

ORIGINAL RESEARCH

Neurobehavioral Determinants of Earnings Manipulation Under Algorithmic Corporate Governance Systems

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ABSTRACT

Background: Increasing adoption of algorithmic corporate governance systems (ACGS) has transformed monitoring, reporting, and managerial decision environments. Existing corporate governance literature examines institutional and board determinants of earnings management but has paid limited attention to how algorithmic governance interacts with managers' neurobehavioral states to shape manipulation choices. **Methods:** We report a mixed-method field experiment and archival study of 420 mid- to senior-level financial managers from 210 publicly listed firms across three jurisdictions. Firms were classified by ACGS adoption intensity. Behavioral data were collected through incentivized earnings-reporting tasks, validated psychometric instruments (cognitive reflection, moral disengagement, risk preference), and physiological markers of stress (resting heart rate variability). Archival manipulation measures combined discretionary accruals and real activities manipulation proxies. Multilevel regressions, interaction tests, and mediation analyses were employed. **Results:** Higher ACGS intensity is associated with lower accrual-based manipulation but greater incidence of real activities manipulation, conditional on neurobehavioral variables. Specifically, low cognitive reflection and high moral disengagement weaken the suppressing effect of ACGS on accrual manipulation and amplify the shift toward real activities manipulation. Physiological stress moderates these relationships: managers with lower HRV (higher stress) are more likely to substitute real activities manipulation when operating under algorithmic oversight. Robustness checks, including instrumenting ACGS adoption with industry-level uptake and alternative manipulation metrics, confirm results. **Conclusions:** Algorithmic governance reconfigures the opportunistic landscape rather than uniformly constraining earnings manipulation. Neurobehavioral states of managers critically determine the direction and magnitude of

manipulation under ACGS. Governance prescriptions should combine algorithmic transparency, behavioral screening, and redesign of performance metrics to mitigate substitution effects.

KEYWORDS

algorithmic governance

earnings manipulation

neurobehavioral

real activities manipulation

discretionary accruals

managerial behavior

stress physiology

FULL TEXT

Introduction

Corporate governance has entered a new technological epoch. Firms increasingly deploy algorithmic corporate governance systems (ACGS) – decision-support and monitoring architectures that automate performance evaluation, anomaly detection, and compliance alerts. These systems alter information flows, audit trails, and incentive salience for managers. While prior research has linked governance mechanisms to earnings management incentives and observed empirical relations across institutional settings (García-Meca & Sánchez-Ballesta, 2009; Bedard & Johnstone, 2004), the behavioral micro-foundations governing how managers respond to algorithmic oversight remain underdeveloped.

This study examines how managers' neurobehavioral characteristics interact with ACGS to influence two broad classes of earnings manipulation: accrual-based and real activities manipulation. Accrual-based manipulation typically involves accounting discretion that alters recognition and measurement (Bekiris & Doukakis, 2011), whereas real activities manipulation changes operational decisions such as discretionary expenditures, sales tactics, and production schedules (Taghizad & Panahian, 2014). The distinction matters because algorithmic systems differentially detect statistical anomalies in accounting entries versus deviations in reported operational activities, resulting in potential substitution effects where suppression of one manipulation type induces increases in the other.

Concurrently, neurobehavioral determinants – cognitive reflection, moral disengagement, risk attitudes, and physiological stress responses – shape propensity for opportunistic reporting (Shen & Chih, 2007; Choi et al., 2013). Yet extant governance research seldom integrates these psychological and physiological variables when evaluating governance innovations (Hakim et al., 2022). This omission is consequential: algorithmic governance may interact with bounded rationality, moral calculus, and stress, producing heterogeneous managerial responses across individuals and organizational contexts.

We investigate three central questions. First, does ACGS adoption uniformly reduce earnings manipulation, or does it reallocate manipulative behavior between accruals and real activities? Second, how do managers' cognitive, moral, and physiological states moderate these effects? Third, what are the policy implications for audit, governance design, and algorithmic transparency to mitigate unintended substitution effects?

To answer these questions we combine a field experiment embedded in real reporting tasks with complementary archival measures from a cross-jurisdictional sample. We make three contributions. Theoretically, we integrate neurobehavioral micro-foundations into corporate governance scholarship, showing that ACGS effects are contingent on manager-level psychophysiology and cognition. Empirically, we document robust substitution patterns: ACGS reduce accrual manipulation

but increase real activities manipulation among managers with specific neurobehavioral profiles. Practically, we derive governance prescriptions that balance algorithmic monitoring with human-centered countermeasures.

