Proposed structure of the planification phase	Establish the approach, Ordering, Project Scope Statement, WBS, Prioritized Activity List, Network diagram, Activities and Resources Estimate, Critical path, Project Schedule, Cost Management, Quality Standards, Roles and Responsibilities, Communication and Stakeholder plan, Risk Management, Formal approval and kick-off	Executive summary, Objectives, Scope, Deliverables, Project Organization, Risk Management, Quality Management, Communication and reporting, Logistic and Resources, Acceptance and Closure
Development life cycle	Hybrid (Proposed at the beginning of the planification)	Hybrid (Proposed on the 8th prompting iteration, after specific questioning about it)
Proposed phases of the planification of the project	Analysis, Design, Document Proposal, Present Proposal, Approve Proposal, Update Proposal, Implementation, Migration, Optimization, Test, Adjustment	Project Initiation, Analysis, Design, Development and Migration, Testing and Validation, Deployment, Training and Documentation, Maintenance, Change Requests (1st iteration)

(Source: Authors comparison based on the two approaches responses)

4.3 Benchmark analysis

This is a comparison of the two approached based on the ten PMBOK sixth edition knowledge areas, as described by Thoughts C (2025). In the following imagine (Figure 8) it was used Project schedule as described in PMBOK, instead of project time management as mentioned by Thought.

PMBOK knowledge areas	Human Basis approach		Artificial intelligence approach	
	Mentioned	Processes	Mentioned	Processes
Project Integration Management	Yes	Develop Project Management Plan	Yes (but integration not named)	Develop Project Management Plan
Project Scope Management	Yes	Plan Scope Management	Yes	Plan Scope Management
		Collect Requirements	Yes	Requirements
		Define Scope	No	No
		Create WBS	Yes	Create WBS
Project Schedule management	Yes	Plan Schedule Management	No	
		Define Activities	partially mentioned	Activities
		Sequence Activities	Yes	Sequence Activities
		Estimate Activity Duration	partially mentioned	Estimated duration
		Develop Schedule	Yes	Develop Schedule
Project Cost Management	Yes	Plan Cost Management	No; Only mentioned once	Plan Cost Management
		Estimate Costs	No	Estimate Costs
		Determine Budget	No	Determine Budget
Project Quality Management	Yes	Plan quality management	Yes	Quality management (not mentioned as a plan)
Project Resource management	Yes	Plan Resource Management	Partially mentioned- Not mentioned as a plan	
		Estimate Activity Duration	No	
Project Communication management	Yes	Plan Communication Management	Yes	Communication Plan
Project Risk management	Yes	Plan Risk Management	No	not mentioned as a plan
		Identify Risks	Yes	Identify Risks
		Perform Qualitative Risk Analysis	No	Perform Qualitative Risk analysis
		Perform Quantitative Risk Analysis	No	Perform Quantitative Risk Analysis
		Plan Risk Responses	No	Plan Risk Responses
Project Procurement Management	No	not applicable	No	not applicable
Project stakeholder management	Yes	Plan stakeholder engagement	partially mentioned	not mentioned as a plan

Figure 8: Comparison between human and AI considering PMBOK benchmark and Mulcahy's book
(Source: Author comparison based on best practices)

On the human approach, the alignment with the process was 9 out of 9 and on the AI approach, the alignment was 7 out of 9 partially mentioned.

4.4 SWOT analysis

On the below table (Table 3) was created a SWOT analysis (Strengths, Weaknesses, Opportunities and Threats) for both the artificial intelligence and human approach.

Table 3: SWOT Analysis

	Human Approach	AI-Driven Approach
Strengths	Context understanding and tailoring Methodological rigor Supporting reasoning Stakeholder awareness Communication skill focus Creativity (for instance utilization of different tools) Specific and details annexes (requirement list, assumptions, stakeholder engagement etc) Compliance with PMBOK	Fast plan generation Clear Structure Deliverable list Access to large sets of data Continuous improvement using prompt engineering The information reveals and is presented in more details if asked specific in prompts Include more standards than the PMBOK (such as ISO, Software development practices)
Weaknesses	Time consuming Subjectivity Dependent on individual expertise Potential over-documentation Can be prone to human errors	Limited contextual adaptation Potential factual inaccuracies and omissions of important references Presented a lot of details and duplicate information Lack of specific details (example of risk register, stakeholder matrix, RACI) Partial compliance with PMBOK
Opportunities	Integration with AI tools Access to possibility to generate automated templates	Can be used by non-experts to create a good plan in a fast way
Threats	Human biases Dependence on individual experience Limited knowledge in industry or project management best practices	Ethical and data privacy concerns Prompt bias Risk of inaccurate information that cannot be detected by new-entry in the field

(Source: Authors analysis on the two approaches)

4.5 Framework evaluation

On the below table is presented each approach based on the proposed framework criteria and a score given for each line.

Table 4: Comparison between human and AI approach considering the proposed framework

Area	Criteria	Human approach	Artificial intelligence approach	Score human vs GenAI
Scope and Structure	Level of planning depth	detailed and structured	structured moderated detailed	4 vs 3
	Working methodology	described and explained	described and explained	5 vs 5
	Completeness of the list of activities and deliverables	detailed and structured	detailed and structured	4 vs 4
	Assumptions, constraints, exclusions	detailed	not mentioned specifically	4 vs 1
	Acceptance criteria	detailed	minimal	4 vs 1
	Clarity and completeness of task breakdown	detailed with specific activities from the projects using a schema	detailed with phases in the project	3 vs 2
Schedule	Logical sequencing of activities	detailed steps /explicitly addressed	detailed with phases, not activities of the projects	4 vs 3
	Gantt chart	detailed on each activity	detailed with phases	4 vs 3
Resources	Clarity of resource requirements	clearly detailed	minimal mention	5 vs 1
	Roles and responsibilities	detailed in RACI	minimal mention, but not detailed, nor structured	4 vs 1
Risk	Resource breakdown structure	detailed in schema	minimal mention	4 vs 1
	Identification and analysis depth	detailed with cause, consequence, trigger, owner	moderated detailed	4 vs 2
Quality Stakeholders	Alignment with project standards	slightly mentioned	moderately detailed	1 vs 3
	Stakeholder plan	detailed with level of engagement, communication needs, method and frequency	not mentioned specifically	4 vs 1
	Stakeholder analysis	identified and categorised on function, role, power and interest	not mentioned specifically	4 vs 1
Communication	Communication planning structure and clarity	detailed with description, frequency, channel, audience and owner	detailed but not in a structured manner	4 vs 3
Cost	Budget	slightly mentioned	mentioned once	2 vs 1
Integration	Level of integration plan	not mentioned specifically	not mentioned specifically	1 vs 1
Procurement	Planification for the procurement	not mentioned specifically	not mentioned specifically	1 vs 1

(Source: Authors analysis on the two approaches)

The total score for the human approach in this particular case is 66 points and for artificial intelligence is 38. It is very important to mention that this does not mean that ChatGPT tools does not know how to create a more detailed and structured plan. This scored was given specific on the results presented from both side giving the same input (to act as a project manager and do the planification phase). Since AI did not receive specific instruction to deliver specific documents, it did not provide nor mention, hence the lower score. Most likely if in prompting, it was added all the above criteria in requests, the result and score would have been different. However, the comparison proposed was

based on the same input and the same level of details provided. Since nor the human project manager did not receive specific instruction to provide a certain documentation, this is the reason why neither the AI did not receive it.

Another reason for this score differences could be these specific criteria selected, that were based on the knowledge area from PMBOK.

At the same time, the scoring was performed based on qualitative analysis considering the criteria proposed for each component. Higher score was provided to the elements that presented detailed and structured documentation, based on the best practices. The lower score means missing details, or briefly mentioned or vague presented. It needs to be considered that might exist the evaluator bias, since the scoring was done based on subjective assessment.

The differences between the approaches, could also be because the human professional has a certain experience based on the project that managed in his experience, the industry knowledge and knowledge about how a response to a public auction could be written based on his experience. The AI is not limited to one person experience, but it has a very big database. However the response depends on the input provided, requirement given and on the development of the AI model used at the moment of the analysis.

The impact that this could have for project management practice, depends on how is using AI. If a junior professional is using the AI tool, can receive a useful input. However, it might not be able to distinguish on what is wrong information, because it does not have enough experience or knowledge to compare or to identify misleading details.

AI tool can be used as a very good start, but it should be checked with an official and recognized methodology.

5. Discussions

5.1 How does the study case respond to research questions

The proposed study case question is: “How it is different the planning done by a human compared with an artificial intelligence, in terms of structure, sequencing, logic, time, completeness of the documents proposed, compared with project management best practices?” In the next table (Table 5) are described details for each approach, on different criteria, such as structure, sequencing, logic, time consumed, completeness and comparison with the best practice in this field. Based on this question, it can be seen that there are similarities and differences. In terms of proposed structure, the order is different and the human project manager presented more details deliverables and processes proposed, respecting the best practices. If asked specifically, the artificial intelligence can also give good input about these topics, but was not included in the first broad prompt response.

Based on the time involved, the human project manager spent 3 days on the planification for this project. The prompting took approximately 1 h for all 8th iterations, considering also the reading of the description followed by specific input. The response of the AI is immediately (under a minute), the rest of the time is based only on the reading of the provided information, processing and establishing the next steps. At a first sight, the human based approach seems to be more complete than the artificial intelligence but only based on the experience and theoretical knowledge of the project manager. At the same time, the generative AI response, can become better, if asked specific for a certain output.

Table 5: Discussion based on the research question

	Human Approach	AI approach
Structure	Fundamental structure, mixed with contextual details	Clear, standardized plan- organized with heading and logical flow
Sequencing	Dynamic sequencing, considering constraints and risks	Linear sequencing, and lack justification (if not asked specifically)
Logic	Specific why methods were chosen	Formal logic
Time	Substantial investment of time (3 days)	Very fast, almost instant responses (1h)
Completeness	Broader completeness (assumption details, constraints, backlog list, activity list, stakeholder engagement strategies)	Enumerate standards and project deliverables, however some without details
Comparison with best practices	Align with processed and knowledge areas	Align with PMBOK; the link with the processes is not mentioned

(Source: Authors based on the responses presented in this study case)

5.2 How does the study case respond to the proposed questions

On this study there were proposed 4 questions, as follows:

1. How is the overall structure of the two proposals?
2. What level of details are proposed by the two parts?
3. Do both actors propose the same documents and deliverables?
4. Does any of the actors have wrong or incomplete information?

In the following table (Table 6) are presented the similarities and differences between the two approaches for each question proposed.

Table 6. How does the study case respond to the proposed questions

Question	Human approach	AI approach
How is the overall structure of the two proposals?	Structured aligned with project management standards Logical integration Contextual adaptation Explanatory flow	Structured plan Formal completeness
What level of details are proposed by the two parts?	Expanded discussion for each management process Include templates, annex references (such as WBS, RACI, risk matrix, stakeholder matrix) Include tools recommendation (Miro, Jira) Describe rationale for chosen methods	Extensive list of deliverables, without explanation in detail on how the elements were added or validated (if not asked specifically) Elaborates phases, milestones and deliverables, without elaborate more details or assumptions or decision making
Do both actors propose the same documents and deliverables?	Both approaches overlap a big number of deliverables (project backlog, requirements traceability matrix, WBS, Activity list, Risk register) Connects deliverable to a process	List the deliverables to be produced sequentially
Does any of the actors have wrong or incomplete information?	Connects each deliverable to a process Covers assumptions, constraints Can have incomplete output, based on the experience of the professional project manager	Can have omissions – lack certain documents Lack contextual clarifications Does not present any specific details based on the requirements (backlog, activity list, risk register) Present unclear details (initiation, closure-different from planification phase)

(Source: Authors based on the responses presented in this study case)

The overall structure of the two proposal is slightly different. The response of the same planification performed by different professionals could be very different and it is based exclusively on experience and theoretical knowledge of the individual. Both approaches cover the main essential requirements, while the human approach has some details that were not mentioned by the artificial approach. The AI response is general and not related in detail with the initial requirement. The human based approached is more detailed and specific to context described in the tender.

As an overview of the results received in this study, generative artificial intelligence (ChatGPT) can be used complementary rather than in replacement. A human project manager expertise could be beneficially when integrating tailoring specific to context and apply ethical reasoning. At the same time, artificial intelligence can be used for a fast generation of information, automatization of the tasks, such as utilization of the templates for different deliverables.

In this study it was emphasized that the human project management expert judgement could be considered as irreplaceable for interpreting ambiguous requirements, at least at this point of the artificial intelligence evolution. A human professional that would direct, correct and filter AI result is strongly still needed. At least for the near future, the professionals human project managers should validate AI responses and make contextualized outputs, rather than producing all content manually and save a lot of time.

6. Research motivation

The authors selected the second phase of a project, meaning the planning phase, that can be referred as the most time-consuming and that needs extensive project management knowledge. This can be considered because the list of strict activities that needs to be done in a certain order, as described by Mulcahy on process on domains chart.

In addition, there is growing discussion today about AI and its impact on the workplace of project management field. The authors aimed to search for empirical evidence on whether artificial intelligence can truly replicate expert human reasoning in project management planning. This same case study would likely present different results in six months or in one to two years and it will be interesting to document how the impact of AI is evolving and it is integrated in real life projects.

7. Ethical considerations

Applying the planning-phase analysis to an actual project within a specific company was not feasible, so the study used a publicly available set of documents to avoid confidentiality risks. Another ethical concerned is related to the content generated by artificial intelligence (ChatGPT) that lack traceability in order to verify sources.

A potential ethical concern is related to the fact that there is a dual role of the human project manager and one of the co-authors. This dual role could produce potential biases. To mitigate this, the co-authors selected a document requirement that the authors have no prior exposure and unrelated to the field that the project manager is working currently. In addition, the results were compared with the best practices in the field. In order to minimize bias associated with self-knowledge, all procedures were documented systematically. In addition, there are included the output evidence for traceability. All these actions were done in order to ensure methodological differences comparison and a neutral rather than subjective interpretation.

8. Assumptions, constraints, limitation of the study case

This study has several limitations, which are outlined in the following sentence. The sample size is small and include only one human project manager, who is also one of the co-authors. In addition, the comparison was done once, and this might limit the consistency of the findings. Future research could involve multiple AI tools and a larger number of project managers working with the same requirements, allowing comparison across professionals. In addition, future studies could incorporate external expert review to validate plan generated by the human professional. Another proposal to extend this study could also be expanded to include multiple project documents rather than a single case.

It can be considered as another limitation that the planning activity was created by a project manager and not by multiple participants with different roles. In companies, the planning typically involves contributions from various roles, such as business analysts for requirement breakdown or development teams for effort estimation.

A further limitation concerns is related to the quality of the plan generated by the AI that depends heavily on the prompts provided. Since prompting skills vary with the user's experience, the outputs may differ across individuals. Considering the experience of the person that introduce the prompting, the quality of the result can be different.

9. Conclusion

This study presented empirical evidence for the comparative results between the two actors involved, the human professional project manager and the generative AI. This evidence was provided under comparative input and differences and similarities were presented. The human project manager can overlook to include certain elements due to limited experience or domain knowledge. At the same time, the AI tool can be used exactly with this purpose, to help identify missing components or to offer alternative ideas.

Also, the human project manager perspective is shaped by the professional exposure and practical judgement, while the AI can rely on extensive knowledge that is not always delivered in the most useful way. Specific, as it is presented in the article, AI may provide either excessive details without meaningful substance or insufficient information that do not cover all required aspects. Moreover, based on the prompter experience, the response can be very different.

This study provides practical evidence that AI can support traditional project planning by speeding up the process while still producing a complete structure, although it can be considered limited in understanding context. The combination between human expertise and AI can be effective, because based on the project manager expertise, the AI can develop specific requirements that were not displayed on a broader question. Typically, a more precise prompt, can generate more insightful and relevant output.

Overall, the human plan aligns with the PMBOK sixth edition areas at a detailed level, and integrates judgement, making it an adaptable and tailored plan. In contrast, the AI plan aligns at a conceptual level, significantly reduce time and effort providing a well structured plan, but omits documentation level depth.

In conclusion, at this stage of technological development, the generative artificial intelligence can be viewed as a collaborative tool that can be used by professionals in order to increase efficiency, generate templates or refine outputs.

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Cash as a Strategic Buffer: Mitigating the Impact of Geopolitical Risk on Firm Performance in Indonesia

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ARTICLE INFO	ABSTRACT
Article History Received 30/03/2026 Accepted 28/05/2026 <i>JEL Classifications</i> G30, G32	Purpose: This study investigates the impact of geopolitical risk (GPR) on firms' financial performance and evaluates the extent to which internal liquidity serves as a buffer against geopolitical uncertainty. In particular, it explores the moderating effects of net changes in cash, operating cash flow, investing cash flow, and financing cash flow in mitigating the adverse consequences of geopolitical risk on firm performance. Design/methodology/approach: This study employs a fixed-effects regression model as the primary empirical approach. Furthermore, quantile regression analysis is performed to provide additional insights into the distributional effects. To address potential endogeneity concerns, a two-stage least squares (2SLS) estimation is implemented, utilizing geopolitical risk indices from selected ASEAN countries—namely Malaysia, the Philippines, Thailand, and Vietnam—as instrumental variables. Findings: The empirical findings indicate that geopolitical risk (GPR) exerts a statistically significant negative effect on firm financial performance. While net changes in cash mitigate this adverse impact on average, cash flows from investing and financing activities do not exhibit significant buffering effects. In contrast, firms with higher levels of operating cash flow demonstrate a stronger capacity to offset the detrimental effects of geopolitical risk on performance. These results remain robust across a range of specifications, including the use of alternative measures of the GPR index, variations in the sample period, and the inclusion of macroeconomic controls. Research limitations/implications: The results underscore the importance of internal liquidity generation in enhancing firms' resilience to geopolitical shocks. Accordingly, the study suggests that firm managers prioritize operational efficiency, cost management, and revenue stability, while avoiding excessive or non-essential investments and maintaining prudent leverage levels. From a policy perspective, governments may consider providing targeted incentives or tax relief during periods of heightened geopolitical uncertainty to support corporate stability. Originality/value: This study contributes to the existing literature in several important ways. First, by utilizing data from 1996 to 2023, it comprehensively captures major geopolitical risk events affecting Indonesia over an extended period. Second, this study incorporates multiple dimensions of cash flow, rather than focusing solely on net cash flow, by examining operating, investing, and financing cash flows. This approach provides a more complete understanding of the role of liquidity in mitigating geopolitical risk. Third, the study employs geopolitical risk indices from ASEAN countries with similar economic and cultural contexts—Malaysia, the Philippines, Thailand, and Vietnam—as instrumental variables, thereby strengthening the identification strategy.

Keywords:

corporate finance,
geopolitical risk, cash flow,
Indonesia

1. Introduction

Firms worldwide have increasingly faced heightened uncertainty arising from various geopolitical and economic events, including trade protectionism, the Brexit referendum, the first trade war in 2018 and the second trade war in 2025 between the United States and China (Bermpei et al., 2022; Ou et al., 2023). In addition, numerous conflicts and terrorist activities have significantly disrupted business operations. For instance, the bombings of U.S. embassies in Kenya and Tanzania increased security costs for multinational corporations operating in Africa; the terrorist attacks on the World Trade Center on September 11, 2001 triggered global economic downturns, particularly affecting the aviation, insurance, and tourism sectors; the emergence of ISIS in Iraq and Syria in 2014 destabilized global energy markets; the Russia–Ukraine war led to sharp increases in commodity prices, especially in energy (natural gas) and agricultural products (wheat); and the COVID-19 pandemic beginning in 2020 severely disrupted global economic activity. These events collectively generated geopolitical risk, defined as the risk associated with wars, terrorist acts, and escalating interstate conflicts that create uncertainty in international relations (Caldara & Iacoviello, 2022; Wang et al., 2024). Consequently, identifying effective strategies to mitigate the adverse effects of such uncertainty and enhance corporate resilience has become an increasingly important research issue (Ou et al., 2023).

Meanwhile, a growing body of literature has documented the significant adverse effects of geopolitical risk (hereafter GPR) on both macroeconomic and microeconomic outcomes. Geopolitical risk has been shown to negatively affect economic growth (Akadiri et al., 2020; Wang et al., 2024), oil prices (Bouoiyour et al., 2019; Qin et al., 2020), stock markets (Balcilar et al., 2018; Smales, 2021), GDP growth (Akadiri et al., 2020; Caldara & Iacoviello, 2022), as well as economic contraction and declining consumption (Cheng & Chiu, 2018). At the firm level, GPR influences corporate investment decisions (Gupta, 2023), debt financing costs (Waisman et al., 2015), and cash holdings (Demir et al., 2019; Sandra & Kim, 2022; Wang et al., 2024). Moreover, geopolitical risk has been identified as a major threat to global financial stability (Phan et al., 2022). Consistent with these findings, central bank officials, financial institutions, investors, entrepreneurs, and corporate managers increasingly view geopolitical risk as a critical factor shaping corporate operations and financial performance (Caldara & Iacoviello, 2022; Sandra & Kim, 2022), and as a key determinant of economic decision-making by policymakers and firm managers (Demir & Ersan, 2017).

Firms have adopted various strategies to mitigate the adverse effects of uncertainty arising from geopolitical risk (GPR), including maintaining higher levels of cash and liquid assets (Demir et al., 2019; Ou et al., 2023). Wang et al. (2024) investigated the impact of GPR on corporate cash holdings using a geopolitical risk index covering the period from 2003 to 2021 and reported a significantly negative effect of geopolitical risk on firms' cash reserves. This negative relationship was found to be more pronounced among firms operating in environments with stronger regulatory capacity and more developed legal systems. Moreover, their findings suggest that corporate cash holding decisions can partially offset the negative impact of geopolitical risk on firm value. Similarly, Kotcharin and Maneenop (2020) examined the influence of geopolitical risk on firms' cash holding behavior and demonstrated that GPR significantly affects corporate liquidity management decisions. In addition, Ozdemir et al. (2023) documented that heightened uncertainty exerts a significant adverse effect on financial performance. Accordingly, this study seeks to address the following research question:

Does cash flow mitigate the impact of geopolitical risk on financial performance?

Recent research examining the impact of geopolitical risk on Indonesian firms remains relatively limited (Sandra & Kim, 2022). Moreover, as an emerging economy, Indonesia is particularly vulnerable to uncertainty, including geopolitical instability (Cheng & Chiu, 2018). The Southeast Asian financial crisis of 1997–1998 provides a clear illustration of this vulnerability. While several countries in the region, such as Singapore, Malaysia, Thailand, and Indonesia, experienced severe economic disruptions during this period, Indonesia required more than two years to fully recover from the crisis. Accordingly, this study aims to investigate the impact of geopolitical risk on firm financial performance in Indonesia.

Specifically, this study examines the effect of geopolitical risk (GPR) on corporate financial performance and explores the role of cash flow components—including cash flow from operations, investing activities, and financing activities—in mitigating the adverse impact of GPR. A fixed-effects panel regression model is employed, along with a series of robustness tests to ensure the reliability of the results. Following Ou et al. (2023), the robustness checks include using alternative measures of the GPR index, excluding macroeconomic influences, and varying the sample period. To address potential endogeneity concerns, this study applies a two-stage least squares (2SLS) approach, using GPR indices from selected ASEAN countries—namely Malaysia, the Philippines, Thailand, and Vietnam—as instrumental variables. The empirical findings indicate that GPR has a significantly negative effect on firm financial performance. Furthermore, net cash holdings and operating cash flow mitigate the detrimental impact of geopolitical risk, whereas cash flows from investing and financing activities do not exhibit buffering effects.

Indonesia represents a particularly relevant setting for investigating the corporate consequences of geopolitical risk due to its unique economic, demographic, and geopolitical characteristics. As the world's fourth

most populous nation, with over 285 million inhabitants distributed across more than 17,000 islands, Indonesia exhibits substantial social and cultural diversity, including over 1,300 ethnic groups, more than 700 local languages, and six officially recognized religions. This diversity contributes to a complex institutional and socio-political environment in which geopolitical uncertainty may exert significant effects on economic activity and corporate behavior. Moreover, Indonesia's strategic location along major international maritime trade routes and its proximity to the geopolitically sensitive South China Sea increase its vulnerability to external geopolitical shocks. The country's abundant reserves of critical natural resources, such as nickel, tin, copper, gold, and coal, further heighten its exposure to global geopolitical competition and resource-related tensions. These characteristics make Indonesia an ideal empirical setting for examining how geopolitical risk influences firm-level financial performance.

This study contributes to the existing literature in several important ways. First, by utilizing data from 1996 to 2023, it comprehensively captures major geopolitical risk events affecting Indonesia over an extended period. Second, this study incorporates multiple dimensions of cash flow, rather than focusing solely on net cash flow, by examining operating, investing, and financing cash flows. This approach provides a more complete understanding of the role of liquidity in mitigating geopolitical risk. Third, the study employs geopolitical risk indices from ASEAN countries with similar economic and cultural contexts—Malaysia, the Philippines, Thailand, and Vietnam—as instrumental variables, thereby strengthening the identification strategy.

The remainder of the paper is organized as follows. Section 2 presents the literature review, Section 3 discusses the data and methodology, Section 4 reports and discusses the empirical results, and Section 5 concludes the study.

2. Review of Literature

Caldara and Iacoviello (2022) define geopolitical risk as the occurrence and escalation of threats and adverse events associated with wars, terrorism, and tensions among states and political actors that disrupt peaceful international relations. Geopolitical risk concerns the ability of nations to control and compete over territory, and when such uncertainty cannot be resolved, it adversely affects business operations and economic cycles, thereby harming firms' financial performance (Caldara & Iacoviello, 2022; Gupta, 2023). Moreover, geopolitical risk influences macroeconomic conditions through various channels, including loss of human life, destruction of capital stock, and increased military expenditures (Caldara & Iacoviello, 2022). Consequently, geopolitical risk has become an important determinant of decision-making for policymakers, investors, and firm managers (Demir et al., 2019).

Geopolitical risk is associated with a higher probability of economic disruptions and lower expected GDP growth (Akadiri et al., 2020; Caldara & Iacoviello, 2022). Baker et al. (2016) demonstrate that uncertainty negatively affects macroeconomic performance by reducing managers' ability to forecast regulatory, fiscal, and monetary policies. Similarly, Ozdemir et al. (2023) show that uncertainty influences demand for goods and services, as consumers tend to delay or reduce consumption despite maintaining essential expenditures, leading to declining firm revenues. Prior studies further indicate that firms postpone investment and adopt more conservative strategies during periods of uncertainty (Yuan et al., 2022), which ultimately affects corporate investment, innovation, and financial performance (Iqbal et al., 2020). These effects arise due to higher operational and financing costs (Çolak et al., 2017; Ou et al., 2023), increased information asymmetry (Bermpei et al., 2022), and declining sales performance (Wang et al., 2021). Yung and Root (2019) also find that uncertainty significantly affects earnings management, which in turn influences firm value.

Qin et al. (2020) report that geopolitical risk significantly increases energy market volatility, leading to higher business operating costs. Moreover, geopolitical risk raises firms' cost of capital and risk premiums (James et al., 2024) while making access to external financing more difficult and expensive (Pringpong et al., 2023; Waisman et al., 2015). In response to these adverse conditions, firm managers tend to adopt more cautious financial policies, such as reducing capital investment (Gulen & Ion, 2015) and limiting earnings manipulation (Kim & Yasuda, 2021). As uncertainty is unavoidable and affects firms regardless of size or financial condition (He et al., 2020), its impact is widespread across industries and economies.

Empirical evidence supports these arguments. Trakarnsirinont et al. (2023), using Thai firm data, find that uncertainty significantly affects financial performance. Similarly, Ozdemir et al. (2023) document a significant negative impact of geopolitical risk on firm performance.

Based on prior research, the following hypothesis is proposed:

H1: Geopolitical risk significantly reduces firms' financial performance.

Geopolitical uncertainty exacerbates information asymmetry between corporate managers and external stakeholders. Events such as military conflicts, economic sanctions, oil price shocks, trade restrictions, and disruptions to global supply chains increase uncertainty regarding firms' future prospects and cash flow

generation. As a result, external investors and creditors face greater difficulties in assessing firm value and risk, leading to higher information asymmetry and financing frictions.

According to the Pecking Order Theory, firms follow a hierarchical financing preference in response to information asymmetry. Internal funds are preferred because they do not involve adverse selection costs or require firms to reveal private information to external capital providers. When internal funds are insufficient, firms seek debt financing, while equity issuance is considered the least desirable alternative because it may dilute existing shareholders' ownership and signal potential overvaluation to the market (de Jong et al., 2007). Under heightened geopolitical uncertainty, creditors tend to adopt more conservative lending standards and demand higher risk premiums, thereby increasing the cost of external financing. Consequently, firms become more reliant on internally generated funds to support their operational and investment activities.

