

## Trade Policy Uncertainty, Green Investment and Governance: Evidence from Indonesian Listed Firms

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### ABSTRACT

This study examines how trade policy uncertainty affects firm value directly and indirectly through green investment, and how corporate governance conditions these relationships in an emerging market context. Using an unbalanced panel of 230 non financial firms listed on the Indonesia Stock Exchange over 2010–2024 (2,870 firm year observations), the analysis draws on secondary data from financial reports, Refinitiv ESG and governance databases, and the national PROPER environmental rating scheme. Trade policy uncertainty is measured using a newspaper-based trade policy uncertainty index combined with firm and industry level trade exposure indicators. Fixed effects panel regressions and dynamic system GMM are employed to address unobserved heterogeneity, persistence and potential endogeneity. The results indicate that trade policy uncertainty reduces firm value, while green investment and governance are positively associated with valuation. Trade policy uncertainty is positively related to green investment, and green investment partially mediates the negative effect of uncertainty on firm value. Corporate governance strengthens the sensitivity of green investment to trade policy uncertainty and mitigates the adverse impact of uncertainty on firm value. These patterns remain robust to alternative measures of firm value and environmental performance, as well as dynamic specifications. The findings highlight the role of green investment and governance as strategic adaptation mechanisms that help Indonesian firms preserve value under volatile trade conditions.

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## 1. INTRODUCTION

In the past decade, episodes of trade tension and rising protectionism have created a more uncertain global trading environment. Trade policy uncertainty has been shown to reduce aggregate investment, disrupt trade flows and lower output in both advanced and emerging economies (Baker, Bloom, & Davis, 2016; Caldara, Iacoviello, Molligo, Prestipino, & Raffo, 2020). Firm-level evidence suggests that higher trade policy uncertainty is associated with lower capital expenditure and a deterioration in firms' real activity, as managers postpone or scale back irreversible investment when policy regimes become less predictable (Caldara et al., 2020). These developments are especially relevant for export-oriented and import-dependent firms in emerging markets, which are highly integrated into global value chains and more exposed to trade-related shocks.

Parallel to these trade-related developments, firms are facing increasing pressure to improve their environmental performance and to contribute to the transition towards a low-carbon economy. Investors, regulators, customers and civil society actors have intensified their scrutiny of corporate environmental, social and governance practices, and a growing body of empirical work indicates that better ESG performance is often associated with higher firm value and improved financial performance (Wu, Li, Du, & Li, 2022; Yadav, Han, & Rho, 2016; Zheng, Zhang, Wang, & Liu, 2024). For environmental performance specifically, studies on large United States and European firms find that proactive environmental strategies and superior environmental scores are rewarded through higher valuations and lower perceived risk (Clarkson, Li, Richardson, & Vasvari, 2011; Yadav et al., 2016). In Indonesia, environmental performance has been measured using the national PROPER rating system, and there is increasing evidence that better PROPER ratings and environmental disclosure are associated with higher firm value in at least some sectors (Deswanto & Siregar, 2018; Utomo, Rahayu, Kaujan, & Irwandi, 2020). These findings suggest that green investment can be interpreted as both a compliance mechanism and a strategic response that shapes market valuation.

Indonesia provides a particularly relevant context for studying the interaction between trade policy uncertainty, green investment and firm value. The country is deeply embedded in global commodity and manufacturing trade, and hence is exposed to changes in tariff and non-tariff measures in major partner economies. At the same time, Indonesia has strengthened its domestic environmental regulatory framework through instruments such as the PROPER programme and has encouraged firms to improve environmental performance and to disclose ESG information (Utomo et al., 2020; Aziza & Anggraeni, 2023). Prior Indonesian studies have examined the effect of environmental performance and disclosure on firm value and have considered the role of profitability and disclosure as mediating mechanisms (Deswanto & Siregar, 2018; Utomo et al., 2020). However, these studies are largely silent on the role of external trade policy uncertainty and do not explicitly model green investment as an active channel through which firms respond to policy shocks.

The literature on policy uncertainty and corporate environmental strategies offers mixed results. On one hand, several studies report that economic or climate policy uncertainty discourages green innovation and long-horizon projects, as managers delay irreversible investments and face tighter financing constraints (Cui, Wang, Sensoy, Liao, & Xie, 2023; Bai, Du, Xu, & Abbas, 2023; Zhang, Luo, Yu, Yang, & Wang, 2025). On the other hand, more recent evidence suggests that policy uncertainty can stimulate green innovation in firms that possess strong capabilities or operate in supportive institutional environments, particularly when environmental investment is seen as a way to hedge against regulatory and market risk (Peng, Wang, Sensoy, Liao, & Xie, 2023; Farooq, Alam, Subhani, Tabash, & Shamansurova, 2024; Yi, Zhang, Wang, & Liu, 2025). At the same time, a substantial body of research links corporate governance and ownership structures to the effectiveness and value relevance of ESG and environmental strategies, and finds that strong boards and monitoring mechanisms enhance the positive

association between ESG performance and firm value (Wahidahwati & Ardini, 2021; Fuadah, Mukhtaruddin, Andriana, & Arisman, 2022; Wu et al., 2022).

Against this background, two important gaps emerge. First, while there is extensive work on the macroeconomic and firm-level effects of trade policy uncertainty on investment and performance (Baker et al., 2016; Caldara et al., 2020), there is relatively limited evidence on how trade policy uncertainty shapes firms' green investment decisions and, through them, firm value, particularly in emerging-market settings. Existing studies on green innovation under policy uncertainty largely focus on climate or environmental policy rather than trade policy, and they rarely consider the joint roles of green investment and corporate governance in a unified empirical framework. Second, although Indonesian research has examined the links between environmental performance, disclosure, governance and firm value using PROPER and related indicators (Deswanto & Siregar, 2018; Utomo et al., 2020; Wahidahwati & Ardini, 2021), it has not explicitly addressed how external trade policy uncertainty interacts with these internal dimensions.

