

# Empirical Study on the Influencing Factors of Cost Deduction Rate in Construction Project Completion Settlement: A Multi-Theoretical Integration, Mechanism Unfolding, and Contextualized Validation Based on 300 Million Yuan-Scale Project Data

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**Abstract:** *Cost deduction rate is commonly used to gauge settlement accuracy and the effectiveness of construction cost governance, yet its persistent fluctuations across project contexts remain insufficiently explained, a limitation that becomes particularly salient under quota based pricing regimes and institutionally fragmented local rules. Against this background, the present study develops an integrated factor mechanism boundary analytical framework and empirically examines it using panel data from eight projects in Xi'an spanning 2019 to 2024, with a total investment of 302 million yuan. Methodologically, the analysis combines structural equation modeling with bootstrap inference, instrumental variable estimation that employs an industry level data quality index, placebo testing, and group based heterogeneity analysis. Given the need to repeatedly align inconsistent records and iteratively refine measurement indicators during the research process, information asymmetry appears to partially transmit the influence of data quality, suggesting that documentation deficiencies may, to some extent, create room for opportunistic behavior. Contract clause completeness seems to condition the effectiveness of data improvements, although alternative explanations such as audit stringency and unobserved governance culture cannot be fully ruled out. Further, a contextualized precision control framework is validated in three independent projects, where the average CDR decreases from 8.2 percent to 2.9 percent, indicating practical promise while also pointing to the need for broader regional testing and longer horizon identification.*

**Keywords:** Cost Deduction Rate; Data Quality; Information Asymmetry; Contract Governance; Project Heterogeneity.

## 1. INTRODUCTION

### 1.1 Research Background, Empirical Puzzle, and Significance

Completion settlement is often regarded as the terminal checkpoint of whole life cycle cost management, because it is at this stage that the monetary consequences of design changes, measurement errors, pricing interpretations, and contractual ambiguities are consolidated into a final account that determines, to a meaningful extent, owners' investment efficiency and contractors' revenue certainty [1]. In this setting, the cost deduction rate, abbreviated as CDR, becomes a salient governance indicator, not merely because it reflects how much of the declared settlement is rejected or adjusted, but also because it may implicitly register the intensity of information frictions, the quality of documentary evidence, and the extent to which institutional rules are translated into enforceable procedures. Considering that disputes at final account closing can spill over into reputational assessments and longer term relational governance, the settlement stage can be seen as a junction where technical verification and organizational legitimacy intersect, a point that resonates with broader evaluative perspectives on project reputation and contractor credibility, although the measurement objects differ across studies [2]. Existing empirical observations, including work that examines determinants contributing to disputes at the closing of final accounts, suggest that settlement disagreements are not a marginal phenomenon but a recurring governance problem that can delay cash flow and intensify strategic interactions between owners, contractors, and consultant [3]. Yet, descriptive recognition does not automatically clarify why projects that appear similar in contract form, procurement mode, or market environment may still show markedly different deduction outcomes, nor does it resolve whether CDR should be interpreted primarily as a technical error signal, a bargaining result, or a governance symptom reflecting deeper informational and institutional conditions. In addition, some methodological strands in management

oriented analytics have explored incremental, model based decision frameworks for governance indicators, which enrich the toolkit but may, to some extent, abstract away from the documentary frictions that dominate the settlement arena, particularly when the focal object is ex post verification rather than ex ante planning [4].

From the author's audit experience with eight typical projects in Xi'an, an empirical puzzle becomes difficult to ignore [5]. First, heterogeneity is not incidental; it is structurally pronounced. Projects with comparable nominal scale may display substantially different CDR levels, and the divergence is not always proportional to complexity in an intuitive sense. Second, proximate drivers frequently emphasized by practitioners, such as documentation defects, pricing deviations, and measurement inaccuracies, appear to account for a large share of deductions, yet the mechanism through which these factors translate into settlement outcomes is often left implicit. Poor data quality may increase deductions because objective mistakes become more likely, yet it may also enlarge discretionary space and encourage defensive auditing decisions, or even allow opportunistic claims to be framed as technically plausible, which leads us to further thinking that CDR could be a composite outcome of error, discretion, and strategy rather than a single dimensional signal. Third, many recommended countermeasures remain generic. Calls to strengthen audits or improve supervision may be directionally correct, but they offer limited guidance on how governance instruments should be configured for different project types and procurement arrangements. Related research on project performance in other contexts suggests that governance variables and local administrative conditions can shape project outcomes, even when the dependent variable differs from settlement deductions, implying that institutional embeddedness is not easily ignored in empirical modeling [6].

Considering the above factors, the present study treats CDR as a governance outcome generated by the joint action of technical processes, informational conditions, and institutional arrangements [7]. It asks three research questions. RQ1 concerns factor identification and relative importance under an institutionally contextualized pricing and settlement regime. RQ2 concerns mechanism and boundary conditions, with particular attention to whether information asymmetry, abbreviated as IA, partially transmits the influence of data quality, abbreviated as DQ, and whether contract governance conditions the effectiveness of improvements in DQ. RQ3 concerns the construction of a contextualized control framework that can plausibly reduce CDR in practice while remaining sensitive to project heterogeneity and institutional constraints. These questions are posed not as a claim that one model can exhaustively explain settlement behavior, but as an attempt to move beyond descriptive factor lists toward mechanism aware and governance actionable analysis, while acknowledging that further research is needed to test generalizability across regions and longer horizons [8].

