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When interactive performance measurement systems matter: innovativeness, technological turbulence, and relative firm performance

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Article Info

Article history:

Received Aug 07th, 2026

Revised Sept 05th, 2026

Accepted Oct 02nd, 2026

Keyword:

Interactive control,
Performance measurement
systems,
Organizational innovativeness,
Technological turbulence,
Relative firm performance

ABSTRACT

Interactive performance measurement systems may be associated with firm performance by encouraging organizational responses to performance information, while technological turbulence may increase the relevance of such interactive use. Drawing on contingency theory and Organizational Information Processing Theory, this study examines whether organizational innovativeness mediates the association between interactive use of performance measurement systems (IPMS) and relative firm performance and whether technological turbulence conditions that indirect association. A cross-sectional, firm-level survey of 102 screened medium-sized manufacturing establishments in Greater Tangerang, Indonesia, was analyzed using PLS-SEM. The multi-item measures showed satisfactory reliability (Cronbach's alpha = 0.792-0.905) and convergent and discriminant validity. Sensitivity analysis indicated that, at alpha = 0.05 and power = 0.80, N = 102 could detect an incremental f^2 of approximately 0.078; the observed interaction f^2 was 0.109. IPMS was positively associated with organizational innovativeness ($\beta = 0.476$, $p < .001$), which was positively associated with relative firm performance ($\beta = 0.456$, $p < .001$). The indirect effect was significant ($\beta = 0.217$, 95% CI [0.122, 0.329]). Technological turbulence moderated the IPMS-to-innovativeness association ($\beta = 0.246$, $p < .001$), and the index of moderated mediation excluded zero (index = 0.112, 95% CI [0.048, 0.182]). Within this cross-sectional sample, the estimated innovation-mediated association was stronger at higher levels of technological turbulence; the findings identify a context-dependent association rather than establishing a universal or causal effect of interactive control.



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Introduction

Interactive performance measurement systems (IPMS) are intended to focus managerial attention on strategic uncertainties, yet their innovation and performance implications are not uniformly positive. Prior research shows that interactive control can support innovation-related processes, but its consequences differ across innovation modes, organizational conditions, and turbulent environments (Bisbe & Otley, 2004; Bedford, 2015; Lewis et al., 2024; Detzen & Verbeeten, 2025; Zeng et al., 2025). The unresolved theoretical issue is therefore not simply whether interactive control is beneficial, but whether an innovation-related mechanism and a technological boundary condition operate jointly. Specifically, it remains unclear whether

technological turbulence changes the strength of the association in which IPMS is linked to organizational innovativeness and, through innovativeness, to relative firm performance.

This question requires distinguishing the presence of performance measures from their interactive use. Financial and non-financial measures do not influence managerial action merely because they are available. Interactive use involves sustained senior-management attention, recurring discussion across organizational levels, and active questioning of the assumptions underlying plans and reported performance (Henri, 2006; Simons, 1995; Widener, 2007). IPMS is therefore treated here as a managerial use practice rather than a technical property of the measurement architecture: performance information becomes interactive when it is used to challenge explanations, connect perspectives across functions, and reconsider action when underlying conditions change (Ferreira & Otley, 2009).

The innovation literature reinforces the need for this more qualified view. Bisbe and Otley (2004) found that interactive control did not automatically generate greater product innovation, while Bedford (2015) showed that the performance implications of management control differ across innovation modes. Subsequent studies have linked interactive or enabling control with management innovation, organizational agility, open innovation, and exploratory and exploitative innovation (Baird et al., 2019; Brüggemann et al., 2022; Le et al., 2023; Phan et al., 2023). More recent evidence further suggests that the innovation relevance of performance-measure use depends on managerial attention, leadership context, organizational capabilities, and environmental turbulence (Lewis et al., 2024; Detzen & Verbeeten, 2025; Zeng et al., 2025). Taken together, this literature supports testing a conditional process rather than assuming a uniform direct benefit of interactive control.

Greater Tangerang provides an empirical setting in which this conditional process can be examined without treating regional context itself as the theoretical explanation. In 2024, manufacturing contributed 33.74% of GRDP in Tangerang Regency and 26.98% in Tangerang Municipality, compared with 8.09% in the more service-oriented South Tangerang Municipality (BPS-Statistics of Tangerang Municipality, 2025; BPS-Statistics of Tangerang Regency, 2025; BPS-Statistics of South Tangerang Municipality, 2025). The study deliberately applies a sampling boundary to establishments employing 20-99 workers, using the BPS worker-based definition of medium-sized firms, to keep organizational scale within a narrower band while examining variation in IPMS, organizational innovativeness, technological turbulence, and relative performance. Technological turbulence is operationalized as a firm-level perceptual moderator using established items, rather than inferred from the regional GRDP differences.