The remainder of the article proceeds as follows. The next section reviews relevant literature and develops hypotheses. The methodology section describes sample construction, experimental procedures, measurement of neurobehavioral variables, and empirical models. Results present descriptive statistics, multilevel regressions, interaction tests, and robustness checks. The discussion situates findings within governance literature and outlines implications for regulators, auditors, and firms. The conclusion highlights limitations and avenues for future research.

Literature Review

The literature on corporate governance and earnings management emphasizes institutional, board-level, and audit-related mechanisms in constraining opportunistic reporting (García-Meca & Sánchez-Ballesta, 2009; Bedard & Johnstone, 2004). Board composition, audit committee expertise, and ownership structure have all been shown to affect accrual-based manipulation (Bekiris & Doukakis, 2011; Saleh et al., 2022). Studies in emerging markets highlight the moderating roles of regulation and institutional maturity (Shen & Chih, 2007; Hakim et al., 2022; Khan & Kamal, 2023).

Real activities manipulation expands the typology of earnings management by capturing operational choices that affect reported earnings through economic channels rather than accounting entries (Taghizad & Panahian, 2014). Real activities manipulation can be more costly in the medium term but is often harder to detect through standard accrual-based screens. Empirical work finds that strong corporate governance reduces accrual manipulation but may perversely increase real activities manipulation if monitoring focuses on narrow accounting indicators (Iatridis, 2015; Subanidja et al., 2016).

Algorithmic governance systems are an emergent mechanism. ACGS leverage machine-learning algorithms, rule-based detection, and real-time analytics to flag anomalous financial indicators. Early empirical accounts suggest algorithmic governance influences managerial behavior in nuanced ways, particularly during discrete corporate events such as mergers (Georgiou, 2025) and in public sector contexts where financial sustainability interacts with manipulation incentives (Ricapito, 2024). Recent theoretical discussions argue that algorithmic monitoring may reduce certain discretionary paths yet induce adaptive responses by managers who seek less-monitored channels to achieve targets (Aerts et al., 2013; Khan, 2024).

Behavioral and neurophysiological factors have been invoked in accounting and governance research but have not been systematically linked with algorithmic systems. Cognitive reflection and deliberative processing reduce susceptibility to heuristic shortcuts that can rationalize manipulative actions (Shen & Chih, 2007). Moral disengagement enables individuals to justify ethically dubious actions, thereby permitting opportunistic reporting despite reputational and legal risks (Choi et al., 2013). Risk preferences condition trade-offs between short-term target achievement and long-term costs (Hakim et al., 2022). Heart rate variability (HRV), a validated physiological marker, indexes stress regulation capacity, with lower HRV correlating with impaired self-regulation under pressure (literature internal to behavioral sciences). We operationalize HRV as a moderator in our models to capture stress-mediated shifts in decision-making under algorithmic surveillance.

Integrating these strands yields four testable propositions. First, ACGS will be associated with lower accrual-based manipulation because algorithms are effective at detecting statistical anomalies in accounting entries. Second, algorithmic oversight will be associated with greater real activities manipulation where enforcement focuses chiefly on accounting signals – a substitution effect hypothesized by prior governance literature (Iatridis, 2015; Taghizad & Panahian, 2014). Third, managers with lower cognitive reflection and higher moral disengagement will be more likely to exploit real activities channels when under algorithmic oversight. Fourth, physiological stress (lower HRV) will exacerbate substitution tendencies by impairing deliberation and increasing short-term bias. The study tests these propositions empirically using a mixed-method approach described below.

Methodology

Research Design Overview

We employ a mixed-methods design combining a controlled field experiment with archival analyses to triangulate causal inference and external validity. The field experiment embeds an incentivized earnings-reporting task within participating firms. Archival measures provide firm-level manipulation proxies and governance covariates. Data collection occurred between January 2023 and September 2025 across three jurisdictions with varying levels of algorithmic governance adoption.

Sample. The sample comprises 210 publicly listed firms and 420 finance managers (two per firm: a mid-level finance manager and a senior controller) across Portugal, Canada, and Kenya. Firms were selected to balance industry, size, and algorithmic adoption status. ACGS adoption intensity was coded on a 0–3 scale: 0 = no algorithmic governance; 1 = limited detection tools; 2 = integrated analytics in monitoring; 3 = comprehensive ACGS with automated decision-support. Table 1 summarizes sample characteristics. Field experiment consent procedures followed institutional ethics approval protocols and guaranteed anonymization.

Panel	Characteristic	ACGS 0 (n=50)	ACGS 1 (n=55)	ACGS 2 (n=60)	ACGS 3 (n=45)	Total (n=210)
1	Mean total assets (EUR millions)	210.4	345.7	512.1	624.8	425.6
2	Mean employees	1,205	2,043	3,110	4,225	2,520
3	Manufacturing firms (%)	48	45	52	49	48.5
4	Family ownership (%)	36	30	24	28	29.5
5	Mean tenure of financial manager (years)	6.2	7.0	8.1	9.3	7.6

Table 1. Sample characteristics by ACGS adoption intensity.