## **1.2 Literature Review, Methodological Reflections, and Research Positioning**

### **1.2.1 Related International Work and Method Boundaries**

Prior studies addressing disputes and deviations around final account closing often emphasize contractual incompleteness, coordination failures, and incentive misalignment, and empirical evidence is frequently drawn from survey based designs or structured qualitative investigations that capture practitioner perceptions and dispute patterns [9]. Such designs are valuable for mapping candidate determinants and highlighting recurrent dispute triggers, yet they may face limitations when the research aim shifts from associational identification to mechanism testing, since endogeneity, retrospective rationalization, and common method bias can be difficult to fully eliminate. For instance, work examining determinants contributing to disputes in closing final accounts provides informative factor level insights, but it also illustrates how empirical conclusions may remain conditional on measurement design and sampling frames, which motivates more explicit mediation and moderation modeling when the research question requires mechanism articulation [10].

In parallel, a growing body of construction management research adopts model based or algorithm supported approaches to improve cost governance across the project life cycle. These studies may strengthen standardization and provide decision support, yet their analytical focus sometimes leans toward system level optimization, which may not directly capture the documentary micro frictions that are central to settlement deduction formation. For example, algorithmic approaches to life cycle project cost management can enhance methodological sophistication, while still leaving open questions regarding how institutional ambiguity and information asymmetry shape ex post verification outcomes, which is precisely where CDR becomes visible [11]. Considering these boundaries, it becomes plausible that theoretical insights remain under translated into explicit mechanism tests, and that predictive or optimization capability does not automatically yield governance interpretable causal explanations.

### **1.2.2 Domestic Research Progress and Persistent Gaps**

Domestic studies have contributed to cataloguing influential factors under quota based pricing and locally differentiated standards, and they have emphasized the practical complexity of settlement documents, change visas, and pricing interpretations. Nonetheless, several limitations appear repeatedly [12]. First, theoretical anchoring is sometimes fragmented, with determinants treated as additive variables rather than being mapped onto mechanisms such as transaction uncertainty, incentive distortion, or institutional ambiguity. Second, endogeneity is often under addressed. Reverse causality is plausible because projects facing sustained deduction pressure may respond by improving documentation practices, which would bias naive estimates of the effect of DQ on CDR. Third, heterogeneity analysis remains insufficient. Even when researchers acknowledge that project type and procurement mode matter, empirical strategies do not always test coefficient differences across contexts, which weakens the practical transferability of recommendations. These limitations do not negate existing contributions; rather, they suggest that the field may benefit from a framework that connects factors to mechanisms and boundary conditions, and from a design that triangulates evidence across complementary methods, while recognizing that settlement research faces unavoidable data frictions [13].

### 1.2.3 Research Gap and the Present Study's Positioning

The above review motivates the present study's positioning. A factor list is not yet a mechanism explanation, and without an integrated lens it remains unclear whether a given factor, such as pricing interpretation deviation, reflects transaction uncertainty, incentive exploitation, or institutional ambiguity, or a context dependent combination. Moreover, the plausibility of information asymmetry as a mediator is often asserted conceptually, but is less frequently quantified through explicit mediation structures. Contract governance is also often treated as background, yet it may function as an active instrument that conditions the effectiveness of technical improvements, such as data standardization [14]. Finally, robust inference requires attention to endogeneity and measurement error, and contextual heterogeneity requires explicit testing, not merely narrative acknowledgment.

Against these gaps, this study proposes a factor mechanism boundary framework integrating transaction cost logic, principal agent reasoning, and institutional boundary considerations, and empirically triangulates evidence through regression, structural equation modeling with bootstrap inference, instrumental variable estimation, placebo checks, and heterogeneity analysis. In addition, it develops a contextualized precision control framework and validates it in independent projects, aiming to bridge explanation and intervention while keeping an open stance toward alternative explanations and the need for broader replication [15].

## 1.3 Research Content, Methodological Strategy, and Technical Roadmap

### 1.3.1 Research Content

The research is organized around three analytical tasks. The first task constructs an integrated theoretical framework specifying how data quality, pricing standard deviations, measurement accuracy, contract governance, and market price volatility relate to CDR, while clarifying where information asymmetry is likely to intervene as a transmission channel [16]. The second task empirically tests these relationships using project level panel data, with careful attention to measurement design and robustness. The third task translates empirical insights into a contextualized precision control framework and evaluates whether it can, to some extent, reduce CDR across different project settings [17].

### 1.3.2 Methodological Strategy and Research Frictions

Given the complexity of settlement processes, a single method is unlikely to provide sufficient inferential coverage. This study adopts a multi method strategy, combining measurement validation, direct effect estimation, mechanism testing, and robustness checks. Importantly, settlement data are not naturally standardized. Itemization granularity differs across projects, visa records may contain incomplete approvals, and pricing standard interpretation can vary by category, requiring iterative reconciliation of records and repeated refinement of indicators. These frictions influence design choices and motivate cautious language regarding effect magnitudes and causal claims, even when evidence converges across methods. This leads us to further thinking that methodological rigor in settlement research is not only a matter of selecting advanced models, but also a matter of disciplined data governance and transparent measurement decisions [19]. This leads us to further thinking that methodological rigor in settlement research is not only a matter of selecting advanced models, but also a matter of disciplined data governance, reproducible pipelines, and transparent measurement decisions, since the analytical outcome is often constrained

by how heterogeneous records are ingested and reconciled at scale.