Organizational innovativeness provides one way to specify that organizational response. In this study, innovativeness refers to an organizational orientation characterized by openness and receptivity to innovation (Hurley & Hult, 1998). This definition matters because innovativeness is often used loosely alongside innovation capability or innovation performance, although the concepts are not interchangeable. Innovation capability concerns the organization's ability to develop or implement innovation, whereas innovation performance concerns realized outputs. Organizational innovativeness instead reflects a disposition toward new ideas, experimentation, alternative technical approaches, and different ways of working (Subramanian & Nilakanta, 1996; Wang & Ahmed, 2004). A firm can therefore be receptive to innovation without necessarily producing a new product or process during the same period.

Interactive PMS may foster this orientation because it changes the way managers engage with evidence that challenges established routines. Repeated discussion of unexpected performance can expose inconsistencies between planned assumptions and operating reality. Cross-functional interpretation can also bring together information that would otherwise remain fragmented across finance, production, quality, procurement, and sales. More importantly, interactive use legitimizes questioning. A variance need not always be treated as an error to be corrected; it may reveal that a process assumption, technical choice, or performance expectation requires reconsideration (Henri, 2006; Widener, 2007).

This argument is consistent with Lewis et al. (2024), who show how interactive control channels managerial attention through linked discussions of strategic uncertainty. Detzen and Verbeeten (2025) likewise indicate that performance-measure use becomes innovation-relevant under supportive organizational conditions. Evidence connecting enabling or interactive control with creativity, organizational agility, and open innovation provides further support for the view that control can create a setting in which alternative courses of action are more readily considered (Baird et al., 2019; Barros & Ferreira, 2023; Brüggemann et al., 2022; Nuhu et al., 2022). The proposed relationship is therefore not that performance measurement directly “creates” innovation. Rather, interactive use is expected to be associated with a managerial environment that is more receptive to new ideas and alternative practices.

H1: The interactive use of performance measurement systems is positively associated with organizational innovativeness.

An innovation-supportive orientation may, in turn, have competitive consequences. Firms that are receptive to new ideas are better positioned to recognize potentially useful technical, process, and managerial changes. This does not mean that every experiment will improve performance or that innovative firms will necessarily become technological leaders. Rather, openness to change increases the likelihood that promising alternatives are considered and adopted instead of being dismissed because they depart from existing routines. Hult et al. (2004) linked innovativeness with business performance in industrial firms, while Subramanian and Nilakanta (1996) associated organizational innovativeness with several dimensions of organizational performance. Evidence from manufacturing further indicates that product, process, organizational, and marketing innovation can contribute to firm outcomes (Gunday et al., 2011).

For the firms examined here, relative performance is more informative than absolute scale. Medium-sized manufacturers can differ considerably in sales or asset size while still competing effectively within their respective markets. What is theoretically relevant is whether a firm's receptivity to useful changes corresponds with a stronger competitive position. When new ideas are translated into workable process, product, or managerial changes, such an orientation may be reflected in market share, sales growth, profitability, and overall performance relative to major competitors. The argument therefore concerns perceived relative firm performance, not objective accounting performance.

H2: Organizational innovativeness is positively associated with relative firm performance.

The first two relationships imply a more specific pathway between interactive PMS and performance. Interactive PMS brings anomalies and competing interpretations into managerial discussion; organizational innovativeness captures whether the firm is receptive to acting on alternatives that emerge from that discussion. The performance relevance of interactive control should therefore depend partly on what happens after managers begin questioning established assumptions. Discussion alone need not improve performance. Its value is more likely to materialize when the organization is prepared to reconsider technologies, methods, processes, or managerial practices in response to what the performance information reveals.

This interpretation is consistent with research showing that the performance implications of management control can operate through innovation and organizational capabilities rather than only through monitoring and corrective action (Baird et al., 2019; Le & Hoang, 2024; Le et al., 2023; Phan et al., 2023). At the same time, organizational innovativeness should not be treated as the only route connecting interactive PMS with performance. Interactive use may also improve coordination, managerial prioritization, or the speed with which corrective action is taken. For this reason, the direct IPMS-to-performance relationship is retained in the structural model rather than assuming full mediation, consistent with the mediation procedures discussed by Nitzi et al. (2016).

H3: Organizational innovativeness mediates the relationship between the interactive use of performance measurement systems and relative firm performance.

A remaining question is whether this pathway is equally relevant under different technological conditions. There is little reason to expect it to be. Technological turbulence captures the rate and unpredictability of technological change within an industry (Jaworski & Kohli, 1993). In relatively stable environments, technologies, routines, and technical assumptions remain useful for longer periods. Managers can often interpret deviations against a reasonably stable set of expectations. When technological turbulence is high, production technologies, automation options, digital interfaces, technical standards, and product possibilities can change more rapidly. The central managerial question then becomes more demanding: a deviation may no longer mean that execution has departed from the plan; it may mean that the plan itself rests on assumptions that are becoming obsolete.