The importance of internal liquidity under uncertainty is further supported by Keynesian Liquidity Preference Theory. Keynes (1936) argues that economic agents hold liquid resources for transaction, precautionary, and speculative motives. In the corporate context, operating cash flow represents a firm's ability to continuously generate internal liquidity from its core business activities. Strong operating cash flow enables firms to finance routine operations and meet short-term obligations (transaction motive), maintain financial flexibility against unexpected shocks and future cash flow volatility (precautionary motive), and exploit profitable investment opportunities that may arise during periods of uncertainty (speculative motive). Consequently, firms with higher operating cash flows are less dependent on costly external financing and are better positioned to withstand the adverse effects of geopolitical uncertainty on financial performance. This argument is consistent with Han and Qiu (2007), who suggest that internally generated liquidity enhances firms' ability to cope with uncertainty and sustain investment activities.

Therefore, operating cash flow is expected to mitigate the detrimental impact of geopolitical risk on firm financial performance by reducing financing constraints, enhancing financial flexibility, and supporting the continuity of operational and investment activities during periods of heightened uncertainty.

Cash policy is one of the most important corporate financial strategies. Firms tend to hold substantial cash reserves for prudential and precautionary motives (Demir & Ersan, 2017; Ou et al., 2023). The main motives for cash holdings include transaction, tax, and precautionary purposes (Bates et al., 2009; James et al., 2024; Wang et al., 2024). According to precautionary motive theory, higher cash reserves enable firms to cope with unexpected cash flow fluctuations, meet daily operational needs, and manage risks arising from geopolitical uncertainty. Pinkowitz et al. (2003) further argue that firms hold cash to minimize transaction costs. Additionally, firms accumulate cash to finance growth and investment projects when external financing becomes costly or volatile (Hasan et al., 2022).

During periods of uncertainty, firms actively utilize cash reserves to buffer adverse shocks (Demir & Ersan, 2017). Empirical studies confirm that firms increase cash holdings during uncertain times (Hasan et al., 2022; Sandra & Kim, 2022). Adequate cash holdings enhance liquidity, reduce financial risk (James et al., 2024), and lower managerial risk exposure (Guedhami et al., 2021). Firms experiencing volatile cash flows or limited access to external capital tend to hold more cash as a risk management strategy (Bates et al., 2009; Han & Qiu, 2007; Opler et al., 1999). Geopolitical risk introduces uncertainty in product markets and revenue streams, compelling firms to adjust policies and maintain higher cash balances (Hasan et al., 2022; Lee & Wang, 2021). Therefore, cash holdings play a crucial role in sustaining business operations during periods of geopolitical instability.

Several studies find a significant relationship between geopolitical risk and corporate cash holdings (Demir & Ersan, 2017; Lee & Wang, 2021; Wang et al., 2021). Moreover, substantial cash reserves act as an effective hedge against the negative effects of geopolitical risk on firm performance (Ozdemir et al., 2023). Sandra and Kim (2022) provide evidence from Indonesian firms showing that geopolitical risk significantly affects cash reserves. Nguyen et al. (2024) further demonstrate that cash reserves reduce default risk, which is closely linked to financial performance. Although Wang et al. (2024) find a negative relationship between geopolitical risk and cash holdings, they confirm that cash reserves mitigate the adverse impact of geopolitical risk on corporate value.

Accordingly, the following hypothesis is proposed:

H2: Net change in cash significantly mitigate the negative impact of geopolitical risk on firms' financial performance.

Firms particularly rely on cash generated from operating activities as a buffer against uncertainty (Bates et al., 2009). According to pecking order theory, firms prefer internal financing—such as operating cash flow—over external funding to minimize transaction costs and maintain control (Korolo & Korolo, 2025). Internal financing is also less costly than external sources (Gupta, 2023). Geopolitical risk generates uncertainty in labor costs, production expenses, and transportation costs, making operating cash flow a critical indicator of firms' ability to meet obligations and sustain growth (Ahmed & Elnahass, 2024).

Thus, the following hypothesis is proposed:

H3: Cash flow from operating activities significantly mitigates the negative impact of geopolitical risk on firms' financial performance.

Geopolitical risk disrupts the business environment, increases costly decision-making errors (Le & Tran, 2021), reduces economic growth, and weakens consumer purchasing power (Lee & Lee, 2020; Lee & Wang, 2021). Evidence indicates that manufacturing activity slows during periods of heightened geopolitical risk, as reflected by declining Purchasing Managers' Index (PMI) values (Lee & Wang, 2021). Under such conditions, investment returns become uncertain, making cash flows from investing activities less effective in supporting firm performance.

Accordingly, the following hypothesis is proposed:

H4: Cash flow from investing activities does not significantly mitigate the negative impact of geopolitical risk on firms' financial performance.

During periods of geopolitical instability, firms' cash flows become more volatile, and information asymmetry between firms and creditors intensifies (Khoo & Cheung, 2021; Yaghoubi, 2025). Creditors perceive higher risk and consequently charge higher borrowing costs (Nguyen & Thuy, 2023; Waisman et al., 2015). Increased financing costs negatively affect firms' profitability and financial stability.

Therefore, the following hypothesis is proposed:

H5: Cash flow from financing activities does not significantly mitigate the negative impact of geopolitical risk on firms' financial performance.

3. Methodology

This study employs annual data on Indonesian firms' financial reports, foreign exchange rates, inflation, and geopolitical risk spanning the period from 1996 to 2023. Firm-level financial data are obtained from Compustat. The foreign exchange rate used in this study is the USD/IDR rate, sourced from Investing.com, while inflation data are collected from the World Bank database. Geopolitical risk (GPR) data are obtained from Caldara and Iacoviello's official database.

The sample includes all non-financial firms listed in Compustat, with financial institutions—such as banks, insurance companies, securities firms, and leasing companies—excluded due to their distinct regulatory frameworks and financial structures.

The dependent variable is Return on Assets (ROA), which serves as a proxy for firm financial performance. The key independent variable is the Indonesian Geopolitical Risk (GPR) Index developed by Caldara and Iacoviello (2022). This index measures geopolitical tensions, conflicts, wars, and terrorist activities by calculating the share of newspaper articles that reference adverse geopolitical events across multiple countries, including Indonesia. The objective of the index is to capture distinct dimensions of geopolitical risk affecting economic conditions.

Following Gupta (2023), this study aggregates monthly GPR values into annual measures by computing both the average and median over the twelve months of each fiscal year. GPRMEAN denotes the annual average geopolitical risk index, while GPRMEDIAN represents the annual median value.

Extant literature addressing corporate responses to uncertainty has largely concentrated on cash holdings as a vital precautionary liquidity buffer (Han & Qiu, 2007). In contrast, this study utilizes cash flow from operating activities (OPS) as the primary variable of interest. This methodological choice rests on the premise that OPS captures a firm's ongoing capacity to generate internal funds from core business activities, whereas cash holdings merely reflect a static stock of accumulated liquidity at a given point in time. According to the pecking order theory, information asymmetry and financial constraints compel firms to prioritize internal financing over external capital, which often carries prohibitive costs and adverse selection risks (Myers & Majluf, 1984). Furthermore, Fazzari et al. (1988) posit that when external capital markets are constrained, corporate investment becomes highly sensitive to internal fund availability. Thus, under conditions of heightened uncertainty, OPS offers a more direct metric of a firm's self-financing capacity. While Han and Qiu (2007) demonstrate that firms accumulate cash reserves to counter cash flow volatility, their underlying logic underscores the broader value of liquidity and financial flexibility. Extending this rationale, firms with robust operating cash flows should exhibit superior financial flexibility, reduced external capital dependence, and enhanced resilience to geopolitical shocks. OPS is therefore a superior proxy for analyzing how internally generated liquidity shields firm performance from geopolitical risks.

The interaction variables capture firms' cash flow components, including net change in cash (CASH), cash flow from operating activities (OPS), cash flow from investing activities (INVS), and cash flow from financing activities (FIN).

Control variables include total asset turnover (TATO), fixed asset turnover (FATO), accounts receivable turnover (ARTO), inventory turnover (INTO), gross profit margin (GPM), net income margin (NIM), debt-to-equity ratio (DER), EBIT-to-interest expense ratio (EIXP), and current ratio (CURR).

To mitigate the influence of extreme values, all continuous variables are winsorized at the 2nd and 98th percentiles.

To test Hypothesis 1, the following baseline econometric model is estimated:

$$ROA_{it} = \alpha_{it} + \beta_1 GPRMEAN_{it} + \lambda Control_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (1)$$

Where ROA_{it} denotes firm i 's return on assets in year t , $GPRMEAN_{it}$ represents geopolitical risk, $CONTROL_{it}$ is a vector of control variables, μ_i captures firm-specific effects, δ_t captures time-specific effects, and ε_{it} is the error term.

To examine the moderating role of cash flow components in the relationship between geopolitical risk and financial performance, the following interaction models are estimated:

$$ROA_{it} = \alpha_{it} + \beta_1 (GPRMEAN_{it} \times CASH_{it}) + \beta_2 GPRMEAN_{it} + \beta_3 CASH_{it} + \lambda Control_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (2)$$

$$ROA_{it} = \alpha_{it} + \beta_1 (GPRMEAN_{it} \times OPS_{it}) + \beta_2 GPRMEAN_{it} + \beta_3 OPS_{it} + \lambda Control_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (3)$$

$$ROA_{it} = \alpha_{it} + \beta_1 (GPRMEAN_{it} \times INVS_{it}) + \beta_2 GPRMEAN_{it} + \beta_3 INVS_{it} + \lambda Control_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (4)$$

$$ROA_{it} = \alpha_{it} + \beta_1 (GPRMEAN_{it} \times FIN_{it}) + \beta_2 GPRMEAN_{it} + \beta_3 FIN_{it} + \lambda Control_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (5)$$

Where $GPRMEAN_{it} \times CASH_{it}$, $GPRMEAN_{it} \times OPS_{it}$, $GPRMEAN_{it} \times INVS_{it}$, and $GPRMEAN_{it} \times FIN_{it}$ represent the interaction terms between geopolitical risk and the respective cash flow components.

4. Results and Discussion

4.1 Descriptive Statistics

Table 1 presents the descriptive statistics of the variables employed in the regression analysis, including the mean, standard deviation, minimum, and maximum values. The mean ROA is 4.535006, with a standard deviation of 6.367135, ranging from -9.89 to 25. This indicates substantial variation in firm financial performance across the sample.

The average value of GPRMEAN is 0.0541794, with a standard deviation of 0.0285102, a minimum of 0.0233, and a maximum of 0.1070. Similarly, GPRMEDIAN has a mean of 0.0434, a standard deviation of 0.251024, and ranges from 0.0077 to 0.1134, reflecting considerable fluctuations in geopolitical risk over the sample period.

Regarding cash flow variables, the mean values of net change in cash (CASH), cash flow from operating activities (OPS), cash flow from investing activities (INVS), and cash flow from financing activities (FIN) are 4.053831, 32.5383, -29.3513, and -0.25845, respectively. CASH and OPS exhibit positive average values, indicating that firms, on average, generate positive net cash and operating cash flows. In contrast, INVS and FIN display negative mean values, suggesting that firms tend to spend more on investment activities and experience net cash outflows from financing over the sample period.

4.2 Fixed Effect Regression Result

Table 2 reports the fixed-effects regression results. Column (1) shows that GPRMEAN has a coefficient of -4.826 with a p-value of 0.000, indicating a statistically significant negative effect on ROA at the 1% significance level. This result supports Hypothesis 1 and suggests that heightened geopolitical risk adversely affects firm financial performance.

This finding is consistent with prior studies, including Ozdemir et al. (2023) and Trakarnsirinont et al. (2023), which documented a detrimental relationship between uncertainty and firm performance. One plausible explanation is the significant slowdown in consumer consumption during periods of elevated geopolitical uncertainty (Ozdemir et al., 2023), as consumers tend to postpone spending for precautionary reasons (Caldara & Iacoviello, 2022). This behavior generates uncertainty in firms' sales and profit streams (Wang et al., 2021).

In addition, geopolitical risk increases operational costs and exacerbates information asymmetry between firms and external stakeholders (Bermpei et al., 2022; Çolak et al., 2017; Ou et al., 2023), thereby further weakening financial performance. Collectively, these mechanisms explain why geopolitical risk exerts a significantly negative impact on firm profitability.

Table 1: Descriptive Statistic

Variables	Obs	Mean	Std. Dev.	Min	Max
ROA	10,080	4.535006	6.367135	-9.89	25
GPRMEAN	22,624	.0541794	.0285102	.0233023	.1070437
GPRMEDIAN	22,624	.0434969	.0251024	.0076805	
.1134431					
CASH	10,845	4.053831	29.10868	-71.7	136.7
OPS	10,857	32.52834	85.90408	-34.2	461.8
INVS	10,723	-29.35132	72.1911	-386.9	15.1
FIN	10,584	-.2584475	57.47486	-211	211.6
TATO	10,019	.9115221	.801178	.029	3.67
FATO	9,896	8.022785	18.45193	.107	106
ARTO	9,478	16.008	27.36062	.986	158
INTO	9,149	15.50398	32.82556	.114	185
GPM	10,902	29.73758	20.87902	-7.86	84.8
NIM	10,773	2.160474	24.79511	-102.4	55.9
EIXP	7,919	14.21672	30.7114	.136	163.1
CURR	10,979	2.444274	3.046716	.131	17.2
DER	9,499	112.8143	173.4525	.221	948.4
FOREXCHG	22,624	.1390276	.6040924	-.1783831	
3.228908					
INFLATION	22,624	.0844588	.1041364	.0156013	
.5845104					

Source: Compustat, processed by authors

Column (2) of Table 2 shows that the coefficient of the interaction term between GPR and CASH is 0.0865, with a p-value of 0.01, indicating a statistically significant positive effect on ROA at the 1% significance level. This result provides empirical support for Hypothesis 2, suggesting that net change in cash (CASH) can mitigate the negative impact of geopolitical risk (GPR) on firm financial performance. This finding aligns with the results of Wang et al. (2024), who documented that firms increase cash holdings to buffer against external shocks and maintain smooth operations during periods of uncertainty. Holding sufficient cash enhances a firm's financial stability, its capacity to generate profits, its ability to meet obligations, and its resilience against geopolitical risk (Ahmed & Elnahass, 2024; Wang et al., 2021). Therefore, cash reserves serve as an effective mechanism for reducing the detrimental effects of geopolitical risk on corporate performance.

Column (3) of Table 2 shows that the coefficient of the interaction term between GPR and OPS is 0.0484, with a p-value of 0.000, indicating a statistically significant positive effect on ROA at the 1% level. This result supports Hypothesis 3 and suggests that cash flow from business operations (OPS) can mitigate the negative impact of geopolitical risk (GPR) on firm financial performance. Cash flow from operations reflects the underlying performance and efficiency of a firm's core business activities (Ahmed & Elnahass, 2024). Firms with stable and robust operating cash flow are better equipped to manage day-to-day operations and respond effectively to uncertainty, including geopolitical risk. This financial flexibility allows such firms to sustain profitability and operational resilience during periods of elevated external risk.

Table 2: GPRMEAN

	(1) ROA	(2) ROA	(3) ROA	(4) ROA	(5) ROA
GPRMEAN	-4.826*** (0.000)	-5.193*** (0.000)	-7.123*** (0.000)	-6.240*** (0.000)	-6.008*** (0.000)
TATO	5.297*** (0.000)	5.337*** (0.000)	5.339*** (0.000)	5.388*** (0.000)	5.357*** (0.000)
FATO	-0.00934** (0.031)	-0.00890** (0.039)	-0.00790* (0.064)	-0.00934** (0.030)	-0.00901** (0.036)
ARTO	0.00770*** (0.003)	0.00784*** (0.002)	0.00732*** (0.004)	0.00790*** (0.002)	0.00752*** (0.003)
INTO	0.00897*** (0.000)	0.00820*** (0.000)	0.00824*** (0.000)	0.00900*** (0.000)	0.00799*** (0.000)
GPM	0.233*** (0.000)	0.233*** (0.000)	0.225*** (0.000)	0.234*** (0.000)	0.235*** (0.000)

NIM	0.0452*** (0.000)	0.0457*** (0.000)	0.0460*** (0.000)	0.0459*** (0.000)	0.0462*** (0.000)
EIXP	0.0250*** (0.000)	0.0247*** (0.000)	0.0227*** (0.000)	0.0246*** (0.000)	0.0240*** (0.000)
CURR	0.00913 (0.678)	0.00336 (0.878)	0.0202 (0.352)	0.0139 (0.526)	0.0148 (0.500)
DER	-0.000517* (0.072)	-0.000449 (0.119)	-0.000252 (0.376)	-0.000382 (0.186)	-0.000430 (0.135)
FOREXCHG	0.209** (0.020)	0.215** (0.022)	0.312*** (0.001)	0.215** (0.021)	0.264*** (0.005)
INFLATION	5.302*** (0.000)	5.418*** (0.000)	6.429*** (0.000)	5.390*** (0.000)	5.542*** (0.000)
GPRMEANxCASH		0.0865*** (0.010)			
CASH		-0.000481 (0.799)			
GPRMEANxOPS			0.0484*** (0.000)		
OPS			0.00453*** (0.000)		
GPRMEANxINVS				-0.0364** (0.011)	
INVS				0.000665 (0.458)	
GPRMEANxFIN					-0.0507*** (0.005)
FIN					-0.000456 (0.656)
_cons	-7.052*** (0.000)	-7.060*** (0.000)	-7.136*** (0.000)	-7.165*** (0.000)	-7.113*** (0.000)
Firm Fixed Effect	Yes	Yes	Yes	Yes	Yes
N	6317	6275	6277	6262	6259
R ²	0.545	0.552	0.562	0.553	0.554

Source: Compustat, processed by authors p -values in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The results for the interaction term between GPR and cash from investing (INVS) are presented in column (4) of Table 2. The coefficient is -0.0364 with a p -value of 0.011 , indicating a statistically significant negative effect on ROA at the 5% level. This finding supports Hypothesis 4, suggesting that cash from investing (INVS) cannot mitigate the adverse impact of geopolitical risk (GPR) on firm financial performance. This result is consistent with Demir et al. (2020). Geopolitical risk increases the difficulty of forecasting and magnifies the downside risk to GDP growth (Caldara & Iacoviello, 2022), while also raising investment costs and risk premiums (James et al., 2024). Consequently, cash allocated to investing activities may not provide sufficient flexibility to buffer firms against geopolitical uncertainty.

Similarly, column (5) of Table 2 reports the results for the interaction between GPR and cash from financing (FIN). The coefficient is -0.0507 with a p -value of 0.005 , indicating a statistically significant negative effect on ROA at the 1% level. This finding supports Hypothesis 5, suggesting that cash from financing (FIN) also fails to mitigate the impact of GPR on firm financial performance. During periods of geopolitical uncertainty, firms face higher debt costs and an increased likelihood of credit default (Waisman et al., 2015; Wisniewski & Lambe, 2015), which reduces the effectiveness of financing-related cash flows in protecting profitability.

Unlike operating cash flow, investing cash flow does not mitigate the adverse effects of geopolitical risk on firm performance, as investment-driven liquidations become inefficient sources of liquidity amid uncertainty. Positive investing cash flows generally reflect the sale of long-term assets like machinery or facilities; however, heightened geopolitical risks often cause investors to postpone acquisitions in favor of a wait-and-see strategy. This behavior reduces asset market liquidity, making rapid and favorable asset divestment difficult for firms. Conversely, increasing capital allocations during geopolitical crises is equally unappealing due to rising risk premiums and uncertain future returns. Consistent with real options theory, firms facing substantial uncertainty

tend to delay irreversible investments. For these reasons, investing cash flows provide a restricted capacity to shield corporate financial performance from geopolitical shocks.

Furthermore, financing cash flows fail to cushion the adverse effects of geopolitical risk (GPR) on firm performance, primarily because heightened uncertainty increases external capital costs and constrains credit accessibility. This phenomenon is rooted in amplified information asymmetry and elevated risk perceptions among investors and creditors during periods of geopolitical distress, which prompts lenders to extract higher risk premiums and equity investors to demand steeper discounts. Consequently, firms are subjected to elevated borrowing costs, stringent covenants, and diminished market receptivity for seasoned equity offerings. Framed within Myers and Majluf's (1984) Pecking Order Theory, firms systematically prioritize internal liquidity over external financing to minimize adverse selection costs. In the wake of intense geopolitical shocks, these frictional financing costs escalate, thereby nullifying the utility of external financing cash flows as an effective buffer. Under these deteriorating operating conditions, a forced reliance on incremental debt financing can ultimately exacerbate firm underperformance by intensifying fixed financial obligations and interest burdens.

4.3 Robustness Test

Following Ou et al. (2023), this study conducts robustness tests by: (1) using an alternative measure of geopolitical risk, (2) varying the sample period, and (3) controlling for the potential effects of macroeconomic factors.

4.3.1 Replacing the Measurement of Geopolitical Risk (GPR)

To further examine the impact of geopolitical risk (GPR) on firm financial performance and the moderating role of cash, this study conducts regression analysis using the median of the geopolitical risk index (GPRMEDIAN). The results are presented in Table 3. The coefficient of GPRMEDIAN is -3.782 with a p-value of 0.018, indicating a statistically significant negative effect on ROA at the 5% level.

The interaction term between GPRMEDIAN and net change in cash (CASH) has a coefficient of 0.107 with a p-value of 0.019, suggesting a positive and significant moderating effect on ROA at the 5% level. Similarly, the interaction between GPRMEDIAN and cash from operations (OPS) has a coefficient of 0.0552 with a p-value of 0.000, indicating a positive and highly significant effect on ROA at the 1% level.

In contrast, the interaction terms of GPRMEDIAN with cash from investing (INVS) and cash from financing (FIN) have negative coefficients of -0.0573 ($p = 0.002$) and -0.0541 ($p = 0.025$), respectively, indicating statistically significant negative effects on ROA at the 5% level. These results confirm that while net cash holdings and operating cash flows help mitigate the adverse impact of geopolitical risk, cash from investing and financing do not provide such a buffer.

4.3.2 Changing The Sample Period

Several significant geopolitical risk events occurred in Indonesia prior to and around 2007, largely due to increased terrorist activities. Notable incidents include the Christmas Eve church bombings across 11 churches in major cities on December 24, 2000; the Bali Bombing I in Kuta on October 12, 2002; the JW Marriott Hotel bombing in Jakarta on August 5, 2003; the Australian Embassy bombing in Jakarta on September 9, 2004; the Bali Bombing II in Kuta on October 1, 2005; and multiple bomb explosions in Poso, Central Sulawesi, on July 29, 2007. In light of these events, this study uses data from 2007 onwards as part of the robustness test

Table 3: GPRMEDIAN

	(1) ROA	(2) ROA	(3) ROA	(4) ROA	(5) ROA
GPRMEDIAN	-6.992*** (0.000)	-7.548*** (0.000)	-9.982*** (0.000)	-9.043*** (0.000)	-8.042*** (0.000)
TATO	5.309*** (0.000)	5.349*** (0.000)	5.351*** (0.000)	5.399*** (0.000)	5.375*** (0.000)
FATO	-0.00952** (0.028)	-0.00910** (0.034)	-0.00809* (0.057)	-0.00960** (0.026)	-0.00911** (0.034)
ARTO	0.00762*** (0.003)	0.00774*** (0.003)	0.00727*** (0.004)	0.00780*** (0.002)	0.00742*** (0.004)
INTO	0.00904*** (0.000)	0.00826*** (0.000)	0.00851*** (0.000)	0.00916*** (0.000)	0.00800*** (0.000)
GPM	0.233*** (0.000)	0.233*** (0.000)	0.225*** (0.000)	0.234*** (0.000)	0.235*** (0.000)
NIM	0.0451***	0.0455***	0.0458***	0.0458***	0.0461***

EIXP	(0.000) 0.0249***	(0.000) 0.0247***	(0.000) 0.0226***	(0.000) 0.0245***	(0.000) 0.0240***
CURR	(0.000) 0.0119	(0.000) 0.00633	(0.000) 0.0231	(0.000) 0.0167	(0.000) 0.0174
DER	(0.589) -0.000498*	(0.773) -0.000427	(0.286) -0.000224	(0.447) -0.000364	(0.428) -0.000402
FOREXCHG	(0.084) 0.204**	(0.138) 0.209**	(0.431) 0.312***	(0.209) 0.209**	(0.163) 0.265***
INFLATION	(0.023) 5.414***	(0.026) 5.542***	(0.001) 6.558***	(0.026) 5.516***	(0.005) 5.643***
GPRMEDIANxCASH	(0.000)	(0.000) 0.0875***	(0.000)	(0.000)	(0.000)
CASH		(0.009) -0.000467			
GPRMEDIANxOPS		(0.804)	0.0693*** (0.000)		
OPS			0.00427*** (0.000)		
GPRMEDIANxINVS				-0.0474*** (0.005)	
INVS				0.000767 (0.372)	
GPRMEDIANxFIN					-0.0577*** (0.007)
FIN					-0.000648 (0.513)
_cons	-7.038*** (0.000)	-7.043*** (0.000)	-7.112*** (0.000)	-7.134*** (0.000)	-7.124*** (0.000)
Firm Fixed Effect	Yes	Yes	Yes	Yes	Yes
<i>N</i>	6317	6275	6277	6262	6259
<i>R</i> ²	0.545	0.553	0.563	0.553	0.555

Source: Compustat, processed by authors p -values in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Change Sample Period and Excluding Macroeconomics

	Change Sample Period					Excluding Macroeconomics				
	(1) ROA	(2) ROA	(3) ROA	(4) ROA	(5) ROA	(6) ROA	(7) ROA	(8) ROA	(9) ROA	(10) ROA
GPRMEAN	-3.422*** (0.004)	-3.764*** (0.002)	-6.797*** (0.000)	-4.784*** (0.000)	-4.527*** (0.000)	-2.811** (0.014)	-3.139*** (0.006)	-4.794*** (0.000)	-4.170*** (0.001)	-3.862*** (0.001)
TATO	5.459*** (0.000)	5.509*** (0.000)	5.453*** (0.000)	5.587*** (0.000)	5.525*** (0.000)	5.333*** (0.000)	5.373*** (0.000)	5.376*** (0.000)	5.420*** (0.000)	5.391*** (0.000)
FATO	-0.00659 (0.118)	-0.00630 (0.134)	-0.00532 (0.200)	-0.00673 (0.109)	-0.00636 (0.130)	-0.00946** (0.031)	-0.00895** (0.040)	-0.00823* (0.057)	-0.00946** (0.030)	-0.00905** (0.037)
ARTO	0.00792*** (0.002)	0.00783*** (0.002)	0.00768*** (0.003)	0.00790*** (0.002)	0.00751*** (0.004)	0.00741*** (0.004)	0.00761*** (0.003)	0.00719*** (0.005)	0.00771*** (0.003)	0.00727*** (0.005)
INTO	0.00986*** (0.000)	0.00941*** (0.000)	0.00916*** (0.000)	0.0104*** (0.000)	0.00896*** (0.000)	0.00958*** (0.000)	0.00888*** (0.000)	0.00911*** (0.000)	0.00968*** (0.000)	0.00876*** (0.000)
GPM	0.237*** (0.000)	0.234*** (0.000)	0.226*** (0.000)	0.236*** (0.000)	0.237*** (0.000)	0.248*** (0.000)	0.248*** (0.000)	0.244*** (0.000)	0.249*** (0.000)	0.250*** (0.000)
NIM	0.0440*** (0.000)	0.0445*** (0.000)	0.0435*** (0.000)	0.0446*** (0.000)	0.0446*** (0.000)	0.0401*** (0.000)	0.0409*** (0.000)	0.0403*** (0.000)	0.0411*** (0.000)	0.0412*** (0.000)
EIXP	0.0237*** (0.000)	0.0235*** (0.000)	0.0222*** (0.000)	0.0233*** (0.000)	0.0231*** (0.000)	0.0236*** (0.000)	0.0233*** (0.000)	0.0214*** (0.000)	0.0232*** (0.000)	0.0227*** (0.000)
CURR	0.00760 (0.726)	0.00236 (0.913)	0.0154 (0.471)	0.0145 (0.502)	0.0126 (0.560)	0.00978 (0.660)	0.00415 (0.851)	0.0186 (0.398)	0.0139 (0.529)	0.0147 (0.509)
DER	0.000866*** (0.007)	-0.000774** (0.015)	-0.000625** (0.048)	-0.000705** (0.028)	-0.000762** (0.017)	0.0000613 (0.829)	0.000127 (0.657)	0.000384 (0.177)	0.000184 (0.521)	0.000161 (0.573)
FOREXCHG	0.901** (0.022)	0.910** (0.020)	0.508 (0.190)	0.862** (0.028)	0.839** (0.033)					
INFLATION	1.783 (0.226)	1.937 (0.187)	6.456*** (0.000)	1.769 (0.230)	2.455* (0.098)					
GPRMEANx CASH		0.0875** (0.0328)					0.0846** (0.0339)			
CASH		-0.000658 (0.721)					-0.000713 (0.708)			
GPRMEANx OPS			0.0488*** (0.000)					0.0462*** (0.000)		
OPS			0.00455*** (0.000)					0.00329*** (0.000)		
GPRMEANx INVS				-0.0383*** (0.006)					-0.0334** (0.021)	

INVS		0.000240 (0.789)					0.000958 (0.290)				
GPUMEAN _x		-0.0491*** (0.005)					-0.0476*** (0.008)				
FIN		0.000440 (0.662)					-0.000101 (0.922)				
_cons		-7.258*** (0.000)	-7.233*** (0.000)	-7.330*** (0.000)	-7.380*** (0.000)	-7.317*** (0.000)	-7.303*** (0.000)	-7.317*** (0.000)	-7.398*** (0.000)	-7.404*** (0.000)	-7.372*** (0.000)
Firm Effect	Fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
<i>N</i>		5918	5898	5900	5885	5884	6317	6275	6277	6262	6259
<i>R</i> ²		0.550	0.555	0.566	0.557	0.556	0.536	0.543	0.550	0.544	0.545

Source: Compustat, processed by authors *p-values in parentheses* **p* < 0.10, ***p* < 0.05, ****p* < 0.01

Columns (1) to (5) of Table 4 present the regression results using data from 2007 to 2023. The coefficient of GPRMEAN is -3.422 with a p-value of 0.004, indicating a statistically significant negative effect on ROA at the 5% level. The interaction term between GPRMEAN and net change in cash (CASH) has a coefficient of 0.0875 and a p-value of 0.0328, demonstrating a positive and significant effect on ROA at the 5% level. Similarly, the interaction between GPRMEAN and cash from operations (OPS) has a coefficient of 0.0488 with a p-value of 0.000, indicating a positive and highly significant impact on ROA. In contrast, the interaction terms of GPRMEAN with cash from investing (INVS) and cash from financing (FIN) have coefficients of -0.0383 ($p = 0.006$) and -0.0491 ($p = 0.005$), respectively, indicating significant negative effects on ROA. These results suggest that while net cash holdings and operating cash flows help mitigate the adverse impact of geopolitical risk, cash from investing and financing activities do not provide such a buffer.