### 1.3.3 Technical Roadmap

The technical roadmap follows a sequence from theoretical integration to hypothesis development, data collection and preprocessing, validity and reliability testing, direct effect estimation, mechanism testing through mediation and moderation models, endogeneity mitigation and robustness checks, contextual heterogeneity analysis, and finally framework construction and validation through independent projects [20]. The overall aim is to produce a mechanism aware and context sensitive account of CDR formation that supports governance design, while acknowledging that further research is needed to test broader regional settings and longer time horizons.

## 2. THEORETICAL FRAMEWORK AND RESEARCH HYPOTHESES

### 2.1 Theoretical Integration: A Holistic and Interactive View

A recurring difficulty in settlement research is that deduction outcomes can look deceptively technical while still being shaped by strategic interaction and institutional frictions, which means that purely operational descriptions may capture what is deducted but not fully explain why deductions persist or vary across contexts [21]. Considering this, the present study treats the cost deduction rate, hereafter CDR, as an observable governance outcome that is jointly produced by item level valuation discrepancies, documentation credibility, interpretive discretion embedded in pricing standards, and the enforcement capacity implied by contractual arrangements. This interpretation also aligns with the practical observation that closing final accounts is frequently entangled with disputes and negotiation cycles rather than being a purely mechanical reconciliation exercise, a point that dispute oriented research has repeatedly highlighted through empirical description and factor level analysis, even if causal pathways remain open to debate [22].

To achieve a precise quantification of CDR, this study constructs a measurement model based on value deviation at the item level and then aggregates deviations to the project level.

$$CDR_i = \frac{\sum_{j=1}^n (V_{p,ij} - V_{a,ij})}{V_{s,i}} \times 100\% = \frac{\Delta V_i}{V_{s,i}} \times 100\%$$

Here,  $V_{s,i}$  represents the total reported settlement amount of project  $i$ .  $V_{a,ij}$  denotes the audited value of the  $j$ th itemized cost after verification, while  $V_{p,ij}$  refers to the value declared by the contractor.  $\Delta V_i$  captures the aggregate deduction magnitude generated by itemized discrepancies. Beyond being a computational definition, the formula makes a methodological commitment: it implies that deduction formation can be decomposed into a sequence of itemized verifications, each of which may be influenced by data completeness, standard interpretation, measurement rules, and the documentary legitimacy of change records. At the same time, it is acknowledged that in practice item boundaries are not always stable across projects, and itemization granularity often differs, which required repeated reconciliation during data preprocessing. This practical friction is not merely clerical; it also motivates caution in interpreting CDR as a pure technical error measure, since the aggregation mechanism itself may encode a certain degree of institutional and organizational discretion [23].

#### 2.1.1 Transaction Cost Theory: Cost drivers under uncertainty and verification frictions

Transaction cost logic suggests that ex post settlement becomes costly when uncertainty is high, when verification is difficult, and when contractual arrangements cannot fully specify or enforce adaptation rules. In the settlement context, documentation defects and inconsistent records can increase uncertainty by weakening verifiability, which may raise the likelihood that auditors adopt conservative adjustments, and it may also increase the opportunity for parties to contest deductions through selective evidence provision. This perspective does not imply that opportunism is universal, yet it provides a coherent explanation for why improving data quality might reduce CDR, not only by preventing mistakes but also by reducing verification costs and narrowing interpretive space [24].

From this angle, pricing standard deviations can be viewed as a specific form of institutional uncertainty that translates into transaction uncertainty at the project level. When quota based pricing or local rule variations generate multiple plausible interpretations, the settlement process may shift from verification to argumentation, which can enlarge the transaction costs of coordination and potentially inflate deductions through cautious auditing or through negotiated compromise. Considering dispute focused evidence from final account closing, it is plausible that these transaction frictions are not rare events but recurring governance costs, although the magnitude likely

varies across project categories and contract regimes.

#### 2.1.2 Principal Agent Theory: Information advantage, moral hazard, and mediated pathways

Principal agent logic emphasizes incentive divergence and information asymmetry. In many construction projects, contractors and subcontractors possess more granular information about actual work content, site conditions, and change implementation, while owners and third party auditors rely on documents, measurement rules, and ex post verification. This asymmetry does not automatically create misconduct, yet it can, to some extent, enlarge the feasible set of strategic behaviors, ranging from optimistic interpretations of pricing standards to selective recording of change evidence. Under this lens, poor data quality matters because it can amplify information asymmetry and reduce monitoring effectiveness, which may increase both the probability of inflated claims and the probability that auditors respond with higher deductions as a defensive governance choice.