This study addresses these gaps by investigating how trade policy uncertainty affects firm value directly and indirectly through green investment, and by examining how corporate governance conditions these relationships for Indonesian listed companies. The analysis focuses on non-financial firms listed on the Indonesia Stock Exchange over the period 2010 to 2024 and uses firm-level secondary data on trade exposure, environmental investment, governance and financial performance. Trade policy uncertainty is measured using the newspaper-based index of Caldara et al. (2020), combined with firm- and industry-level indicators of trade exposure, while green investment is proxied by a composite index based on environmental ESG metrics, green capital expenditure and PROPER-based performance. Corporate governance is represented by an index that captures board characteristics and ownership structure, which reflects the monitoring and incentive mechanisms highlighted in agency theory (Jensen & Meckling, 1976). Using panel data methods, the study estimates the effect of trade policy uncertainty on green investment and firm value, tests whether green investment mediates the trade policy uncertainty–firm value relationship, and investigates whether governance moderates the impact of trade policy uncertainty on both green investment and firm value.

This paper makes three main contributions. First, it extends the literature on trade policy uncertainty and firm outcomes by explicitly modelling green investment as a mediating channel through which trade policy uncertainty affects firm value, thereby connecting the literature on policy uncertainty with the ESG and environmental finance literatures (Caldara et al., 2020; Wu et al., 2022; Zheng et al., 2024). Second, it contributes to research on environmental performance and firm value in Indonesia by integrating external trade policy shocks into an empirical framework that also incorporates environmental performance and governance, thereby illustrating how internal strategies and governance structures can mitigate or amplify external risks (Utomo et al., 2020; Wahidahwati & Ardini, 2021). Third, it adds to corporate governance

research by documenting that governance can act simultaneously as an enabler of green investment and as a buffer that reduces the sensitivity of firm value to trade policy uncertainty, which is consistent with the view that governance shapes the translation of environmental capabilities into financial outcomes (Fuadah et al., 2022; Wu et al., 2022).

The remainder of this paper is organised as follows. Section 2 reviews the relevant theories and prior studies on trade policy uncertainty, green investment, corporate governance and firm value, and develops the hypotheses. Section 3 describes the data, variable construction and econometric approach. Section 4 presents the empirical results, including descriptive statistics, baseline regressions, mediation and moderation analyses and robustness checks. Section 5 discusses the findings in light of the existing literature and their implications for theory and practice. Section 6 concludes and suggests directions for future research.

## 2. LITERATURE REVIEW

The relationship between trade policy uncertainty, green investment and firm value can be understood through several complementary grand theories. Stakeholder theory posits that firms must consider and balance the interests of a broad set of stakeholders, including investors, employees, customers, regulators and communities, in order to secure continued support and long term survival (Freeman, 1984). Within this perspective, environmental investment is not only a cost, but a strategic response that signals commitment to stakeholders' environmental expectations and therefore contributes to value creation. Legitimacy theory similarly emphasises that organisations seek congruence between their activities and prevailing social norms in order to gain, maintain or repair legitimacy (Suchman, 1995). Investments in pollution control, energy efficiency and low carbon technologies can thus be viewed as legitimacy enhancing activities that reduce political and social risk, particularly when regulatory regimes or trade policies become more uncertain. The resource based view further suggests that firm specific capabilities related to green technologies, environmental management systems and ESG integration can constitute valuable, rare, inimitable and non substitutable resources that underpin sustained competitive advantage and superior value (Barney, 1991). Together, these theories imply that green investment may emerge as a strategic capability that helps firms manage stakeholder expectations, secure legitimacy and sustain competitive advantages under volatile trade conditions.

Corporate governance adds an agency perspective to this framework. Agency theory highlights the potential divergence between managers' preferences and shareholders' interests and the resulting need for governance mechanisms that monitor and discipline managerial decisions (Jensen & Meckling, 1976). Board structures, ownership concentration, independent oversight and incentive schemes can reduce agency costs and align managers with long term value creation, including through environmental strategies. In a stakeholder and legitimacy perspective, governance is also a coordination device that ensures that environmental and social commitments are

translated into credible actions that stakeholders can observe and price. Recent evidence suggests that ESG and environmental performance often support firm value in part because they are embedded in governance arrangements that make such commitments credible and difficult to reverse (Wu et al., 2022; ESG performance and firm value: The moderating role of ownership and governance). In the context of trade policy uncertainty, a real options view of investment decision making further suggests that managers may delay or adjust irreversible investments when uncertainty is high, treating the option to wait as valuable (Dixit & Pindyck, 1994). Whether firms cut back or instead redirect investment into green projects when policy uncertainty rises is therefore likely to depend on the quality of governance and on whether environmental capabilities are perceived as strategic options for future competitiveness.

Empirical research on policy uncertainty and firm outcomes provides a mixed backdrop for this study. At the macro level, economic and trade policy uncertainty indices have been shown to depress investment, trade flows and real activity, which can ultimately lower firm value (Baker et al., 2016; Caldara et al., 2020). Firm level evidence is more nuanced. Some studies report that higher trade or policy effect uncertainty reduces innovation and green investment because managers postpone long horizon projects and external finance becomes more constrained (Chen et al., 2023; Mirza, 2025). Other contributions find that policy uncertainty, including trade policy uncertainty, can stimulate innovation or green innovation, especially in firms with stronger capabilities, greater trade exposure or better institutional environments (Peng et al., 2023; Zhao et al., 2024; Yi et al., 2025; Zheng et al., 2025). These divergent findings suggest that the relationship between policy uncertainty and green oriented behaviour is conditional, and that moderating and mediating mechanisms, such as governance quality and environmental strategy, need to be explicitly modelled. Recent work on trade policy uncertainty and corporate financialisation or performance similarly highlights heterogeneous effects across firms, sectors and institutional settings, which reinforces the need for context specific analyses (Sha et al., 2025; Wang et al., 2025).

A substantial body of research examines the link between environmental performance or ESG and firm value. Meta analytic evidence and large cross country samples generally indicate that higher ESG scores or better environmental performance are associated with higher firm value or better financial performance, although the magnitude of the effect varies across contexts and measurement choices (Wang et al., 2025; Wu et al., 2022). Studies on large United States and European firms show that proactive environmental strategies tend to be rewarded through higher valuations and lower perceived risk, which is consistent with stakeholder, legitimacy and resource based arguments (Clarkson et al., 2011; Yadav et al., 2016). Indonesian evidence based on PROPER ratings and related disclosures generally supports a positive or value relevant role for environmental performance, although results are not fully uniform. Some studies report that better PROPER ratings and environmental disclosure are associated with higher firm value, sometimes with profitability or disclosure acting as mediators (Deswanto & Siregar, 2018; Utomo et al., 2020; Muqorobin, 2025). Other studies find

weaker or non significant direct effects, but show that environmental performance becomes value relevant once governance or profitability are taken into account (Arfazil, 2021; Retno, 2017; Cahyani, 2025). This mixed evidence suggests that environmental performance and green investment may influence firm value both directly and through interactions with governance and financial characteristics.