4.3.3 Excluding Macroeconomics

Following Ou et al. (2023), this study also examines the robustness of the results by excluding the impact of macroeconomic factors on ROA, specifically removing the FOREXCHG and INFLATION variables. The results are presented in columns (6) to (10) of Table 4. The coefficient of GPRMEAN is -2.811 with a p-value of 0.014, indicating a negative effect on ROA that is significant at the 5% level. The interaction term between GPRMEAN and net change in cash (CASH) has a coefficient of 0.0846 and a p-value of 0.0339, showing a positive and significant effect on ROA at the 5% level. Similarly, the interaction between GPRMEAN and cash from operations (OPS) has a coefficient of 0.0462 with a p-value of 0.000, indicating a positive and highly significant effect on ROA at the 1% level. In contrast, the interaction terms of GPRMEAN with cash from investing (INVS) and cash from financing (FIN) have coefficients of -0.0334 ($p = 0.021$) and -0.0476 ($p = 0.008$), respectively, indicating statistically significant negative effects on ROA. These results confirm that net cash holdings and operating cash flows can mitigate the negative impact of geopolitical risk, whereas cash from investing and financing do not provide an effective buffer even after controlling for macroeconomic influences.

4.4 Endogeneity Issue

This study employs instrumental variables to address potential endogeneity issues arising from omitted variables. Following Ou et al. (2023), a two-stage least squares (2SLS) estimation is conducted, using the geopolitical risk (GPR) indices of Malaysia, the Philippines, Thailand, and Vietnam as instrumental variables. Each index is measured as the average of the twelve months of the fiscal year. These countries were selected because, along with Indonesia, they are members of the Association of Southeast Asian Nations (ASEAN) and share similar cultural and economic characteristics, as well as exposure to comparable geopolitical risks.

Table 5: First Stage Regression

Variables	First Stage (Dependent Variable: GPRMEAN)
GPRMYS	-0.165^{***} (0.000)
GPRPHIL	0.424^{***} (0.000)
GPRTHA	0.635^{***} (0.000)
GPRVNM	0.054^{***} (0.000)
Controls	Yes
Firm FE	Yes
Observations	6317
Within R ²	0.239
First-stage F-statistic	302.79^{***} (0.000)

Note: The dependent variable is GPRMEAN. Control variables include TATO, FATO, ARTO, INTO, GPM, NIM, EIXP, CURR, DER, FOREXCHG, and INFLATION. The first-stage F-statistic refers to the joint significance test of the excluded instruments (GPRMYS, GPRPHIL, GPRTHA, and GPRVNM). p-values are reported in parentheses. *

$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The results of the first-stage regression are presented in Table 5. The geopolitical risk indices of the neighboring ASEAN nations—namely Malaysia, the Philippines, Thailand, and Vietnam—serve as statistically significant predictors of Indonesia's geopolitical risk. Crucially, the excluded instruments exhibit joint significance, yielding a first-stage-statistic of 302.79 ($p < 0.001$). Because this value substantially surpasses the conventional rule-of-thumb threshold of 10, these diagnostics confirm that the selected instruments are highly relevant and robust against weak-instrument biases.

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Table 6 presents the 2SLS regression results. The coefficient of GPRMEAN is -12.95 with a p-value of 0.000, indicating a statistically significant negative effect on ROA at the 1% level. The interaction term between GPRMEAN and net change in cash (CASH) has a coefficient of 0.166 with a p-value of 0.009, showing a positive and significant moderating effect on ROA at the 1% level. Likewise, the interaction between GPRMEAN and cash from operations (OPS) has a coefficient of 0.104 with a p-value of 0.000, indicating a positive and highly significant impact on ROA at the 1% level.

In contrast, the interaction terms of GPRMEAN with cash from investing (INVS) and cash from financing (FIN) have coefficients of -0.0957 ($p = 0.001$) and -0.119 ($p = 0.000$), respectively, indicating statistically significant negative effects on ROA. These findings confirm that net cash holdings and operating cash flows effectively mitigate the negative impact of geopolitical risk, whereas cash from investing and financing do not serve as effective buffers even after addressing endogeneity.

Table 6: Instrumental Variable

	(1) ROA	(2) ROA	(3) ROA	(4) ROA	(5) ROA
GPRMEAN	-12.95*** (0.000)	-12.71*** (0.000)	-16.66*** (0.000)	-15.71*** (0.000)	-15.05*** (0.000)
TATO	3.498*** (0.000)	3.504*** (0.000)	3.485*** (0.000)	3.552*** (0.000)	3.459*** (0.000)
FATO	-0.0478*** (0.000)	-0.0475*** (0.000)	-0.0432*** (0.000)	-0.0471*** (0.000)	-0.0463*** (0.000)
ARTO	-0.00788*** (0.001)	-0.00773*** (0.002)	-0.00775*** (0.001)	-0.00776*** (0.002)	-0.00778*** (0.001)
INTO	-0.0000763 (0.964)	-0.000264 (0.874)	-0.00185 (0.266)	-0.000806 (0.635)	-0.000523 (0.753)
GPM	0.0928*** (0.000)	0.0917*** (0.000)	0.0855*** (0.000)	0.0902*** (0.000)	0.0901*** (0.000)
NIM	0.108*** (0.000)	0.108*** (0.000)	0.103*** (0.000)	0.108*** (0.000)	0.108*** (0.000)
EIXP	0.0432*** (0.000)	0.0429*** (0.000)	0.0401*** (0.000)	0.0430*** (0.000)	0.0407*** (0.000)
CURR	-0.152*** (0.000)	-0.157*** (0.000)	-0.103*** (0.000)	-0.128*** (0.000)	-0.134*** (0.000)
DER	0.000237 (0.529)	0.000257 (0.493)	0.000281 (0.446)	0.000280 (0.455)	0.000406 (0.288)
FOREXCHG	0.337*** (0.006)	0.326** (0.013)	0.369*** (0.004)	0.320** (0.013)	0.386*** (0.003)
INFLATION	9.441*** (0.000)	9.391*** (0.000)	9.846*** (0.000)	9.524*** (0.000)	9.622*** (0.000)
GPRMEANxCASH		0.166*** (0.009)			
CASH		0.00114 (0.709)			
GPRMEANxOPS			0.104*** (0.000)		
OPS			0.00305** (0.014)		
GPRMEANxINVS				-0.0957*** (0.001)	
INVS				0.000273 (0.848)	
GPRMEANxFIN					-0.119*** (0.000)
FIN					-0.00245 (0.127)
_cons	-0.634*** (0.007)	-0.650*** (0.007)	-0.656** (0.011)	-0.683** (0.010)	-0.474** (0.044)
Firm Fixed Effect	Yes	Yes	Yes	Yes	Yes
N	6317	6275	6277	6262	6259
R ²	0.431	0.436	0.459	0.436	0.443

Source: Compustat, processed by authors p -values in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4.5 Further Analysis

This study employs quantile regression as a supplementary analysis to examine whether the effects of net change in cash and operating cash flow vary across different levels of firm performance. Ordinary Least Squares (OLS) estimates the average conditional effect of explanatory variables and implicitly assumes that the relationship between liquidity and firm performance is homogeneous across firms. However, this assumption may be restrictive in the context of geopolitical risk, as firms differ substantially in their financial capacity, liquidity positions, and ability to utilize internal funds.

The capacity of operating cash flow and net changes in cash to buffer geopolitical uncertainty may exhibit considerable heterogeneity across the performance distribution. For instance, low-cash-flow firms likely prioritize available liquidity to sustain basic daily operations and satisfy immediate short-term obligations. Conversely, their high-cash-flow counterparts possess the requisite financial flexibility to strategically deploy liquidity toward innovation, structural operational adjustments, and emergent growth opportunities. Consequently, the mitigating efficacy of internal liquidity is expected to diverge substantially between low- and high-performing cash flow regimes.

Quantile regression allows the impact of operating cash flow and net change in cash to be estimated at different points of the firm performance distribution, thereby providing a more comprehensive understanding of whether liquidity buffers geopolitical risk uniformly or whether the effect is concentrated among specific groups of firms.

This study divides net change in cash (CASH) and cash from operations (OPS) into four quantiles: below 0.25, 0.25–0.5, 0.5–0.75, and above 0.75. These two variables were selected because, based on the statistical results, they are the only interaction variables that have demonstrated the ability to mitigate the detrimental impact of geopolitical risk (GPR) on ROA, unlike the other interaction variables.

Table 7: Quantile of Net Cash Holdings

	(1) <0.25	(2) 0.25 – 0.5	(3) 0.5 – 0.75	(4) >0.75
GPRMEANxCASH	-0.0565 (0.553)	-6.298 (0.500)	0.254 (0.940)	0.0844 (0.112)
GPRMEAN	-4.089 (0.182)	-12.65*** (0.003)	-10.03** (0.043)	-2.955 (0.346)
CASH	0.00637 (0.303)	-0.404 (0.495)	0.161 (0.418)	-0.00139 (0.667)
TATO	5.094*** (0.000)	5.137*** (0.000)	4.749*** (0.000)	6.251*** (0.000)
FATO	-0.0120 (0.338)	-0.0230** (0.030)	-0.0115 (0.263)	-0.0147 (0.150)
ARTO	0.0133** (0.010)	-0.00980 (0.195)	-0.00262 (0.723)	0.0153*** (0.003)
INTO	0.00419 (0.348)	0.00976 (0.157)	0.0203** (0.010)	0.00952** (0.021)
GPM	0.231*** (0.000)	0.211*** (0.000)	0.257*** (0.000)	0.244*** (0.000)
NIM	0.0360*** (0.000)	0.0580*** (0.000)	0.0310*** (0.005)	0.0517*** (0.000)
EIXP	0.0300*** (0.000)	0.0103** (0.044)	0.0280*** (0.000)	0.0227*** (0.000)
CURR	0.0535 (0.237)	0.107* (0.051)	-0.121* (0.081)	0.0634 (0.123)
DER	0.000431 (0.494)	0.000364 (0.598)	-0.00116* (0.082)	-0.000241 (0.714)
FOREXCHG	0.236 (0.201)	0.182 (0.469)	0.0617 (0.786)	-0.125 (0.503)
INFLATION	2.335** (0.026)	4.842*** (0.003)	8.766*** (0.000)	4.632*** (0.000)
_cons	-6.709*** (0.000)	-6.503*** (0.000)	-7.113*** (0.000)	-8.136*** (0.000)
Firm Fixed Effect	Yes	Yes	Yes	Yes
N	1699	1180	1476	1920
R ²	0.559	0.466	0.503	0.630

Source: Compustat, processed by authors p -values in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Columns (1) to (4) of Table 7 present the results of the quantile regression for the interaction between net change in cash (CASH) and GPR. The results show that this interaction variable is statistically insignificant across all quantiles, indicating that net cash holdings can mitigate the detrimental impact of GPR on ROA on average but not consistently at specific points of the distribution. This pattern suggests a threshold or nonlinear relationship, where only firms with exceptionally high levels of net cash holdings—likely in the extreme upper tail—can effectively buffer against geopolitical shocks. However, net cash holdings may not be an ideal variable for mitigating the impact of GPR because it aggregates cash from various sources, including cash from financing (debt) and cash from investing (asset sales), which may not be as directly linked to operational resilience during periods of geopolitical uncertainty.

Table 8: Quantile of Cash from Operation

	(1) <0.25	(2) 0.25 – 0.5	(3) 0.5 – 0.75	(4) >0.75
GPRMEANxOPS	-0.146 (0.553)	-3.061 (0.345)	-0.109 (0.791)	0.0268** (0.031)
GPRMEAN	-11.15*** (0.001)	-5.229 (0.268)	-4.934 (0.321)	-3.648 (0.159)
OPS	-0.00522 (0.723)	0.503** (0.012)	0.0605** (0.019)	0.00414*** (0.000)
TATO	3.058*** (0.000)	4.779*** (0.000)	5.819*** (0.000)	8.198*** (0.000)
FATO	0.0115 (0.101)	-0.00703 (0.431)	-0.0153 (0.180)	-0.0197* (0.089)
ARTO	0.0107 (0.102)	0.00203 (0.720)	-0.00539 (0.365)	0.0110*** (0.006)
INTO	-0.00218 (0.716)	0.0128** (0.028)	0.00406 (0.348)	0.00861** (0.010)
GPM	0.175*** (0.000)	0.162*** (0.000)	0.256*** (0.000)	0.240*** (0.000)
NIM	0.0261*** (0.000)	0.0386*** (0.000)	0.0431*** (0.000)	0.0524*** (0.000)
EIXP	0.0163*** (0.000)	0.0105** (0.014)	0.0283*** (0.000)	0.0156*** (0.000)
CURR	-0.0661 (0.123)	0.0463 (0.337)	0.0290 (0.577)	0.0917** (0.018)
DER	0.000491 (0.417)	-0.00164** (0.015)	0.000986* (0.083)	0.0000383 (0.943)
FOREXCHG	0.226 (0.216)	0.304 (0.195)	0.549*** (0.010)	0.278 (0.108)
INFLATION	4.717*** (0.001)	10.62*** (0.000)	7.940*** (0.000)	5.736*** (0.000)
_cons	-3.729*** (0.000)	-6.015*** (0.000)	-8.658*** (0.000)	-9.711*** (0.000)
Firm Fixed Effect	Yes	Yes	Yes	Yes
N	1270	1198	1746	2063
R ²	0.410	0.430	0.599	0.700

Source: Compustat, processed by authors p -values in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8 presents the results of the quantile regression for the interaction between cash from operations (OPS) and GPR. The results show that this interaction variable has a positive and statistically significant impact on ROA only at the highest quantile (above 0.75, column 4). This indicates that only firms with high levels of cash from operations can effectively mitigate the detrimental impact of geopolitical risk on financial performance. Cash from operations is derived from revenues minus all operating costs, reflecting the firm's ability to generate sufficient internal cash flow. A high level of operational cash indicates that the business is running efficiently and possesses adequate liquidity to cover operating costs and withstand uncertainty, even during periods of geopolitical instability.

The quantile regression estimates reveal that cash from operation (OPS) alleviates the adverse impacts of geopolitical risk exclusively within the highest performance distribution. This finding underscores the heterogeneous value of internally generated liquidity across different corporate strata. For firms situated in the lower quantiles, OPS is primarily absorbed by routine operations and immediate liquidity maintenance, leaving a marginal residual capacity to absorb geopolitical shocks. Conversely, upper-quantile firms possess superior financial flexibility, enabling them to strategically deploy surplus OPS toward operational adaptation, innovation, and proactive risk-management initiatives. Accordingly, it operates not merely as a passive liquidity buffer, but as a strategic asset that cultivates

resilience against macroeconomic disruptions. These insights directly align with the precautionary motive and pecking order theories, reinforcing the critical role of self-financing mechanisms during heightened uncertainty.

5. Conclusion and Recommendations

This study examined the impact of geopolitical risk (GPR) on firm financial performance and the role of cash flow and cash holdings in mitigating this impact. Using annual financial data of Indonesian firms from 1996 to 2023, the results demonstrate that GPR has a significant negative effect on firm financial performance. While net cash holdings can mitigate the impact of GPR at the highest quantile (above 0.75), they are not an ideal tool for managing geopolitical risk due to their composition, which includes cash from financing and investing. In contrast, cash from operating activities effectively mitigates the negative impact of GPR on firm performance, particularly at high levels, whereas cash from investing and cash from financing do not provide a significant buffer.

These findings have important implications for both corporate managers and policymakers. Chief Financial Officers (CFOs) should prioritize operational efficiency, cost control, and revenue stability, avoid aggressive or non-essential investments, and manage leverage prudently. Policymakers should anticipate potential sources of geopolitical risk, such as terrorism or regional conflicts, and consider providing incentives or tax breaks during periods of heightened uncertainty. Such measures can alleviate financial pressure on firms, particularly those directly affected by geopolitical disruptions.

The limitations of this study include its reliance on data from 1996 to 2023 and the use of a limited set of statistical methods. Future research could explore additional variables and alternative methodologies to better understand mechanisms that help firms mitigate the adverse effects of geopolitical risk on financial performance.

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Crises and Global Tourism: Economic, Accounting and Capital Market Dimensions

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ARTICLE INFO	ABSTRACT
Review Article	Purpose: The main aim of the study was to develop a tri-dimensional analytical framework classifying global crises into four typologies - Financial/Economic Crises, the COVID-19 Pandemic, Geopolitical Crises and Wars, and Terrorism - and to examine their differentiated impacts on global tourism across economic, accounting, and capital market dimensions.
Received 28/04/2026 Accepted 28/05/2026 <i>JEL Classifications</i> Z30, G01, M41, G15, L83	Design/methodology/approach: The study employs a structured narrative review methodology to synthesize diverse literature. The primary search was conducted across Scopus and Web of Science (1990–2025), utilizing representative Boolean search strings to identify quantitative, empirically-grounded studies on crisis impacts across the four typologies. To ensure transparency, inclusion and exclusion criteria were applied to filter the corpus, while a structured narrative synthesis was used to manage the methodological heterogeneity of the sources. The analysis integrates peer-reviewed empirical studies with published industry and intergovernmental reports to triangulate findings, ensuring both academic rigour and empirical grounding in verified sectoral data.
Keywords: Tourism finance, Crisis management, Financial crisis, COVID-19, Geopolitical risk, Terrorism, Stock market; RevPAR, Structured narrative review	Findings: The analysis found that all four crisis typologies generate negative demand shocks but differ fundamentally in speed, depth, spatial reach, and recovery trajectory. COVID-19 produced the most severe disruption, with international arrivals declining by 73% and hotel RevPAR collapsing by 84% in April 2020 - an impact 18 times greater than the GFC. Financial crises were found to operate through income and credit compression; pandemics through universal mobility disruption; geopolitical conflicts through asymmetric market displacement; and terrorism through psychological risk perception and reputational impairment. The study also identified four differentiated exit frameworks - Liquidity, Vaccine and Trust, Redirection, and Security and Communication - each calibrated to the specific mechanisms of the corresponding crisis typology.
	Research limitations/implications: The research relied on published literature, which may introduce publication bias toward statistically significant crisis effects. Cross-country aggregation of quantitative indicators obscures heterogeneity across destinations and firms. The overlapping boundaries between crisis typologies represent a classification limitation. Future research is encouraged to validate the proposed framework empirically using firm-level panel data across multiple crisis episodes.
	Originality/value: This study provides a structured tri-dimensional comparison. It contributes to theory by integrating crisis management with financial economics and accounting perspectives, contributing to an emerging dialogue between tourism management and financial economics that remains underdeveloped in the literature. At a practical level, the study offers tourism practitioners, policymakers, and researchers an operational, typology-specific policy guide that extends general recovery models into actionable crisis management frameworks.

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1. Introduction

Tourism's place in the global economy is marked by a remarkable paradox. While it is one of the most powerful economic sectors in the world, it remains extremely vulnerable to external forces that are impossible to control. Before the outbreak of the pandemic, the sector had developed into a huge economic engine, contributing around 10% of global GDP and generating export earnings of more than \$1.7 trillion, according to UNWTO data for 2019. In fact, this activity supported over 320 million jobs in a wide range of services, from hospitality and aviation to retail, catering and culture.

As Heraclitus noted, "everything flows", but the flow of tourists across borders is proving to be one of the most fragile economic constants. Over the past three decades, the global tourism industry has been challenged by a series of crises with radically different characteristics, starting with the terrorist attacks of September 11, 2001, and the SARS epidemic in 2003. This was followed by the global financial crisis of 2007-2009, the Arab Spring with its regional repercussions in 2011-2013, as well as the escalation of geopolitical conflicts in various regions of the world. More recently, the COVID-19 pandemic has dealt the sector an unprecedented blow. In 2020 alone, the number of international visitors fell by a dramatic 73%, a decline that has lasted for thirty years. Revenue losses reached \$1.1 trillion, while 62 million jobs were put at immediate risk, according to UNWTO (2021) data. Each of these events confirms the extreme vulnerability of tourism to what is defined in the literature as exogenous shocks (Ritchie, 2009; Duan et al., 2022).

These are sudden and unpredictable shocks that originate from the external environment of the tourism system and disrupt the data in a very short period. Despite the growing body of research on tourism crises, the academic literature still shows a significant gap, as most studies focus on specific events, treat them as stand-alone phenomena, and omit a systematic comparison of transmission mechanisms, accounting effects, or capital market responses. This picture is further complicated by the large methodological heterogeneity, with approaches ranging from event studies and panel VAR models to qualitative case analyses, which makes direct comparison of results difficult and leads to a fragmented knowledge base. In particular, while Duan et al. (2022) systematically map the effects of the crisis at the macroeconomic and microeconomic levels, their framework does not extend to accounting effects at the firm level or capital market responses. Similarly, Ritchie and Jiang (2019) in their review of 142 studies on risk and disaster management focus mainly on the operational and strategic dimensions of recovery, leaving financial reporting and the implications for investors largely unexamined. Studies of individual crises, such as the global financial crisis (Smeral, 2010), the COVID-19 pandemic (UNWTO, 2021) or terrorism (Walters et al., 2019), provide depth within a typology, but prevent a cross-typological comparison of transmission mechanisms and recovery profiles.

This article attempts to fill this gap by developing a comprehensive, three-dimensional comparative framework. This framework is defined as the simultaneous analysis of the effects of the crisis in three distinct, but empirically interrelated dimensions: (a) macroeconomic variables that capture demand shocks to tourist arrivals and revenues; (b) company-level accounting measures that document the deterioration of balance sheets, compression of revenue per available room (RevPAR) and asset values according to IFRS; and (c) capital market indicators that capture investor reactions through changes in stock market values, capital expenditures (CapEx) and financial indicators of systemic risk.

To implement this framework, four crisis typologies are defined: financial/economic crises, the COVID-19 pandemic, geopolitical crises/wars and terrorism. The study is based on Ritchie's (2009) crisis management model and synthesizes a broad set of empirical and institutional data from international organizations, such as UNWTO, OECD, IMF, IATA and the World Economic Forum, to examine three central research questions:

RQ1: How do the four crisis typologies differ in their mechanisms of transmission to tourism demand and financial performance?

RQ2: What is the typology-specific accounting and capital market effects at the firm and sectoral levels?

RQ3: What differentiated exit strategy frameworks are most effective for each crisis typology?

This study contributes to the literature in three ways. First, it provides a structured, three-dimensional comparative analysis of the four main typologies of crises in global tourism. This allows for a direct assessment of macroeconomic, accounting, and financial impacts within a single framework, a synthesis that is not available in existing studies that tend to be unidimensional or focus on a single typology. Second, it links crisis management theory (Ritchie, 2009; Coombs, 2007) with financial economics perspectives (Mishkin, 1992; Smeral, 2010; O'Neill and Mattila, 2006). In doing so, it enhances the emerging dialogue between tourism management and finance. Third, it proposes specialized exit scenarios per crisis typology, thereby enriching the normative literature on tourism recovery beyond the general guidelines of Ritchie's (2009) prevention-response-recovery model.

The structure of the article is as follows: Section 2 presents the methodology, while Section 3 defines the conceptual and typological framework through a comprehensive comparative table. Sections 4 to 7 develop the analysis per typology (financial crises, COVID-19, geopolitical crises/wars and terrorism). Section 8 attempts a combined comparative analysis of all four categories. Finally, Section 9 proposes differentiated exit strategy scenarios, while Section 10 concludes the study with implications for research and policy.

2. Methodology

To map the complex landscape of global tourism crises, this study uses the methodology of structured narrative review. This approach is considered the most appropriate for the thematic scope of the research, as it allows for the combined analysis of different crisis types, analytical dimensions and scientific disciplines. Through this method, it is possible to identify broader comparative patterns that often remain invisible in individual case studies (Tranfield et al., 2003; Duan et al., 2022). The review was structured in four clear phases: targeted literature search, screening, relevance assessment and finally a structured narrative synthesis.

The choice of a structured narrative review over a standard systematic review (SLR) was dictated by specific methodological reasons. First, the nature of the research is deliberately broad and comparative, requiring a flexibility that is not consistent with the strictly limited research questions of the SLR protocols (Tranfield et al., 2003). Second, the search strategy was purposive rather than exhaustive, focusing on studies that provide quantified data on demand in tourism and capital markets (Duan et al., 2022). Furthermore, the significant methodological heterogeneity of the existing literature makes it impossible to apply uniform criteria for qualitative assessment. Finally, the synthesis of the results is organized thematically, following the example of established reviews with similar scope in the field (Ritchie and Jiang, 2019; Khardani and Schmude, 2024).

The search process was conducted in the main academic databases Scopus and Web of Science (WoS), which cover the leading journals in the fields of tourism, economics, finance and accounting. Following the international practice of structured narrative search, the strategy was based on a targeted search with Boolean operators (Duan et al., 2022). The search terms included combinations of terms such as “financial crisis” or “economic crisis” in conjunction with the terms “tourism” or “hospitality”, as well as specialized terms for the COVID-19 pandemic, geopolitical risks and terrorism. These terms were iteratively refined to isolate studies with strong empirical and quantitative evidence. As the main objective was a comparative synthesis rather than a complete bibliography, the final sample was determined based on strict inclusion criteria.

The selection process involved the systematic screening of 380 initial entries. After screening based on relevance to the three-dimensional analytical framework, the final list was reduced to 66 sources. Of these, 54 studies and institutional reports form the main part of the synthesis, while the remaining 12 provide the necessary theoretical background (organizational theory, market efficiency). The time period of the research (1990–2025) was deliberately chosen to combine fundamental crisis management theories with the most recent data from the post-pandemic period. To ensure a complete picture, benchmark data from international organizations such as UNWTO, OECD, IATA, IMF and World Economic Forum were also integrated.

Each source was subjected to a three-point assessment. The required inclusion criteria: (a) direct relevance to the selected crisis typologies, (b) publication in reputable journals (Scopus/WoS), and (c) provision of quantifiable empirical evidence. In contrast, purely theoretical works, studies that focused exclusively on natural disasters, and data before 1990 - the year that symbolizes the beginning of modern, globalized tourism flows - were excluded.