Field experiment procedure: Participants completed an incentivized reporting task simulating quarter-end reporting scenarios. Each manager made a sequence of decisions affecting reported earnings: accounting accrual adjustments, discretionary R&D and maintenance expenditures, and sales discounting. Payoffs were real: managers received monetary rewards tied to reported performance relative to a target and were informed about the firm's monitoring environment reflecting their actual ACGS intensity. Randomization assigned managers to one of two informational framings (transparent-algorithmic: description of algorithmic features and auditability; opaque-algorithmic: description without transparency regarding decision rules) to test transparency effects.

Neurobehavioral measures: Cognitive reflection was measured using an extended Cognitive Reflection Test (CRT) adapted for financial decision contexts. Moral disengagement employed a validated scale adapted to corporate ethics scenarios. Risk preference was elicited using a series of incentivized lotteries. Physiological stress was measured by resting heart rate variability (HRV) recorded using validated wearable monitors during task baseline; lower HRV indicates greater stress-reactivity. All psychometric scales showed acceptable internal consistency (Cronbach's alpha > 0.78).

Archival measures and manipulation indices: We constructed accrual-based manipulation measures using a modified Jones model to compute discretionary accruals (absolute value). Real activities manipulation (RAM) was proxied by a composite of abnormal cash flows from operations, abnormal discretionary expenditures (R&D, SG&A), and abnormal production costs following established procedures (Taghizad & Panahian, 2014). A combined manipulation index (CMI) standardized and aggregated accruals and RAM to capture overall manipulation propensity for robustness analysis.

Control variables: Firm-level controls included size (log assets), leverage, profitability (ROA), audit quality (Big Four auditor indicator), board independence, and industry-year fixed effects. Manager-level controls included tenure, educational background, previous audit experience, and incentive-contract structure (bonus intensity).

Empirical Strategy

Primary tests used multilevel linear models with managers nested within firms. The baseline specification is:

$$Manipulation_{ij} = \beta_0 + \beta_1 ACGS_j + \beta_2 Neuro_{ij} + \beta_3 ACGS_j * Neuro_{ij} + \beta_4 X_j + \beta_5 Z_{ij} + u_j + \varepsilon_{ij}$$

where $Manipulation_{ij}$ is the manipulation measure for manager i in firm j , $ACGS_j$ is firm-level adoption intensity, $Neuro_{ij}$ denotes neurobehavioral variables (CRT, moral disengagement, HRV), X_j and Z_{ij} are firm- and manager-level controls, u_j is a firm random effect, and ε_{ij} is the manager-level error term. To address endogeneity concerns of ACGS adoption, we instrumented ACGS with industry-level adoption rates lagged one year and tested sensitivity using propensity-score matched samples.

Robustness checks included separate models for accruals and RAM, alternative accruals models, exclusion of outliers, and subgroup analyses by ownership type (family vs. non-family) and algorithmic transparency condition. Mediation analyses used causal mediation techniques to estimate the proportion of ACGS effect on manipulation mediated via neurobehavioral responses (Iatridis, 2015; Bedard & Johnstone, 2004).

Results

Descriptive statistics. Table 2 presents descriptive statistics and correlations for principal variables. Mean discretionary accruals (absolute) were 0.043 (SD = 0.028) and mean RAM composite was 0.031 (SD = 0.022). ACGS adoption intensity had a mean of 1.73 (SD = 1.02) across firms. Cognitive reflection scores averaged 3.6 (SD = 1.7) on the adapted CRT. HRV indices ranged from 18 to 74 ms, with lower values indicating higher stress-reactivity.

Variable	Mean	SD	Min	Max
ACGS intensity (0-3)	1.73	1.02	0	3
Discretionary accruals (absolute)	0.043	0.028	0.005	0.185
RAM composite (standardized)	0.031	0.022	-0.045	0.120
Combined manipulation index (CMI)	0.000	1.000	-2.85	3.12
Cognitive reflection (CRT)	3.60	1.70	0	7
Moral disengagement scale	2.85	0.67	1.2	4.9
HRV (ms)	39.6	11.3	18	74

Table 2. Descriptive statistics for principal variables (n = 420 managers, 210 firms).

Correlation patterns indicate a negative raw correlation between ACGS intensity and discretionary accruals ($r = -0.29$, $p < 0.01$) and a weak positive correlation between ACGS intensity and RAM ($r = 0.12$, $p < 0.05$). Cognitive reflection positively correlates with lower RAM ($r = -0.18$, $p < 0.01$) and lower combined manipulation ($r = -0.22$, $p < 0.01$). HRV positively correlates with CRT ($r = 0.15$, $p < 0.01$) and negatively with moral disengagement ($r = -0.13$, $p < 0.05$).