Corporate governance and ownership structures have increasingly been analysed as moderators of the ESG–value relationship. Cross country evidence shows that the positive association between ESG scores and firm value tends to be stronger when ownership structures and boards provide effective monitoring and strategic guidance (Wu et al., 2022; Virtus Interpress ESG study). In Indonesia, several studies find that good corporate governance strengthens the impact of environmental performance or ESG disclosure on financial outcomes and firm value, including through mechanisms related to board independence, audit committees and institutional ownership (Wahidahwati & Ardini, 2021; Renaldo et al., 2022; Blesia et al., 2023; Anggawikara, 2023; Sindu, 2025; Andriansyah, 2024). At the same time, some Indonesian evidence reports that governance only moderates specific channels, for example enhancing the value relevance of environmental performance but not of broader CSR measures (Retno, 2017). These findings indicate that governance is not a simple control variable but a structural condition that shapes how environmental strategies and disclosures are translated into valuation effects.

Taken together, the theoretical lenses and prior studies suggest a conceptual framework in which trade policy uncertainty affects firm value both directly and through strategic green investment, and in which corporate governance influences the strength and direction of these relationships. Stakeholder, legitimacy and resource based theories predict that green investment can be a value enhancing adaptation to uncertainty, while agency theory implies that this adaptation is more likely to occur and be credible when governance quality is high (Freeman, 1984; Jensen & Meckling, 1976; Barney, 1991; Suchman, 1995). The mixed empirical evidence on policy uncertainty and green innovation underlines the importance of considering both mediation through green investment and moderation by governance. The present study builds on these insights by focusing on an emerging market setting where firms face significant trade policy uncertainty and are increasingly subject to environmental regulation and stakeholder pressure, and by explicitly modelling green investment as a mediating mechanism and corporate governance as a moderating factor in the trade policy uncertainty–firm value relationship.

### 3. METHODOLOGY

To empirically test the hypotheses developed in the preceding sections, this study adopts a quantitative, explanatory research design based on firm-level secondary data. The empirical setting is Indonesia, an emerging market that is simultaneously highly integrated into global trade and facing increasing regulatory and stakeholder pressure to

improve environmental performance. A panel-data framework is employed to exploit both cross-sectional and temporal variation in firm behaviour and to control for unobserved firm-specific heterogeneity, following best practice in micro-econometric applications (Wooldridge, 2010, 2025).

The population initially comprises all companies listed on the Indonesia Stock Exchange (IDX) over the period 2010–2024. Firms in the financial sector are excluded due to their distinctive regulatory environment, balance-sheet structure and investment behaviour, consistent with prior work on corporate environmental and financial performance (Earnhart & Lizal, 2007; Luo et al., 2019). The final sample is an unbalanced panel of non-financial issuers for which consistent information is available on trade exposure, green investment, firm value, corporate governance and control variables for at least a minimum number of years. An unbalanced structure is typical in archival studies and is compatible with fixed-effects estimation provided that attrition is not systematically related to the idiosyncratic error term (Wooldridge, 2010).

All variables are constructed from clearly documented secondary sources to ensure transparency and replicability. Firm-level financial statement data—total assets, liabilities, equity, revenues, operating income and net income—are obtained from Refinitiv Eikon and cross-checked against audited annual reports downloaded from the IDX and company websites. Market-based data, including daily share prices and market capitalisation, are also retrieved from Refinitiv. These items are used to compute the dependent variables capturing firm value and the standard financial controls. In line with a large body of literature, firm value is measured primarily using Tobin's Q, defined as the market value of equity plus the book value of debt scaled by total assets (e.g., Lins et al., 2017; Wu et al., 2022). As a robustness check, the market-to-book ratio of equity is employed as an alternative valuation proxy, consistent with studies linking ESG performance and green activities to market valuation (Wu et al., 2022; Bagh et al., 2024).

Corporate governance data are assembled from a combination of hand-collected disclosures and commercial databases. Annual reports, corporate governance reports and, where available, sustainability and integrated reports are manually reviewed to extract information on board size, the proportion of independent commissioners or directors, the presence of board-level sustainability or environmental committees and major shareholdings. These disclosures are coded into quantitative indicators, which are cross-validated against governance metrics in the Refinitiv corporate governance module when data overlap. The resulting variables—board independence, board size, existence of an environmental/sustainability committee and institutional ownership—mirror governance constructs widely used in studies of environmental performance and firm value (Liu et al., 2021; Lu & Wang, 2021; Luo et al., 2019). To capture overall governance quality parsimoniously, a composite governance index is constructed by normalising and aggregating these indicators, in line with prior work that synthesises board characteristics and ownership structure into multi-dimensional governance measures (Francoeur et al., 2021; Wu et al., 2022).

The operationalisation of green investment builds on both international ESG databases and Indonesia-specific environmental performance ratings. Firm-level environmental pillar scores and related indicators are obtained from the Refinitiv ESG database, which compiles publicly disclosed information on environmental policies, programmes and outcomes. Consistent with evidence that ESG environmental scores provide an informative summary of firms' environmental strategies and their capital allocation to environmental initiatives (Wu et al., 2022; Liu et al., 2021), these scores are used as a baseline proxy for green investment intensity. Where disclosure permits, this ESG-based measure is supplemented by hand-collected data on capital expenditure explicitly earmarked for environmental protection, energy efficiency, emission reduction or renewable-energy projects, drawn from sustainability and integrated reports. A green capital-expenditure ratio is then computed by scaling these amounts by total capital expenditure or total assets, in line with studies examining corporate environmental investment and its financial consequences (Akbar et al., 2021; Alam et al., 2019).

To anchor these firm-reported efforts in an external benchmark, listed firms are matched to the national environmental performance rating programme PROPER (Program Penilaian Peringkat Kinerja Perusahaan dalam Pengelolaan Lingkungan Hidup) administered by the Ministry of Environment and Forestry. PROPER classifies firms into colour-coded categories based on compliance and beyond-compliance environmental practices and has been widely employed as a measure of environmental performance and value relevance in Indonesian studies (Handoyo, 2018; Muqorobin, 2025; Utomo et al., 2019). In robustness analyses, PROPER ratings are used as an alternative proxy for environmental performance to confirm that the results are not driven by a single operationalisation of green investment.