In the next phase, we moved to a structured narrative synthesis (Duan et al., 2022). The choice of this method allowed us to classify the results around our analytical model, using comparison tables that make the evaluation clearer (benchmarking). The biggest advantage here is that the methodological specificity of each study is not offset, but its informative richness is maintained. We integrated a wide range of tools into the analysis: from heterogeneous Bayesian panel VARs (Papagianni et al., 2024) and connectivity studies (Gunay et al., 2025) to event studies (Kolaric and Schiereck, 2016; Yousaf et al., 2022). We have also examined more specialized approaches, such as fractional integration of time series (Gil-Alana and Poza, 2020), quantile regressions (Lee and Chen, 2022), Markov regime switching models (Lin and Falk, 2021), and qualitative case analyses (Goodrich, 2002; Araña and León, 2008).

This diversity of data is examined through three different perspectives:

- The macroeconomic dimension focuses on demand management by national authorities.
- The accounting dimension focuses on financial reporting (IFRS/GAAP) for management and auditors.
- The capital markets dimension monitors systemic risks for analysts and supervisors.

Finally, some methodological limitations must be explicitly mentioned. Reliance on published literature can lead to publication bias in favor of statistically significant results. Furthermore, the aggregation of data from different geographic regions can obscure idiosyncratic responses of specific destinations or companies. The boundaries between crisis typologies also remain fluid. For example, a geopolitical conflict can trigger economic pressures through energy prices, while a pandemic can cause both geopolitical tensions and supply chain disruptions. Such multidimensional episodes contain a complexity that a strict typological framework cannot fully capture.

3. Typology of Crises: Definitions, Characteristics and Comparative Framework

The conceptual foundation for this article's typological framework rests on established definitions from both crisis management theory and financial economics. According to Ritchie (2009) and Coombs (2007), a crisis is 'an event that threatens to harm human development, damage organizations, and lead to negative outcomes.' In the tourism context, the distinguishing features of a crisis are sudden shock, disruption of travel flows, uncertainty of demand, and acute difficulty in restoring destination reputation (Ritchie, 2009). Complementing this perspective, Mishkin (1992) defines

a financial crisis more narrowly as 'a deterioration in the ability of financial markets to allocate funds efficiently', a definition that captures the supply-side financial impairment mechanism that is central to the GFC typology but largely absent in terrorism or geopolitical crises. From a financial economics perspective, our analytical model is based on three strong theoretical traditions. First, Kindleberger's (1978) model of financial transmission is used to explain how crises spread systemically through networks of credit and market confidence. In parallel, the efficient market hypothesis (Fama, 1970) serves as a reference point for the analysis of abnormal returns. On this basis, the stock market reactions to the four crisis typologies, as recorded in event studies, are assessed. Finally, the framework is complemented by agency theory (Jensen and Meckling, 1976). This approach is essential for understanding management decisions in hotels and airlines regarding accounting difficulties, especially when these are made under the weight of asymmetric information and extreme demand uncertainty. Together, these definitions establish that different crisis typologies operate through fundamentally distinct primary mechanisms: financial impairment, mobility disruption, political conflict, and psychological insecurity respectively.

Table 1 summarizes the four typologies of crises across five comparative dimensions: causal origin, geographic scope, speed of onset, depth of impact, and recovery horizon. This approach provides a structured basis for the differentiated analysis that follows, revealing patterns of sharp contrasts and subtle nuances that directly affect management strategies and policymaking.

The causal origin dimension categorizes crises based on their fundamental generative mechanism. Financial crises arise endogenously from systemic dysfunctions in the banking and credit system, such as the accumulation of toxic assets and the collapse of liquidity. The lack of confidence initially spreads to financial markets before reaching the real economy as a demand contraction (Mishkin, 1992). In contrast, the pandemic is a purely exogenous biological event, the origins of which lie entirely outside economic systems, rendering preventive economic policies before the outbreak virtually powerless.

Geopolitical crises and wars stem from the breakdown of political and diplomatic order, driven by state strategic calculations and military escalation. Although these forces are exogenous to the tourism system, their impact is transmitted primarily through changes in the costs and sense of security of travel. Finally, terrorism represents a distinct category of intentional violence, where the main mechanism of influence on tourism is primarily psychological rather than material. It operates by cultivating uncertainty and changing risk perceptions, rather than by physically destroying the hospitality infrastructure (Walters et al., 2019; Goodrich, 2002).

Geopolitical crises are primarily regional in their initial scope, centred on the conflict theatre and its immediate neighbours, though their secondary effects, energy cost escalation, aviation route disruptions, capital market uncertainty, and market displacement flows, can ripple globally, as the Russia–Ukraine war demonstrated from 2022 onwards. Terrorism is typically local or at most regional in its direct impact, with the destination-level shock geographically concentrated around the affected site, even as global airline networks experience indirect systemic effects following high-profile attacks such as 9/11.

The third and fourth dimensions, event speed and depth of crisis, capture the temporal dynamics and magnitude of the initial shock respectively, and together constitute the core of the typological framework's analytical power. The most important contrast is between COVID-19, characterised by sudden onset and extreme depth, and the GFC, characterised by gradual onset and high but not catastrophic global depth. The pandemic produced a simultaneous, complete shutdown of both tourism supply and demand within a matter of weeks, a scenario without historical precedent in modern tourism that generated impacts 18 times greater in terms of arrival declines than the GFC's worst year (see Table 3). The GFC, by contrast, compressed demand through income reduction and credit tightening over a period of months, providing some opportunity for business adaptation and partial demand management. Terrorism shares the sudden, high-velocity onset of pandemic-type shocks but is vastly more limited in global depth, precisely because its geographic concentration prevents systemic market failure at the aggregate level, even as the impact at the destination level can be severe and prolonged. Geopolitical crises can exhibit either gradual escalation or sudden outbreak depending on the specific episode, with depth that is typically moderate to high but subject to significant variance depending on the scale and geographic reach of the conflict.

The fifth dimension, recovery time, shows an ordering that broadly, but not perfectly, corresponds to crisis depth: COVID-19 requires the longest recovery horizon (3–5 years, with global arrivals returning to 2019 levels only in 2024 according to WEF, 2024), followed by geopolitical crises (1–3 years, with important variation across affected and unaffected destinations), financial crises (12–18 months for demand-side indicators, though balance-sheet recovery for heavily leveraged firms extends considerably longer), and terrorism (6–18 months at the global level). However, this apparent ordering obscures an important asymmetry specific to geopolitical crises: 'recovery' in that typology is differentially distributed, with displacement-beneficiary destinations recovering immediately while conflict-adjacent destinations endure prolonged losses (Araña and León, 2008; Önder and Mucuk, 2019). For terrorism, global-level recovery occurs faster than destination-level recovery, where reputational damage and altered traveller risk perceptions can persist well beyond the headline recovery window (Walters et al., 2019).

Table 1: Comparative Typology of Crises in Tourism

Typology	Cause	Geographical Scope	Event Speed	Depth of Crisis	Recovery Time
Financial (GFC)	Systemic banking risk	Global	Gradual (months)	High	12–18 months
Pandemic (COVID-19)	Biological factor	Global	Sudden (weeks)	Extremely high	3–5 years
Geopolitics / War	Political conflict	Regional / Global	Gradual to sudden	Medium–High	1–3 years
Terrorism	Human violence	Local / Regional	Sudden (minutes)	Medium	6–18 months

4. Financial Crises and Tourism: The GFC 2007–2009 as a Model

The Global Financial Crisis (GFC), which began with the collapse of the subprime mortgage market in the US in 2007 and culminated in the bankruptcy of Lehman Brothers on September 15, 2008, is the most significant economic crisis since World War II. The analysis reveals a transmission mechanism operating through three interrelated channels that progressively compressed demand for tourism: the income channel, through which declining household wealth and rising unemployment reduced discretionary spending on travel; the credit channel, through which tighter economic conditions increased costs and reduced the availability of financing for both tourism businesses and consumer credit for holiday spending; and the business travel channel, through which corporate cost-cutting programs reduced conference, incentive and executive travel, a high-margin segment for hotels and airlines (Papatheodorou et al., 2010).

The macroeconomic impact of the COVID-19 pandemic on global tourism, although severe, was significantly more limited than the subsequent shock of the pandemic. International arrivals fell by 4% worldwide in 2009, the first annual decline in two decades, with tourism receipts recording a 6% contraction (UNWTO, 2009). Greece experienced a more pronounced adjustment, as the country's sovereign debt crisis exacerbated the global recession: arrivals fell from around 16 million in 2008 to 14.9 million in 2009, a decrease of 6.7%, while the crisis in the domestic tourism sector continued for 15 consecutive months, with the sector returning to 2007 arrival levels only in 2013 (Papatheodorou and Arvanitis, 2014; Pegkas, 2022). Globally, the recovery trajectory followed a “V-shape” at an aggregate level, with total arrivals recovering by +7% in 2012 and exceeding pre-crisis levels by 2013. Table 2 summarizes the key economic and accounting indicators for the GFC period, documenting the trajectory from peak to trough and subsequent recovery.

A pattern that stands in sharp contrast to the protracted, piecemeal recovery seen after the pandemic. At a company-level accounting level, the Global Financial Crisis (GFC) triggered a series of balance sheet deteriorations across the hospitality and aviation value chain. Revenue per available room (RevPAR) for European hotels fell by an average of 18.5% in 2009, reflecting the combined impact of declining occupancy and compressed average daily rates (ADR) as operators competed for a shrinking demand pool (O'Neill and Mattila, 2006). EBITDA margins (Earnings Before Interest, Taxes, Depreciation and Amortisation) deteriorated by 23–30% across the hotel sector, causing widespread defaults on credit facilities that had been structured on pre-crisis revenue assumptions, particularly for highly leveraged portfolio acquisitions undertaken during the peak of the 2005–2007 period.

Table 2 examines Greece as a typical destination case alongside global figures. Its selection was not accidental: its pre-existing public debt burden makes it an excellent example of how a country's structural weaknesses can act as “multipliers” of global demand shocks. However, it should be noted that sector averages often “hide” large internal variations. For example, limited-service hotels have proven to be much more resilient in terms of RevPAR compared to luxury accommodations. This is explained by the fact that the upper segment caters to corporate clients and high-income tourism – two segments that have been severely “frozen” as businesses have reduced travel costs and wealthy consumers have shifted their luxury spending (Singh and Dev, 2015). Similarly, while global data point to a rapid V-shaped recovery around 2012–2013 (Smeral, 2010), local data contradict this simplistic narrative. As Papatheodorou and Arvanitis (2014) document, it took Greece until 2015 to see the numbers of 2007 again. This fact shows that the speed with which a destination recovers is inextricably linked to its internal problems, such as debt and fiscal austerity, which general global indicators tend to ignore.

The impact of the GFC on the capital market was equally dramatic. The S&P 500 Travel and Leisure Index fell 52% from its peak in May 2007 to its trough in March 2009, broadly comparable to the 55% decline in the overall market, but with a faster and more aggressive recovery profile thereafter (Smeral, 2010). Airline stocks (as tracked by IATA indices) underperformed even this depressed sector average, falling by 60–70% as the revenue collapse combined with pre-existing structural vulnerabilities, high fixed costs, fuel price exposure, and labour inflexibility, to compress operating margins to near-zero or negative levels. Capital expenditure by hospitality companies was severely curtailed as a result: global investment in new hotel construction was reduced by approximately 40% between 2008 and 2010, with projects either deferred or abandoned as credit became unavailable and debt service pressures crowded outgrowth spending (DesJardine et al., 2019).

Table 2: Economic and Accounting Impacts of the 2007–2009 GFC on Tourism

Indicator	2007 (Base)	2008	2009	Recovery (2012)
International Arrivals (billion)	0.92	0.92	0.88 (−4%)	1.04 (+18%)
Tourism Receipts (\$trillion)	\$1.08	\$1.09	\$1.03 (−6%)	\$1.12
Average RevPAR Europe (€)	€85	€82	€69 (−18.5%)	€78
Arrivals Greece (million)	16.2	15.9	14.9 (−6.3%)	15.5
IATA Airline Revenue (\$trillion)	\$0.47	\$0.51	\$0.42 (−17%)	\$0.60
S&P Travel & Leisure Index	1.00	0.72	0.48 (−52%)	0.88
Hotel Property Prices (index)	100	90	72 (−28%)	81

Three patterns emerge from Table 2. First, the impact on RevPAR (−18.5%) was significantly out of proportion than the decline in arrivals (−4%), reflecting the pricing pressure operators faced as they competed for a contracted demand pool. Second, Greece’s steeper arrival decline (−6.3% vs −4% globally) illustrates how pre-existing structural vulnerabilities amplify global shocks at the destination level. Third, the recovery column confirms the V-shape trajectory at aggregate level, though as noted above, this masks substantial destination-level and firm-level heterogeneity in recovery speed.

5. The COVID-19 Pandemic: The Greatest Shock in the History of Tourism

Unlike the global financial crisis, the COVID-19 pandemic has dealt a fundamentally different and historically unprecedented blow, causing simultaneous and global disruptions to both supply and demand in the global tourism market. This difference is not only quantitative, but also qualitative, as no demand management tool, price adjustment or marketing strategy could have saved tourism flows when 217 countries had already imposed strict travel restrictions by the end of March 2020 (UNWTO, 2020).

The mechanism of cascading effects of the pandemic has developed at a rapid pace. Since the emergence of the virus in late 2019, its global spread has been achieved through the same international flight networks that are freezing tourism. By March 2020, when the WHO officially declared a pandemic, IATA recorded the withdrawal of more than 80% of international commercial air traffic, leading to an almost total and simultaneous closure of borders. The figures that followed confirm the scale of the disruption: international arrivals fell by 73% in 2020, falling to 1990 levels in a single year. This is a decline 18 times greater than the worst period of the global financial crisis (UNWTO, 2021). With tourism revenues shrinking by \$1.1 trillion and 62 million jobs at risk, a sector that accounted for 10% of global GDP was brought to a virtual standstill in a matter of weeks. The scale of this disruption, relative to the GFC, is quantified across key dimensions in Table 3.

This ratio is derived from a comparison of peak annual arrival declines: −4% in 2009 (UNWTO, 2009) against −73% in 2020 (UNWTO, 2021) and should be interpreted as an indicator of relative demand shock magnitude rather than a precise econometric estimate. The ratio is sensitive to the choice of base year and crisis window: comparing cumulative multi-year losses rather than single worst-year figures would yield a different but complementary picture of relative severity. With this caveat in mind, the 18× figure remains a useful order-of-magnitude indicator of the structural discontinuity between the two typologies.

Table 3: Comparative Impacts of GFC vs COVID-19 on Global Tourism

Indicator	GFC 2009 (worst year)	COVID-19 2020 (worst year)	Intensity Ratio
Drop in International Arrivals	−4%	−73%	18.25×
Fall in Tourist Receipts	−6%	−64% (−\$1.1 trillion)	10.7×
Jobs at Risk	6–8 million	62 million	~8–10×
Decline in RevPAR	−18.5%	−57% (annual), −84% (Apr.)	3–4.5×
Airline Revenue Drop	−17%	−65%	3.8×
Tourism Stock Index Drop	−52%	−65% (in 5 weeks)	Speed ×15+
State Support (EU)	Moderate	Huge (SURE, RRF)	Scale ×10+

Table 3 reveals that the COVID-19 shock differed from the GFC not only in magnitude but in kind. The arrivals column confirms the 18× ratio discussed above, but the labour market row is equally instructive: 62 million jobs at risk represents 8–10 times the GFC exposure, disproportionate even to the arrival decline ratio, reflecting the structural difference between a demand-side compression and a full operational shutdown that eliminates labour utilisation regardless of capacity. The state support row reveals a further policy discontinuity: the unprecedented fiscal interventions deployed during COVID-19 (SURE, RRF, national furlough schemes) confirm that the pandemic required a fundamentally different policy paradigm rather than an amplified version of existing crisis response toolkits. The speed and capital market dimensions of the shock are examined in detail below.

On an accounting level, the impact of the pandemic has created situations for which existing financial reporting frameworks have no precedent. RevPAR for US hotels collapsed from \$90 in January 2020 to \$14.5 in April of the same year. This 84% decline in a single quarter transformed the industry's most important revenue metric from a performance evaluation tool into an indicator that now reflects almost zero operational activity (O'Neill and Mattila, 2006; UNWTO, 2021).

It should be noted that this RevPAR trough of \$14.5 reflects the US national lodging market aggregate at its most acute phase (UNWTO, 2021); cross-sectional variation was substantial. Resort and leisure properties in drive-to destinations recovered considerably faster than urban and airport hotels dependent on business and international travel, a heterogeneity that aggregate RevPAR figures obscure but that carried significant implications for asset valuation and impairment testing at the individual property level.

A critical observation regarding the accounting dimension is the escalation of Impairment Risk during the pandemic. Under IAS 36, the requirement for impairment testing became particularly challenging as the lockdowns rendered future cash flow estimations highly speculative. While the 2008 Financial Crisis primarily affected asset values through credit tightening and market devaluations, the COVID-19 era introduced an unprecedented level of uncertainty in Discounted Cash Flow (DCF) models. This forced many hospitality and tourism entities to recognize significant impairment losses on goodwill and long-lived assets, reflecting the total disruption of their income-generating capacity compared to the more gradual impact observed in previous economic downturns.

Major chains reported unprecedented losses: Marriott International recorded a Q1 2020 loss of \$267 million, against a profit of \$331 million in the same period of 2019, a \$598 million swing in a single quarter attributable almost entirely to the pandemic demand collapse. Across the airline industry, passenger revenue fell by an estimated \$118.5 billion in 2020 (IATA, 2021), with the 7-day moving average of global flights remaining approximately 42% below pre-pandemic levels even at year-end. At the balance sheet level, the pandemic forced a series of accounting adjustments with no recent precedent: airlines reclassified significant portions of their fleets as non-current assets with impaired carrying values, conducting write-off tests that in some cases reduced aircraft valuations by 20–30%; hotel chains reviewed and, in many cases, impaired the carrying values of goodwill attached to franchise brands in severely affected markets; and governments developed emergency accounting frameworks such as the Greek 'Refundable Advance' programme, that did not exist prior to the crisis. The European Commission's Joint Research Centre estimated that between 6.6 and 11.7 million EU tourism jobs were directly at risk from the pandemic shock, underscoring that the accounting crisis at the firm level translated directly into a social crisis at scale (Rodriguez-Anton et al., 2020).

The capital market response to the pandemic was both rapid and severe. The MSCI Hotels & Cruises index declined by approximately 65% within the first five weeks of 2020, a pace of deterioration without precedent in modern financial markets (Yousaf et al., 2022). Airline stocks fell by 65–72% over the same period, compressing operating margins well below zero as revenue collapsed while fixed costs (aircraft leases, labour contracts, maintenance obligations) remained largely inflexible. Event study evidence from 65 countries confirms that the severity of stock market declines was positively associated with the stringency of lockdown measures (Lee and Chen, 2022). Critically, however, the subsequent partial recovery of tourism equities in 2021 must be interpreted with caution: Yousaf et al. (2022) note that extraordinary monetary policy interventions (including near-zero interest rates and central bank asset purchase programmes) inflated asset valuations broadly, potentially decoupling financial market performance from the underlying demand fundamentals of the sector. This disconnect implies that capital market indicators may overstate the pace of genuine operational recovery in the immediate post-pandemic period.

6. Geopolitical Crises and Wars: The Asymmetric Threat to Tourism

Geopolitical crises and armed conflicts represent a category of tourism shocks with fundamental differences from the economic or health typologies previously examined. Their main feature is the strong asymmetry that governs them, since while war zones face a dramatic, often total, collapse of inbound tourism, competing destinations tend to benefit significantly from the relocation of travel flows to safer areas.

The study by Papagianni et al. (2024), which applied a Bayesian Heterogeneous Panel VAR model to 14 emerging economies, confirms that geopolitical shocks have severe and medium-term negative impacts on tourism flows. In this context, the Russian invasion of Ukraine in February 2022 represented the most significant geopolitical crisis in Europe since World War II and provides a real-time analysis of how geopolitical risks are transmitted to tourism through different channels.

The direct demand channel has led to the sudden disappearance of Russian and Ukrainian travellers, who accounted for about 12% of arrivals in popular Mediterranean resorts, leading to serious revenue shortfalls in markets such as Greece, Turkey and Cyprus (Papagianni et al., 2024). At the same time, the energy channel has transmitted the crisis through a sharp increase in prices, with the price of jet fuel reaching \$175 per barrel in the summer of 2022 (Gunay et al., 2025; IATA, 2022). This development has increased the operating costs of airlines by 40–60%, squeezing profit margins that were just recovering from the pandemic. In addition, the network restructuring channel has brought additional burdens due to the closure of Russian airspace, which has forced European airlines to take detours that have increased the time and cost of flights to Asia by 20–40%. This change has disproportionately affected companies such as Finnair, whose strategic advantage has traditionally been based on the use of the Russian corridor (Finnair Oyj, 2023).

The cross-country evidence, however, reveals important heterogeneity that the Russia–Ukraine case study alone cannot capture. Papagianni et al. (2024), analysing 14 emerging economies, find that geopolitical shocks generate severe medium-term contractions in tourism demand, but Caldara and Iacoviello (2022) demonstrate that the magnitude of these effects varies substantially with structural country characteristics, particularly energy import dependence and trade openness. Countries with diversified energy supply and lower dependence on conflict-zone source markets absorb geopolitical shocks considerably faster than those structurally exposed to affected trade routes. This implies that the 1–3-year recovery horizon cited in the typological framework should be treated as a central estimate around which substantial variance exists, rather than a fixed recovery trajectory.

Finally, the assessment of these crises by the capital market follows the same asymmetric pattern, as airlines directly exposed to the affected routes show unusually negative returns of -8% after the announcement of hostilities. Conversely, tourism companies in competitive and safe destinations can show positive returns, as investors value the phenomenon of tourist displacement directly to them (Kolaric and Schiereck, 2016).

7. Terrorism and Tourism: The Psychological Multiplier Phenomenon

Terrorism is the most psychologically specific category of the four crisis typologies examined, as the way it affects tourism is radically different from the others. While financial crises affect incomes, pandemics affect mobility, and geopolitical conflicts affect costs and territories, the main mechanism of terrorism is the manipulation of perceived risk. Through deliberate and projected violence, the aim is to spread fear, which creates a paradoxical relationship between real infrastructure and demand. A destination can remain functionally intact but suffer an overall decline in visitors simply because the subjective sense of safety of travellers has changed.

Understanding this mechanism is crucial for developing communication strategies and interpreting economic data. Goodrich (2002) laid the groundwork for this analysis after September 11, 2001, and found that the reluctance of travellers to visit the United States lasted for three full years. Although the physical capacity of air traffic was fully restored within a few months, traffic did not return to crisis levels until July 2004. Subsequently, Araña and León (2008) showed that the reduction in demand, which typically ranges from 6% to 30% of arrivals, depends not so much on the extent of the attack as on the intensity of media coverage and how it changes global perceptions of risk.

An important methodological caveat applies here. Araña and León (2008) find that demand reductions attributable to terrorism depend more on the intensity of media coverage than on the objective severity of the attack, a finding with significant implications for cross-study comparability. Studies that use different proxies for media exposure, or that measure impact over different time windows, may generate systematically divergent impact estimates even for the same event. The wide range of reported arrival declines, from 6% to 30% across studies, likely reflects this methodological heterogeneity at least as much as genuine variation in attack severity or destination vulnerability.

A notable recent example is the attacks in Barcelona in August 2017. Although the city's infrastructure was intact, air traffic was significantly reduced in the following months, costing Spain hundreds of millions of euros in tourism revenue. At the same time, Portugal and Greece, which were considered safer alternatives, recorded measurable gains from the displacement phenomenon. This confirms that terrorism, just like geopolitical crises, creates “winners and losers” on the global tourism map by redistributing flows based on perceptions of security.

From an accounting perspective, terrorism creates a distinct impact profile that focuses on intangible assets rather than the physical or financial assets affected by other types of crises. Destination goodwill (the accumulated reputational capital of a tourism brand) is an off-balance sheet resource that decisively determines the valuation of hotel franchise agreements, travel agency contracts and airline rights, but does not appear as a recognized asset under IFRS or national GAAP. Large chains with franchise networks in the affected markets, AccorHotels after the Paris attacks (2015), IHG after the London bombings (2005), have undertaken IFRS 3 impairment reviews and revisions to the guidance on future EBITDA that formalized reputational damage as a recognized accounting cost. Furthermore, the country risk premium used in discounted cash flow (DCF) valuations of hotel properties increases after attacks, reducing the estimated present value of future cash flows and triggering further asset write-downs, particularly for properties in markets where risk perceptions remain high for prolonged periods. Third, business interruption insurance provisions are re-evaluated and travel insurance products are restructured to cover terrorism risk, creating additional escalation in insurance costs for operators in affected markets.

The effects of terrorism on the capital market are characterized by three distinctive features that collectively differentiate this typology from all others: extreme speed of onset, high initial magnitude, and relatively rapid partial recovery. Following the September 11 attacks, the S&P 500 fell 14.3% in the first five trading days after the market opened on September 17, 2001. Airline stocks, particularly American Airlines and United Airlines, whose aircraft were used in the attacks, plunged 40–50% in the first week of trading, reflecting both the immediate impact on revenues and an extreme repricing of aviation demand risk. Hotel stocks in unaffected markets and cruise lines recovered relatively faster than airlines, as the substitution of land-based vacations for air travel partially offset the losses in hospitality demand. Unlike the Global Financial Crisis and the pandemic, where stock market declines were sustained by ongoing fundamental deterioration, terrorism-related declines tend to exhibit faster mean reversion as the destination's natural recovery becomes apparent and behavioural adjustment reduces initial fear responses. Research by Walters et al. (2019) finds, however, that this apparent rapid recovery in aggregate indicators masks a persistent micro-level effect: terrorism systematically reduces travellers' willingness to pay and increases risk aversion

over extended periods of time, suppressing the quality-adjusted demand levels that determine long-term profitability, even when key arrivals figures return to pre-attack levels. Table 4 documents the stock market and RevPAR impacts of the five most significant terrorist events of the past two decades, illustrating both the initial shock magnitude and the destination-specific recovery horizons.

Table 4: Stock Market Impacts of Major Terrorist Events on Tourism

Event	Date	Airline Index Drop	RevPAR Impact	Recovery Time
9/11 USA	Sept. 2001	−40% to −50%	−15 to −25%	3–4 years
Bombing of Madrid	March 2004	−8% to −12% (Spain)	−10%	12 months
London bombing	Jul. 2005	−5% to −8% (UK)	−12% (London)	6–9 months
Paris / Brussels	2015–2016	−6% to −10% (France/Belgium)	−18 to −22%	12–18 months
Barcelona	Aug. 2017	−4% to −6% (Spain)	−8 to −12%	8–12 months

Table 4 reveals two patterns that aggregate terrorism impact assessments typically obscure. First, airline stock declines were systematically larger and more prolonged than RevPAR impacts, reflecting the network-wide demand repricing that follows high-profile attacks even for routes unconnected to the affected destination. Second, recovery time correlates inversely with attack scale at the global level but not necessarily at the destination level; Barcelona recovered faster in aggregate indicators than Madrid or Paris, yet destination-level reputational effects persisted beyond the headline recovery window in all cases.

8. Comparative Analysis: Four Typologies, One Integrated Framework

The comparison of the four types of crises through the prism of macroeconomics, accounting and the capital market, reveals a series of structural findings that form the core of our research. The analysis presented in Table 5 essentially implements the theoretical framework of Table 1, converting the theoretical distinctions into specific quantitative data, which are divided into nine different dimensions of performance.

A methodological note on the quantitative ranges presented in Table 5 is warranted. The figures represent central estimates derived from the reviewed literature and institutional sources; the ranges reflect genuine cross-study and cross-destination variation rather than measurement error. Direct numerical comparison across typologies should be treated with caution, as the underlying studies differ in geographic scope, time window, and measurement methodology, factors that limit the precision of cross-typology ratio calculations such as the 18× arrival decline comparison between COVID-19 and the GFC. The figures in Table 5 are accordingly intended to indicate orders of magnitude and directional differences rather than precise equivalences and should be read in conjunction with the destination-level and firm-level caveats documented in Sections 4–7.

The relationship between the speed, depth and width of each crisis forms four completely different profiles. In this context, the COVID-19 pandemic occupies a rather unique position, as it is the only case that combines global scope and sudden occurrence with extreme depth and an extremely slow recovery process, simultaneously affecting all three dimensions of our analysis. This combination of factors, which is often described in the literature as a "complete shutdown of the market", explains why the decline in total demand 18 times was greater compared to the global financial crisis – a ratio that is not found in any other case.