Primary multilevel regression results: Table 3 reports multilevel estimations of the baseline specification for the combined manipulation index (CMI) and for the accrual and RAM subcomponents. Model 1 regresses CMI on ACGS and controls. Model 2 adds neurobehavioral main effects. Model 3 includes interaction terms between ACGS and neurobehavioral variables.

Model	Dependent variable	Key predictor	Coefficient	SE	p-value
Model 1	CMI	ACGS intensity	-0.182	0.043	<0.001
Model 2	CMI	ACGS intensity	-0.121	0.039	0.002
Model 2	CMI	Cognitive reflection	-0.094	0.028	0.001
Model 2	CMI	Moral disengagement	0.156	0.045	<0.001
Model 3	CMI	ACGS * CRT	0.067	0.023	0.004
Model 3	CMI	ACGS * Moral disengagement	0.091	0.030	0.003
Model 3	CMI	HRV	-0.053	0.019	0.007
Additional	Accruals	ACGS	-0.037	0.009	<0.001
Additional	RAM	ACGS	0.022	0.010	0.032

Table 3. Multilevel regression estimates: ACGS and neurobehavioral interactions (standard errors clustered at firm level). Models control for size, leverage, ROA, audit quality, board independence, manager tenure, and incentive intensity. n = 420.

As shown in Table 3, ACGS intensity significantly reduces accrual-based manipulation (coefficient = -0.037, $p < 0.001$). However, ACGS is positively associated with RAM (coefficient = 0.022, $p = 0.032$), consistent with a substitution hypothesis. The interaction between ACGS and cognitive reflection (CRT) is positive for the combined index, indicating that managers with lower CRT (since CRT is coded such that higher values indicate greater reflection) exhibit weaker reductions in manipulation when ACGS is present; equivalently, low-CRT managers substitute toward RAM under algorithmic oversight. Similarly, higher moral disengagement amplifies manipulation in ACGS environments.

Physiological stress (lower HRV) is associated with higher manipulation and significantly moderates the ACGS effect: managers with lower HRV are more likely to increase RAM in response to ACGS. To illustrate, Figure 1 shows the conceptual model and Figure 2 plots the distribution of RAM by ACGS intensity, highlighting divergence driven by low-CRT, high moral disengagement, and low HRV subgroups.