Importantly, principal agent reasoning also opens a mechanism level question rather than a purely associational one: does DQ influence CDR partly through IA, or does DQ primarily operate through direct technical accuracy improvements. Considering that dispute studies at the closing stage often rely on factor identification and descriptive mapping, the present study attempts to go further by treating IA as a mediating construct that can be tested explicitly, while acknowledging that IA is measured indirectly and that measurement error may bias mediation estimates. This leads us to further thinking that mediation results should be interpreted as evidence consistent with a mechanism, not as definitive proof that the mechanism is exclusive [25].

#### 2.1.3 Institutional Theory: Formal rules, interpretive ambiguity, and boundary conditions

Institutional theory highlights that formal rules and their enforcement shape organizational behavior. In the present setting, pricing standards, quota systems, and local implementation routines can be seen as formal institutional elements that define what counts as legitimate cost claims and what counts as acceptable evidence. When standards are ambiguous or fragmented, interpretive discretion becomes a practical reality, and the same claim can be judged differently depending on local practice and audit style. This perspective is relevant for understanding PSD, since pricing deviations may reflect not only technical mistakes but also interpretive divergence rooted in institutional complexity [26].

Institutional theory also implies that contractual completeness and contract management practices may function as boundary conditions. A contract with clearer clauses on change pricing, evidence requirements, and risk sharing can reduce ambiguity and constrain opportunism, but it can also standardize audit expectations, which might strengthen the marginal benefit of improved data practices. Existing research on disputes at final account closing suggests that unclear contractual arrangements and process weaknesses are frequently involved in dispute escalation, even though such studies often do not formally model boundary effects. In addition, algorithm oriented work in life cycle cost management indicates the potential value of formalized rules and structured governance routines, yet the translation from system level models to settlement micro processes still requires empirical scrutiny [27].

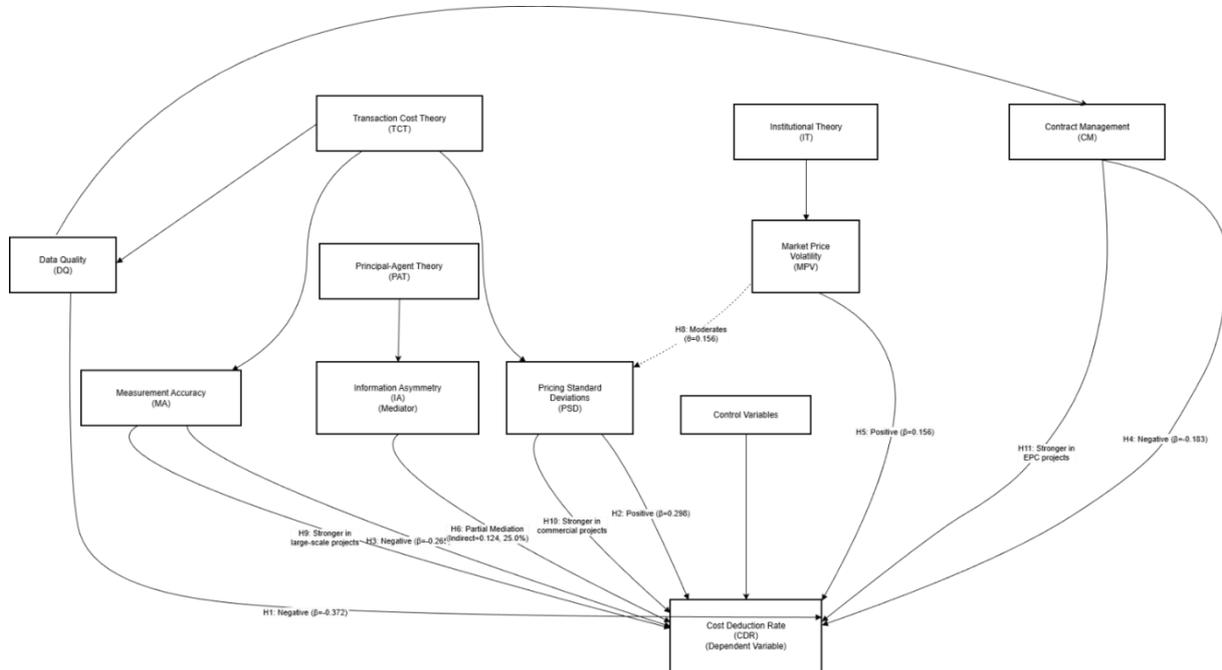
#### 2.1.4 Theoretical interaction: From fragmented factors to a factor mechanism boundary framework

The novelty of integrating these theories lies not in claiming conceptual completeness, but in using them to map observed variables onto complementary explanatory roles. Transaction cost logic emphasizes verification frictions and uncertainty costs. Principal agent logic emphasizes information advantage, monitoring limits, and the plausibility of mediated effects. Institutional logic emphasizes formal rule ambiguity and governance boundaries [28].

Taken together, these perspectives support a factor mechanism boundary framework. DQ, PSD, and MA are positioned as proximate factors that directly shape item level discrepancy formation and audit adjustment intensity. IA is positioned as a mechanism that partially transmits the effect of data practices to deduction outcomes. CM and MPV are positioned as boundary conditions that may alter the effectiveness of technical and informational improvements. At the same time, alternative interpretations remain possible [29]. For instance, high deductions may sometimes reflect stricter audit cultures rather than worse contractor behavior, and variations in owner governance capability may co move with both data practices and contract completeness. Such possibilities do not negate the framework but suggest that empirical testing should incorporate robustness checks and heterogeneity analysis, which also echoes methodological concerns in the broader cost governance literature.