On the other hand, the global financial crisis was clearly deeper and more systemic than terrorism or geopolitical crises, but its evolution was slower, allowing market participants to adapt at least partially. Again, terrorism, while characterized by tremendous speed and depth at the local level, has a limited geographical extent and leads to a relatively quick recovery if we look at it on a global scale. Finally, geopolitical crises, depending on the situation, can escalate either gradually or abruptly, leaving behind moderate to severe chronic effects, which, however, present large discrepancies between destinations due to the phenomenon of the displacement of travellers.

Table 5: Comparative Characteristics of Four Crisis Typologies - Economic, Accounting and Capital Market Dimensions

Dimension	Financial Crisis	COVID-19	Geopolitical Crisis	Terrorism
Main Mechanism	Income / Credit	Mobility / Fear	Cost / Market Loss	Fear / Reputation
Change in Arrivals	-4% to -8%	-73%	-10% to -30%	-6% to -30% (local)
RevPAR Impact	-18% to -25%	-57% to -84%	-8% to -20%	-10% to -22%
Airline Stock Drop	-40% to -60%	-65% to -72%	-8% to -15%	-5% to -50%
EBITDA Impact	-25% to -35%	Negative (absolute)	-10% to -25%	-5% to -20% (local)
Impairment Risk	Medium-High	Very High	Moderate	Low-Medium
Arrivals Recovery	12-18 months	3-5 years	12-36 months	6-18 months
Displacement Effect	Small	Non-existent	Important	Important
State Intervention	Regulatory / Fiscal	Massive (fiscal)	Geopolitical	Security

A close reading of Table 5 reveals clear patterns that characterize each type of crisis. The series on ****Main transmission mechanisms**** shows us the channel through which each crisis "hits" tourism: financial crises suppress income and credit, the COVID-19 pandemic imposes restrictions on movement and causes fear, geopolitical crises increase costs and lead to lost markets, while terrorism is based on fear and damage to the reputation of the destination. These differences are not just theoretical, as they determine which management tools are effective. For example, the provision of liquidity in economic crises, health protocols in pandemics, market diversification in geopolitics and correct communication in terrorism help.

The series on ****Changes in arrivals**** shows with absolute clarity the extent of the damage to overall demand. The differences are substantial: from the globally synchronized but modest -4% to -8% of economic crises, we arrive at the devastating -73% of the pandemic. Therefore, the series for the ****RevPAR**** indicator shows that, while all types of crises reduce hotel revenues, they do so in different ways. The drop of -57% to -84% due to COVID-19 meant the complete disappearance of customers, while the drop of -18% to -25% during the 2008 financial crisis was mainly due to the reduction of prices (ADR), as hotels competed fiercely for a limited clientele.

But perhaps the most important distinction for destination strategy lies in the series of ****displacement phenomena****. Only geopolitical crises and terrorism divert tourists from the affected destination to its competitors. COVID-19 was the only exception, as it did not cause displacement: all destinations were "lost" at the same time and none benefited from the collapse of the others. This happened because the pandemic simultaneously closed the supply worldwide, eliminating the possibility of replacing one destination with another.

For destination management organisations (DMOs), this distinction carries important practical implications. A geopolitical or terrorist crisis at a competitor represents a real market opportunity that requires immediate investment to attract displaced flows. In contrast, a global pandemic offers no such opportunities, as the problem is universal.

9. Crisis Exit Scenarios: Differentiated Frameworks by Typology

The analytical framework developed in previous sections converges on a single practical conclusion: the crisis exit strategy cannot be one-size-fits-all. Each crisis typology requires a distinct "policy color" – a differentiated mix of instruments, institutions, stakeholders and time horizons calibrated to the specific mechanisms through which the typology disrupts tourism flows and degrades economic performance. The provision of liquidity and fiscal stimulus tools appropriate for economic crisis recovery would be of no use against the geopolitical root causes of a Russia-Ukraine-style conflict. Ritchie's (2009) three-phase model of prevention, response and recovery provides the fundamental structure, but its broad guidelines require substantial typological specialization to create operational policy guidance. Pricing flexibility through aggressive ADR management, combined with value-for-money positioning, recaptured price-sensitive leisure segments during the income-constrained recovery phase. Greece's return to 2007 arrival levels only in 2013–2015 demonstrates that even well-designed sectoral recovery measures cannot fully overcome the binding constraint of general economic performance and consumer confidence.

For pandemic recovery, the fundamental constraint, the absence of a medical solution to cross-border transmission risk, defined a clear sequencing of recovery tools. The EU Digital COVID Certificate, deployed in June 2021, demonstrated that technology-enabled health credentialing can serve as an effective 'trust signal' enabling international travel even before disease elimination, and that the summer 2021 European tourism season's partial recovery (particularly in Greece, Italy, and Spain) was meaningfully attributable to this specific policy tool. Holland et al.'s (2021) NIESR modelling confirms the global economic cost of vaccine distribution inequity: failure to achieve equitable access would have reduced global trade by approximately 0.8% compared to the baseline, with a corresponding 12–18-month delay in tourism recovery illustrating that tourism recovery policy extends well beyond the tourism sector itself into global public health governance. Beyond vaccination, pandemic exit required

differentiated strategies by segment: the luxury travel segment recovered earliest (2021), benefiting from the wealth effects of asset price inflation and the pent-up demand of high-income consumers; mass market leisure recovered through 2022–2023 as vaccination coverage expanded and travel confidence grew; MICE (Meetings, Incentives, Conferences and Events) tourism recovered last, reaching near-2019 levels only in 2023–2024 as corporate travel policies adapted to post-pandemic hybrid work norms. Globally, total international arrivals returned to 2019 levels only in 2024, confirming COVID-19's status as a 3–5-year recovery typology (WEF, 2024).

Geopolitical crisis recovery requires a strategic reorientation from restoration to redirection an acknowledgement that the specific market flows disrupted by conflict cannot be quickly restored and that sustainable recovery depends on their systematic replacement by alternative markets. Greece's 2022–2023 response to the Russia–Ukraine war provides the most instructive recent case study: the collapse of Russian and Ukrainian tourist flows was partially replaced through aggressive marketing campaigns targeting the US, Middle Eastern, and Indian markets, with US arrivals increasing by 42% in 2022, a redirection that required investment in new distribution channels, travel agent relationships, and targeted digital marketing campaigns.

Investments in energy efficiency have proven to be significant for the resilience of the industry. Hotels and tourism businesses that planned to invest in renewable energy sources (RES) before the conflict saw their costs increase by 15–20% less than their fossil fuel-based competitors. This confirms that investments in structural resilience, when made in calm times, create a meaningful advantage in the face of geopolitical shocks. At the same time, airlines have managed to compensate for some of the capacity lost due to the closure of Russian airspace by developing new routes and rerouting their flights to alternative markets to maintain connectivity.

When it comes to recovering from terrorist attacks, the most critical factor is the speed of response, with communication management as a key tool. According to the World Economic Forum (2016), destinations that respond with fast, transparent and honest communication with travellers and partners recover 30–40% faster than those that follow a slow or overly corporate and defensive approach — a finding directionally consistent with the academic literature on destination crisis communication (Ritchie and Jiang, 2019), though precise quantification of recovery speed differentials remains methodologically challenging given the absence of controlled comparison cases. Campaigns such as “Bonjour Paris” and “Visit Barcelona” are examples of this approach, as they have managed to convey a message of resilience, reassure the public about security and give travellers practical incentives not to cancel their reservations.

In addition, the visible reinforcement of security measures - such as increased police presence in tourist areas and better crowd management - acts as a reassurance signal that can mitigate the psychological uncertainty caused by terrorism and moderate travellers' perception of residual attack risk. The development of specialized terrorism insurance products also helps in this direction, strengthening the confidence of travellers even in high-risk environments.

Finally, cooperation between competing destinations can prove extremely fruitful. For example, joint campaigns in the Mediterranean region, jointly promoting Greece, Spain, Italy and Portugal as safe alternatives, can transform the individual advantage of tourist displacement into a general regional strategy that benefits all participating countries. Table 6 provides a consolidated comparative policy guide, mapping each crisis typology to its primary exit scenario, operational tools, recovery horizon, and documented pilot case.

Table 6: Crisis Exit Scenarios Comparative Policy Guide

Typology	Main Exit Scenario	Basic Tools	Horizon	Success Pilot
Financial Crisis	"Liquidity"	VAT relief, credit guarantees, promotion	12–18 months	Greece 2012–2014, USA 2010–2011
COVID-19	"Vaccine & Trust"	Digital certificate, domestic tourism, luxury-first	3–4 years	EU Digital Certificate 2021
Geopolitics	"Redirection"	Market diversification, RES, safe haven image	1–2 years	Greece/EU 2022–2023
Terrorism	"Security & Communication"	Visible security, rapid comms, campaigns	6–12 months	Paris 2016, Barcelona 2017

The comparative reading of Table 6 underscores a central finding of this study: no single recovery instrument is effective across typologies. Liquidity provision, the primary tool for financial crisis recovery, is irrelevant against pandemic-era border closures; communication campaigns, central to terrorism recovery, have no fiscal analogue in economic crises. The horizon column further illustrates that recovery speed is not simply a function of shock severity: terrorism, despite its acute initial impact, generates the shortest recovery horizon at the global level, while the pandemic, despite massive state intervention, required the longest.

10. Conclusions: Towards a Resilient Tourism Economy

This study developed a three-dimensional framework for the analysis of four types of crises, demonstrating that the general term “tourism crisis” does not capture the substantial differences observed in causality and recovery mechanisms. In the context of the first research question (RQ1), it was found that the transmission of shocks follows radically different paths. In particular, financial crises act through a slowly escalating compression of disposable income, while pandemics cause an immediate and universal disruption of mobility that requires a multi-year recovery period. At the same time, geopolitical conflicts cause an asymmetric shift of flows towards safer destinations, while terrorism operates mainly psychologically, making reputation management more important than the restoration of physical infrastructure.

Regarding the second research question (RQ2), the pandemic was the only crisis that caused absolute EBITDA losses, thus differing from the simple compression of profit margins that characterize financial crises. The risk of asset value deterioration reached its peak during COVID-19, while the decline in capital markets was more severe than in any other historical economic cycle. Furthermore, it was found that, although the speed of recovery is usually inversely proportional to the intensity of the shock, this rule was broken in the case of the pandemic, due to the structural damage suffered by airlines and companies' balance sheets.

Analysing RQ3, effective recovery requires accurate diagnosis before measures are implemented. The “Liquidity Scenario” for economic crises is powerless against travel restrictions, while the “Communication Scenario” for terrorism has no fiscal analogue in other types of crises. Geopolitical turmoil requires the “Redirection Scenario”, which aims for long-term energy and purchasing diversification.

The theoretical contribution of the research is threefold: it offers a structured tri-dimensional comparison of crises, contributing to an emerging dialogue between crisis management and financial economics, and transforms general prevention models into specialized policy guides. At a practical level, authorities should develop differentiated action protocols and businesses should incorporate pandemic and geopolitical risks into stress-testing models. Despite the limitations of using aggregated data, the study confirms the resilience of tourism. Its future survival, however, depends on the quality of institutional frameworks and the robustness of balance sheets against the next crisis, which is already being prepared beyond the current horizon of visibility.

The aggregate patterns documented across the four typologies should, however, be interpreted with caution: as demonstrated in Sections 4–7, recovery trajectories and impact magnitudes vary substantially across regions, market segments, and firm types. Limited-service hotels showed greater resilience than luxury properties during financial crises; resort destinations recovered faster than urban hotels during the pandemic; and geopolitical shocks produced winners and losers simultaneously depending on proximity to conflict zones. Future research is encouraged to validate the proposed framework empirically at the destination and firm level, disaggregating the aggregate indicators into market-specific analyses.

Notwithstanding these limitations, the tri-dimensional framework developed in this study offers a theoretically grounded and practically applicable lens through which policymakers, financial analysts, and tourism managers can anticipate, diagnose, and respond to the next crisis — whatever typology it may take.

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The Effect of Organizational Learning on Internationalization: An Empirical Study of Taiwan Semiconductor Industry

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ARTICLE INFO	ABSTRACT
<i>Article History</i> Received 28 May 2026 Accepted 30 September 2026 <i>JEL Classifications</i> D83, M16, L29 Keywords: Explorative learning, Absorptive capacity, Internationalization, organizational learning	Purpose: This study investigates the relationship between organizational learning and internationalization within Taiwan's semiconductor industry. Specifically, it addresses two main objectives: first, examining the relationship between an explorative learning orientation and the degree of internationalization; and second, analyzing the role of absorptive capacity in mediating the impact of organizational learning on internationalization in this sector. Design/methodology/approach: This study focuses on Taiwanese semiconductor companies, with a total of 129 public listed semiconductor firms included in the sample. This study uses financial and patent data to measure variables such as explorative learning orientation, absorptive capacity and internationalization. The study collected financial data from the Taiwan Economic Journal which has complete data of public listed firms in Taiwan and patent data from USPTO (United States Patent and Trademark Office). Findings: The empirical results of this article demonstrate that explorative learning orientation has a positive influence on a firm's degree of internationalization. In addition to that, absorptive capacity plays the role of mediator on the relationship between exploration orientation and internationalization. Research limitations/implications: The extent of a firm's internationalization is certainly not only determined by its level of exploration orientation alone. Other factors such as integration of knowledge (Casillas et al., 2009) or dynamic capabilities (Prange & Verdier, 2011) also may exert some kind of influences on a firm's internationalization. Future researchers can examine the impacts of these factors and compare their separate effects on internationalization. Originality/value: Theoretically, our mediation findings point to the possibility that it may not be so much the exploration orientation itself that matters for the degree of internationalization but rather the underlying absorptive capacity mediation. If the underlying mechanism is such that exploration orientation has a positive impact on absorptive capacity which, in turn, is a key driver of internationalization, this means that the insufficiency of exploration orientation could potentially be transcended by building firm's absorptive capacity. We believe that this is the important contribution to the growing body of literature on organizational learning and internationalization.

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1. Introduction

In an era of intensified global competition, firms—regardless of size—can no longer operate under the assumption that they remain insulated within their domestic markets. The inherently global nature of contemporary innovation is well exemplified by the rise of emerging-market enterprises, such as Indian firms integrating into global production networks (Krishna et al., 2012). To address these competitive pressures, firms are increasingly expanding their operational domains through foreign market entry and export activities; internationalization has thus shifted from a strategic choice to an imperative. Consequently, internationalization occupies a pivotal position in corporate strategy, with its strategic relevance poised to grow as global market integration deepens. Nevertheless, cross-border

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expansion presents substantial challenges. Successful internationalization requires firms to bridge the 'knowledge gap' (Petersen, Pedersen, & Lyles, 2008) between their existing capabilities and the requirements of foreign markets. This endeavor demands substantial resource commitment to organizational learning and knowledge accumulation. Knowledge and learning capabilities therefore serve as core drivers of internationalization, particularly for high-technology firms navigating volatile and turbulent market environments.

As such, in the internationalization process, learning and knowledge are ascribed vital roles as maintained by the process theory of internationalization (Johanson & Vahlne, 1977, 1990). As Autio, Sapienza, & Almedia (2000, p. 910) also indicate: "Knowledge and learning can be expected to have an impact on international growth in that internationalizing firms must apprehend, share, and assimilate new knowledge in order to compete and grow in markets in which they have little or no previous experience". Thus, for firms to operate in foreign markets it is necessary to learn knowledge from external environment, market or technological. The problem is what kind of knowledge is useful for firms engaging in the internationalization process. It is related not only to how effective their knowledge is learned but also related to the environment they face. Simply put, when a firm decides to internationalize it firstly has to make sure what knowledge it lacks. While prior studies address direct learning-internationalization links, they often treat the underlying knowledge integration as a 'black box.' Absorptive capacity operates as the essential internal mechanism.

For a high-tech firm to operate in an environment as complex as foreign markets, explorative learning seems to be a more effective learning strategy to enhance its absorptive capacity to cope with the complexity of foreign markets. Thus, in this paper we argue that a firm's internationalization process has to do with its level of absorptive capacity which is determined partly by its exploration orientation. Taiwanese semiconductor sector—an environment characterized by high-velocity innovation, severe technological turbulence, and a strong international orientation. In such a dynamic context, path-dependent experiential accumulation (exploitative learning) is insufficient for firms to mitigate international market uncertainties. Instead, sustained overseas expansion hinges critically on explorative, boundary-spanning knowledge acquisition coupled with robust internal R&D absorptive capabilities.

There is a large stream of literature studying the effects of knowledge and learning on internationalization (Autio et al., 2000; Brennan & Garvey, 2009; Casillas, Moreno, Acedo, Gallego, & Ramos, 2009; Eriksson, Johanson, Majkgard, & Sharma, 1997; Eriksson, Majkgard, & Sharma, 2000; Fletcher & Harris, 2012; Forsgren, 2002; Hsu & Pereira, 2008; Johanson & Vahlne, 1977, 1990, 2003, 2006, 2009; Kogut, & Zander, 1993; Petersen, Pedersen, & Sharma, 2003; Petersen et al., 2008; Prange & Verdier, 2011). For example, the study of Casillas et al. (2009, p. 320) "considers the internationalization process to be a learning process per se". This paper aims to contribute to this new stream of literature by analyzing the role of explorative learning orientation and absorptive capacity in the internationalization of firms in Taiwan semiconductor industry. There are two purposes in this paper: first, we analyze the relationship between explorative learning orientation and the extent of internationalization; second, what role absorptive capacity plays in the effect of organizational learning on the internationalization process.

The paper is structured as follows: after theoretically analyzing how exploration orientation and absorptive capacity influence the development of internationalization, a number of hypotheses and an explanatory model are presented. We test these hypotheses using financial data and patent data and then discuss the empirical results. Finally, we conclude with a discussion of the results, limitations, managerial implications and suggestions for further research.

2. Theoretical Background and Hypotheses

This section delineates the core theoretical constructs and examines the relationships among them, as depicted in the conceptual framework (Figure 1). First, we introduce the concept of exploration orientation, originally proposed by Sidhu, Volberda, and Commandeur (2004) to capture an organization's propensity to engage in explorative learning. While their operationalization focuses on external *information* acquisition, this study adapts the construct to emphasize external *knowledge* acquisition. Second, we incorporate absorptive capacity, which serves as a foundational platform for future learning. Specifically, the proposed framework posits that exploration orientation exerts a direct positive effect on firm internationalization, while this relationship is concurrently mediated by the level of absorptive capacity.

Our explanatory framework necessarily provokes some doubt – why explorative learning and not exploitative learning? As we indicate in the following section, explorative and exploitative learning are both crucial to an organization. It is not possible to put an emphasis on one by ignoring another. The statement of Prange & Verdier (2011, p.127, emphasis added) helps us explain it: "The internationalization process depicts the path a firm decides to follow in order to seize worldwide opportunities. This typically takes place in a rather exploratory, testing and probing way by exploiting home advantages and transferring them abroad". This statement answers the above doubt and fits perfectly well with the reasoning behind our explanatory framework since our explanatory framework demonstrates that the degree of internationalization depends on the extent of explorative learning orientation and absorptive capacity. As we will explicate in the latter section stating absorptive capacity, the other reason why we do not include exploitative learning in our framework is that exploitation is one component of absorptive capacity (Zahra & George, 2002) which has been incorporated in our framework.

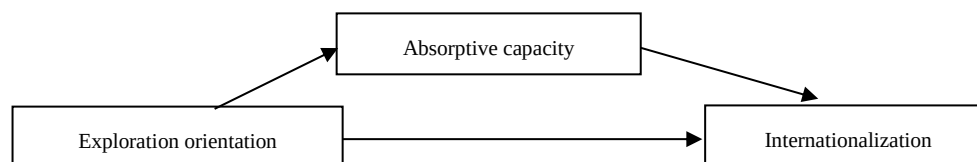


Figure 1: Research Framework

2.1. Exploration Orientation

Organizational learning involves two related dynamics of exploration and exploitation (March, 1991). The former refers to “learning gained through processes of concerted variation, planned experimentation, and play” whereas the latter refers to “learning gained via local search, experiential refinement, and selection and reuse of existing routines” (Baum, Li, & Usher, 2000, p. 768). March (1991, p. 85) also makes a distinction between the two different ways of learning and indicates that “the essence of exploitation is the refinement and extension of existing competencies, technologies, and paradigms ... The essence of exploration is experimentation with new alternatives”. From the viewpoint of organizations, both exploitation and exploration are deemed critical for their survival and prosperity because organizational “adaption requires both exploitation and exploration to achieve persistent success” (March, 1991, p. 205) and “exploitation and exploration are crucial both to the stable ongoing operations of organizations and to organizational change” (Holmqvist, 2004, p. 70).

The main difference between explorative and exploitative learning pertains to how new learning takes place. To the former, learning primarily occurs along an entirely different trajectory with old knowledge while learning in the latter goes along the same old trajectory. Based on this difference, we define exploration orientation as ‘the tendency of a firm to acquire external new knowledge from explorative learning’. Although we make this definition in reference to Sidhu et al. (2004) it is obviously inconsistent with their definition. Their definition is interpreted in terms of external information acquisition. However, they do not deny that “exploration ... is also an important way about pursuit of knowledge, experimentation and risk-taking” (Sidhu et al., 2004, p.917, emphasis added). Not only that, they also state that they “leave it to future work to ascertain whether an operational measure of exploration should be expanded to also explicitly include knowledge, experimentation and risk-taking items” (p.918). Hence, our definition seems to be not only appropriate but also expand their definition.

2.2. Absorptive Capacity

For organizational learning to be effective, it is necessary for a firm to have some level of absorptive capacity (Cohen & Levinthal, 1990). Absorptive capacity refers to “the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends” (Cohen & Levinthal, 1990, p. 128). Since absorptive capacity can “reinforce, complement, or refocus the firm’s knowledge base” (Lane, Koka, & Pathak, 2006, p.833), it is critical for a firm to develop and maintain its absorptive capacity to ensure its long-term survival.

The notion of absorptive capacity is first proposed by Cohen & Levinthal (1989, 1990) and latter extended and refined by Zahra & George (2002), Lane et al. (2006) and Todorova & Durisin (2007). The original concept of absorptive capacity proposed by Cohen & Levinthal (1990) has indicated its multidimensional nature involving “three basic capacities in relation to new knowledge: (a) recognition of its value; (b) its assimilation; and (c) its application for commercial ends” (Vega-Jurado, Gutierrez-Gracia, & Fernandez-de-Lucio, 2008, p. 393). The latter refinement of Zahra & George (2002) has expanded this concept into four dimensions grouped under two categories – potential absorptive capacity (including the two dimensions of knowledge acquisition and assimilation) and realized absorptive capacity (including the two dimensions of knowledge transformation and exploitation). Knowledge acquisition denotes “a firm’s capability to identify and acquire externally generated knowledge that is critical to its operations”. Assimilation refers to “the firm’s routines and processes that allow it to analyze, process, interpret, and understanding the information obtained from external sources”. Knowledge transformation refers to “a firm’s capability to develop and refine the routines that facilitate combining existing knowledge and the newly acquired and assimilated knowledge”. Finally, exploitation denotes an organizational capability that “is based on the routines that allow firms to refine, extend, and leverage existing competencies or to create new ones by incorporating acquired and transformed knowledge into its operations” (Zahra & George, 2002, p. 189-190).

Van den Bosch, Volberda, & de Boer (1999) suggest that the implicit feedback loop of Cohen & Levinthal, i.e. absorptive capacity facilitates learning and this in turn leads to new absorptive capacity, is mediated by the environment with which a firm needs to tackle to survive and prosper. In the context of this study, we consider the internationalization as an important environmental background that a firm faces when it tries to expand its domain of operations abroad. Environmental turbulence is often divided into technological turbulence and market turbulence (Droge, Calantone, & Harmancioglu, 2008). Technological turbulence refers to the rate of technological change (Lichtenthaler & Ernst, 2007) whereas market turbulence is related to the uncertainty of a firm’s markets (Helfat, Finkelstein, Mitchell, Peteraf, Singh, Teece, & Winter, 2007). The corresponding knowledge needed to tackle with market turbulence is market knowledge whereas the corresponding knowledge for technological turbulence is technological knowledge. In this study, we focus on the acquisition of external technological knowledge to face the

challenge of technological turbulence since what we investigate is the high-tech firms in Taiwan semiconductor industry. Therefore, it is justified to focus on technological knowledge in that the importance of technological knowledge is far greater than that of market knowledge.

2.3. Exploration Orientation and Internationalization

The study of Autio et al. (2000) also indicates that knowledge and learning are important determinants in internationalization process especially for firms in high-tech industries. Their study finds that the greater the firm's knowledge intensity, the more rapidly they grew internationalization. This means that the more a firm explores external knowledge the stronger its knowledge intensity which leads to rapid internationalization. When expanding internationally, firms inevitably confront the liability of foreignness and heightened environmental turbulence. In such settings, relying solely on path-dependent routines is insufficient; instead, explorative learning becomes decisive in enabling firms to overcome unfamiliar institutional and technological barriers and identify novel opportunities abroad.

On the other hand, Lichtenthaler (2009, p. 822) indicates that "the benefits from learning strongly depend on the degree of environmental turbulence" with exploitative learning having positive effects in stable environments and negative effects under dynamic environments whereas explorative learning having negative effects in stable environments and positive effects under dynamic environments. The study of Jansen, Van den Bosch, & Volberda (2006) also demonstrates the same conclusion.

Foreign markets are often environments characterized by more turbulence than domestic markets. When a firm internationalizes it must acquire totally new knowledge. Facing the challenge of environmental turbulence in foreign markets, firms have to commit most of their resources to explorative learning to take on completely new knowledge to engage in internationalization operations effectively. Thus, it is reasonable to argue that when operating in the turbulent environment such as foreign markets, explorative learning is more effective than exploitative learning. In other words, higher exploration learning orientation can lead to greater extent of internationalization. We therefore propose the following hypothesis:

H1: The stronger the exploration orientation a firm demonstrates the greater the degree of its internationalization

2.4. Absorptive Capacity as A Mediator on the Relationship between Exploration Orientation and internationalization

Exploration learning orientation can be a powerful source of absorptive capacity. In the literature of absorptive capacity, it is assumed that prior, related knowledge constitutes the basis for an organization's latter knowledge accumulation. The implicit feedback loop of Cohen & Levinthal's absorptive capacity is that existing absorptive capacity constitutes the basis for learning and learning, whether explorative or exploitative, leads to the formation of new absorptive capacity. Thus, explorative learning constitutes the important antecedent of absorptive capacity.

Absorptive capacity has, in turn, been identified as a key driver of internationalization in previous literature (Peterson et al., 2008). For example, the study of Petersen et al. (2008, 1097, emphasis original) indicates that a firm's internationalization process is contingent upon the gap identified by the firm 'between the knowledge possessed and the knowledge needed' in foreign markets. They term this gap "perceived knowledge gap". Their study thus focuses on addressing the factors that close the perceived knowledge gap. One of the primary factors they think will reduce this perceived knowledge gap is the absorptive capacity of the firm. However, their empirical results show that the effect of absorptive capacity on reducing the perceived knowledge gap in foreign markets is not very significant. There occurs a countervailing effect of absorptive capacity. That is, absorptive capacity can have a greater narrowing effect on 'real knowledge gap' (Petersen, Pedersen, & Lyles, 2008, 1109, emphasis original) than on 'perceived knowledge gap'. In other words, the higher the level of absorptive capacity a firm possesses the narrower its real knowledge gap for internationalizing operations. Thus, absorptive capacity constitutes an important antecedent for internationalization.

Lichtenthaler (2009, p. 824) also indicates that "the impact of absorptive capacity may substantially differ according to the level of environmental turbulence". In greater turbulent environment, the impact of absorptive capacity is also greater. Thus, in an environment as turbulent as the foreign market, we can expect that absorptive capacity will result in greater effect. Furthermore, Cohen & Levinthal (1990, p. 149) maintain that the greater the firms endeavor to absorb new knowledge, the more effective latter retrieval will be. When a firm fails to enhance its level of absorptive capacity in the internationalization process, it is difficult for it to retrieve the knowledge it has explored, leading to the narrower degree of internationalization. Drawing on the knowledge-based view (KBV), we argue that external explorative learning impacts internationalization exclusively through absorptive capacity. External knowledge acquired via exploration does not automatically confer a cross-border competitive advantage; rather, it must be systematically assimilated, transformed, and integrated into the firm's proprietary knowledge architecture through its absorptive capacity. Consequently, explorative learning alone is insufficient to drive international market success, as its strategic value is realized only when channeled through internal absorptive capacity. This conceptualization substantiates a full mediation mechanism. Therefore, we propose the following hypothesis:

H2: The relationship between exploration orientation and the degree of its internationalization is positively mediated by the level of a firm's absorptive capacity.