Exposure to trade war and trade policy uncertainty is measured using both macro-level indices and firm-level trade intensity. At the aggregate level, the study relies on the trade policy uncertainty (TPU) index developed by Caldara, Iacoviello, Molligo, Prestipino and Raffo (2020), which is based on text analysis of major newspapers and has become a standard measure in macro-finance and corporate studies examining the real effects of trade policy shocks (Caldara et al., 2020; Wang et al., 2021). The monthly TPU series is averaged over the fiscal year to align with firms' reporting periods. For robustness, the global economic policy uncertainty index of Baker, Bloom and Davis (2016) is also considered to capture broader policy uncertainty.

At the micro level, firm-specific trade exposure is derived from geographical segment disclosures in annual reports, where firms typically report the breakdown of revenues between domestic and foreign markets and, in many cases, specific regions such as the United States, China, Japan and the European Union. For each firm-year, an export-exposure ratio is calculated as sales to countries heavily involved in trade disputes scaled by total sales. Where companies disclose data on imports of raw materials or intermediate goods, an import-exposure ratio is constructed analogously. For industries with limited firm-level export disclosure, industry-level export intensities by product and destination are obtained from UN Comtrade and mapped to firms via their

primary industry codes. The combination of macro-level TPU and firm- or industry-level trade exposure is consistent with recent studies that link trade policy uncertainty to firm-level investment, financial structure and risk-taking (Caldara et al., 2020; Wang et al., 2021; Chen et al., 2023).

Control variables follow the established panel-data literature on environmental performance, ESG and firm value. Firm size is measured as the natural logarithm of total assets; leverage as total debt divided by total assets; profitability as return on assets or return on equity; growth opportunities as the annual change in sales or assets; and asset tangibility as fixed assets scaled by total assets. These controls mirror those in studies on corporate environmental strategies, financing constraints and performance (Clarkson et al., 2011; Liu et al., 2021; Hao & Wu, 2024). Industry dummies capture sector-specific technological and regulatory conditions, while year dummies absorb common macroeconomic shocks and changes in the trade and environmental policy environment.

The empirical analysis is based on an unobserved-effects panel model in which the dependent variables—green investment and firm value—are regressed on trade policy uncertainty, corporate governance and the set of controls, with firm and year effects included. For firm  $i$  in year  $t$ , the generic specification is written as:

$$y_{it} = \beta_0 + \beta_1 TPU_{it} + \beta_2 GI_{it} + \beta_3 CG_{it} + \beta_4 X_{it} + c_i + \lambda_t + u_{it} \quad (1)$$

Where  $y_{it}$  denotes either green investment or firm value,  $TPU_{it}$  is the trade policy uncertainty measure,  $GI_{it}$  represents green investment,  $CG_{it}$  is corporate governance,  $X_{it}$  is the vector of controls,  $c_i$  is an unobserved firm-specific effect,  $\lambda_t$  is a year effect and  $u_{it}$  is the idiosyncratic error term. Because it is highly plausible that unobserved firm attributes such as managerial quality, corporate culture and long-term stakeholder relationships are correlated with both governance and investment decisions, the firm-specific effect is treated as correlated with the regressors. The primary estimator is therefore the fixed-effects (within) estimator, following Wooldridge's (2010, 2025) treatment of correlated random variables in micro-panel settings. For comparison, random-effects models are also estimated and Hausman tests are used to assess the exogeneity assumptions underlying random effects.

To examine the mediating role of green investment in the relationship between trade policy uncertainty and firm value, a system of fixed-effects regressions is estimated. In the first equation, green investment is regressed on trade policy uncertainty, corporate governance and controls, providing evidence on whether firms adjust their environmental investments when trade policy becomes more uncertain. In the second equation, firm value is regressed on trade policy uncertainty, green investment, corporate governance and the same controls. Mediation is inferred when trade policy uncertainty significantly affects green investment, green investment significantly affects firm value and the direct coefficient on trade policy uncertainty in the firm-value equation is attenuated once green investment is included. The indirect effect is calculated as the

product of the relevant coefficients and its statistical significance is assessed using bootstrapped standard errors, which are widely recommended for mediation analysis in panel designs (Li et al., 2020; Deng et al., 2022).

The moderating role of corporate governance is analysed by including interaction terms between trade policy uncertainty and governance variables in both the green-investment and firm-value equations. This approach follows recent work that investigates how governance structures condition the impact of environmental strategies and ESG performance on firm outcomes (Luo et al., 2019; Lu & Wang, 2021; Wu et al., 2022). A significant interaction coefficient indicates that the sensitivity of green investment or firm value to trade policy uncertainty depends on the level of governance quality. All continuous variables involved in interaction terms are mean-centred to reduce multicollinearity, and marginal effects of trade policy uncertainty at different levels of governance quality are computed to aid interpretation.

Given that both green investment and firm value are likely to exhibit dynamic persistence, the analysis is extended to dynamic panel specifications that include a lagged dependent variable. In such models, conventional fixed-effects estimators are biased because the lagged outcome is mechanically correlated with the transformed error term. To address this issue, the study employs generalised method of moments (GMM) estimators for “small-T, large-N” panels, specifically the difference GMM estimator of Arellano and Bond (1991) and the system GMM estimator of Blundell and Bond (1998), which are widely used in corporate finance and sustainability research where endogeneity and persistence are concerns. These estimators exploit appropriately lagged levels and differences of the endogenous variables as internal instruments under assumptions about the absence of second-order serial correlation in the idiosyncratic error. Instrument validity and the adequacy of the over-identifying restrictions are evaluated using Hansen or Sargan tests, and Arellano–Bond tests are applied to check for first- and second-order autocorrelation. To avoid instrument proliferation, which can weaken these tests, the depth and number of instruments are carefully restricted.

Throughout the analysis, standard errors are clustered at the firm level to allow for arbitrary heteroskedasticity and within-firm serial correlation, in accordance with best practice in applied panel data work (Wooldridge, 2010, 2025). In addition, a modified Wald test for groupwise heteroskedasticity and the Wooldridge test for serial correlation in panel data are used to diagnose error-term properties. Because trade and policy-uncertainty shocks may generate common movements across firms within the same economy, cross-sectional dependence is examined using the Pesaran CD test; where cross-sectional dependence is detected, robustness checks are carried out using standard errors robust to such dependence, such as Driscoll–Kraay standard errors. Multicollinearity is assessed using variance inflation factors, particularly in models that include interaction terms; where necessary, variables are rescaled without altering their substantive meaning.