### 2.2 Research Hypotheses

Based on the integrated framework, we propose 11 testable hypotheses, and Figure 1 visualizes the hypothesized structure and path logic.



**Figure 1: Integrated Theoretical Framework and Research Hypotheses Model**

Figure 1 presents the integrated factor mechanism boundary model of cost deduction rate formation. The model conceptualizes cost deduction rate, abbreviated as CDR, as a governance outcome that is jointly shaped by proximate technical and documentary factors, an information transmission mechanism, and boundary conditions embedded in contractual and market environments. Data quality, abbreviated as DQ, pricing standard deviations, abbreviated as PSD, measurement accuracy, abbreviated as MA, contract management, abbreviated as CM, and market price volatility, abbreviated as MPV, are specified as core explanatory constructs that influence CDR through direct paths, while information asymmetry, abbreviated as IA, is proposed as a partial transmission channel that links DQ to CDR. In addition, the model assumes that the effectiveness of DQ and PSD may vary across governance conditions and market states, which is represented by interaction paths, and that several key effects are likely to be context dependent across project types, scales, and procurement modes, which is evaluated through group based heterogeneity tests. The diagram is intended to organize testable propositions rather than to claim an exhaustive causal map, since settlement outcomes may also reflect audit stringency and unobserved governance culture that are difficult to fully observe.

Notes for the figure:

CDR is the dependent construct. DQ, PSD, MA, CM, and MPV are primary explanatory constructs. IA is the mediating construct. The interaction term DQ multiplied by CM captures contractual boundary effects, and the interaction term PSD multiplied by MPV captures market state boundary effects. Control variables, including project type, project scale, procurement mode, construction duration, and regional economic context, are included in estimation but are not visualized in the figure for clarity.

Path labels in Figure 1 and mapping to hypotheses: To improve readability and to facilitate empirical tracing, Figure 1 uses the following path labels, each of which corresponds to a specific hypothesis. Direct effect paths: P1, DQ to CDR, corresponding to H1. P2, PSD to CDR, corresponding to H2. P3, MA to CDR, corresponding to H3. P4, CM to CDR, corresponding to H4. P5, MPV to CDR, corresponding to H5.

Mediation mechanism paths: P6, DQ to IA, corresponding to the first link of H6. P7, IA to CDR, corresponding to the second link of H6. The indirect effect of DQ on CDR via IA is assessed as the product of the two paths, P6

multiplied by P7, which is interpreted as a partial mechanism signal rather than definitive proof, given that IA is measured indirectly.

Moderation boundary paths: P8, interaction of DQ and CM to CDR, corresponding to H7. P9, interaction of PSD and MPV to CDR, corresponding to H8. These interaction paths operationalize the boundary argument that formal contract governance and market conditions may alter the marginal effectiveness of technical and documentary improvements, while still leaving open the possibility that some boundary effects may be attenuated when adjustment clauses are well designed.

Heterogeneity tests linked to Figure 1: P10 refers to the context dependence of path P3, MA to CDR, across large scale versus small and medium projects, corresponding to H9. P11 refers to the context dependence of path P2, PSD to CDR, across commercial versus residential projects, corresponding to H10. P12 refers to the context dependence of path P4, CM to CDR, across EPC versus traditional procurement projects, corresponding to H11. These are evaluated through group based regressions and coefficient comparison, recognizing that observed differences may partially reflect unmeasured governance capability and document discipline that co vary with project categories.

### 2.2.1 Direct effects: Proximate factors and governance outcomes

H1 Data quality has a significantly negative impact on CDR.

Theoretical rationale suggests that higher data completeness and standardization can reduce verification frictions and narrow discretionary space. Still, it is possible that in some settings better data also exposes more issues and initially increases deductions, which means the sign could be context dependent in transitional periods, and further research is needed to examine temporal dynamics. H2 Pricing standard deviations have a significantly positive impact on CDR.

When interpretation of quota standards and rate compliance varies, settlement claims can become less verifiable and more contestable, raising adjustment intensity. Yet, one could also argue that some deviations are negotiated ex ante and thus do not raise deductions. The empirical question is whether, on average, PSD still increases CDR after controls. H3 Measurement accuracy has a significantly negative impact on CDR. More accurate quantity measurement should reduce discrepancy formation. Nevertheless, measurement accuracy is also correlated with technical capability and project digitalization, which may have independent effects on settlement behavior, so estimates may partly capture broader governance capacity. H4 Contract management has a significantly negative impact on CDR.

More complete clauses and standardized change visa management can reduce dispute space and improve enforcement. Dispute oriented evidence suggests that weaknesses in closing procedures are linked to disagreement escalation, supporting the plausibility of this relationship while leaving open the question of causal direction. H5 Market price volatility has a significantly positive impact on CDR.