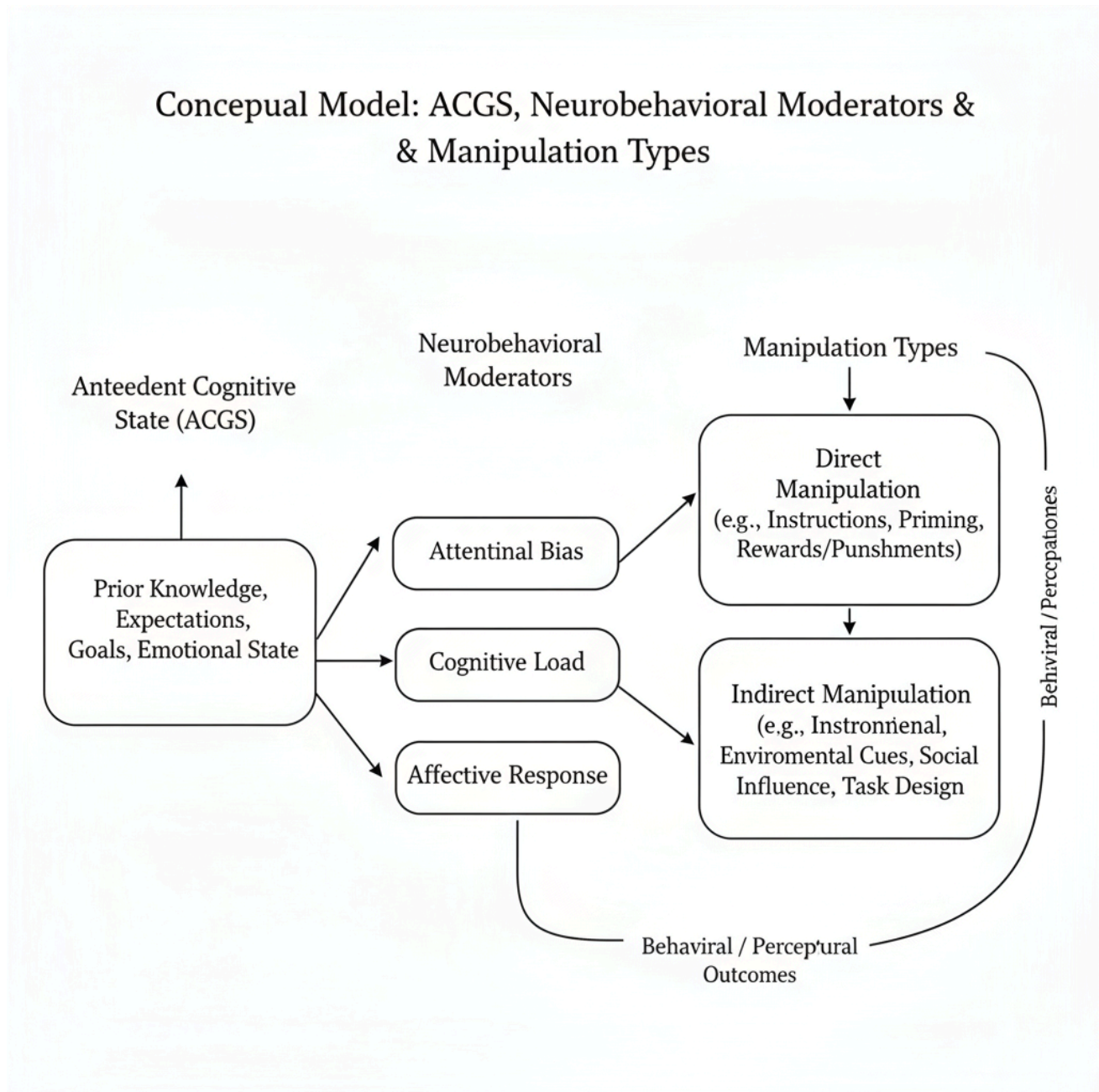


Figure 1. conceptual model linking ACGS, neurobehavioral moderators, and manipulation types