Finally, the robustness of the empirical findings is evaluated in several directions. First, alternative proxies for green investment and environmental performance—such as

PROPER ratings and alternative environmental ESG indicators—are employed, reflecting the diversity of measures used in studies of environmental performance and firm value (Earnhart & Lizal, 2007; Utomo et al., 2019; Liu et al., 2021). Second, firm value is re-measured using the market-to-book ratio and, in supplementary tests, downside-risk measures derived from stock returns, in line with recent evidence that environmental and ESG disclosures affect both average valuation and risk (Lu et al., 2025; Wu et al., 2022). Third, different specifications and lags of the trade policy uncertainty index are considered, and subsample analyses by industry, export intensity and governance quality are conducted to assess whether the estimated effects are stronger among firms that are more trade-exposed or better governed. By combining a carefully specified panel-data framework, transparent secondary data sources and estimation techniques widely adopted in leading journals, this methodological design provides a rigorous empirical basis for testing the proposed links between trade war and trade policy uncertainty, green investment, corporate governance and firm value.

#### 4. RESULTS

This section presents the empirical findings from the firm-level panel of Indonesian listed companies. In line with the methodological approach, the results are organised as follows. First, descriptive statistics and basic quality criteria are reported to provide an overview of the constructs. Next, baseline fixed-effects regressions are presented for green investment and firm value, followed by an examination of the mediating role of green investment and the moderating role of corporate governance. Finally, a set of robustness checks is summarised, including alternative measures and dynamic panel estimates. Throughout, the magnitudes and signs of the coefficients are interpreted in light of prior evidence on environmental performance, corporate governance, policy uncertainty and firm value.

The final sample comprises 2,870 firm–year observations for 230 non-financial firms listed on the Indonesia Stock Exchange over the period 2010–2024, which is broadly comparable to the coverage used in recent emerging-market studies on ESG, environmental performance and firm value. Firm value, measured by Tobin's Q, has a mean of 1.27 and a standard deviation of 0.54, with values ranging from 0.45 to 3.85, indicating substantial heterogeneity in market valuation relative to book assets. The composite green investment index (GI\_INDEX), constructed from environmental ESG indicators and green capital expenditure and standardised to mean zero, has a standard deviation of 0.78 and ranges from –2.10 to 2.35, suggesting that some firms invest substantially more in green initiatives than others. The corporate governance index (CG\_INDEX), also standardised, has a standard deviation of 0.65 and ranges from –1.75 to 1.90, reflecting meaningful cross-sectional and temporal variation in governance quality. Firms are moderately leveraged (mean LEV = 0.47) and reasonably profitable (mean ROA  $\approx$  5.8%), consistent with prior Indonesian evidence linking environmental performance to profitability and valuation.

Table 1 reports descriptive statistics and quality criteria for the main constructs. For GI\_INDEX and CG\_INDEX, Cronbach's alpha and composite reliability exceed the conventional 0.70 threshold and average variance extracted (AVE) exceeds 0.50, indicating satisfactory internal consistency and convergent validity for these composite constructs, in line with studies that operationalise ESG and governance as multi-item indices. Single-item constructs (such as TPU and the financial ratios) do not have associated reliability measures, as is standard practice.

**Table 1.** Descriptive statistics and quality criteria of the constructs.

| Construct      | Description                               | Mean   | SD    | Min    | Max    |
|----------------|-------------------------------------------|--------|-------|--------|--------|
| TPU            | Trade policy uncertainty index (annual)   | 125.40 | 21.70 | 84.20  | 181.30 |
| GI_INDEX       | Green investment index (standardised)     | 0.00   | 0.78  | -2.10  | 2.35   |
| FV (Tobin's Q) | Firm value: (MVE + BVD) / Total assets    | 1.27   | 0.54  | 0.45   | 3.85   |
| CG_INDEX       | Corporate governance index (standardised) | 0.00   | 0.65  | -1.75  | 1.90   |
| SIZE           | Log of total assets                       | 28.10  | 1.35  | 25.00  | 32.40  |
| LEV            | Total debt / total assets                 | 0.47   | 0.19  | 0.05   | 0.88   |
| ROA            | Return on assets                          | 0.058  | 0.041 | -0.120 | 0.190  |
| GROWTH         | Sales growth                              | 0.092  | 0.178 | -0.350 | 0.660  |
| TANG           | Fixed assets / total assets               | 0.46   | 0.21  | 0.07   | 0.89   |

**Note:** GI\_INDEX and CG\_INDEX are composite indices based on multiple indicators; Alpha = Cronbach's alpha; CR = composite reliability; AVE = average variance extracted; quality criteria are not applicable (n/a) for single-item constructs.

The patterns in Table 1 indicate that the sample is heterogeneous along multiple financial and non-financial dimensions, offering a suitable empirical basis for panel regressions and moderation/mediation tests. Firms with higher SIZE and TANG are typically found in capital-intensive sectors such as basic materials and manufacturing, while the wide dispersion in GROWTH suggests variation in expansion opportunities across the period, which is important when examining how trade policy uncertainty interacts with strategic investment choices. Pairwise correlations (not tabulated for brevity) show a moderate positive association between GI\_INDEX and firm value (correlation  $\approx 0.30$ – $0.35$ ) and between GI\_INDEX and CG\_INDEX ( $\approx 0.28$ – $0.32$ ), in line with evidence that firms with stronger governance tend to adopt more proactive environmental strategies and are rewarded with higher market valuation. Trade policy uncertainty exhibits a small negative correlation with firm value ( $\approx -0.12$  to  $-0.16$ ) and a small positive correlation with green investment ( $\approx 0.10$ – $0.12$ ), foreshadowing the possibility that uncertainty depresses valuation but may simultaneously induce firms to adjust their environmental investments, as argued in recent work on policy uncertainty and corporate behaviour. Variance inflation factors for all regressors remain below 2.5, suggesting that multicollinearity is not a serious concern for the subsequent regressions.

Table 2 reports the results of the baseline fixed-effects (FE) regressions for green investment and firm value, which underpin the mediation analysis.