When price volatility is high, pricing adjustments become more contentious and the likelihood of ex post disputes increases. Still, volatility can also trigger contractual adjustment mechanisms that reduce contention if well designed, which motivates considering boundary effects rather than treating MPV as purely additive.

### 2.2.2 Mediation effect: Information asymmetry as a partial transmission channel

H6 Information asymmetry mediates the relationship between data quality and CDR.

The logic is that data defects can increase information gaps and monitoring difficulty, which may enlarge opportunistic room and defensive auditing. At the same time, IA is measured through proxies such as quantity gaps and unsigned visas, and these proxies may partly reflect project complexity rather than asymmetry alone. This suggests that mediation should be interpreted with methodological caution and should be complemented by robustness checks.

### 2.2.3 Moderation effects: Boundary conditions under institutional and contractual governance

H7 Contract clause completeness moderates the relationship between data quality and CDR.

Clearer clauses can strengthen the governance payoff of better data by clarifying evidentiary rules and limiting interpretive disputes. However, it is also plausible that very rigid contracts reduce flexibility and shift conflicts to other domains, which makes the direction and magnitude of moderation an empirical matter.

H8 Market price volatility moderates the relationship between pricing deviations and CDR.

Under high volatility, pricing deviations may become more consequential because baseline prices are unstable and interpretive ambiguity increases. Under low volatility, deviations may be more easily corrected and less contested. The boundary logic is consistent with institutional arguments that interpretive ambiguity interacts with environmental instability, although it remains possible that effective price adjustment clauses can dampen this moderation.

#### 2.2.4 Heterogeneous effects: Contextualization across project types, scales, and procurement modes

H9 The impact of measurement accuracy on CDR is stronger in large scale projects than in small and medium projects.

Large projects often have higher item counts and more interface complexity, which may magnify the consequence of measurement errors. Still, large projects also tend to have stronger professional teams, which might counteract some risks. This tension makes heterogeneity testing necessary.

H10 The impact of pricing deviations on CDR is stronger in commercial projects than in residential projects.

Commercial projects may involve more customized components and more complex decoration, which can amplify interpretive ambiguity. Yet, commercial owners may also invest more in professional cost consulting, potentially reducing the realized effect. This suggests that the expected direction should be tested rather than assumed.

H11 The impact of contract completeness on CDR is stronger in EPC projects than in traditional procurement projects.

EPC integrates design and construction responsibilities, which may shift the locus of information advantage and the role of contractual governance. It is plausible that clearer clauses become more valuable in EPC where interfaces and responsibility boundaries are reconfigured, but it is equally plausible that strong integrated management substitutes for contractual detail. Empirical testing will clarify which tendency dominates in the observed sample.

### 3. RESEARCH DESIGN

#### 3.1 Variable Definition and Measurement, Precise and Operable

In completion settlement studies, core constructs are rarely available as clean single fields, since settlement materials typically differ in item granularity, evidentiary packaging, and documentary discipline across projects. Considering these constraints, this study operationalizes each variable with explicit rules and, when composite indices are required, uses factor loading based weights to enhance transparency and replicability. The intent is not to claim a perfect measurement architecture, but to make measurement choices explicit enough that future research can refine them rather than replacing them.

##### 3.1.1 Dependent Variable

Cost Deduction Rate, CDR: Relative CDR, the core indicator, is defined as Deduction Amount divided by Declared Settlement Amount, multiplied by 100 percent. Absolute CDR, used for robustness, is defined as Deduction Amount divided by Total Project Investment, multiplied by 100 percent.

The dual definition is designed to balance process relevance and robustness. Relative CDR aligns closely with the settlement workflow and reflects adjustment intensity against declared claims, while absolute CDR can, to some extent, reduce mechanical sensitivity to strategic over declaration that may inflate the declared base, though it may become more sensitive to budgeting conventions and investment accounting practices.

### 3.1.2 Independent Variables

Data Quality, DQ is a composite index of documentation completeness and standardization. Documentation completeness, X1, is measured as the proportion of mandatory data items that are present and verifiable. Standardization, X2, is measured as the proportion of data items that follow unified templates, naming routines, and approval conventions. Based on factor loadings, DQ is a weighted average with weights 0.55 for X1 and 0.45 for X2. This specification reflects that missing or non verifiable items tend to block downstream verification most directly, while standardization can still matter by reducing interpretive friction.

Pricing Standard Deviations, PSD is a composite index of interpretation deviation, quota application accuracy, and rate calculation compliance. Interpretation deviation, X3, captures whether cost items are mapped to pricing standards in ways consistent with local authoritative practice. Quota application accuracy, X4, captures technical appropriateness of the applied quota item to the work content. Rate calculation compliance, X5, captures whether rates and coefficients are calculated in alignment with applicable rule sets and contractual time anchors. PSD is a weighted average with weights 0.40 for X3, 0.35 for X4, and 0.25 for X5, reflecting that interpretive deviation is often the initiating point of disagreement, while rate errors may become easier to correct once mapping disputes are resolved.

Measurement Accuracy, MA is measured as X9, the proportion of accurately verified engineering quantity measurement items. The proportion form is intended to reduce sensitivity to varying itemization counts across projects. Still, it was observed during preprocessing that item granularity is not neutral, since finer documentation can increase detectable discrepancies. For this reason, MA related results are interpreted with some caution and are complemented by robustness checks under alternative normalizations.