Contingency theory and Organizational Information Processing Theory (OIPT) offer complementary explanations for why this distinction matters. Contingency theory rejects the idea that a control practice has the same value in every setting; its effectiveness depends on the fit between the practice and the conditions facing the organization (Chenhall, 2003). OIPT helps specify the informational problem created by technological turbulence. As uncertainty increases, organizations must gather, interpret, and reconcile more information before managers can reach an adequate understanding of changing conditions (Galbraith, 1974; Tushman & Nadler, 1978). Interactive PMS can support that task by providing recurring forums in which managers discuss deviations, compare weak signals, question established assumptions, and coordinate possible responses (Szukits, 2022; Widener, 2007).

Consider the same unfavorable production variance under two different conditions. When process technology and customer requirements have been stable, the variance may point to an operational problem that can be corrected within the existing system. When technologies are shifting rapidly, the same variance may indicate that the current process, specification, or technical assumption no longer fits the operating environment. In the second case, the value of interactive discussion lies not only in identifying the deviation but also in helping managers determine whether existing routines should still be trusted. Technological turbulence should therefore increase the relevance of interactive PMS for organizational innovativeness because questioning and alternative interpretation become more consequential when established knowledge loses validity more quickly.

Prior evidence supports this contingency argument. Müller-Stewens et al. (2020) show that technological turbulence conditions the innovation consequences of interactive control. Dos Santos et al. (2023) connect technological turbulence with management-control and product-innovation relationships, while Zeng et al. (2025) demonstrate that the relevance of interactive control varies in turbulent innovation environments. Indonesian evidence is also informative. Ludji (2025) reports that perceived environmental uncertainty is associated with greater reliance on interactive control and that interactive control is positively related to innovation among manufacturing managers. Luiz and Beuren (2023) similarly connect environmental uncertainty with MCS use and innovation.

The key implication is not merely that turbulence encourages innovation. The argument is more specific: technological turbulence changes the informational value of interactive control. When technologies remain relatively stable, managers may obtain only limited additional benefit from repeatedly questioning assumptions that continue to work. As technological conditions become less predictable, however, interactive interpretation provides greater scope for recognizing that routines or assumptions need to change. The IPMS-to-innovativeness association should therefore become stronger as technological turbulence increases.

H4: Technological turbulence positively moderates the relationship between the interactive use of performance measurement systems and organizational innovativeness, such that the positive relationship is stronger when technological turbulence is high.

This conditional argument also exposes a gap in how earlier studies have approached the control-innovation-performance relationship. One stream has investigated innovation-related processes as mechanisms through which management control is associated with performance, including exploratory and exploitative innovation (Le et al., 2023). Another has examined technological or environmental turbulence as a contingency affecting control-to-innovation relationships (dos Santos et al., 2023; Müller-Stewens et al., 2020; Zeng et al., 2025). Evidence from these streams establishes the plausibility of the individual links, but examining them separately leaves an important question unresolved: does technological turbulence change the strength of the entire innovation-mediated association between interactive PMS and firm performance?

That question cannot be answered simply by showing that IPMS interacts with technological turbulence. A first-stage interaction demonstrates that the IPMS-to-innovativeness relationship changes across levels of turbulence; it does not establish that the indirect association with performance changes as well. If technological turbulence increases the extent to which interactive PMS is associated with organizational innovativeness, and innovativeness is in turn associated with relative performance, the resulting indirect relationship should itself become stronger under more turbulent technological conditions. Under relative stability, established routines may provide managers with sufficiently reliable guidance, limiting the additional value of interactive interpretation. Under higher turbulence, performance signals require more interpretation and are more likely to provoke reconsideration of existing practices. The innovation-supportive pathway should consequently become more consequential.

H5: The positive indirect effect of interactive use of performance measurement systems on relative firm performance through organizational innovativeness is stronger at higher levels of technological turbulence.

The study therefore moves beyond the broad question of whether interactive control is beneficial. It examines when and through what organizational pathway interactive PMS is associated with relative firm performance among medium-sized manufacturers in Greater Tangerang. The central contribution lies in linking an innovation-related pathway with a technological boundary condition. Rather than treating mediation and contingency as separate explanations, the model tests whether technological turbulence systematically changes the strength of the relationship in which interactive PMS is associated with organizational innovativeness, which in turn is associated with relative firm performance. Contingency theory explains why the relevance of control may vary across environmental conditions, while OIPT clarifies

why interactive interpretation becomes more valuable as technological change increases information-processing demands. OIPT is used here as an explanatory lens for the conditional pattern, since information-processing capacity itself was not measured directly.