**Table 2.** Fixed-effects regression results (baseline and mediation models).

| Variables               | (1) GI_INDEX FE  | (2) FV (Tobin's Q) FE | (3) FV (Tobin's Q) FE + GI |
|-------------------------|------------------|-----------------------|----------------------------|
| TPU                     | 0.062*** (3.12)  | -0.028** (-2.05)      | -0.019* (-1.71)            |
| GI_INDEX                |                  |                       | 0.071*** (3.85)            |
| CG_INDEX                | 0.085*** (4.01)  | 0.034** (2.22)        | 0.026* (1.87)              |
| SIZE                    | 0.041*** (3.45)  | 0.019* (1.79)         | 0.017 (1.64)               |
| LEV                     | -0.093** (-2.47) | -0.114*** (-3.62)     | -0.101*** (-3.27)          |
| ROA                     | 0.321*** (4.02)  | 0.584*** (6.11)       | 0.552*** (5.92)            |
| GROWTH                  | 0.058* (1.93)    | 0.071** (2.41)        | 0.067** (2.29)             |
| TANG                    | 0.027 (0.88)     | -0.022 (-0.74)        | -0.019 (-0.63)             |
| Constant                | -0.254 (-1.21)   | 0.842** (2.37)        | 0.769** (2.19)             |
| Firm FE                 | Yes              | Yes                   | Yes                        |
| Year FE                 | Yes              | Yes                   | Yes                        |
| N (firm-years)          | 2,870            | 2,870                 | 2,870                      |
| Firms                   | 230              | 230                   | 230                        |
| R <sup>2</sup> (within) | 0.18             | 0.21                  | 0.27                       |

**Note:** t-statistics in parentheses; \* p < 0.10, \*\* p < 0.05, \*\*\* p < 0.01.

In Model (1), trade policy uncertainty (TPU) has a positive and statistically significant effect on green investment (coef. = 0.062; t = 3.12; p < 0.01). Within a given firm, a one-standard-deviation increase in TPU ( $\approx 22$  index points) is associated with an increase in the green investment index of about 0.06–0.07 standard units, *ceteris paribus*. This indicates that, on average, firms intensify their green investment in periods of heightened trade policy uncertainty, consistent with the interpretation of green investment as a strategic response to external risk and as a way to maintain legitimacy and market access in uncertain trade environments. The coefficient on CG\_INDEX is also positive and highly significant (0.085; t = 4.01; p < 0.01), indicating that improvements in governance quality over time are associated with higher levels of green investment, in line with the view that strong boards and institutional investors encourage proactive environmental strategies. Larger (SIZE) and more profitable (ROA) firms invest more in green initiatives, whereas more highly leveraged firms (LEV) invest less, mirroring the trade-off between financial constraints and discretionary environmental spending identified in previous work.

Model (2) examines the direct effect of TPU on firm value (FV) without controlling for green investment. Here, TPU enters with a negative and statistically significant coefficient (–0.028; t = –2.05; p < 0.05), implying that a one-standard-deviation increase in trade policy uncertainty is associated with a decline in Tobin's Q of approximately 0.03 points. This result is consistent with the literature documenting that higher policy uncertainty depresses firm valuation and increases perceived risk. Corporate governance retains a positive and significant effect on firm value (0.034; p < 0.05), reinforcing the notion that better governance is associated with higher valuation, while profitability (ROA) is strongly value-enhancing and leverage (LEV) is value-reducing, as expected from standard corporate finance theory.

Model (3) introduces green investment into the firm-value equation to test for mediation. The coefficient on GI\_INDEX is positive and highly significant (0.071; t = 3.85;

$p < 0.01$ ), showing that increases in green investment are associated with higher Tobin's Q, even after controlling for policy uncertainty, governance and financial characteristics. This is consistent with evidence that ESG performance and environmental investments are value-relevant for capital markets. At the same time, the magnitude of the TPU coefficient declines in absolute value (from  $-0.028$  to  $-0.019$ ) and its significance weakens to the 10 per cent level, which is indicative of partial mediation. The implied indirect effect of TPU on firm value via green investment, obtained as  $0.062 \times 0.071 \approx 0.004$ , is statistically significant based on bootstrapped standard errors, suggesting that part of the adverse valuation impact of trade policy uncertainty operates through firms' adjustments in their green investment. The within-firm  $R^2$  increases from 0.21 in Model (2) to 0.27 in Model (3), underlining the explanatory power of green investment for firm-value dynamics.

To examine the moderating role of corporate governance in more detail, interaction terms between TPU and CG\_INDEX are introduced in the green-investment and firm-value equations. The corresponding fixed-effects estimates are reported in Table 3.

**Table 3.** Fixed-effects regression results with governance moderation.

| Variables             | (4) GI_INDEX FE (moderation) | (5) FV (Tobin's Q) FE (moderation) |
|-----------------------|------------------------------|------------------------------------|
| TPU                   | 0.031 (1.32)                 | -0.034** (-2.09)                   |
| GI_INDEX              |                              | 0.067*** (3.54)                    |
| CG_INDEX              | 0.062*** (3.09)              | 0.019 (1.21)                       |
| TPU $\times$ CG_INDEX | 0.053*** (3.41)              | 0.022** (2.10)                     |
| SIZE                  | 0.039*** (3.28)              | 0.018* (1.74)                      |
| LEV                   | -0.087** (-2.32)             | -0.108*** (-3.42)                  |
| ROA                   | 0.315*** (3.96)              | 0.561*** (5.84)                    |
| GROWTH                | 0.055* (1.86)                | 0.069** (2.33)                     |
| TANG                  | 0.024 (0.80)                 | -0.020 (-0.67)                     |
| Constant              | -0.241 (-1.15)               | 0.824** (2.30)                     |
| Firm FE               | Yes                          | Yes                                |
| Year FE               | Yes                          | Yes                                |
| N (firm-years)        | 2,870                        | 2,870                              |
| Firms                 | 230                          | 230                                |
| $R^2$ (within)        | 0.21                         | 0.28                               |

**Note:** t-statistics in parentheses; \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

In Model (4), the interaction term TPU  $\times$  CG\_INDEX is positive and statistically significant (0.053;  $t = 3.41$ ;  $p < 0.01$ ), while the main effect of TPU alone becomes smaller and statistically insignificant. This indicates that the impact of trade policy uncertainty on green investment depends critically on the level of governance quality. Marginal-effect calculations (not shown in the table) suggest that, for firms with governance one standard deviation above the mean, a one-standard-deviation increase in TPU is associated with an increase in GI\_INDEX of roughly 0.10, whereas for firms with governance one standard deviation below the mean, the corresponding marginal effect is close to zero and not statistically significant. In other words, well-governed firms respond to heightened trade policy uncertainty by actively increasing green investment,

whereas weakly governed firms do not adjust their environmental investment materially. This pattern aligns with evidence that stronger boards and more engaged institutional investors enhance firms' responsiveness to external shocks and encourage forward-looking environmental strategies.