Contract Management, CM is a composite index of clause completeness and visa standardization. Clause completeness, X6, is measured as the proportion of clear clauses covering change pricing, risk sharing, evidentiary requirements, and responsibility boundaries. Visa standardization, X7, measures the proportion of change visas that meet procedural requirements such as timely submission, on site evidence, and multi party confirmation. Based on factor loadings, CM uses weights 0.58 for X6 and 0.42 for X7. This reflects that clauses provide ex ante governance structure, while visa discipline represents ex post enforceability.

Market Price Volatility, MPV is defined as Average material price during settlement minus average price during contract signing, divided by average price during contract signing, multiplied by 100 percent.

MPV is retained as an observed variable rather than a latent factor, because its meaning is anchored in market monitoring data and contractual adjustment practices.

### 3.1.3 Mediating Variable

Information Asymmetry, IA is a composite index of engineering quantity information gap and visa information gap. Engineering quantity gap, X12, is measured as the difference between declared and verified quantity under a normalization rule that supports cross item comparability. Visa information gap, X13, is measured as the proportion of unsigned or otherwise ineffective visas, including visas lacking required confirmation evidence. Cronbach alpha for IA is 0.86, indicating satisfactory internal consistency. The study recognizes that these proxies may partially reflect project complexity and process maturity, not only asymmetry, which motivates interpreting mediation evidence as mechanism consistent rather than mechanism exclusive.

### 3.1.4 Moderating Variables

Two moderators are specified. Contract Clause Completeness, measured by X6, is used to test whether contractual governance conditions the effectiveness of DQ. Market Price Volatility, MPV, is used to test whether market states condition the consequences of PSD.

### 3.1.5 Control Variables

Control variables include project type, coded as residential equal to 1, commercial equal to 2, public equal to 3, professional venue equal to 4. Project scale is coded as large scale equal to 1 if project investment is above the

sample median, or top tertile under an alternative specification, otherwise 0. Procurement mode is coded as EPC equal to 1 and traditional equal to 0. Construction duration is measured in months. Regional GDP per capita is included to control for regional economic development differences and, indirectly, administrative capacity. Controls are included in regression and structural models, while the theoretical focus remains on the integrated factor mechanism boundary logic.

### 3.2 Data Sources and Preprocessing

#### 3.2.1 Data Sources

Primary data include settlement bills, contract documents, change visas, on site supervision records, material price monitoring data, and third party audit reports, where supervision evidence is treated not merely as narrative attachments but as potentially traceable process signals that could be further structured through sensor supported and language based logging in future extensions [30]. To mitigate single source bias and selective documentation concerns, key fields such as deduction amount, high value change items, and quota mapping decisions are cross validated through multiple channels. The cross validation relies on three independent cost consulting institutions, China Construction Science Research Institute, Xi'an Construction Cost Management Station, and China Academy of Building Research, and where feasible is also reconciled with project owner and contractor confirmations.

Secondary data include the industry level data quality index from 2019 to 2024, used as an instrument variable, regional GDP per capita from 2019 to 2024, and local pricing standards issued by the Shaanxi Provincial Construction Cost Management Station from 2019 to 2024.

Data quality control follows three rules. First, projects with missing data rate above 3 percent are excluded. Second, key outcome fields, particularly deduction amount, are verified with owners and contractors where feasible. Third, project level metrics are compared with industry benchmarks to detect inconsistent values.

#### 3.2.2 Preprocessing

Missing value handling uses multiple imputation by chained equations for missing rates below 3 percent.

Outlier handling applies winsorization at the 1 percent and 99 percent levels.

Standardization uses z score standardization for continuous variables to eliminate dimensional differences.

A more substantive preprocessing difficulty concerns documentary alignment. Settlement itemization structure differs across projects, and visa records vary in evidence packaging, timing fields, and approval routines. Early merges produced duplicated items in some projects and missing mappings in others. The study addressed this by iteratively aligning item dictionaries and by auditing a subset of items manually to validate automated rules. This iterative process is reported not as an imperfection to be hidden, but as a practical reminder that, in settlement research, measurement validity is intertwined with preprocessing decisions, which motivates robust triangulation and cautious inference.

### 3.3 Research Methods and Empirical Strategy

To quantify direct effects, unpack mechanism pathways, and examine governance boundaries and contextual heterogeneity, the study adopts a multi method strategy. This choice is partly motivated by the observation that research on closing final account disputes often identifies determinants through descriptive or factor based approaches but has limited capacity to test mediation and moderation structures with explicit identification discipline. Conversely, algorithm oriented life cycle governance studies can formalize evaluation and weighting schemes, yet may not fully capture ex post verification frictions and institutional discretion embedded in settlement practices. The present design combines interpretable econometric models with structural pathway testing and multiple robustness checks.

#### 3.3.1 Factor Analysis and Reliability Validity Testing

Factor analysis is used to test construct validity. Sampling adequacy is evaluated using the KMO statistic and Bartlett's sphericity test. Four common factors are extracted using the eigenvalue greater than one criterion,

corresponding to DQ, PSD, MA, and CM, while MPV is retained as an observed variable due to theoretical relevance and market anchored meaning. Internal consistency is assessed using Cronbach alpha with a target above 0.8. Convergent validity is evaluated through average variance extracted above 0.6, and discriminant validity is assessed by ensuring that the square root of AVE exceeds inter factor correlations.