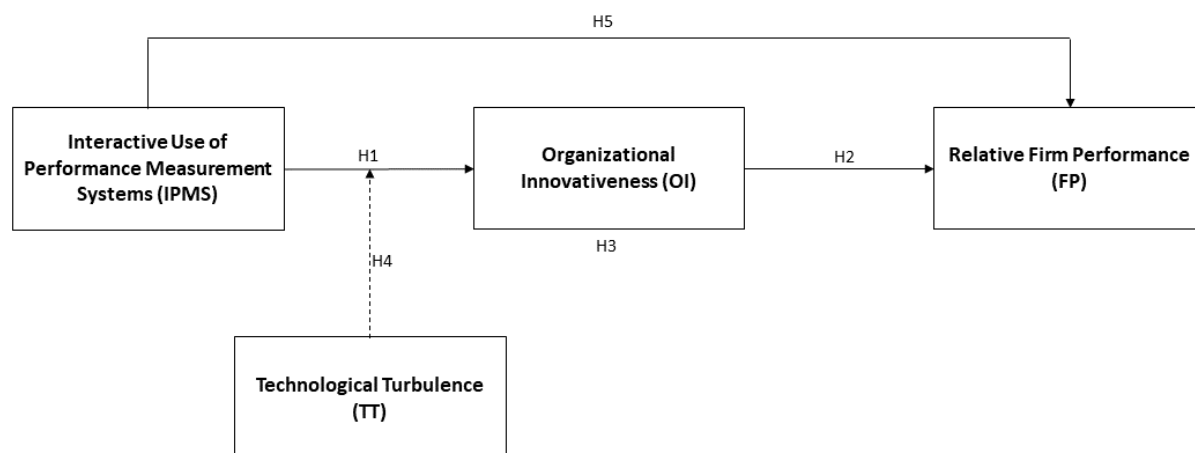


Figure 1. Proposed conditional process model

Note. H3 represents the indirect effect, H4 the moderating effect of technological turbulence, and H5 the conditional indirect effect. The direct relationship between IPMS and firm performance is included for mediation assessment but is not hypothesized.

Method

Research design and setting

This study employed a cross-sectional, firm-level survey of medium-sized manufacturing establishments in Greater Tangerang, Banten, Indonesia, covering Tangerang Municipality, Tangerang Regency, and South Tangerang Municipality. Data were collected in 2026 from managerial informants familiar with their firms' performance and decision-making processes, with the manufacturing establishment as the unit of analysis. The archived dataset contains the final usable responses and screening information but does not preserve a complete contemporaneous contact log, verifiable recruitment counts by mode, or a reconstructable nonresponse history. Consequently, a formal response rate and direct statistical test of nonresponse bias cannot be produced, and the 102 establishments are treated as a screened analytical sample rather than a probability-representative sample of all medium-sized manufacturers in Greater Tangerang. A numerical recruitment flowchart is not presented because the unavailable contact and nonresponse counts cannot be reconstructed without creating unsupported precision. Instead, the manuscript reports the verifiable eligibility criteria, respondent-selection rules, data-quality procedures, and final analytical sample, and carries this sampling limitation into the interpretation of generalizability.

Population, screening, and respondent selection

Medium-sized manufacturing establishments were defined as firms employing 20 to 99 workers, consistent with the worker-based classification of BPS-Statistics Indonesia (2025), and eligibility was based on the current number of employees at the Greater Tangerang establishment. Restricting the study to this worker-size band provided a consistent operational sampling boundary while allowing the analysis to focus on differences in management-control use and technological conditions rather than on very large differences in organizational scale. For multi-plant firms, respondents reported only on the establishment located within the study area. One knowledgeable informant was selected from each establishment, including owner-managers, directors, general managers, finance or accounting managers, controllers, operations managers, and production managers. Eligible respondents had at least one year of tenure and were involved in budgeting, performance review, strategic planning, investment decisions, or operational decision-making, consistent with key-informant research emphasizing respondent knowledge and involvement (Kumar et al., 1993). Respondents without managerial involvement were excluded, and each establishment contributed only one observation. Because the structural model included an interaction term, sample-size sensitivity was assessed rather than relying on the conventional 10-times rule. With three predictors, $\alpha = 0.05$, power = 0.80, and $N = 102$, the minimum detectable incremental effect was approximately $f^2 = 0.078$, compared with the observed interaction effect of $f^2 = 0.109$ (Faul et al., 2009). These calculations are presented as sensitivity

information rather than as proof of sample adequacy, and the structural estimates are interpreted together with their bootstrap confidence intervals.