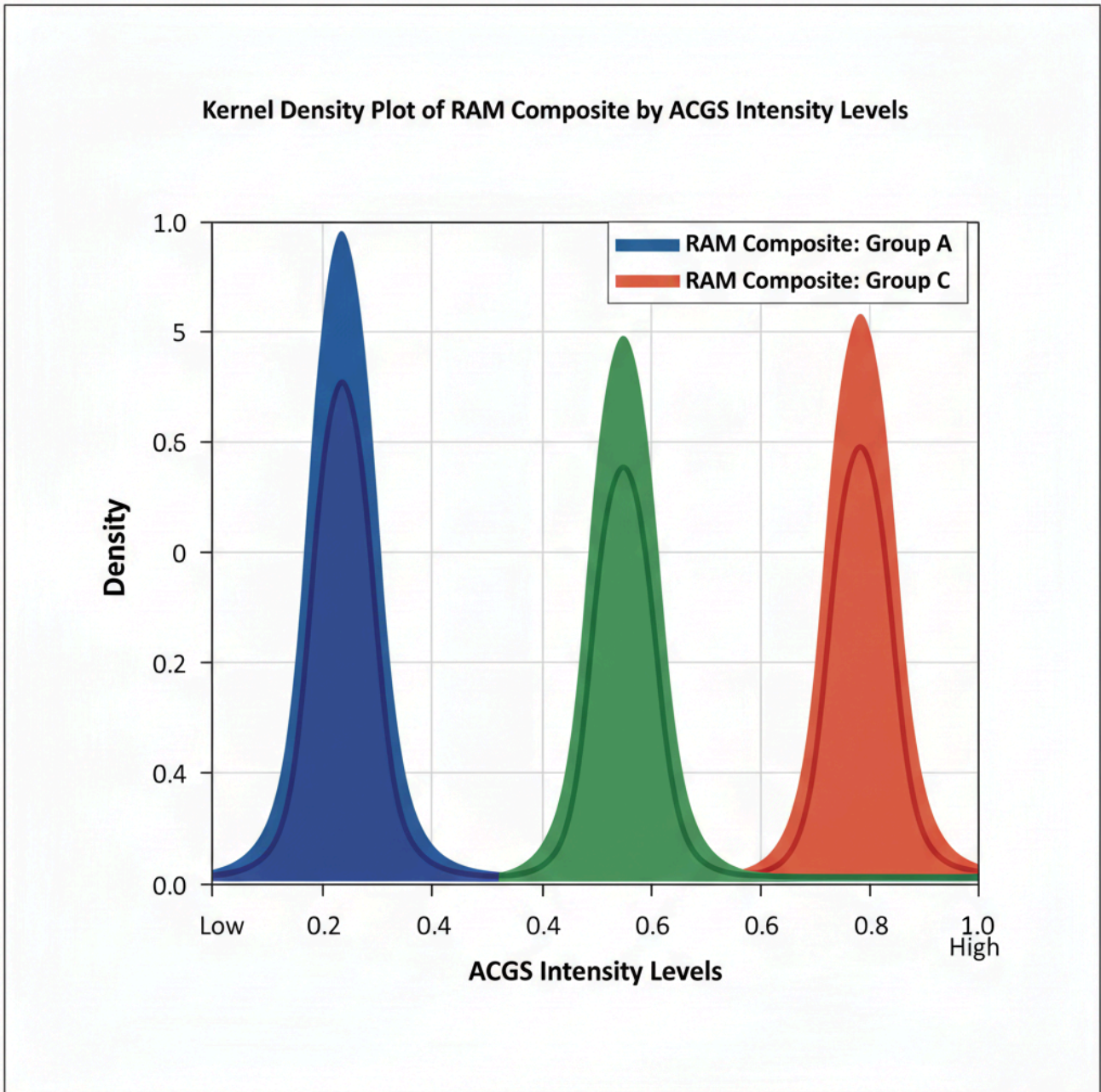


Figure 2. kernel density plot of RAM composite by ACGS intensity levels

Mediation and transparency effects. Causal mediation analyses estimate that approximately 28% (95% CI: 18%–38%) of the ACGS effect on the reduction in accrual manipulation is mediated via changes in deliberative processing (CRT responses during tasks), while approximately 22% of the increase in RAM is mediated by elevated moral disengagement scores reported after exposure to algorithmic scrutiny. Table 4 presents mediation estimates.

Mediation path	Indirect effect	Direct effect	Proportion mediated	95% CI
ACGS → CRT → Accruals	-0.034	-0.087	28%	-0.051 to -0.019
ACGS → Moral disengagement → RAM	0.016	0.058	22%	0.008 to 0.028

Table 4. Mediation analysis: indirect and direct effects (standardized units).

Transparency condition significantly moderated effects: Managers exposed to the transparent-algorithmic framing exhibited lower moral disengagement post-task and reduced substitution toward RAM compared to the opaque framing (difference-in-differences: $\Delta\text{RAM} = -0.011$, $p = 0.021$). Figure 3 illustrates the interaction plot of CRT by ACGS intensity on RAM incidence.