3. Methodology

3.1. Data Collection

To minimize potential confounding size effects and circumvent the severe lack of financial transparency among private enterprises, this research restricts its target sample to publicly listed semiconductor firms in Taiwan. Over the 2009–2011 observation window, 129 listed semiconductor firms met the sampling criteria, forming a three-year balanced panel dataset. Corporate financial indicators were sourced from the Taiwan Economic Journal (TEJ), a reliable database encompassing all public firms in Taiwan, while patent data were gathered from the United States Patent and Trademark Office (USPTO).

3.2 Measurers

3.2.1 Independent Variable- Exploration Orientation

A patent is built on the basis of prior patents, which might be from the same technology field or from other technology fields. Experimental learning strategy is measured by the percentage of backward citation for the focal firm's field patents that belong to its non-competitors (Fang, Wang, & Lilien 2009). This study modified Fang et al. (2009) measure method. While a patent cites patents from the same technology field, then it could be the exploitation learning. On the contract, if a patent cite patent from other different technology fields, then this kind of learning is called exploration learning. And to be represented exploration learning orientation, this study utilizes the patent information which this study collected the citing information hidden behind patents from USPTO. More precisely, exploration learning orientation is measured by the percentage of backward citation for the focal firm's field patents that belong to other non-semiconductor industries.

3.2.2 Mediator Variable- Absorptive Capacity

Absorptive capacity measures the capability to acquire, assimilate, and exploit new knowledge (Petersen, B., Pedersen, T., & Lyles, M. A., 2008). The development of absorptive capacity is highly dependent on previous R&D investment realized by firms (Cohen & Levinthal, 1990). R&D expenditure often influences the performance of internationalized companies (Kotabe, Srinivasan, & Aulakh, 2002). This study follows the measure by R&D intensity (Brouthers, Nakos, Hadjimarcou, & Brouthers, 2009). Absorptive capacity is estimated by expenditure of R&D divided by sale revenue.

3.2.3 Dependent Variable- Internationalization

An internationalized firm captures market opportunities not only within its domestic market but also abroad. Brouthers, Nakos, Hadjimarcou, and Brouthers (2009) suggest that a firm's level of internationalization is more accurately captured by export intensity than by export performance. This study follows the precious researches (Contractor, Kundu, & Hsu, 2003; Brouthers & Nakos, 2005) that use exportation revenue as the percentage of total sale revenue to represent the level of internationalization.

4. Results

Table 1 presents the descriptive statistics and bivariate correlations for all key variables. The mean values for exploration orientation, absorptive capacity, and internationalization level are 51.93%, 12.29%, and 60.83%, respectively. While the standard deviations for exploration orientation and internationalization remain smaller than their respective means, absorptive capacity exhibits a standard deviation that exceeds its mean, indicating substantial variance across the sampled firms. In terms of correlations, the association between absorptive capacity and exploration orientation is moderate ($r = 0.2319$), which is higher than the correlations between exploration orientation and internationalization ($r = 0.1013$) and between absorptive capacity and internationalization ($r = 0.1214$).

This study performed regression analysis in order to assess the effects of exploration orientation and absorptive capacity on the level of internationalization; these are shown in Table 2. The empirical result supports the hypothesis (H1) and was statistically significant at the 0.05 level. The stronger the exploration orientation a firm demonstrates the greater the degree of its internationalization ($\beta = 6.103$). Another research finding indicates that the effect of exploration orientation on absorptive capacity ($\beta = 6.602$) exceeds that of absorptive capacity on internationalization ($\beta = 0.257$).

To assess whether there is a mediation effects through absorptive capacity in this study, empirical results of three regression analyses are shown in Table 2. Exploration orientation positively affects a firm's absorptive capacity, which was significant at the 0.01 level. Absorptive capacity also positively affects a firm's level of internationalization (significant at the 0.05 level). And further, this study investigates the effect of exploration orientation and absorptive capacity on the level of internationalization. The coefficient of exploration orientation ($\beta = 4.658$) decreased and lost its statistical significance, thus giving initial support to hypotheses H2. The relationship between exploration orientation

and the degree of its internationalization is positively and completely mediated by the level of a firm's absorptive capacity.

To address potential concerns regarding the sensitivity of our baseline findings and ensure the stability of the reported results, we perform a robustness check by employing an alternative measurement for our mediator, absorptive capacity. In our baseline specification, absorptive capacity is operationalized using R&D intensity. To ensure the robustness of our findings and following established literature in strategic management and international business (e.g., Cohen & Levinthal, 1990; Kotabe et al., 2002), we re-estimated the mediation model using R&D expenditure as an alternative proxy for absorptive capacity. The empirical results of this alternative specification are reported in Table 3. Crucially, the robust estimates remain highly consistent with our primary findings. Absorptive capacity continues to exert a full mediating effect on the relationship between exploration orientation and internationalization. Notably, the statistical significance of both the individual path coefficients and the overall model specification improves even further, reaching the 0.01 level (***), thereby providing robust and consistent empirical support for our hypotheses (H2). Collectively, these sensitivity analyses reinforce the validity of our conceptual framework and demonstrate that our core conclusions are remarkably robust to alternative variable measurements.

Table 1: Descriptive Statistics and Correlations

Variables	Statistics		Correlations		
	Mean	Std.	(1)	(2)	(3)
(1)Exploration orientation	51.93%	46.55%	-		
(2)Absorptive capacity	12.29%	13.27%	0.2319***	-	
(3)Internationalization	60.83%	28.04%	0.1013**	0.1214**	-

Note: ^a **significant at 0.05 level ***significant at 0.01 level

Table 2: Results of regression analysis

	Variables	Parameter value			
H1	Exploration orientation -> Internationalization	6.103** (3.05)			
H2	Exploration orientation -> Absorptive capacity		6.602*** (1.41)		
	Absorptive capacity -> Internationalization			0.257** (0.11)	
	Exploration orientation -> Internationalization				4.658 (3.13)
	Absorptive capacity -> Internationalization				0.219** (0.11)
F-Value		3.993**	5.757**	21.879***	3.996**

Note: ^a estimated standard errors are in parentheses.

^b **significant at 0.05 level ***significant at 0.01 level

Table 3: Robustness Check: Alternative Measurement of Absorptive Capacity

	Variables	Parameter value		
H2	Exploration orientation -> Absorptive capacity	1.302*** (0.37)		
	Absorptive capacity -> Internationalization		1.303*** (0.41)	
	Exploration orientation -> Internationalization			4.549 (3.07)
	Absorptive capacity -> Internationalization			1.194*** (0.42)
F-Value		12.490**	9.982***	6.101**

Note: ^a estimated standard errors are in parentheses.

^b **significant at 0.05 level ***significant at 0.01 level

5. Conclusion and Suggestion

5.1. Conclusion

This study investigates the impact of organizational learning on internationalization. Specifically, we examine the interrelationships among exploration orientation, absorptive capacity, and firm internationalization, utilizing financial and patent data from Taiwanese semiconductor firms. The empirical findings reveal that an explorative learning orientation positively influences a firm's degree of internationalization. Furthermore, absorptive capacity plays a critical mediating role in this relationship. Based on these findings, important theoretical and managerial implications are discussed.

Theoretically, our mediation findings reveal that firm internationalization is driven less by exploration orientation itself than by the underlying mechanism of absorptive capacity. By demonstrating that exploration orientation fosters absorptive capacity, which subsequently fuels international expansion, our results suggest that internal absorptive capacity can potentially compensate for a firm's deficiencies in external exploration. This insight offers a meaningful contribution to the burgeoning literature at the intersection of organizational learning and international business strategy.

5.2. Managerial Relevance

Several managerial implications can be derived from the empirical findings of this article. First, our empirical results demonstrate that an explorative learning orientation exerts a positive influence on a firm's degree of internationalization. This suggests that to successfully expand operational domains abroad, high-tech firms in particular should allocate significant resources to explorative learning. In practical terms, this study recommends establishing cross-industry collaborative R&D, internal knowledge-sharing platforms, and targeted talent development programs—initiatives that help managers effectively operationalize an exploration orientation and build the requisite absorptive capacity for foreign market entry and growth. However, prioritizing exploration does not imply that exploitative learning should be neglected. As noted in the introduction, both explorative and exploitative learning are essential for an organization pursuing internationalization, requiring firms to maintain a balanced approach between them. Nevertheless, in the specific context of high-tech firm internationalization, explorative learning remains the more dominant and impactful driver of cross-border success.

5.3. Limitations and Future Research Directions

There are some limitations in this study and future researchers can overcome these limitations. Nevertheless, the extent of a firm's internationalization is certainly not only determined by its level of exploration orientation alone. Other factors such as integration of knowledge (Casillas et al., 2009) or dynamic capabilities (Prange & Verdier, 2011) also may exert some kind of influences on a firm's internationalization. Future researchers can examine the impacts of these factors and compare their separate effects on internationalization. In addition to that, although our research indicates that absorptive capacity influences internationalization it is hard to assert it as a causal relationship since other streams of research demonstrate an opposite causal direction, i.e. the extent of internationalization influences the level of absorptive capacity (Kafourous, Buckley, Sharp, & Wang, 2008). Future researchers can do their work based on longitudinal data to determine more precisely how their casual relationship operates.

Second, exploration orientation is a multidimensional organizational construct, yet the study measures it solely through technological patent citations. This approach may overlook other important dimensions of exploration such as experimentation, strategic alliances, market learning or organizational risk-taking. The measurement of exploration orientation focuses only on explicit technological knowledge without taking into account of tacit knowledge. This is the limitation prevalent in secondary database. Future works can consider tacit knowledge, or as Sidhu et al. (2004) suggest, experimentation or risk-taking etc. to form a more complete measure of exploration orientation.

Third, Fletcher & Harris (2012) has proposed an organizational learning framework for internationalization process. In their framework, there are four new knowledge acquisition sources: direct experience, indirect experience, internal information, external search. It is obvious that our research has only investigated one type of these knowledge sources – external search due to the limitations of our databank. It is urged that future works can discuss other types of knowledge sources to deepen our understanding about the role of knowledge in internationalization process.

Final, the findings of this study should be interpreted with caution due to several constraints: a relatively small sample size, a focus on a single industry within one country, a short three-year observation period, and the inability to infer definitive causal relationships from the data. We recommend that future research utilize cross-national, multi-industry, and longer longitudinal datasets to better establish causal relationships among variables and enhance external validity.

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The Carbon Price of Growth: Assessing Sectoral Contributions to the Environmental Kuznets Curve Hypothesis in Cameroon

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ARTICLE INFO	ABSTRACT
Article History Received 29 May 2026 Accepted 29 July 2026 <i>JEL Classifications</i> Q01, Q56 Keywords: CO2 emissions, disaggregated GDP, environmental Kuznets curve, ARDL model, Cameroon	Purpose: This study examines the Environmental Kuznets Curve (EKC) hypothesis in Cameroon, investigating how the relationship between economic growth and CO2 emissions changes when GDP is disaggregated by source (i.e. the primary, secondary and tertiary sectors), rather than being treated as an aggregate measure. The aim is to establish whether the conventional EKC finding obscures divergent growth-emissions dynamics in different sectors, and to derive differentiated policy recommendations accordingly. Design/methodology/approach: The study is based on time-series data from the World Development Indicators and the National Institute of Statistics' National Accounts (INS Comptes Nationaux) for Cameroon. The Autoregressive Distributed Lag (ARDL) bounds testing approach is employed to estimate the long- and short-run relationships between CO2 emissions and GDP. First, total (aggregated) GDP is used, and then GDP is disaggregated by primary, secondary and tertiary sector contributions. Findings: The results of long-run estimation with total GDP show that the EKC hypothesis does exist in Cameroon. The results of long-run estimation with disaggregated GDP present the U relationship between CO2 emissions and GDP that comes from the primary and secondary sectors. But, we have the inverted-U relationship between CO2 emissions and GDP from the tertiary sector. Research limitations/implications: The study is based on a limited sample of country-specific time series, which limits its generalizability. In terms of research implications, policymakers should support eco-friendly and climate-smart farming, while penalising abusive logging to protect primary-sector carbon sinks. They should incentivise low-carbon manufacturing, and shift secondary-sector industries toward hydroelectric and natural gas power. They should leverage tertiary-sector growth through digitalisation of financial and logistical services, and reform trade policy by tightening environmental standards on imported machinery, while investing in low-emission urban transit. Originality/value: This study advances existing knowledge by decomposing Cameroon's GDP into sectoral components, moving beyond the assumption that all economic activities affect the environment uniformly, and offers the empirical precision needed for sector-specific mitigation policies.

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1. Introduction

International discourse and numerous global treaties have centered on the escalating climate change crisis. This sustained focus stems from the profound and multifaceted risks that global warming poses to both human health and the stability of global economic systems.

Reports from the Intergovernmental Panel on Climate Change (IPCC) identify carbon dioxide (CO₂) as a primary driver of global warming (Tamba et al., 2014; IPCC, 2023), highlighting the critical link between climate change and sustainable economic development. A key concept in this context is the Environmental Kuznets Curve (EKC)

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hypothesis, which suggests a functional relationship between economic growth and emission levels (Acheampong, 2018; Mardani et al., 2019). However, empirical validation of this relationship remains inconclusive. While some studies emphasize a unidirectional impact of growth on CO₂ emissions (Zhao et al., 2017; Han et al., 2018), others argue for a reciprocal, bidirectional relationship between these two variables (Bildirici, 2017; Antonakakis et al., 2017).

Extensive research has investigated the relationship between economic growth and environmental quality, with a particular focus on the Environmental Kuznets Curve (EKC) hypothesis (Kuznets, 1955). The EKC framework suggests a non-linear, inverted U-shaped trajectory: initial stages of industrialization typically correlate with rising pollution levels, but once a specific income threshold is reached, further economic progress tends to mitigate environmental degradation, such as CO₂ output (Shafik and Bandyopadhyay, 1992; Vehmas et al., 2007). The EKC hypothesis remains a focal point in contemporary scientific discourse regarding sustainable development. Theoretical models, such as those proposed by Van Alstine and Neumayer (2010), suggest that higher income levels reduce pressure on the environmental sinks. One prominent explanation for this shift is the structural transition from a carbon-intensive manufacturing base toward a service-oriented economy (Jänicke et al., 1997). Consequently, development driven by the tertiary sector is generally considered to be less ecologically damaging than growth rooted in heavy industry.

Empirical evidence regarding the EKC hypothesis remains inconclusive. While several studies provide support for the inverted U-shaped relationship (Kohler, 2013; Shahbaz et al., 2014; Zambrano-Monserrate et al., 2016; Nchofoung and Asongu, 2022; Azam et al., 2025), others fail to find such an association (Govindaraju and Tang, 2013; Baek, 2015; Lacheheb et al., 2015). These disparities are heavily influenced by the methodology used. Broad cross-country panel studies usually confirm the macro-EKC by considering general regional characteristics (Tamazian and Rao, 2010; Azam et al., 2025). However, single-country time-series models that use autoregressive distributed lag (ARDL) or Toda-Yamamoto models often reveal localised linear, neutral or inconsistent paths. In the specific context of Cameroon, research has yielded diverse and mixed insights that challenge uniform, macro-level assumptions. For example, while some single-country ARDL assessments identify a clear inverted U-shaped curve linking economic development to long-term emission stabilization (Njoke et al., 2019), other domestic analyses reveal a linear relationship in which growth consistently increases atmospheric pollution (Nkengfack et al., 2014; Djepang Kouamo and Adamou Hadji, 2021). In this localized debate, Tamba (2017) identified a bidirectional, reciprocal link between CO₂ and growth, and Engo (2018) emphasized the impact of industrial growth on decoupling CO₂ emissions from economic growth in Cameroon. Furthermore, Hossain et al. (2021) identified economic activity as the main driver of rising CO₂ emissions during the late 20th century. This empirical instability is fundamentally tied to Cameroon's idiosyncratic sectoral composition, in which an infrastructure-constrained manufacturing sector, an intensive primary sector and a transport-heavy informal tertiary sector exhibit highly independent emission trajectories (Htike et al., 2022). Disaggregating these sectors is therefore vital in order to ascertain whether Cameroon's ongoing structural transitions are promoting genuine ecological decoupling.

Despite the growing body of literature on this topic, a significant gap remains: existing research treats gross domestic product (GDP) as a monolithic entity. Relying on aggregate GDP data can lead to incomplete or misleading conclusions. Aggregate models mask the vastly different pollution trajectories of individual sectors by smoothing over the structural variations inherent in a developing economy. For example, expansion in a carbon-intensive industrial sector can generate very different environmental outcomes to growth driven by services or agriculture, even if both result in identical aggregate GDP growth. Consequently, failing to isolate these structural shifts can misclassify the true turning point of the EKC and lead to poorly targeted environmental policies.

This study advances existing knowledge by explicitly decomposing Cameroon's GDP into its sectoral components. This granular approach moves beyond the oversimplification that all economic activities impact the environment uniformly (Jänicke et al., 1997). By disentangling the specific ecological footprints of agriculture, industry, and services, this paper provides the empirical precision needed to design effective, sector-specific structural mitigation policies and targeted technological upgrades.

In Cameroon, it is observed that CO₂ emissions have highly increased (48%) since 1971, passing from 0.246 metric tons per capita in 1991 to 0.306 metric tons per capita in 2019. In the same period, there is a low increase (3.3%) of CO₂ emissions in Western and Central Africa. Beside this growth of CO₂, the economic performances of Cameroon have been unstable and negative over the period from 1986 to 1994. However, since the devaluation in 1994, the national economy has found positive economic growth path (passing from 2.063% in 1994 to 3.6% in 2022 - WDI, 2024), with a contribution of a secondary sector of less than 30% on average per year (INS_Comptes Nationaux, 2019).

This study contributes to the existing literature in three distinct ways. First, departing from traditional aggregate models, we re-evaluate the Environmental Kuznets Curve by disaggregating GDP into its primary, secondary, and tertiary components. This approach allows for a precise determination of how various economic sectors specifically drive CO₂ emissions. Second, this research expands the EKC framework by integrating a comprehensive suite of control variables—including trade openness (Lau et al., 2014; Farhani and Ozturk, 2015), energy consumption (Saboori and Sulaiman, 2013; Baek, 2015; Zambrano-Monserrate et al., 2016; Azam et al., 2025), and population density (Shafiei and Salim, 2014; Apergis and Ozturk, 2015)—to ensure a more robust econometric specification. Finally, we address a methodological gap in previous Cameroonian studies (e.g., Nkengfack et al., 2014; Tamba et al., 2014) by incorporating a quadratic (squared) GDP term. By doing so, we are able to empirically identify

the specific income threshold, or 'turning point,' at which CO₂ emissions begin to decouple from economic growth in Cameroon.

The subsequent sections of this paper are structured as follows: Section 3 provides details of the data sources, variable definitions, and the econometric methodology employed. Section 4 provides a comprehensive report and discussion of the empirical findings. Section 5 concludes the study by summarising the results and relevant policy implications.

2. Data and methods

Data for this study was collected from World Development Indicators (CD-ROM, 2024) and INS_Comptes Nationaux (1975–2019) for GDP per sector. It includes annual data on an environmental indicator defined as per capita CO₂ emissions in metric tons, per capita real GDP (total and by sectors) in constant 2000 LCU (local currency), energy use (kg of oil equivalent per capita), trade openness [(imports of goods and services (constant LCU) plus exports of goods and services (constant LCU) divided by GDP (constant LCU)], and population density (people per square km of land area).

The main way in which carbon-intensive industrial production is transmitted is through energy consumption. As clean energy constitutes a very small proportion of Cameroon's industrial energy mix, aggregate energy consumption is a much more accurate indicator of the country's actual carbon footprint. Population density indicates demographic pressure on local ecosystems, while trade openness shows the extent to which Cameroon is integrated into global markets, thus testing the 'pollution haven' hypothesis. Although institutional quality is a vital driver, we excluded it from the econometric estimates because reliable institutional quality datasets, such as the World Bank's Worldwide Governance Indicators (WGI), only begin in 1996. Including them in our estimates would further reduce our already small sample size. Furthermore, including additional macroeconomic regressors in a model with only 41 observations would severely reduce our degrees of freedom, potentially leading to over-parameterised models and multicollinearity. Table 1 shows the summary statistics of each variable used in the analysis.

Table 1: Descriptive statistics of time series

Variables	Variable names (Definition and Units)	Obs*	Mean	Std. Dev.	Min	Max
CO ₂	carbon dioxide emissions (metric tons per capita)	54	0.2385789	0.1680646	0.0506136	0.6744345
GDPprimca	GDP from primary sector per capita (constant LCU)	41	107520	23283.45	73970.31	149178.7
GDPsecondca	GDP from secondary sector per capita (constant LCU)	41	128736.2	37706.96	55027.1	214874.9
GDPtertca	GDP from tertiary sector per capita (constant LCU)	41	154333.5	29070.53	100518.8	221999.7
gdpcapita	GDP per capita (constant LCU)	56	429881.1	85031.05	306392.6	648525.9
energyuse	energy use (kg of oil equivalent per capita)	44	388.6156	31.23886	317.9248	429.4072
popdensity	population density (people per square kilometer)	55	26.23598	11.35978	11.58112	49.38372
trade_open	Trade openness captured using trade flows divided by GDP. (Exports+imports)/GDP	56	0.3474105	0.0842926	0.224977	0.5249875
gdpc _{a2}	Gross domestic product (GDP) per capita-squared	56	1.92e+11	7.87e+10	9.39e+10	4.21e+11
GDPprimca ₂	GDP from primary sector per capita-squared (constant LCU)	41	1.21e+10	5.18e+09	5.47e+09	2.23e+10
GDPsecondca ₂	GDP from secondary sector per capita-squared (constant LCU)	41	1.80e+10	1.05e+10	3.03e+09	4.62e+10
GDPtertca ₂	GDP from tertiary sector per capita-squared (constant LCU)	41	2.46e+10	9.13e+09	1.01e+10	4.93e+10

Note: * the number of observations differs because of missing data.

In Table 1, the average value of Carbon dioxide (CO₂) per capita is 0.238, which implies that the average individual in this country contributed about 0.238 metric tons of CO₂ per year. The average per capita Gross Domestic Product (GDP) value for the entire sample is 429 881 FCFA, and 107 520 FCFA, 128 736 FCFA and 154 333 FCFA, respectively in the primary, secondary and tertiary sectors. This implies that on an average, a person living in Cameroon earns about 429 881 FCFA per annum. But this differs according to different sectors. Thus, a person earns annually about 107 520 FCFA in primary, 128 736 FCFA in secondary, and 154 333 FCFA in tertiary

sector. With regards to the value of trade during the period, the entire sample had an average value of 34.7% of trade as a share to the GDP. We also note in table 1 that a person living in Cameroon uses energy for about 388.6 kg of oil equivalent per year. The current population of Cameroon in 2022 is 27,914,536. The density of the population is 26 people. This means that, in Cameroon, on average, 26 people live in each square kilometer of land area.

This study applied the Pesaran et al. (2001) autoregressive distributed lag (ARDL) approach to test the presence of cointegration within the variables and estimate the long-run and short-run coefficients of the variables. Comparing to other approaches, the ARDL approach has several advantages (Engle and Granger, 1987; Jalil and Mahmud, 2009). One of the main advantages of this method is that it allows different integration orders for each series. Furthermore, it can also aid in avoiding problems associated with estimating short-time series data (Haug, 2002; Al-mulali et al., 2016). Moreover, the appropriate modification of the orders of ARDL model is sufficient to correct residual serial correlation and endogeneity (Pesaran and Shin, 1999; Saboori and Sulaiman, 2013). Finally, the estimation is possible even when the explanatory variables are endogenous (Pesaran and Shin, 1999; Pesaran et al., 2001). The ARDL model is suited to handling potential endogeneity between economic growth and carbon emissions without relying on external instrumental variables. Pesaran and Shin (1999) and Pesaran et al. (2001) demonstrated that, once an appropriate lag length has been selected, the dynamic structure of the ARDL model inherently controls for endogeneity. Augmenting the regression with a sufficient number of lagged changes of both the dependent variable and the regressors enables the ARDL dynamic framework to filter out contemporaneous correlation between the regressors and the error term. The Akaike Information Criterion (AIC) was used to select the optimal lag structure for the ARDL model. In this study, the ARDL unrestricted model is used with aggregated GDP (equation 1) and disaggregated GDP on different sources of GDP such as the primary, secondary and tertiary sectors (equation 2).

$$\begin{aligned} \Delta CO2 = & c + \sum_{i=1}^k \alpha_0 \Delta CO2_{t-i} + \sum_{i=0}^k \alpha_1 \Delta gdp capita_{t-i} + \sum_{i=0}^k \alpha_2 \Delta gdp capita 2_{t-i} + \\ & \sum_{i=0}^k \alpha_3 \Delta energy use_{t-i} + \sum_{i=0}^k \alpha_4 \Delta pop density_{t-i} + \sum_{i=0}^k \alpha_5 \Delta trade_open_{t-i} + \\ & \eta_0 CO2_{t-1} + \eta_1 gdp capita_{t-1} + \eta_2 gdp capita 2_{t-1} + \eta_3 energy use_{t-1} + \\ & \eta_4 pop density_{t-1} + \eta_5 trade_open_{t-1} + \varepsilon_t \end{aligned} \quad (1)$$

$$\begin{aligned} \Delta CO2 = & \gamma + \sum_{i=1}^k \delta_0 \Delta CO2_{t-i} + \sum_{i=0}^k \delta_1 \Delta GDP prim ca_{t-i} + \sum_{i=0}^k \delta_2 \Delta GDP second ca_{t-i} + \\ & \sum_{i=0}^k \delta_3 \Delta GDP tert ca_{t-i} + \sum_{i=0}^k \delta_4 \Delta GDP prim ca 2_{t-i} + \sum_{i=0}^k \delta_5 \Delta GDP second ca 2_{t-i} + \\ & \sum_{i=0}^k \delta_6 \Delta GDP tert ca 2_{t-i} + \sum_{i=0}^k \delta_7 \Delta energy use_{t-i} + \sum_{i=0}^k \delta_8 \Delta pop density_{t-i} + \\ & \sum_{i=0}^k \delta_9 \Delta trade_open_{t-i} + \beta_0 CO2_{t-1} + \beta_1 GDP prim ca_{t-1} + \beta_2 GDP second ca_{t-1} + \\ & \beta_3 GDP tert ca_{t-1} + \beta_4 GDP prim ca 2_{t-1} + \beta_5 GDP second ca 2_{t-1} + \beta_6 GDP tert ca 2_{t-1} + \\ & \beta_7 energy use_{t-1} + \beta_8 pop density_{t-1} + \beta_9 trade_open_{t-1} + v_t \end{aligned} \quad (2)$$

$C, \alpha_j, \eta_j, \gamma, \delta_I$ and β_I are the estimated coefficients (with j = from 0 to 5; I = from 0 to 9). ε_t and v_t are error terms, t is year, and k is number of lag. Variables in the level form terms capture the long-run effect while those in first difference (Δ) capture the short-run effects. Given the implications of trade openness, energy use, and population density on carbon emissions (Acheampong, 2018; Haroldo et al., 2019; Zarco-Periñán et al., 2021; Lachehed et al., 2015), the incorporation of these variables in the model will provide more information and also prevent variable omission bias.

The long-run relationship among the variables is verified using the ARDL bounds test where the null hypothesis representing no cointegration is $\eta_0 = \eta_1 = \eta_2 = \eta_3 = \eta_4 = \eta_5 = 0$ in equation (1) and $\beta_0 = \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = \beta_8 = \beta_9 = 0$ in equation (2); and the alternative hypothesis representing cointegration is $\eta_0 \neq \eta_1 \neq \eta_2 \neq \eta_3 \neq \eta_4 \neq \eta_5 \neq 0$ in equation (1) and $\beta_0 \neq \beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq \beta_6 \neq \beta_7 \neq \beta_8 \neq \beta_9 \neq 0$ in equation (2). The calculated F-statistics value is compared with lower critical bound and higher critical bounds from Pesaran et al. (2001). Narayan (2005) suggested alternative critical values which fit better for small sample sizes. For cointegration it is required that the null hypothesis is rejected. The selection of the optimal lag length is analysed through the Schwarz information criteria.