Questionnaire and measures

The questionnaire comprised 20 indicators adapted from established measures: seven for interactive use of performance measurement systems (IPMS), five for organizational innovativeness (OI), four for technological turbulence (TT), and four for relative firm performance (FP). IPMS was measured using a seven-point extent scale adapted from Henri (2006) and Widener (2007), capturing the use of performance information to stimulate discussion, question assumptions, develop shared interpretations, connect organizational units, and focus attention on critical issues. OI was assessed using five seven-point agreement items based on Hurley and Hult (1998), Subramanian and Nilakanta (1996), and Wang and Ahmed (2004), reflecting openness to new ideas, new methods, experimentation, technical innovation, and measured innovation risk; it is therefore interpreted as a broad innovation-supportive orientation rather than realized innovation output. TT was measured with four seven-point agreement items adapted from Jaworski and Kohli (1993), covering the pace and unpredictability of technological change, technology-created opportunities, forecasting difficulty, and new product or process possibilities. FP was assessed using four seven-point competitor-relative items covering market share, sales growth, profitability, and overall performance, drawing on Gerschewski and Xiao (2015), Mura et al. (2021), Zhou et al. (2007), and Islam et al. (2026). The questionnaire was administered in Indonesian, while Supplementary Table S1 presents English translations of the adapted items. Table 1 summarizes the number of indicators, example items, response scales, and primary sources used to operationalize each construct.

Table 1. Construct operationalization

Construct	No. of items	Example item	Scale	Primary source / status
Interactive use of PMS (IPMS)	7	Performance information is used to challenge underlying data, assumptions, and action plans.	1 = not at all; 7 = to a very great extent	Henri (2006); Widener (2007)
Organizational innovativeness (OI)	5	Management actively seeks new ideas and ways of doing things.	1 = strongly disagree; 7 = strongly agree	Hurley & Hult (1998); Wang & Ahmed (2004)
Technological turbulence (TT)	4	Technology in our industry is changing rapidly.	1 = strongly disagree; 7 = strongly agree	Jaworski & Kohli (1993)
Relative firm performance (FP)	4	Compared with major competitors, our profitability during the past three years has been...	1 = much worse; 7 = much better	Gerschewski & Xiao (2015); Mura et al. (2021); Zhou et al. (2007)

Common method safeguards

Because all focal constructs were reported by the same managerial informant, the study combined procedural safeguards with a post-hoc diagnostic to address potential common method bias. IPMS, OI/TT, and relative firm performance were presented in separate measurement blocks and used different response anchors, helping to reduce respondents' tendency to apply the same response pattern across constructs (Podsakoff et al., 2003). Full-collinearity VIF values ranged from 1.123 to 2.100, below the 3.3 threshold suggested by Kock (2015). This result provides no indication of severe common method contamination, but it does not rule out method bias. A marker-variable test was not available because the questionnaire did not include a theoretically unrelated marker construct; accordingly, no post-hoc marker variable was introduced after data collection. Harman's single-factor test was also not used as the principal diagnostic; the manuscript instead reports the procedural safeguards and the full-collinearity assessment actually implemented. The use of a single informant for all focal measures therefore remains a limitation and is considered alongside possible social-desirability, perceptual-consistency, and retrospective-recall biases in the Discussion.

Ethics and informed consent

Formal ethics committee approval was not obtained for this non-interventional organizational survey of adult managerial respondents. The study involved no experimental intervention and collected no clinical or sensitive personal information. Participation was voluntary. Before completing the questionnaire, respondents were informed of the study's purpose and the confidentiality of their responses, and only those who agreed to participate proceeded with the survey.

Data analysis

The hypotheses were tested with partial least squares structural equation modeling (PLS-SEM) in SmartPLS 4, which allowed the reflective measurement model, mediation, latent-variable interaction, conditional indirect effects, and predictive performance to be assessed within the same model (Hair et al., 2019, 2022). The analysis used 102 firm-level observations and 10,000 bootstrap subsamples, with two-tailed tests at $\alpha = 0.05$. Measurement quality was examined using indicator loadings, Cronbach's alpha, ρ_A , composite reliability, average variance extracted (AVE), and the heterotrait-monotrait ratio (HTMT) (Hair et al., 2022; Henseler et al., 2015). TT3 was retained despite its loading being below 0.708 because the TT construct continued to satisfy reliability and AVE criteria and the item captured a theoretically relevant aspect of technological turbulence; complete loadings are reported in Supplementary Table S2. Structural assessment covered inner collinearity, standardized coefficients, bootstrap standard errors, t values, p values, 95% percentile bootstrap confidence intervals, R^2 , and f^2 effect sizes. Predictive performance was examined using Q^2 predict and $PLSpredict$ with 10-fold cross-validation repeated 10 times against a linear-model benchmark (Shmueli et al., 2019). The direct IPMS-to-FP path was retained for mediation assessment but was not hypothesized (Nitzl et al., 2016). For H4, the IPMS $\times$ TT interaction was estimated using the two-stage approach and interpreted with simple slopes at low, mean, and high TT. H5 was evaluated from conditional indirect effects and the index of moderated mediation (Hayes, 2015), with the conditional indirect effect calculated as $(a1 + a3TT)b$, where $a1$ denotes the IPMS-to-OI coefficient, $a3$ the interaction coefficient, and b the OI-to-FP coefficient.