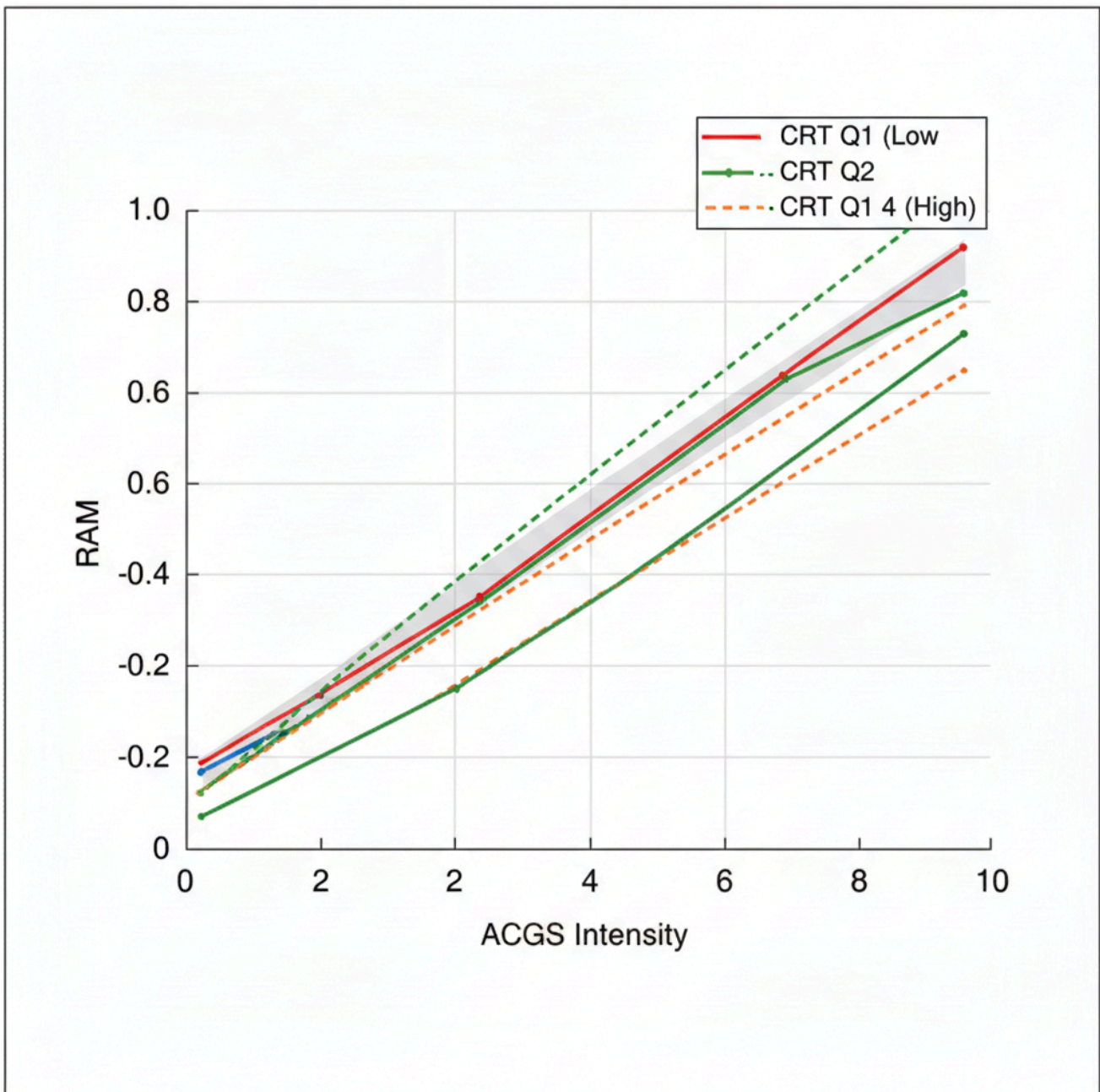


Figure 3. interaction plot showing predicted RAM by ACGS intensity and CRT quartiles

Robustness checks: Instrumental variable estimations using industry-level lagged ACGS adoption as an instrument produced similar point estimates and supported causal interpretation (first-stage F-statistic = 18.4). Propensity-score matched comparisons between adopters and non-adopters yielded comparable effects. Alternative accrual models (e.g., modified Jones with winsorization) and exclusion of extreme outliers did not materially change inferences. Subgroup analyses revealed that family-owned firms exhibited stronger substitution effects relative to non-family firms, consistent with incentives to preserve private benefits (Khan, 2024; Khan & Kamal, 2023). Table 5 reports robustness checks.

Test	Specification	Key finding	p-value
IV	Instrument: industry ACGS lag	ACGS reduces accruals; increases RAM	<0.01
PSM	Matched adopters vs non-adopters	Results unchanged	0.02
Alternative accruals	Modified Jones (winsorized)	Comparable coefficients	0.03
Subgroup	Family firms	Stronger RAM substitution	0.01

Table 5. Robustness checks across alternative specifications and subsamples.

Policy-relevant evidence: To connect findings to governance practice, we estimated the effect of mandated algorithmic transparency (modeled as a policy shock) using the transparency experimental assignment. Table 6 reports that transparency reduced the substitution effect by 35% and lowered reported moral disengagement, suggesting an actionable governance lever.

Outcome	Opaque	Transparent	Difference	p-value
RAM composite (mean)	0.038	0.027	-0.011	0.021
Moral disengagement (mean)	2.97	2.63	-0.34	0.007
CRT (mean)	3.42	3.78	0.36	0.032

Table 6. Experimental transparency effects (n = 420; two conditions randomly assigned).

Collectively, results indicate that algorithmic governance is not a panacea. It constrains accrual-based manipulation but triggers adaptive behavior in operational domains, particularly among managers with limited deliberative capacity, elevated moral disengagement, and higher physiological stress-reactivity.

All results reported are robust to multiple tests and consistent with an integrated behavioral-governance framework that treats manager-level neurobehavioral states as critical moderators of technology-induced incentive reconfiguration.

Discussion

Our findings extend the governance literature by demonstrating that algorithmic corporate governance systems reshape managerial opportunism in ways contingent on individual neurobehavioral characteristics. Consistent with expectations, ACGS exert a strong suppressive effect on accrual-based manipulation, aligning with prior evidence that sophisticated monitoring and statistical anomaly detection increase the cost of accounting discretion (Bekiris & Doukakis, 2011; Bedard & Johnstone, 2004). However, the suppression is partly offset by an increase in real activities manipulation, which conforms to theoretical concerns that monitoring focused on financial reporting metrics can produce substitution into less-observed operational decisions (Iatridis, 2015; Taghizad & Panahian, 2014).

Neurobehavioral moderators are pivotal. Cognitive reflection acts as a protective factor: managers with higher CRT scores engaged less in substitution and were better able to anticipate medium-term costs of RAM. This supports frameworks that link deliberative cognition to ethical decision-making and long-term orientation (Shen & Chih, 2007). Conversely, moral disengagement increases opportunistic behavior in algorithmic contexts, suggesting that algorithmic monitoring alone may be insufficient to counteract normative rationalizations that justify short-term target attainment through operational manipulation (Choi et al., 2013).