3. Result and Discussion

The empirical analysis started with the stationarity tests of the series (see table 2). In table, we can note that the CO₂, GDPprimca, GDPtertca, gdpcapita, energyuse, popdensity, gdpcapita2, GDPprimca2, and GDPtertca2 variables are individually integrated of order one, I(1); but GDPsecondca, trade_open, and GDPsecondca2 variables are stationary in level, I(0). Thus, an I(0) is a stationary process, and the mean is constant over the series while I(1) is a non-stationary process, and the mean is not constant over series. Therefore, the first differences are used to make an I(1) stationary.

Table 2: Unit root test

Variables	ADF test statistics				k	I(n)
	Model with intercept and trend	Model with intercept	Model without intercept and trend			
Co2	-2.654	-2.586	-1.072	1		I(1)
Δ Co2	-6.529***	-6.576***	-6.621***	1		
GDPprimca	-1.382	-1.121	-0.460	1		I(1)
Δ GDPprimca	-4.434	-4.464***	-4.503***	1		
GDPsecondca	-3.422	-3.258**	-0.361	1		I(0)
GDPtertca	-2.212	-2.220	0.236	1		I(1)
Δ GDPtertca	-3.319*	-3.342**	-3.371***	1		
gdpcapita	-1.770	-1.694	0.327	1		I(1)
Δ gdpcapita	-3.767**	-3.806***	-3.780***	1		
energyuse	-2.154	-0.810	-0.637	1		I(1)
Δ energyuse	-5.527***	-4.915***	-4.861***	1		
popdensity	0.770	0.662	-0.275	3		I(1)
Δ popdensity	-6.158***	0.142	0.529	3		
trade_open	-3.317*	-0.325	1.167	1		I(0)
gdpcapita2	-1.946	-1.886	-0.190	1		I(1)
Δ gdpcapita2	-3.648**	-3.688***	-3.679***	1		
GDPprimca2	-1.632	-1.136	-0.646	1		I(1)
Δ GDPprimca2	-4.681***	-4.735***	-4.774***	1		
GDPsecondca2	-3.526*	-3.267**	-1.203	1		I(0)
GDPtertca2	-2.315	-2.320	-0.198	1		I(1)
Δ GDPtertca2	-3.314*	-3.346**	-3.370***	1		

Note: *, **, *** Indicate statistical significance at 10%, 5% and 1% levels, respectively. k is the lag length. Δ represents 1st difference, I(n) means integrated of order n.

In addition, the unit root test results confirm the absence of I(2). Thus, ARDL model is used given that this approach can be used regardless of whether the data are integrated of order I(0) or I(1). ARDL model results are presented in two parts, one with aggregated GDP (3.1) and another with disaggregated GDP by sector (3.2).

3.1. Relationship between aggregated GDP and Co₂ emissions

Tables 3 and 4 show, respectively, the long and short-run relationships between CO₂ emissions and economic growth, energy use, population density, and trade openness. In order to verify a long-run relationship between these variables (i.e. cointegration), F-statistic of cointegration is estimated. Since the calculated value of F exceeds critical value for I(1) regressors at 10%, 5% and 2.5% of significance (see F-Bounds Test in tables 3 or 4), the null hypothesis is rejected: a cointegration relationship between CO₂ emissions, economic growth, energy use, population density, and trade openness can be justified.

The estimated model also passes the diagnostic tests of serial correlation, heteroskedasticity, normality, and stability test (the results of these tests are reported in the lower part of table 3). Results do not suggest the presence of any serial correlation and heteroskedasticity. They also show that the residuals follow a normal distribution and the coefficients of the aggregated model are stable (see also CUSUM and CUSUMQ techniques from fig. 1 in the appendix which display that the plots of CUSUM and CUSUMSQ statistics are well within the critical bounds, implying that the coefficients in the model are stable).

Table 3: Long run estimates (levels Equation)
Case: restricted Constant and No trend

Dependant variable: <i>CO2t</i>				
Variables	Coefficient ^a	Standard error	T-statistic	
gdpcapita	1.20E-05**	4.70E-06	2.551614	
gdpcapita2	-1.11E-11**	4.78E-12	-2.324121	
energyuse	-0.001921	0.001709	-1.124368	
popdensity	-0.017318*	0.009679	-1.789280	
trade_open	1.455513*	0.856392	1.699588	
c	-2.072372**	1.005566	-2.060901	
EC=CO2-(0.0000*gdpcapita-0.0000*gdpcapita2-0.0019*energyuse 0.0173*popdensity+1.4555*trade_open-2.0724)			-	
F-Bounds test Null Hypothesis: No levels relationship				
Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	3.834962	10%	2.08	3
k	5	5%	2.39	3.38
		2.5%	2.7	3.73
		1%	3.06	4.14
Diagnostic test statistics		Test-stats	p-Value	
Serial correlation		0.677	0.4106	
Normality		4.17	0.1244	
Heteroskedasticity		1.04	0.3084	
Model stability		0.4029	1.3581	
Estimated turning points: 545 454.545 FCFA				

Note ^a : *, **, *** Indicate statistical significance at 10%, 5% and 1% levels, respectively.

Table 4: Short run estimates (ARDL Error Correction Regression)
Case: restricted Constant and No trend, Selected model ARDL(1,1,1,1,0,0)

Dependant variable: D(CO2)				
Variables		Coefficient ^a	Standard error	T-statistic
D(gdpcapita)		9.28E-08	3.90E-06	0.023763
D(gdpcapita2)		1.57E-12	4.03E-12	0.390719
D(energyuse)		0.002583	0.001851	1.395840
CointEq(-1)		-0.829623***	0.146938	-5.646071
R-squares		0.484847	Mean dependent var	0.004527
Adjusted R-squares		0.444177	S.D. dependent var	0.141888
S.E. of regression		0.105783	Akaika info criterion	-1.564466
Sum squared resid		0.425220	Schwarz criterion	-1.398974
Log likelihood		36.85379	Hannan-Quinn criter	-1.503807
Durbin-Watson stat		1.852496	Number of observation	42
F-Bounds test Null Hypothesis: No levels relationship				
Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	3.834962	10%	2.08	3
k	5	5%	2.39	3.38
		2.5%	2.7	3.73
		1%	3.06	4.14

Note ^a : *, **, *** Indicate statistical significance at 10%, 5% and 1% levels, respectively.

The results of long-run estimation show that the linear term of GDP is positive and the non-linear term negative, which proves the existence of the inverted-U relationship between economic growth and CO₂ emissions. This inverted U-shape illustrates a transition in which structural and technical effects (driven by growth in the service sector and gradual efficiency gains) eventually outweigh the resource intensive scale effects of the early stages of development. However, this aggregate decoupling is fragile in structure; rather than reflecting a green technological transition within the primary and secondary industries, Cameroon's direct shift from agriculture to services primarily sustains the downward trend. This result is consistent with various studies that examining such relationship (Shahbaz et al., 2014; Kiviyiro and Arminen, 2014 and Apergis and Ozturk, 2015; Azam et al., 2025).

Contrary to Ohlan (2015), Shahbaz et al. (2015) and Zhu and Peng (2012), the long-run coefficient of CO₂ emissions with population density is negative, indicating that an increase of 1 person per square kilometer of the land area will decrease CO₂ emissions per capita by 0,017 metric tons. This result is not consistent with the expected signs of the study. This can be explained by the fact that the people per square kilometer of land area in Cameroon is very low (in average 26 people per square km). This can also be explained by the increase in the level of development in the long-run. In fact, evidence supports the idea that the scaling between emissions and population depends on the degree of economic development (Rybski et al., 2017; Haroldo et al., 2019).

The coefficient of trade openness is positive and statistically significant, indicating the contribution of this variable to environmental degradation in the long-run. This finding is consistent with that of Al-Mulali et al. (2015) in the case of Kenya. It can be explained by the fact that developing countries increase imports of pollution intensive outputs or confirm the pollution haven hypothesis (i.e. the fact that developed countries may now be importing their pollution-intensive output from the developing world and therefore explain the increasing in local air pollution experienced in most developing countries in recent years (Cole, 2004)).

This study showed that the turning point for Cameroon is 545 455 FCFA. Thus, environmental degradation will increase until annual income per capita reached 545 455 FCFA (known as the turning point) and then environmental improvement will occur. Given that the average annual level of income per capita is 429 881 FCFA, this means that Cameroon has not yet reached his turning point. Therefore, this country is still on the increasing slope of Kuznets environmental curve.

Except error-correction term (ECT), all variables in the short-run model are statistically non-significant. This indicates that aggregated GDP has no contribution to CO₂ emissions in the short-term. However, the ECT is negative and statistically significant at 1%, and thus supports the cointegration of the variables included in the long-run model.

3.2. Contribution of disaggregated GDP in CO₂ emissions

Tables 5 and 6 show respectively the long and short run relationships between CO₂ emissions and disaggregated GDP, energy use, population density and trade openness. The calculated value of F exceeds the critical value for I(1) regressors at 10%, 5%, and 1% of significance (see F-Bounds Test in tables 5 or 6). So, we can support the existence of a cointegration relationship between CO₂ emissions, disaggregated GDP, energy use, population density, and trade openness.

The estimated model also passes the diagnostic tests of serial correlation, heteroskedasticity, normality, and stability test (the results of these tests are reported in the lower part of table 5). Results do not suggest the presence of any serial correlation and heteroskedasticity. They also show that the residuals follow a normal distribution and the coefficients of the disaggregated model are stable (see also CUSUM and CUSUMQ techniques from fig. 2 in appendix which display that the plots of CUSUM and CUSUMSQ statistics are well within the critical bounds, implying that the coefficients in the model are stable)

Table 5: Long run estimates (levels Equation)
Case: restricted Constant and No trend

Dependant variable: <i>CO2t</i>					
Variables		Coefficient ^a	Standard error	T-statistic	
GDPprimca		-0.000114***	2.87E-05	-3.951201	
GDPprimca2		5.52E-10***	1.49E-10	3.699488	
GDPsecondca		-2.33E-05***	6.63E-06	-3.509466	
GDPsecondca2		9.05E-11***	2.52E-11	3.588066	
GDPtertca		6.66E-05***	1.51E-05	4.404493	
GDPtertca2		-2.30E-10***	5.66E-11	-4.073409	
energyuse		-0.000649	0.001140	-0.569142	
popdensity		-0.124427***	0.019314	-6.442372	
trade_open		1.126893**	0.460177	2.448827	
c		0.871751	0.508489	1.714394	
EC=CO2-(-0.0001* GDPprimca +0.0000* GDPprimca2-0.0000* GDPsecondca +0.0000* GDPsecondca2+0.0000* GDPtertca-0.0000* GDPtertca2 -0.0006*energyuse -0.1244*popdensity+1.1269*trade_open+0.8718)					
F-Bounds test Null Hypothesis: No levels relationship					
Test Statistic		Value	Signif.	I(0)	I(1)
F-statistic		8.871291	10%	1.8	2.8
k		9	5%	2.04	2.08
			2.5%	2.24	3.35
			1%	2.5	3.68
Diagnostic test statistics			Test-stats	p-Value	
Serial correlation			2.481	0.1153	

Normality	0.98	0.6141
Heteroskedasticity	37.00	0.4691
Model stability	0.2198	1.3581
Estimated turning points for different sector: 103 636.36 FCFA for primary sector, 116 500 FCFA for secondary sector and 133 200 FCFA for tertiary sector		

Note ^a : *, **, *** Indicate statistical significance at 10%, 5% and 1% levels, respectively.

Table 6 : Short run estimates (ARDL Error Correction Regression)
Case: restricted Constant and No trend, Selected model ARDL(2,2,2,1,1,2,2,2,2,1)

Dependant variable: <i>D(Co2)</i>				
Variables		Coefficient ^a	Standard error	T-statistic
D(CO2(-1))		1.138242***	0.133440	8.529214
D(GDPprimca)		-0.000118***	8.99E-06	-13.17794
D(GDPprimca (-1))		9.77E-05***	9.76E-06	10.01408
D(GDPprimca2)		6.07E-10***	4.27E-11	14.20928
D(GDPprimca2 (-1))		-4.58E-10***	4.52E-11	-10.13045
D(GDPsecondca)		-3.15E-06	3.01E-06	-1.047849
D(GDPsecondca2)		-8.31E-13	9.86E-12	-0.084223
D(GDPtertca)		6.66E-05***	5.60E-06	11.88479
D(GDPtertca (-1)))		-8.05E-05***	9.22E-06	-8.728036
D(GDPtertca2)		-1.92E-10***	1.65E-11	-11.64034
D(GDPtertca2 (-1)))		2.32E-10***	2.89E-11	8.028809
D(energyuse)		0.001353	0.000821	1.648348
D(energyuse (-1)))		0.002760**	0.000885	3.117581
D(popdensity)		3.254788**	1.404253	2.317807
D(popdensity (-1)))		13.94547***	1.826945	7.633217
D(trade_open)		0.634329*	0.324108	1.957152
CointEq (-1)		-2.639062***	0.188906	-13.97027
R-squares		0.965657	Mean dependent var	0.004580
Adjusted R-squares		0.938183	S.D. dependent var	0.151368
S.E. of regression		0.037635	Akaike info criterion	-3.418050
Sum squared resid		0.028327	Schwarz criterion	-2.677898
Log likelihood		80.23392	Hannan-Quinn criter	-3.157111
Durbin-Watson stat		2.561582	Number of observation	37
F-Bounds test Null Hypothesis: No levels relationship				
Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	8.871291	10%	1.8	2.8
k	9	5%	2.04	2.08
		2.5%	2.24	3.35
		1%	2.5	3.68

Note ^a : *, **, *** Indicate statistical significance at 10%, 5% and 1% levels, respectively.

The results of long-run estimation show that the linear terms of GDP coming from the primary and secondary sectors are negative and the non-linear term positive, which present the U relationship between these sources of economic growth and CO2 emissions. Whereas, the linear term of GDP coming from the tertiary sector is positive and the non-linear term negative, which shows the inverted-U relationship between this source of economic growth and CO2 emissions. The U-shaped curve for the primary and secondary sectors reflects the transition from the oil boom of the 1970s to economic diversification in the post-1980s era. Initially, the dominance of low pollution crude oil extraction, coupled with the slowdown of traditional agriculture and manufacturing induced by Dutch disease, kept carbon emissions low relative to GDP. However, the severe terms-of-trade crisis of the mid-1980s (Chauvin, 2017) and subsequent structural adjustment programmes forced Cameroon to diversify its economic base. This post-crisis revival led to the expansion of carbon-intensive, low-technology manufacturing, such as cement and wood processing, and the commercialisation of primary agro-industries. Ultimately, this locked these sectors into an emission-intensive path as they scaled up. Conversely, the inverted U-shaped relationship in the tertiary sector reflects a typical structural shift towards cleaner economic activities as a country develops. In the early stages of growth, expansion in Cameroon's tertiary sector is dominated by highly carbon-intensive and unregulated informal activities, particularly inefficient transport and retail networks. As the service sector matures and expands, it undergoes an internal qualitative shift towards lower-emission, high-value services such as telecommunications, finance and digital trade.

This allows service-driven GDP to decouple from carbon emissions. Overall, these findings imply that although Cameroon's tertiary sector is successfully transitioning towards environmental sustainability, its primary and secondary sectors are still heavily dependent on resources and hindered by bottlenecks in low-tech industrialisation, which poses a critical challenge to the clean-growth goals of the country's Vision 2035 development agenda.

The density of population and trade openness variables are statistically significant and remain the same signs that in table 3.

Estimated turning points for the different sector are 103 636 FCFA for the primary sector, 116 500 FCFA for the secondary sector and 133 200 FCFA for the tertiary sector. Given that the average annual level of income per capita in primary, secondary and tertiary sectors are respectively 107 520 FCFA, 128 736 FCFA and 154 333 FCFA, this means that Cameroon has yet reached his turning point in different sectors. Therefore, CO₂ emission is yet increasing (decreasing) with annual income per capita in the primary and secondary (tertiary) sectors of Cameroon.

Except energy consumption and GDP comes from the secondary sector, all variables in the short-run model with disaggregated GDP are statistically significant. The negative and statistically significant (at the 1% level) error correction term (CointEq(-1)) confirms a stable long-run cointegrating relationship among the variables included in the long-run model with disaggregated GDP. With a coefficient of -2.64, it indicates an exceptionally rapid speed of adjustment. This implies that system-wide deviations from long-run equilibrium following an economic shock are corrected within the same year. In the short term, the primary and tertiary sectors maintain significant U- and inverted U-shaped relationships with emissions, respectively, reflecting immediate carbon dynamics during economic fluctuations. Conversely, the secondary sector's short-run coefficients are statistically insignificant, demonstrating that industrial emissions in Cameroon do not respond dynamically to short-term output fluctuations. This insignificance highlights deep structural rigidity: Cameroon's industrial base is constrained by low-technology manufacturing lock-ins and infrastructure bottlenecks, preventing the sector from adapting its emissions profile dynamically in response to short-term business cycles.

4. Conclusion

The objective of this paper is not only to examine the contribution of growth to air pollution but also to identify the contribution of each activity sector to environmental degradation. To achieve the objective of this study, the ARDL approach was utilized with data from World Development Indicators (CD-ROM, 2024) and INS_Comptes Nationaux of Cameroon (1975-2019). The results justify a long-run relationship i.e., cointegration among the considered variables in the models with aggregated and disaggregated GDP while the short run relationship is not significant.

In the model with total GDP, results suggest that CO₂ emissions increase as the economy grows (a 1 FCFA increase in GDP per capita corresponds to a 0.000012 metric ton increase in per capita CO₂ emissions), but eventually decrease once the per capita GDP reaches a certain threshold. At this turning point which is 545 455 FCFA in Cameroon, environmental degradation will decrease when the economy grows (a 1 FCFA increase in GDP per capita will lead to a 0.000000000111 metric ton reduction in per capita CO₂ emissions in the long-run). Considering the average annual level of income per capita, we can say that Cameroon has not yet reached his turning point. In this model we also note that no evidence for EKC in the short-run was obtained.

In the model with disaggregated GDP, the results of long-run estimation show the U relationship between CO₂ emissions and GDP come from the primary and the secondary sector. In fact, before the turning point, a 1 FCFA increase in GDP per capita that coming from the primary or the secondary sector, will lead respectively to a 0.000114 and 0.0000233 metric ton reduction in per capita CO₂ emissions. But, after the turning point, a 1 FCFA increase in GDP per capita coming from the primary or the secondary sector, corresponds respectively to a 5.52E-10 and 0.905E-10 metric ton increase in per capita CO₂ emissions. Moreover, we find the inverted-U relationship between CO₂ emissions and GDP that coming from the tertiary sector. In fact, before the turning point, a 1 FCFA increase in GDP per capita come from tertiary sector corresponds to a 6.66E-05 metric ton increase in per capita CO₂ emissions. But, after the turning point, a 1 FCFA increase in GDP per capita that come from tertiary sector will lead to a 2.30E-10 metric ton reduction in per capita CO₂ emissions. Given the average annual level of income per capita in primary, secondary and tertiary sectors, Cameroon has already reached its turning point in different sectors.

Empirical validation of a U-shaped Environmental Kuznets Curve (EKC) in Cameroon's primary and secondary sectors shows that economic growth in these areas is currently increasing carbon emissions. This requires a change in approach, moving from general green mandates to specific sectoral interventions. In the primary sector, where extensive farming and logging are the main drivers of emissions, the government should subsidise environmentally friendly agricultural inputs and climate-smart agricultural inputs to curb land expansion, as well as enforcing stricter penalties on abusive logging practices in order to preserve the country's natural carbon sinks. In the secondary sector, policymakers must incentivise industrial energy efficiency by offering tax breaks to factories that adopt low-carbon manufacturing technologies, and by transitioning heavy industries away from fossil fuels towards Cameroon's hydroelectric and natural gas capacities. Conversely, the inverted U-shaped relationship found in the tertiary sector indicates that service-driven growth is already aligning with environmental sustainability. This momentum should be accelerated by fast-tracking the digitalisation of financial and logistical services to reduce the economy's overall carbon intensity (for example, digitalisation can eliminate empty runs and wasted trips, thereby reducing the need for physical travel. The transport and logistics sector traditionally emits a lot of carbon). Finally, as trade openness increases pollution and population density reduces it, Cameroon must reform its trade and urban policies. This

requires the implementation of strict environmental standards and age limits on imported industrial machinery, as well as investment in low-emission public transport in expanding metropolitan areas such as Douala and Yaoundé, in order to realise the efficiency gains of urban agglomeration.

While this study provides valuable insights into the emissions trajectory of the Cameroonian economy, some limitations must be acknowledged. Firstly, the empirical analysis relies on a small sample size in a country-specific time-series dataset, which limits the generalisability of the findings to other regional contexts. Secondly, due to the small sample size, institutional quality variables were omitted to prevent over-parameterisation. Similarly, as renewable energy currently constitutes a negligible proportion of Cameroon's industrial energy mix, metrics related to renewable energy were excluded in favour of aggregate energy consumption metrics. Future research could address these limitations and examine how the growth-emission nexus evolves as green energy transitions progress.

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Appendix

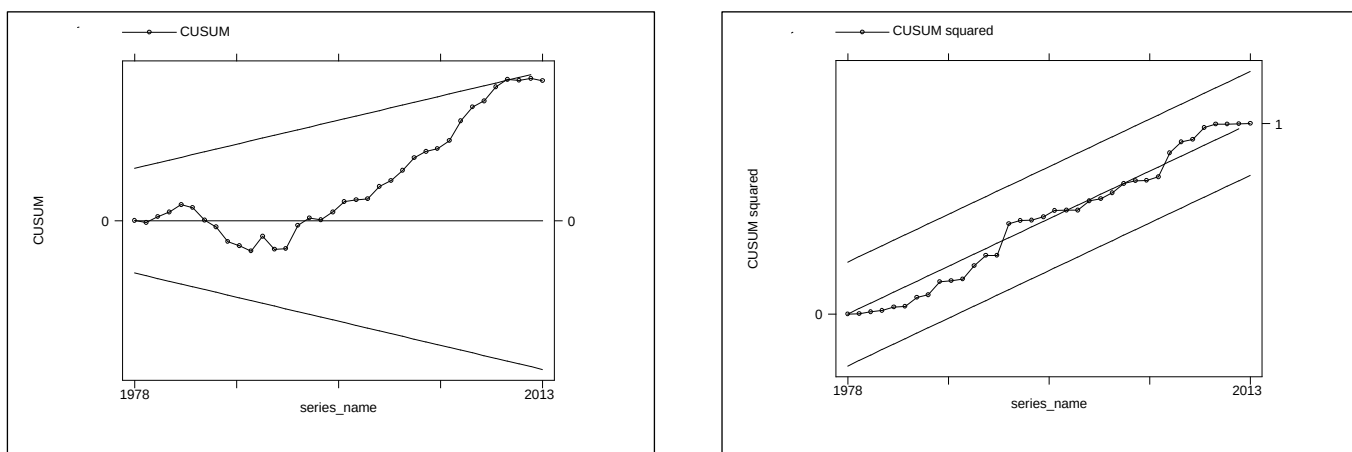


Figure 1: Plot of cumulative sum (and sum of squares) of recursive residual for aggregated model

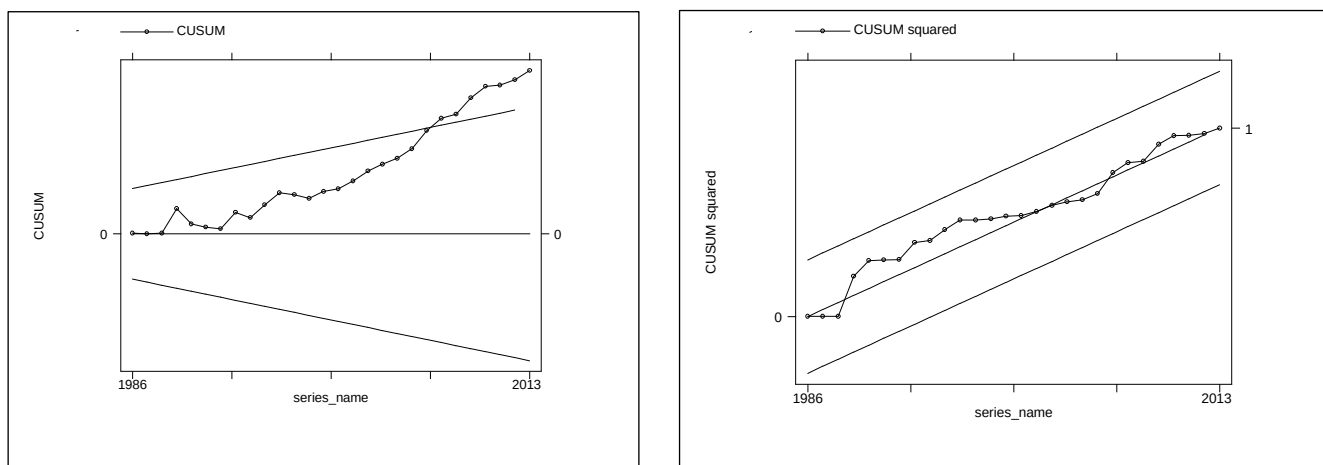


Figure 2: Plot of cumulative sum (and sum of squares) of recursive residual for disaggregated model

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The Impact of off-Farm Income Sources on Agricultural Inputs and Farm Productivity in Cameroon

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ARTICLE INFO	ABSTRACT
Article History Received 28 May 2026 Accepted 29 July 2026 <i>JEL Classifications</i> O13, Q12, Q18 Keywords: off-farm income, off-farm income from self-employment, off-farm wage income, remittance, agricultural inputs, farm productivity, Cameroon	Purpose: In a context of credit constraint faced by smallholders to invest, off-farm activities, while being a good lever for increasing agricultural productivity through the purchase of farm inputs, would also be an element of diversion of efforts from the agricultural sector towards non-agricultural activities. Hence, knowing the type of off-farm activity that can be done in parallel to agriculture without damaging it is of great interest. This article aims to identify non-agricultural activities that can be carried out alongside farming without having an adverse effect on agricultural activities. Design/methodology/approach: The data were collected using a three-stage sampling technique from surveys conducted with 564 farmers in western Cameroon. We use Heckman's two-step procedure to estimate the land productivity equation and the Ordinary least squares method to estimate input demand equations. Findings: The results show that off-farm income has a positive impact on the demand for farm inputs, particularly when derived from remittances or self-employment. Off-farm income also significantly increases farm productivity, particularly when it is derived from remittances. Research limitations/implications: The study's reliance on cross-sectional, self-reported survey data from Western Cameroon restricts causal inference and limits geographical generalisability. Furthermore, prioritising land productivity mitigates severe measurement constraints surrounding informal labour, but omitting total factor productivity prevents a comprehensive evaluation of overall input efficiency gains. Originality/value: This study suggests that diversifying income sources through self-employment and remittances could provide the additional capital needed to increase farm input demand and productivity in a low-income country such as Cameroon, where farmers face credit constraints.

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1. Introduction

Interest in studying the relationship between off-farm¹ income and agricultural productivity is motivated by the classical development of dual economic models formulated by Lewis (1954) and later formalized by Fbi and Ranis (1964). Although they often earn a meagre income from farming, smallholder farmers in low-income countries have managed to survive by combining farming with non-farming activities. Thus, their decisions, from the choice of increasing agricultural investment includes innovation, are often influenced by off-farm income. Innovation could be viewed in terms of the use of modern tools and equipment, machines such as tractors, combine harvesters, sprayers, backhoes, reaper-binder, field cultivators, hullers, and planters for cultivation which entails mechanization, use of

¹ In this study, when we talk about off-farm income (or activities), we are referring to both off-farm and non-farm income (or activities). For the purposes of this study, these two terms will be used interchangeably.

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chemical inputs like pesticides, insecticides, chemical fertilizer, improved seeds, irrigation, improved cultivation methods. It is known that new technologies and innovations have a positive effect on agricultural productivity (Feder *et al.*, 1985; Chen, 2025). This innovation can be supported by off-farm and on-farm income. The extent of off-farm work and its relationship with farm productivity may have important effects on farm productivity (Fernandez-Cornejo *et al.*, 2007). According to Pfeiffer *et al.* (2009), agricultural income portfolios in developing countries are shifting away from agricultural productivity. Non-farm income opportunities have been widely analysed as an important strategy for overcoming credit constraints faced by smallholders to invest, among other things, in agricultural productivity in developing countries (Reardon *et al.*, 1994; Janvry and Sadoulet, 2001; Iiyama *et al.*, 2008; Diiro, 2013; Mishra *et al.*, 2015; Dsouza *et al.*, 2020; Ma *et al.*, 2022). Based on primary survey data from four African countries, Mutsami *et al.* (2025) found that, on average, off-farm sources account for 60% of total household income in rural Africa. The share of off-farm income in the total household income of a farmer in Cameroon increased from 40% in 1995 to 79% in 2004 (Parrot *et al.*, 2010). A growing share of non-agricultural income is evident with differing agricultural production potential. Off-farm income can be an important source of cash income which can potentially improve agricultural productivity if it is used to buy agricultural inputs.