Results and Discussions

Sample profile and data screening

After respondent-eligibility screening and data-quality checks, 102 firm-level responses were retained for analysis. Respondents were drawn primarily from finance/accounting/control (30.4%), owners/directors (29.4%), and operations/production roles (27.5%), and the establishments covered several manufacturing subsectors and all three Greater Tangerang administrative areas. Because the original contact frame and nonresponse history are not verifiable, these distributions describe the analytical sample only and should not be interpreted as population-representative estimates. Table 2 reports the full respondent and firm profile.

Table 2. Sample characteristics

Characteristic	Category	n	%
Respondent role	Owner/director	30	29.4
	Finance/accounting/controller	31	30.4
	Operations/production manager	28	27.5
	Other eligible manager	13	12.7
Respondent tenure	1 to 3 years	33	32.4
	4 to 6 years	46	45.1
	More than 6 years	23	22.5
Firm employment	20 to 49 employees	70	68.6
	50 to 99 employees	32	31.4
Firm age	Less than 10 years	18	17.6
	10 to 20 years	60	58.8
	More than 20 years	24	23.5
Manufacturing subsector	Food/beverage	28	27.5
	Textile/apparel/leather	20	19.6
	Chemicals/rubber/plastics	20	19.6
	Metal/machinery/equipment	28	27.5
	Other manufacturing	6	5.9
Region	Tangerang Regency	46	45.1
	Tangerang Municipality	38	37.3
	South Tangerang Municipality	18	17.6

Measurement model

The measurement results indicate satisfactory reliability and convergent validity across the four constructs. Indicator loadings ranged from 0.678 to 0.883. TT3 produced the lowest loading (0.678), but removing it was not warranted because technological turbulence retained adequate composite reliability ($CR = 0.862$) and average variance extracted ($AVE = 0.612$), while the item captures the forecasting difficulty inherent in technological turbulence. Across the constructs, Cronbach's alpha ranged from 0.792 to 0.905, ρ_A from 0.855 to 0.909, CR from 0.862 to 0.924, and AVE from 0.612 to 0.726 (Table 3). Discriminant validity was

also satisfactory: the highest HTMT value was 0.687, below the conservative 0.85 reference value, and none of the construct pairs approached this threshold (Table 4). Full indicator loadings are reported in Supplementary Table S2.

Table 3. Measurement model assessment

Construct	Indicator loading range	Cronbach's alpha	rho_A	CR	AVE
IPMS	0.762 to 0.838	0.905	0.909	0.924	0.636
OI	0.792 to 0.883	0.885	0.892	0.916	0.686
TT	0.678 to 0.855	0.792	0.855	0.862	0.612
FP	0.830 to 0.879	0.874	0.881	0.914	0.726

Table 4. HTMT discriminant validity

Construct	IPMS	OI	TT	FP
IPMS	-			
OI	0.647	-		
TT	0.485	0.478	-	
FP	0.592	0.687	0.477	-

Structural model and hypothesis tests

Collinearity was not a concern in the structural model, with the highest inner VIF equal to 1.539. The model accounted for 44.8% of the variance in organizational innovativeness ($R^2 = 0.448$; adjusted $R^2 = 0.431$) and 42.3% of the variance in relative firm performance ($R^2 = 0.423$; adjusted $R^2 = 0.399$). As shown in Table 5, IPMS was positively associated with organizational innovativeness ($\beta = 0.476$, $p < .001$), supporting H1, while organizational innovativeness was positively associated with relative firm performance ($\beta = 0.456$, $p < .001$), supporting H2. The interaction between IPMS and technological turbulence was also positive ($\beta = 0.246$, $p < .001$), supporting H4. The corresponding effect sizes were $f^2 = 0.338$ for the IPMS-to-OI relationship, $f^2 = 0.234$ for OI-to-FP, and $f^2 = 0.109$ for the interaction. Among the additional model paths, technological turbulence was positively associated with organizational innovativeness ($\beta = 0.235$, $p = .002$), and the retained direct IPMS-to-FP relationship was positive ($\beta = 0.260$, $p = .001$). Firm age and employee count showed little association with relative performance. These additional estimates are reported in Supplementary Table S5.