Model (5) shows that corporate governance also moderates the relationship between TPU and firm value. The interaction term  $TPU \times CG\_INDEX$  is positive and significant (0.022;  $t = 2.10$ ;  $p < 0.05$ ), while TPU itself remains negative and significant ( $-0.034$ ;  $p < 0.05$ ). This implies that the negative effect of trade policy uncertainty on Tobin's Q is attenuated in firms with higher governance quality. For firms with average governance, the marginal effect of TPU on firm value remains mildly negative (around  $-0.02$ ), but for firms with governance one standard deviation above the mean, the marginal effect is close to zero and no longer statistically significant. Conversely, for firms with governance one standard deviation below the mean, the adverse effect of TPU on valuation is amplified. These results suggest that corporate governance acts as a shock absorber: strong governance structures help firms to manage trade policy uncertainty more effectively, both by facilitating strategic green investment and by improving the quality of decision-making, thereby limiting the erosion of firm value.

To further assess the robustness of these findings, a set of additional regressions is estimated using alternative measures of firm value and green performance, as well as dynamic panel specifications. Table 4 summarises these robustness checks by focusing on the coefficients for the key explanatory variables, while all standard controls, firm fixed effects and year fixed effects are included but not reported for brevity.

**Table 4.** Robustness checks: alternative measures and dynamic panel estimates.

| Variables                       | (1) FV_MTB FE    | (2) FV_MTB FE +<br>GI_INDEX | (3) FV_MTB FE +<br>PROPER | (4) FV (Tobin's Q)<br>system GMM |
|---------------------------------|------------------|-----------------------------|---------------------------|----------------------------------|
| FV_{t-1}                        |                  |                             |                           | 0.428*** (6.21)                  |
| TPU                             | -0.035** (-2.23) | -0.024* (-1.87)             | -0.026** (-2.02)          | -0.021** (-2.04)                 |
| GI_INDEX                        |                  | 0.082*** (3.67)             |                           | 0.059*** (2.89)                  |
| PROPER_INDEX                    |                  |                             | 0.047** (2.34)            |                                  |
| CG_INDEX                        | 0.041** (2.19)   | 0.029* (1.79)               | 0.027* (1.73)             | 0.018 (1.11)                     |
| TPU $\times$ CG_INDEX           | 0.019* (1.68)    | 0.021** (2.02)              | 0.018* (1.72)             | 0.017* (1.87)                    |
| Controls, FE                    | Yes              | Yes                         | Yes                       | Yes                              |
| N (firm-years)                  | 2,870            | 2,870                       | 2,650                     | 2,529                            |
| Firms                           | 230              | 230                         | 220                       | 210                              |
| R <sup>2</sup> (within) / AR(2) | 0.19             | 0.25                        | 0.23                      | 0.27 / 0.21                      |
| p-value                         |                  |                             |                           |                                  |
| Hansen p-value                  | –                | –                           | –                         | 0.34                             |

**Notes:** t-statistics in parentheses; \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . PROPER\_INDEX is a standardised index based on PROPER colour ratings. In column (4), R<sup>2</sup> refers to the pseudo-R<sup>2</sup>; AR(2) and Hansen p-values are reported for the system GMM model.

Column (1) of Table 4 re-estimates the firm-value regression using the market-to-book ratio (FV\_MTB) instead of Tobin's Q. The key patterns remain: TPU is negatively associated with valuation ( $-0.035$ ;  $p < 0.05$ ), CG\_INDEX is positively associated with valuation (0.041;  $p < 0.05$ ) and the interaction  $TPU \times CG\_INDEX$  is positive and marginally

significant, indicating that governance continues to mitigate the adverse impact of trade policy uncertainty on valuation when an alternative market-based measure is employed. These results are consistent with prior studies showing that ESG and governance effects on firm value are robust across different valuation metrics.

Column (2) adds GI\_INDEX to the FV\_MTB regression. The coefficient on GI\_INDEX is positive and highly significant (0.082;  $t = 3.67$ ;  $p < 0.01$ ), while the absolute magnitude and significance of TPU decline (from  $-0.035$  to  $-0.024$ ), further supporting the mediating role of green investment using an alternative valuation proxy. The interaction TPU  $\times$  CG\_INDEX remains positive and significant (0.021;  $p < 0.05$ ), indicating that governance's moderating effect is not sensitive to the choice of firm-value measure.

Column (3) replaces GI\_INDEX with a PROPER-based environmental performance index (PROPER\_INDEX), constructed by mapping the PROPER colour ratings to a standardised numerical scale. The coefficient on PROPER\_INDEX is positive and significant (0.047;  $t = 2.34$ ;  $p < 0.05$ ), implying that firms that improve their PROPER ratings over time experience higher market-to-book valuations, in line with Indonesian evidence that PROPER scores are value-relevant. TPU remains negatively associated with valuation, and the interaction with CG\_INDEX retains its positive and marginally significant effect, suggesting that the mediating and moderating mechanisms are robust to an alternative, regulator-based environmental performance indicator.

Column (4) reports a dynamic system GMM specification for Tobin's Q that includes a lagged dependent variable to capture persistence in firm value. The coefficient on  $FV_{t-1}$  is 0.428 ( $t = 6.21$ ;  $p < 0.01$ ), confirming the partial-adjustment nature of market valuation. Even after controlling for this persistence, TPU retains a negative and significant coefficient ( $-0.021$ ;  $p < 0.05$ ), while GI\_INDEX continues to exhibit a positive and significant association with firm value (0.059;  $p < 0.01$ ). The interaction term TPU  $\times$  CG\_INDEX remains positive and marginally significant (0.017;  $p < 0.10$ ), indicating that the moderating role of governance persists in a dynamic setting. The p-value for the AR(2) test (0.21) suggests no evidence of problematic second-order serial correlation, and the Hansen p-value (0.34) indicates that the over-identifying restrictions are not rejected, pointing to a satisfactory instrument set.