Most studies usually analyse only aggregated off-farm income. We can evoke for example Savadogo *et al.* (1998) in Burkina Faso, Holden *et al.* (2004) in Ethiopia, Kilic *et al.* (2009) in Albania, Pfeiffer *et al.* (2009) in Mexico, Diiro (2013) in Uganda, and Rashidin *et al.* (2020) in Pakistan, Anang and Apedo (2023) in Ghana, Drall and Mandal (2025) in India.

Although these aggregate approaches provide valuable baseline insights, treating off-farm income as a homogeneous entity obscures the distinct microeconomic pathways and labour-capital trade-offs. In a context of credit constraint faced by smallholders to invest, off-farm activities, while being a good lever for increasing agricultural productivity through the purchase of farm inputs, would also be an element of diversion of efforts from the agricultural sector towards non-agricultural activities (Shittu, 2014). Crucially, the net balance between the liquidity-easing and labour-diversion effects is determined by the theoretical nature of the off-farm source itself. Remittances represent an unearned transfer or migration return that provides a direct injection of liquidity without reducing local household farm labour. By relaxing cash constraints without creating an immediate labour bottleneck on the family plot, remittances can uniquely encourage the adoption of inputs. Wage employment usually involves rigid working hours and contractual time commitments, creating a stronger labour diversion effect away from farm management, despite providing a predictable, recurring cash flow for purchasing inputs. Self-employment presents a hybrid dynamic in that it allows for flexible labour allocation alongside farming. However, it demands continuous reinvestment of working capital, which could lead to direct competition for funds between the farm and the non-farm enterprise. It is therefore theoretically essential to distinguish between remittances, self-employment and wage employment in order to untangle these conflicting income and substitution dynamics. By moving beyond aggregate measures, this study advances existing empirical literature by revealing how varying liquidity profiles and labour constraints across distinct off-farm activities differentially shape input investment and agricultural productivity among smallholder farmers. Hence, in this study, we assess the contribution of aggregated and disaggregated off-farm income on agricultural productivity through inputs in West Cameroon.

2. Literature Review

Off-farm income can be defined in various ways. Pfeiffer *et al.* (2009) define off-farm income as income earned from non-agricultural wage work plus remittances sent back to the household by members living outside the country. According to House (2006), off-farm or non-farm income refers to the portion of agricultural household income earned away from the farm, including wages and salaries from non-farm work, pensions, and interest income. In the United States, for example, off-farm income accounts for over 90% of farm household income on average (House, 2006). The significance of off-farm income is further emphasized by the study of Haggblade *et al.* (2005), which shows that local non-farm income makes up between 30 to 45 percent of smallholder incomes in developing countries. Chang and Boisvert (2009) demonstrate that income from off-farm sources for smallholders has continued to narrow the income gap between farm and non-farm households. The effect of off-farm income on agricultural productivity remains a topic of debate. The empirical evidence is mixed. Some studies, such as those by Holden *et al.* (2004), Pfeiffer *et al.* (2009), Mishra *et al.* (2014), Rashidin *et al.* (2020), and Li *et al.* (2022), show that agricultural production declines when access to non-farm employment improves. Therefore, access to off-farm income can reduce farm households' incentives to invest in agriculture. Additionally, Fernandez-Cornejo *et al.* (2007) analyzed the relationship between the adoption of improved corn varieties in the US and household income from either off-farm or on-farm sources. Their results indicate that adoption is not significantly influenced, suggesting that improved corn varieties may be neutral regarding off-farm and on-farm income. Conversely, the study by Reardon *et al.* (1994) in Burkina Faso revealed that when farmers face financial constraints to purchase farm inputs, access to non-farm income can provide additional liquidity needs and lead to increased agricultural intensification. Off-farm income activities might have a positive impact on productivity if smallholders have limited access to credit (Key, 2020). Furthermore, Diagana and Kelly (1994) show that with the disappearance of government subsidies in Senegal, farmers increasingly use off-farm income to buy inputs. Moreover, Egyei and Adzovor (2013) suggest that off-farm income can directly and indirectly influence agricultural productivity through credit and liquidity. It can directly impact productivity by easing

household budget constraints and indirectly by providing households with capital, security, and liquidity necessary to invest in technology or farm inputs.

In synthesising these divergent findings, we observe a general tendency: off-farm income tends to induce a labour diversion effect where credit markets are well developed. However, it acts as a substitute for liquidity financing input adoption where credit is fragmented and state agricultural support is limited. However, this pattern admits notable exceptions. In the United States, for example, despite a well-developed financial system, off-farm income relaxed binding credit constraints for small, credit-constrained farms (Key, 2020). In Pakistan, meanwhile, off-farm income reduced farm income despite comparable credit scarcity because formal credit was disproportionately channelled towards non-farm rather than farm households (Rashidin et al., 2020). Ethiopia represents a further, different kind of exception: in the fragile highland agroecology studied by Holden et al. (2004), characterised by soil fragility, low agricultural productivity, high land fragmentation and frequent droughts, the expansion of non-farm employment opportunities does not neatly fit into either the labour-diversion or liquidity-relaxation channels. Instead, it creates a trade-off between short-term poverty reduction and long-term land degradation as labour and attention are drawn away from soil and water conservation investments needed to sustain the resource base. As most existing literature treats off-farm income as a monolithic aggregate, it obscures the different ways in which distinct non-farm channels - remittances, wage employment and self-employment - interact with credit, labour market and agroecological conditions. By evaluating both aggregated and disaggregated off-farm income streams in Cameroon's specific institutional context, this study moves beyond existing literature to explain how differing liquidity profiles and labour allocations shape smallholder agricultural productivity.

3. Data and Methods

The data for this study were collected through a cross-sectional survey of 564 farming households in western Cameroon. The West Region of Cameroon is heavily reliant on agriculture, which constitutes one of the region's main economic activities and employs more than 60% of its economically active population (National Institute of Statistics [INS], 2024). In the absence of an up-to-date national agricultural census, which would provide accurate information on the size of the farming population in the region, the sample size was determined using Cochran's formula (1977), which is commonly used for large or poorly documented populations. Farmers were selected using a three-stage sampling plan. In the first stage, subdivisions with the highest agricultural production density were selected from among the four divisions in western Cameroon with the highest agricultural production density, known as the 'Barn of Cameroon', bringing the total number of subdivisions to seven. In the second stage, 42 enumeration areas² (ZDs) were randomly selected from BUCREP³ cartographic maps, proportional to population size. This comprised 25 urban and 17 rural zones. To ensure balanced representation between sectors, the final stage involved randomly selecting 11 farmers from each urban ZD and 17 from each rural ZD. This resulted in a sample of 564 farmers. The survey covered in detail crop outputs, inputs, farm income, off-farm income, and other socio-economic characteristics of the farmers and their farms.

The agricultural household model is our framework. Like in many agricultural studies as Yu sheng et al. (2019), we assume that a representative farm production function takes the Cobb-Douglas form:

$$Y = AL^\alpha K^\beta N^\gamma \quad (1)$$

Where α , β , and γ are parameters, all < 1 . A is production technology. L , K , and N are respectively labour, capital, and land.

To measure agricultural productivity, we used only land productivity because in small-holding in West-Cameroon, it is not easy to know precisely how many hours a farmer or member of his family work on the farm a day/week/year. Land productivity, defined as output per unit of cultivated area, is a single-factor productivity indicator that can be calculated directly from a single data source, such as a farm or household survey. This is a key advantage in contexts where data is scarce, which is typical of developing countries (FAO, 2018).

Dividing N into both sides of equation (1) and taking the logarithm, we can derive farmland productivity:

$$\ln\left(\frac{Y}{N}\right) = \ln A + \alpha \ln L + \beta \ln K + (\gamma - 1) \ln N \quad (2)$$

This baseline model is used to estimate the land productivity in addition to socioeconomic characteristics of the farmers and their farms such as off-farm income, farmer's education level, farmer's gender, farmer's access to credit, household size, and farmland fertility. To identify the impact of farm input choices on land productivity, we include these socioeconomic characteristics in the baseline model:

$$\ln(y_i) = \alpha_0 + \alpha_1 \ln L_i + \alpha_2 \ln N_i + \alpha_3 \ln K_i + \alpha_4 \text{Offarm}_i + \alpha_5 \text{Offarm}_i^2 + \beta X_i + \varepsilon_i \quad (3)$$

² An enumeration area is a geographical area designed to accommodate around 200 households.

³ BUCREP stands for the Central Bureau of Census and Population Studies in Cameroon.

Here, $i = \text{farmer}$. α and β are the vector of parameters. y_i is agricultural income⁴ per are (agricultural land productivity). L_i is expenditure on labor during a year. N_i is the land in ares. K_i is the capital, these are expenditures on seed, manure, improved seeds, fertilizer, and pesticides are used as capital. $Offarm_i$ is off-farm income. X_i are a vector of other exogenous farmers/farm variables that influence agricultural productivity; these are farmer's education level, farmer's gender, farmer's access to credit, farmer's experience in farm production, farmer participation in a producer organisation, farmer-owner of land cultivated, marital status of the farmer, household size and farmland fertility. The structural agricultural conditions in Western Cameroon justify excluding distinct variables for irrigation and mechanisation, as production there is almost entirely rain-fed and relies on manual labour using traditional tools. The level of the producer's education, their gender, their experience in agricultural production, their access to credit, their ownership status of the cultivated land, their marital status, and their household size were selected as they constitute the central set of determinants of the adoption of technologies and agricultural performance at household and farm level, as identified in classic literature on the adoption of innovations in the agriculture of developing countries (Feder, Just & Zilberman, 1985). We also considered extension services and market access via a farmer's membership of a peasant organisation. Such organisations are widely documented as a major institutional mechanism through which smallholders in Sub-Saharan Africa access extension services, input supply and market information (Shiferaw et al., 2011). Therefore, including a separate variable for access to extension services would have introduced strong collinearity with participation in a producer organisation without providing additional explanatory power. Table 1 shows the summary statistics of each of the variables used in the analysis.

Table 1: Descriptive statistics by off-farm income status

Variables	Variable names (Definition and Units)	All farmers (mean) N=564	Off-farm income status		Difference
			Without off-farm income (mean) N=160	With off-farm income(mean) N=404	
farmIncome	Total annual farm income (in CFA francs)	652535	459962.3	728801.4	-268839.1***
y	Annual land productivity (in CFA francs)	7904.94	8274.28	7759.58	514.69
labor	Total annual labor for agricultural production (cost in CFA francs)	194349.3	148988.4	212358.6	-63370.17***
land	Farm size (cultivated land in ares)	107.10	89.86	113.89	-24.02**
capital	Annual Capital (expenditures on variable inputs like seed, fertilizer, manure, and pesticides, in CFA francs)	231468.1	65611.52	297153.9	-231542.3
offarm	Total annual off-farm income (in CFA francs)	236824.2	-	236824.2	-
remittance	Annual Off-farm income from transfers and others (in CFA francs)	58865.69	-	58865.69	-
wagemplcom	Annual Off-farm income from wage earnings (in CFA francs)	45554.26	-	45554.26	-
selfempl	Annual Off-farm income from self-employment (in CFA francs)	132404.3	-	132404.3	-
gender	Farmer's gender (1 if a woman and 0 otherwise)	0.82	0.89	0.80	0.09***
age	age of farmer (in years)	44.08	44.21	44.02	0.19
experience	Farmer's experience in farm production (Number of years)	23.61	25.26	22.95	2.30*
educat	Farmer's education level (0 if no education, 1 if has primary education level, and 2 if has secondary education level or higher)	1.17	1.15	1.17	-0.03

⁴ The sum of crops in value. Most smallholding farms in West-Cameroon have a large share of land in mixed cropping. In order to take into account the entire production of this mixed farming, we have opted for the sum of these different crops in value.

fertility	Evolution of the farmland fertility over the past 5 years (0 if the farmland fertility has declined, 1 if soil fertility has not changed and 2 if the farmland fertility has increased)	1.01	0.96	1.03	-0.07
credit	Farmer's access to credit (1 if access to credit, 0 otherwise)	0.34	0.26	0.37	-0.11**
Hsize	Household size (number of persons)	6.59	6.17	6.76	-0.59**
asso	Farmer participation in a producer organization (1 if a member of a producer organization, 0 otherwise)	0.69	0.69	0.69	-0.001
owner	Ownership of land cultivated (1 if owner, 0 otherwise)	0.89	0.86	0.91	-0.05*
maritalstatus	Marital status of the farmer (1 if married, 0 otherwise)	0.80	0.78	0.81	-0.03

Note: *, **, and *** indicate that difference between farmers without off-farm income and farmers with off-farm income is statistically significant at 10, 5, and 1 percent levels respectively

A square term of off-farm income ($Offfarm_i^2$) has been added to the regression to capture the potential non-linear relationship between land productivity and off-farm income ($Offfarm_i$).

Off-farm income variable in the model may be correlated with the error term. Farm income can be invested in the nonfarm economy, and nonfarm income can be invested in agricultural production. To address this potential endogeneity problem, we used the forecast values of off-farm income in the land productivity equation. And Heckman's two-step procedure is used to resolve the problem of selection bias in the land productivity equation.

Table 1 shows descriptive statistics on all the variables used in our analysis for households with and without off-farm income. Households with off-farm represent 72% while households without off-farm represent 28% of the total households surveyed. In this table, 564 farmers of West-Cameroon are considered.

Table 1 presents significantly larger cultivated plots and higher expenditures on labor among farmers with off-farm income compared to those without off-farm income. The households that had off-farm income were slightly larger (6.8 vs. 6.2 members) and had a higher farm income (728 801 vs. 459 962 Fcfa). A larger proportion of farmers with off-farm income were the owner of their cultivated land and had access to credit compared to their counterparts without off-farm income. However, the number of years of experience in agricultural production is significantly higher among farmers without off-farm income. Moreover, the farmers without off-farm income had a higher proportion of female farmers.

4. Results and Discussion

In the context of credit and labour market failures, the link between off-farm and farm activities transits or passes through the effect of income from off-farm activities on input demand. Thus, we will first present the impact of off-farm income on input demand (4.1), then their effect on farm productivity (4.2).

4.1 Off-farm income and agricultural input

Table 2 shows the estimated effects of off-farm income (aggregated (I) and disaggregated (II)) and other variables on input demand. Ordinary least squares regression was used to estimate input demand. In the absence of selection bias vis-à-vis the input demand equations, we are led to estimate these latter by the OLS.

We note that off-farm income has a positive and statistically significant impact on input demand (model I), especially off-farm income from remittance and self-employment (model II). In analysing the effect of off-farm income as a whole, Key (2020) also found that it has a positive impact on agricultural inputs.

Table 2 shows that credit access has a positive and statistically significant effect on input demand. In contrast to male farmers, female farmers negatively impact the demand for inputs, probably because women farmers tend to be less well off than men (with an average annual income of 517 753 vs. 976 920 Fcfa). Indeed, women in Africa, and in Cameroon in particular, are held back by customary laws that restrict their access to land ownership. This excludes them from bank loans due to a lack of collateral. Furthermore, they are solely responsible for unpaid domestic tasks and chores, which significantly reduces the time they can devote to paid work. Soil fertility and household size have a positive effect on input use (except on capital). Indeed, this could be because high production from the fertility of cultivated plots would lead to a high demand for labor for their maintenance. Similarly, increasing the size of the household will also increase the labor force as in Pfeiffer et al. (2009). As much as being the owner of cultivated land has a positive impact on the demand for labor, being married, on the other hand, reduces this demand as well as demand for total inputs. From an economical point of view, land ownership significantly stimulates labour demand, as tenure security encourages long-term, labour-intensive plot investments. Marital status optimises the use of internal

household resources, minimising the need for external production expenditure and allowing uncompensated family labour to substitute for external hired labour.

Table 2: Estimation of the off-farm income – inputs demand relationship ^a

Variables	With aggregated off-farm income (I)			With disaggregated off-farm income (II)		
	total input	labor	capital	total input	labor	capital
offfarm	0.12***	0.06***	0.05***	-	-	-
remittance	-	-	-	0.16***	0.01	0.15***
wagemplcom	-	-	-	0.03	0.02	0.002
selfempl	-	-	-	0.13***	0.10***	0.03*
gender	-78300.00***	-67000.00***	-12700.00	-89300.00***	-64700.00***	-25800.00*
experience	961.71	940.77	-3.52	947.49	932.3	-5.33
educat	16756.41	11492.78	5522.22	21960.48	11349.44	10867.95
fertility	60226.60***	58722.81***	1418.20	59319.57***	60137.43***	-902.03
credit	83131.70***	59015.34***	24072.09*	82501.16***	54642.27***	27834.44**
hsize	18877.07***	16842.66***	2106.85	18942.63***	17260.36***	1741.65
asso	39212.15	30083.09	8522.33	41335.19*	32028.66*	8808.17
owner	50979.02	60317.66**	-8979.24	52116.17	63179.45**	-10800.00
maritalstatus	-50500.00*	-46400.00**	-5763.29	-52200.00*	-48700.00**	-4844.3
Constant	24242.04	-28900.00	55878.98*	26815.21	-35000.00	64114.57**
Nombre d'obs	561	561	562	561	561	562
F-Fisher	19.01	21.68	4.26	16.37	18.78	5.43
Prob > F	0.00	0.00	0.00	0.00	0.00	0.00
R-Squared	0.26	0.28	0.07	0.26	0.29	0.11
Adj R-squared	0.24	0.27	0.05	0.25	0.27	0.09
VIF	1.25	1.25	1.25	1.23	1.23	1.23

Note ^a: *, **, *** on the coefficients indicate statistical significance at 10%, 5%, and 1% levels, respectively.

4.2. Off-farm income and productivity

Table 3 presents the regression for the impact of off-farm income on agricultural land productivity. Heckman's two-step procedure is used to resolve the problem of selection bias in the land productivity equation with the forecast values of off-farm income (to tackle the endogeneity problem). The estimated results are respectively with aggregated and disaggregated off-farm income.

We note in Table 3 that off-farm income is positive and statistically significant at the 5% level. Off-farm income significantly increases farm productivity. This result is consistent with some empirical results (Reardon *et al.*, 1994; Kilic *et al.*, 2009; Babatunde and Qaim 2010; Adelekan and Omotayo, 2017; Anang, 2019; Anang and Apedo, 2023). In fact, as Reardon *et al.* (1994) already said, in a context of credit market failure, as in most African countries (here in Cameroon), off-farm income would be a way for farmers to lift the financial constraint to buy the inputs necessary to boost their agricultural productivity.

The examination of the different components of off-farm income on farm productivity shows that, contrary to De Brauw and Giles (2008) and Akudugu (2016), who found that remittances did not bring productive investment in the farm, the off-farm income which impacts (here, positively) agricultural productivity comes from the remittance. This result is also confirmed in the work of Ngoura and Gankou (2024) in Cameroon. Otherwise, off-farm wage income and self-employment, even if they have a negative sign, they have no statistically significant impact on agricultural productivity. This is because wage employment and self-employment are more restrictive in terms of time. In fact, remittances have a positive and statistically significant impact on productivity. As unearned transfers, they provide direct liquidity to purchase productivity-enhancing inputs, without diverting local family labour away from the farm. By contrast, off-farm wage employment and self-employment yield negative but statistically insignificant coefficients. This reflects the competing forces of liquidity and labour: wage employment requires rigid time commitments, pulling critical labour away from farm management, while self-employment necessitates the continuous reinvestment of working capital, competing directly with the farm for scarce funds. Consequently, the structural time and resource

constraints of wage and self-employment neutralize any potential cash-flow benefits, leaving their net impact on agricultural productivity statistically indistinguishable from zero.

Table 3: Estimation of the off-farm income – land productivity relationship^a

Variables	With aggregated off-farm income (I)		With disaggregated off-farm income (II)	
	Coefficient ^b	T-statistic	Coefficient ^b	T-statistic
lnlabor	0.07	1.50	0.17**	2.10
lnland	-0.64***	-12.15	-0.64***	-7.04
lncapital	0.05	1.25	0.04	0.58
offfarmlcom_predit	1.21e-06**	2.47	-	-
remittance_predit	-	-	3.32e-06***	2.73
wagempllcom_predit	-	-	-1.20e-06	-0.70
selfempl_predit	-	-	-8.54e-07	-0.52
gender	0.38**	2.85	-0.14	-0.42
educat	-0.10*	-1.78	0.15	0.81
fertility	0.24***	3.78	0.22**	2.04
Inverse Mills ratio	-0.88**	-2.07	-1.43*	-1.82
Constant	9.51***	16.56	9.7***	8.16
Number of obs	561		561	
Censored obs	159		159	
Uncensored obs	402		402	
Wald chi2(.)	Wald chi2(7)= 183.93		Wald chi2(9) = 75.14	
Prob > chi2	0.00		0.00	

Note^a: There is a strong correlation between the off-farm income variable and its square term, so the square term of off-farm income has been removed from the model.

^b: *, **, *** Indicate statistical significance at 10%, 5% and 1% levels, respectively.

In both models (with aggregated and disaggregated off-farm income) the variables relating to agricultural inputs have the same sign. We observe that an increase in labor expenditure of 1% makes land productivity increase by 0.175% (in model II). However, we note the inverse relationship between farm size and land productivity. An increase in the land of 1% decreases land productivity by 0.642% (in the model I) and 0.643% (in model II). This result is consistent with those of Chand et al. (2011) and Sheng et al. (2019) who found that an inverse farm size–productivity relationship persists for most small-sized farms. In fact, as farms grow in size, their increased reliance on hired labour introduces moral hazard and agency costs. This results in lower labour intensity and diluted managerial oversight per unit of land. These structural market failures consequently prevent larger farms from achieving the same level of land productivity as labour-intensive smallholders.

Unlike Palacios-López and López (2015) and Campos et al. (2016) gender has a positive effect on land productivity and is significant at the 5% level (model I). This situation is certainly because, in the study area, female farmers have fewer off-farm jobs than male farmers. They, therefore, spend more time in their plot than male farmers. In addition, being a female farmer has a positive effect on remittances⁵, which have a positive impact on farm productivity.

As with Pfeiffer et al. (2009), our analysis of models I and II reveals that greater fertility of the cultivated plot leads to a greater increase in agricultural productivity. Meanwhile, the level of education of farmers has a significantly negative impact on agricultural productivity (model I), which implies that the educated farmers decrease their involvement in agricultural production activities and move to off-farm activities, in particular, to wage off-farm employment (see Table 3A in the appendix). This result is similar to that of Rashidin et al. (2020). Economically, this finding reflects a sharp increase in the opportunity cost of farm labour: higher levels of formal education increase the value of human capital in the non-farm labour market, incentivising farmers to reallocate their time and effort towards off-farm wage employment. Consequently, farming becomes a secondary activity, suffering from reduced direct supervision and less intensive plot management by the household head, who instead relies on lower-skilled labour.

⁵ See table 3A in the appendix.

Therefore, the labour diversion effect away from core agriculture outweighs the direct managerial benefits of education, ultimately reducing overall plot productivity.

5. Conclusion and policy implications

In contexts where smallholder farmers face credit constraints when investing or dealing with agricultural risks, engaging in non-agricultural activities can be a useful means of boosting agricultural productivity by enabling the purchase of agricultural inputs. However, these activities could also divert resources away from the agricultural sector. Therefore, it is important to identify which non-agricultural activities can be carried out alongside farming without negatively impacting it. This study aimed to identify these activities. The results show that off-farm income has a positive and statistically significant impact on the demand for farm inputs, particularly when derived from remittances or self-employment. Off-farm income also significantly increases farm productivity, particularly when it is derived from remittances. Based on the findings, it is concluded that diversifying farmer income sources is important, especially with regard to remittances, and off-farm income from self-employment. Moreover, governments should create more self-employment opportunities to increase and diversify farmer income sources. Indeed, given the proven positive impact of non-agricultural self-employment on agricultural productivity and the relatively low barriers to setting up and running a small business (Nagler and Naudé, 2017), it is clear that this is an attractive option for smallholder farmers. Furthermore, given the seasonal nature of agricultural activities, self-employment in small businesses offers smallholder farmers greater flexibility in terms of working hours than most salaried jobs (Mutsani *et al.*, 2025). Consequently, governments and non-governmental organisations must implement programmes that encourage smallholder farmers to also engage in off-farm activities as self-employed workers. Whilst encouraging farmers to invest in sustainable agriculture, these programmes could include grants, advisory support, short training courses and investments in infrastructure such as roads and electricity.

In the Cameroonian context, this could be achieved by strengthening the network of Common Initiative Groups (CIGs) and cooperatives that are currently supported by the Fonds National de l'Emploi and PIAASI (Programme Intégré d'Appui aux Acteurs du Secteur Informel). These organisations provide start-up grants and short business management training to rural youth and women. Extending these schemes to farm households seeking to diversify into small-scale trade, agri-food processing or artisanal activities would operationalise the self-employment channel identified in this study.

Financial inclusion initiatives are equally important for converting off-farm earnings into productive agricultural investment. Expanding the reach of community microfinance institutions, such as the MC² network (Mutuelles Communautaires de Croissance), and village savings and loan associations (tontines), would enable farmers to save remittance and self-employment income between harvests, while also providing them with access to short-term credit for purchasing inputs. Strengthening the decentralised extension agents of the Ministry of Agriculture and Rural Development (MINADER) as relay points for advisory services would help ensure that the additional capital generated by off-farm income is actually channelled into productivity-enhancing inputs and practices, rather than into non-farm consumption.

With regard to remittance transaction costs specifically, expanding digital financial systems in rural areas via mobile money infrastructure (e.g. MTN Mobile Money and Orange Money) would reduce costs and speed up both domestic and international transfers. Furthermore, the government should reduce the transaction costs associated with remittances more broadly, including on international transfers, which remain an important source of off-farm income.

These household income sources will increase capital to acquire agricultural inputs necessary to increase agricultural productivity and help achieve the Sustainable Development Goals.

6. Study limitations

The limitations of this study should be acknowledged. First, we would like to clarify that the data used in our study is cross-sectional, meaning that no dynamic analysis was performed. Therefore, the relationships identified between off-farm income and agricultural productivity should be understood as associations rather than as strictly causal effects. Undoubtedly, an analysis using longitudinal data would provide more information; a panel-data approach, which follows the same households over several agricultural seasons, would allow these dynamics to be identified and would strengthen causal analysis.

Second, the income variables, particularly the off-farm income and remittances, were self-reported by the respondents. Such data are susceptible to recall bias and under- or over-reporting, particularly with regard to irregular or informal income sources. This can result in measurement error and bias the estimated coefficients. Future studies could address this issue by combining survey data with administrative or mobile money transaction records, when available.

Third, the regional specificity of Western Cameroon means that the findings cannot be generalised to other regions of Cameroon or to other sub-Saharan African countries. Conducting this analysis in other regions of Cameroon and other sub-Saharan African countries would help to establish whether the identified relationships here hold more generally.

Fourth, excluding total factor productivity limits our ability to measure overall efficiency gains across all productive inputs. However, given the severe measurement constraints and recall biases associated with quantifying informal labour in smallholder settings, land productivity remains the most reliable and standard metric.

These limitations naturally motivate future research using longitudinal or panel data, which should extend the analysis to other regions of Cameroon and other sub-Saharan African countries.

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Appendix

Table 3A: Tobit estimation of the off-farm income ^a

Variables	offarm	remittance	wagemplIcom	selfempl
labor	0.38***	-0.01	0.42	0.43**
land	-98.76	-68.38	-721.1	335.6
capital	0.59***	0.51***	0.05	-0.06
gender	-269777***	104884***	-1.038e+06***	-253320***
experience	-2605	-773.8	-17200	-3872
educat	58391	-58791**	576417***	76887
fertility	81241**	57062***	53520	67,654
credit	62638	-4537	40553	128238*
hsize	19105**	10065**	43208	12845
asso	27330	5.9	333031	7327
owner	164737**	116212**	-101064	58052
maritalstatus	4031	-19920	-120147	190135**
Constant	-169808	-314670***	-1.982e+06***	-565122***
Nombre d'obs	560	560	560	560
Chi-square	110.11	49.86	49.81	75.09
Prob > chi2	0.00	0.00	0.00	0.00
Pseudo r-squared	0.01	0.01	0.04	0.01
sigma	524858.2	293275.2	1242663	606114

Note ^a : *, **, *** on the coefficients indicate statistical significance at 10%, 5%, and 1% levels, respectively.

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