Table 5. Hypothesis testing results

Hyp.	Relationship	β	t	p	95% CI	f^2	Decision
H1	IPMS $\rightarrow$ OI	0.476	5.755	< .001	[0.308, 0.632]	0.338	Supported
H2	OI $\rightarrow$ FP	0.456	5.812	< .001	[0.300, 0.608]	0.234	Supported
H4	IPMS $\times$ TT $\rightarrow$ OI	0.246	3.763	< .001	[0.116, 0.369]	0.109	Supported

Note. IPMS = interactive use of performance measurement systems; OI = organizational innovativeness; TT = technological turbulence; FP = relative firm performance. Confidence intervals are percentile intervals based on 10,000 bootstrap subsamples.

Mediation and moderated mediation

The mediation results support the proposed indirect pathway. The overall indirect association between IPMS and relative firm performance through organizational innovativeness was 0.217 (SE = 0.053, $t = 4.130$, $p < .001$, 95% CI [0.122, 0.329]), supporting H3. Because both the indirect association and the retained direct IPMS-to-FP relationship were positive and statistically significant, the results are consistent with complementary mediation rather than full mediation. More importantly, the strength of this indirect association varied with technological turbulence. The conditional indirect estimate increased from 0.105 at low turbulence (95% CI [-0.008, 0.235]) to 0.217 at the mean (95% CI [0.122, 0.329]) and 0.329 at high turbulence (95% CI [0.212, 0.458]). H5 is supported by the index of moderated mediation, which was positive and excluded zero (index = 0.112, SE = 0.034, 95% CI [0.048, 0.182]), rather than by comparing the significance of the conditional estimates across levels of turbulence. The simple slopes show the same directional pattern: the IPMS-to-OI coefficient increased from $\beta = 0.230$ at low TT ($p = .069$) to $\beta = 0.476$ at mean TT ($p < .001$) and $\beta = 0.722$ at high TT ($p < .001$). Supplementary Table S6 provides the full conditional estimates and simple slopes.

Table 6. Mediation and moderated mediation results

Hyp.	Effect	Estimate	Bootstrap 95% CI	Decision
H3	IPMS → OI → FP	0.217	[0.122, 0.329]	Supported
H5	Index of moderated mediation	0.112	[0.048, 0.182]	Supported

Note. H3 reports the standardized overall indirect effect. For H5, the estimate represents the index of moderated mediation. Bootstrap confidence intervals that exclude zero indicate support for the corresponding indirect or moderated mediation relationship.

Robustness and predictive assessment

The robustness analysis produced the same substantive pattern after OI5, the item most directly capturing innovation-related risk, was excluded from the organizational innovativeness measure. Using standardized unit-weighted composites, the IPMS × TT interaction remained positive ($\beta = 0.270$, $p = .001$), as did the relationships between OI and performance ($\beta = 0.442$, $p < .001$) and between IPMS and performance ($\beta = 0.267$, $p = .007$). The conditional indirect effect at mean technological turbulence was 0.210 (95% CI [0.113, 0.327]), while the index of moderated mediation remained positive and its confidence interval excluded zero (index = 0.120, 95% CI [0.050, 0.203]). These results indicate that the moderated mediation finding is not dependent on the risk-oriented OI5 item. Predictive assessment also yielded consistent evidence: all nine endogenous-indicator Q^2 predict values were positive, ranging from 0.144 to 0.322, and PLS RMSE was lower than the linear-model benchmark for every indicator. The estimated-model SRMR was 0.070. Detailed robustness and prediction results are reported in Supplementary Tables S3 and S4.

The first result refines the distinction between having a performance measurement system and using performance information interactively. The IPMS construct in this study directly captures discussion, questioning of assumptions, development of shared interpretations, cross-unit connection, and attention to critical issues; managerial interpretation was not modeled as a separate latent variable. The positive IPMS-organizational innovativeness association is consistent with Henri (2006) and Widener (2007), but it should not be read as a simple confirmation that more interactive control always produces more innovation. Bisbe and Otley (2004) reported that interactive use did not automatically generate product innovation, and Bedford (2015) showed that control-performance relationships differ across innovation modes. The present finding is closer to the conditional accounts of Lewis et al. (2024) and Detzen and Verbeeten (2025): interactive use appears relevant when it organizes attention, discussion, and challenge under particular organizational conditions.