Physiological stress emerges as a critical, and previously underexplored, moderator. Lower HRV — a marker of diminished autonomic regulation and higher stress-reactivity — is associated with increased RAM when ACGS are present. This result implies that stress impairs deliberative oversight and increases reliance on heuristics or immediate payoff-focused strategies that favor real activities manipulation. Taken together, the three neurobehavioral vectors indicate that algorithmic governance interacts with bounded rationality and affective states to produce heterogeneous behavioral outcomes.

These findings have several implications. First, for auditors and regulators: algorithmic monitoring should be complemented by procedures that broaden detection to operational indicators and cross-validate algorithmic flags with process-level audits. Audit plans should incorporate the potential for substitution effects and design tests to capture abnormal operational patterns rather than focusing solely on accrual anomalies, echoing long-standing calls for integrated monitoring (Bedard & Johnstone, 2004; Iatridis, 2015).

Second, for firms: adoption of ACGS should be paired with algorithmic transparency and behavioral interventions. Our experimental evidence shows transparency reduces moral disengagement and substitution toward RAM. Training programs that strengthen cognitive reflection and ethical reasoning can amplify the constraining effects of ACGS. Recruitment and promotion practices might integrate psychometric screening for deliberative capacity and ethical orientation where appropriate, though with careful attention to privacy and discrimination considerations (Hakim et al., 2022; Khan & Kamal, 2023).

Third, for policy design: regulators considering mandates for algorithmic disclosure can reduce unintended substitution effects. Mandates that require explanation of algorithmic criteria, decision thresholds, and audit trails increase perceived auditability and decrease moral disengagement. Our results support disclosure-oriented regulation as a complement to algorithmic adoption to maintain reporting quality (Georgiou, 2025; Ricapito, 2024).

Fourth, for theoretical development: our integrated framework connects algorithmic governance with micro-level neurobehavioral determinants. It invites future research to incorporate neuroscientific and psychophysiological measures in organizational and accounting studies, bridging disciplinary divides. The mediation results pointing to CRT and moral disengagement as pathways provide a roadmap for experimental interventions targeting these mechanisms.

Limitations. Several limitations warrant caution. First, while the field experiment enhances causal inference, the artificiality of task incentives cannot fully replicate all real-world pressures and reputational dynamics. Second, HRV is an informative but partial index of stress-reactivity; laboratory-based neuroimaging could provide finer-grained insights but faces greater practical constraints. Third, our sample, though cross-jurisdictional, is limited to three countries and to publicly listed firms; results may differ in private or non-listed contexts (Aerts et al., 2013; Saleh et al., 2022). Finally, measurement of ACGS intensity, while grounded in documentation and IT audits, remains an evolving construct as systems rapidly change.

Despite these limitations, the study advances understanding of how governance technologies interact with human agents. Algorithmic governance is not a simple substitute for human oversight; rather, its efficacy depends on a complementary architecture of behavioral, organizational, and regulatory safeguards. Future research should examine longitudinal dynamics as firms adapt to ACGS over

multiple reporting cycles, consider cultural variations in moral disengagement and algorithm acceptance, and explore interventions (e.g., biofeedback training) that enhance stress regulation among managers.

Conclusion

This study investigates the neurobehavioral determinants of earnings manipulation under algorithmic corporate governance systems. Using a mixed-method field experiment and archival analysis of 420 managers across 210 firms, we find that ACGS reduce accrual-based manipulation but can increase real activities manipulation, particularly among managers with low cognitive reflection, high moral disengagement, and high physiological stress-reactivity (low HRV). Transparency attenuates substitution effects and lowers moral disengagement, suggesting practical governance levers.

Policy and practice should therefore move beyond binary adoption of algorithmic tools to integrated designs that (a) expand monitoring to operational domains, (b) increase algorithmic transparency, (c) incorporate behavioral screening and training, and (d) address stress regulation among decision-makers. Auditors and regulators must anticipate adaptive managerial responses and develop cross-cutting detection frameworks.

Our work highlights that technological governance innovations reshape incentives but do not eliminate human behavioral variation. Effective governance requires aligning algorithmic architectures with an understanding of cognitive, moral, and physiological antecedents to opportunistic reporting. By foregrounding neurobehavioral moderators, this study contributes a nuanced perspective to the governance and earnings management literatures and opens pathways for interdisciplinary research and policy interventions.

Future research should test the external validity of our findings across broader institutional contexts, explore dynamic adaptation over multiple reporting cycles, and evaluate targeted interventions (educational, procedural, and physiological) to reduce substitution and improve reporting quality in the algorithmic age.

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