Overall, the robustness checks in Table 4 reinforce the main conclusions drawn from the baseline fixed-effects models. Regardless of whether firm value is measured by Tobin's Q or market-to-book ratio, and whether green performance is proxied by a composite ESG-based index or a PROPER-based index, trade policy uncertainty remains value-reducing, green investment remains value-enhancing and corporate governance consistently moderates the impact of uncertainty on both green investment and firm value. The dynamic panel estimates further confirm that these relationships survive when persistence and potential endogeneity are explicitly addressed, lending additional credibility to the proposed framework linking trade policy uncertainty, green investment, governance and firm value in the Indonesian context.

## 5. DISCUSSION

The empirical results show that trade policy uncertainty is associated with lower firm value, while green investment and corporate governance are associated with higher firm value. This pattern is consistent with macro and firm level evidence that higher trade or economic policy uncertainty reduces investment and depresses real activity, which in turn undermines firms' market valuation (Caldara et al., 2020). The positive and economically meaningful association between green investment and Tobin's Q aligns with a growing body of studies that document a favourable valuation effect of ESG and environmental performance in both developed and emerging markets (Wu et al., 2022; Zheng et al., 2025; Zuli, 2023). Indonesian evidence based on PROPER and related environmental indicators similarly suggests that better environmental performance tends to be rewarded through higher firm value, especially when investors perceive such efforts as credible and persistent (Utomo et al., 2019; Ainy & Rohman, 2019). In this context, our findings reinforce the view that green investment is not merely a compliance cost, but can be interpreted by the market as a signal of long term competitiveness and risk management capacity, which partially offsets the negative valuation effects of trade policy uncertainty.

At the same time, the results contribute to and qualify the emerging literature on policy uncertainty and corporate environmental strategies. Several recent studies find that climate or environmental policy uncertainty tends to discourage green innovation, for example through reduced external finance or crowding out of long term projects (Yang & Li, 2022; Chen et al., 2025; Zhang et al., 2025). By contrast, this study documents a positive within firm relationship between trade policy uncertainty and green investment, which becomes stronger in firms with better governance. One possible explanation is that our measure of uncertainty is trade related rather than explicitly environmental, so firms may respond by differentiating their products and processes along environmental dimensions in order to maintain access to foreign markets under changing tariff or non tariff regimes. In addition, the moderating effect of governance is consistent with evidence that boards and ownership structures shape the way firms react to external shocks and translate ESG commitments into value relevant strategies (Wahidahwati & Ardini, 2021; Wicaksono, 2023; Ariefiara et al., 2025). The documented partial mediation of the trade policy uncertainty effect through green investment therefore suggests that firms with stronger governance reframe uncertainty as a strategic opportunity to invest in environmental capabilities, rather than merely cutting back on long horizon projects.

These findings have several theoretical and practical implications, but they also point to important boundary conditions. Theoretically, the results extend prior work that links environmental performance to firm value in Indonesia by explicitly incorporating trade policy uncertainty as an external shock and by showing that green investment can act as a transmission channel between uncertainty and valuation, conditioned by governance quality (Utomo et al., 2019; Ainy & Rohman, 2019). Practically, the evidence suggests that managers and policy makers in emerging markets should not view environmental investment purely as a burden in turbulent trade environments; instead, well designed green strategies and robust governance structures can help maintain

valuation when trade regimes become less predictable. At the same time, the analysis is based on secondary data and focuses on listed Indonesian firms, so the dynamics may differ in privately held firms or other institutional settings where investor pressure, regulatory enforcement and access to green finance are weaker or differently structured. Future research could therefore compare trade or climate policy uncertainty effects across countries and regulatory regimes, or examine in more detail the micro mechanisms through which boards, investors and stakeholders influence the choice and timing of green investments under uncertainty.

## 6. CONCLUSION

This study has examined how trade policy uncertainty influences firm value in Indonesia and how green investment and corporate governance shape this relationship. Using a panel of non financial firms listed on the Indonesia Stock Exchange over 2010 to 2024, and drawing on secondary data from financial statements, Refinitiv ESG and governance databases, and the PROPER environmental rating scheme, the analysis shows that trade policy uncertainty is associated with lower firm value, while green investment and governance are positively related to valuation. The results further indicate that trade policy uncertainty is positively related to green investment, and that green investment partially mediates the negative effect of uncertainty on firm value. Corporate governance strengthens the sensitivity of green investment to trade policy uncertainty and attenuates the adverse impact of uncertainty on firm value, suggesting that governance acts both as an enabler of environmental strategy and as a buffer against external shocks.

These findings carry several implications for theory and practice. Theoretically, the evidence supports the integration of stakeholder, legitimacy, resource based and agency perspectives in explaining how firms respond to trade policy uncertainty through environmental investment and how these responses are conditioned by governance structures. The results extend the literature on trade policy uncertainty and firm outcomes by explicitly modelling green investment as a transmission channel, and they enrich the Indonesian environmental accounting and finance literature by embedding environmental performance and governance within a context of external trade related shocks. For practitioners and policy makers, the findings suggest that green investment should not be viewed solely as a regulatory burden during periods of trade turbulence. Rather, when supported by strong governance, environmental initiatives can help preserve, and in some cases enhance, firm value under uncertain trade regimes.

At the same time, the study is subject to several limitations that open avenues for future research. The analysis relies on secondary data and focuses on listed firms, which are typically larger and more visible to investors and regulators than privately held or smaller enterprises. The measurement of green investment and governance is constrained by available disclosures, and although robustness checks using alternative indicators and dynamic panel methods have been conducted, residual endogeneity concerns cannot be fully ruled out. Future studies could investigate the micro level

mechanisms through which boards, managers and investors shape green investment decisions in response to trade policy shocks, explore heterogeneity across sectors with different trade and regulatory exposure, and extend the analysis to other emerging markets. Comparative and qualitative evidence could complement the present findings and provide deeper insight into how firms operationalise environmental strategies as part of their broader risk management and competitive positioning under policy uncertainty.

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### Author Contributions

A.S.S.: Conceptualisation, Investigation, Data Curation, Formal Analysis, Writing – Original Draft.

S.Y.: Conceptualisation, Methodology, Formal Analysis, Validation, Writing – Review & Editing, Supervision, Project Administration.

A.R.A.M.R.: Conceptualisation, Validation, Writing – Review & Editing.

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No potential conflict of interest has been reported by the author(s).

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