The mediation result extends this interpretation by locating organizational innovativeness as one plausible pathway rather than the only mechanism linking IPMS with relative performance. This is compatible with Baird et al. (2019), Brüggemann et al. (2022), Nuhu et al. (2022), Le and Hoang (2024), Le et al. (2023), Phan et al. (2023), and Barros and Ferreira (2023), which connect management control with innovation, agility, creativity, capabilities, or performance through different organizational processes. The coexistence of a significant indirect association through innovativeness and a significant direct IPMS-performance association is therefore theoretically informative: it suggests complementary mediation, not an exhaustive innovation-only explanation. Coordination, managerial prioritization, organizational learning, and faster corrective action remain plausible omitted mechanisms. Because the study is cross-sectional, however, reverse ordering is also possible; firms that are already more innovative or better performing may be more inclined to use performance information interactively.

Technological turbulence provides the study's central boundary condition. The estimated IPMS-to-innovativeness association was larger at higher levels of technological turbulence, and the conditional indirect association with relative performance increased in the same direction. This pattern is consistent with Müller-Stewens et al. (2020), dos Santos et al. (2023), Zeng et al. (2025), Luiz and Beuren (2023), and Ludji (2025), all of which indicate that uncertainty or turbulence changes the relevance of management-control use for innovation-related outcomes. The extension here is that the contingency is not confined to the first-stage IPMS-innovativeness path: the moderated mediation analysis shows that the estimated innovation-mediated association with performance also varies across levels of technological turbulence.

This conditional pattern refines rather than overturns existing arguments about interactive control. Contingency theory explains why the relevance of a control practice may differ across environmental conditions (Chenhall, 2003), while Organizational Information Processing Theory offers an explanatory account of why rapidly changing technologies increase demands for discussion, reconciliation of signals, and reconsideration of assumptions (Galbraith, 1974; Tushman & Nadler, 1978). The contribution is therefore not that technological turbulence universally improves the effectiveness of IPMS, but that the association between interactive control, organizational innovativeness, and relative performance is systematically

stronger under higher turbulence in this sample. OIPT remains an interpretive lens rather than a directly tested mechanism because information-processing capacity itself was not measured.

For managers of medium-sized manufacturing firms, the results support a cautious practical implication: performance reviews may be more useful when they create structured opportunities to question why deviations occur and whether existing assumptions still fit current technological conditions, rather than simply expanding the number of measures reported. Indicators such as quality, delivery, cost, throughput, or product development can therefore be used as prompts for cross-functional discussion as well as monitoring. This implication is intentionally bounded to an association observed in the present sample and should not be interpreted as evidence that increasing interactive control will necessarily cause higher performance in every firm.

Several limitations place boundaries around these interpretations. The cross-sectional design cannot establish temporal or causal direction, so reverse causality remains plausible, and unmeasured variables such as leadership style, strategic orientation, digital maturity, or other organizational capabilities could partly account for the observed mediation pattern. All focal measures were reported by one managerial informant. Although procedural safeguards and full-collinearity diagnostics did not indicate severe common-method contamination, they cannot eliminate common method bias; social-desirability, perceptual-consistency, and retrospective-recall bias may also affect self-reports. Relative performance was assessed perceptually against competitors over a three-year reference period and was not independently verified with audited accounting data. The available recruitment records do not permit calculation of a formal response rate or direct examination of nonresponse bias, so the 102 medium-sized manufacturers in Greater Tangerang should not be treated as a probability-representative sample. Future research should use longitudinal or time-lagged designs, multiple informants or objective performance records, and documented probability or frame-based recruitment where feasible, while distinguishing innovation orientation, capability, and realized innovation outcomes more explicitly.

Conclusions

Among 102 manufacturing establishments meeting the BPS worker-based definition of medium-sized firms (20-99 employees) in Greater Tangerang, IPMS was positively associated with organizational innovativeness and relative firm performance. The coexistence of significant direct and indirect associations is consistent with complementary mediation, implying that organizational innovativeness represents one plausible pathway rather than an exhaustive mechanism linking interactive control with performance. The estimated IPMS-to-innovativeness association and the conditional indirect association were larger at higher levels of technological turbulence; this pattern should be interpreted as a cross-sectional conditional association, not evidence that turbulence causally increases the effect of IPMS. The interaction effect size was $f^2 = 0.109$, and the sensitivity analysis indicated that $N = 102$ could detect an incremental effect of approximately $f^2 = 0.078$ at 80% power under the stated assumptions. Generalization is constrained by the unavailable response-rate information, the inability to directly assess nonresponse bias, single-informant measurement, possible common-method, social-desirability, and recall biases, and the perceptual measure of relative performance. Accordingly, the contribution is bounded to showing that, within this screened sample, the innovation-related association between interactive control and relative performance varies systematically with technological turbulence.

Acknowledgments

The authors gratefully acknowledge the managers and representatives of manufacturing firms in Greater Tangerang who participated in the survey and contributed their time and organizational insights to this study. The authors also appreciate the academic support and constructive feedback received during the development and refinement of the manuscript.

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