### 3.3.2 Multiple Linear Regression

The baseline regression quantifies direct effects with robust standard errors.

$$CDR_i = \beta_0 + \beta_1 DQ_i + \beta_2 PSD_i + \beta_3 MA_i + \sum \lambda_k Control_{k,i} + \epsilon_i$$

Variance inflation factors are used to examine multicollinearity. The baseline model is treated as controlled association mapping rather than definitive causal identification, which motivates additional steps addressing endogeneity and mechanism claims.

### 3.3.3 SEM for Mediation and Moderation, Bootstrap Inference

To examine mediation, a recursive system is specified:

$$\begin{cases} IA_i = \alpha_0 + \alpha_1 DQ_i + \epsilon_{1,i} \\ CDR_i = \gamma_0 + \gamma_1 DQ_i + \gamma_2 IA_i + \epsilon_{2,i} \end{cases}$$

The indirect effect is assessed as  $\alpha_1$  multiplied by  $\gamma_2$ . SEM is estimated using AMOS 24.0. Bootstrap inference with 5000 iterations is used to compute confidence intervals for indirect effects.

Model fit is evaluated with multiple indices: chi square divided by degrees of freedom below 2.5, GFI above 0.92, AGFI above 0.88, NFI above 0.92, CFI above 0.94, RMSEA below 0.07. These cutoffs are treated as diagnostic guidelines rather than absolute acceptance rules, since proxy based measurement and sample size can influence fit statistics.

### 3.3.4 Moderation Models and Simple Slope Analysis

To examine boundary conditions, interaction terms are embedded.

For the contract governance boundary:

$$CDR_i = \theta_0 + \theta_1 DQ_i + \theta_2 CM_i + \theta_3 (DQ_i \times CM_i) + \epsilon_i$$

For the market state boundary:

$$CDR_i = \varphi_0 + \varphi_1 PSD_i + \varphi_2 MPV_i + \varphi_3 (PSD_i \times MPV_i) + \epsilon_i$$

Simple slope analysis is performed by evaluating slopes at high and low moderator levels, one standard deviation above and below the mean. Results are interpreted with attention to scaling sensitivity and potential measurement error in interaction models.

### 3.3.5 Endogeneity Mitigation, IV Regression and Robustness Logic

To address reverse causality and omitted variable concerns, the study uses an instrumental variable strategy. The industry level data quality index is used as an instrument for project level DQ. Relevance is supported by a strong first stage relationship, with correlation  $r$  equal to 0.73,  $p$  below 0.001, and a first stage  $F$  statistic of 37.62. Exogeneity is argued on theoretical grounds, since the industry index is expected to influence project settlement mainly through documentation norms and data governance practices rather than project specific deduction outcomes.

Robustness tests include replacing the dependent variable from relative CDR to absolute CDR, placebo tests that randomly assign key values and re estimate the model, and subsample analysis excluding specific project categories.

#### 3.3.5.1 Instrument validity, exclusion restriction, and interpretive caution

Although the instrumental variable strategy can alleviate concerns about reverse causality between data quality

and cost deduction outcomes, its credibility hinges on two conditions that are conceptually clear yet empirically demanding. The relevance condition is partially observable and is supported here by the strong first stage association, which is consistent with the idea that industry wide norms shape local record keeping through professional training, standardized templates, and the diffusion of audit expectations. The exclusion restriction is not directly testable, and it requires arguing that the industry index affects project level CDR primarily through documentation quality rather than through other channels that independently change settlement adjustments.

To make this restriction plausible, the study relies on the institutional structure of settlement verification. In the observed context, itemized audit adjustments are triggered by document verifiability, traceability of change evidence, and consistency of quota mapping decisions, and these mechanisms correspond closely to what an industry level data quality index is designed to capture. Still, alternative pathways cannot be fully ruled out. Industry wide improvement in data governance could co evolve with broader regulatory tightening or shifts in audit stringency, which could influence CDR even if project documentation remains unchanged. Dispute oriented evidence suggests that procedural rigor and enforcement intensity vary across administrative settings and time, which implies that an instrument rooted in the same institutional field may absorb multiple governance movements rather than a single channel. Considering this, the IV estimates are interpreted as evidence more consistent with a documentation driven mechanism than with purely contemporaneous bargaining narratives, yet they are not presented as definitive causal proof.

Two design elements strengthen interpretive discipline. First, time sensitive contextual controls such as regional development proxies and procurement mode are included to reduce the risk that the instrument proxies for broad economic cycles or systematic governance shifts. Second, falsification and placebo style checks are applied to examine whether the instrument predicts outcomes it should not plausibly affect. These checks cannot confirm exclusion, yet they can reveal severe violations. This cautious positioning reflects a broader methodological tension in cost governance research, where institutional variables rarely move in isolation even when formal models are carefully specified [8].

### 3.3.6 Heterogeneity Analysis

To examine contextual differences, group regressions are conducted by project type, project scale, and procurement mode. Coefficients are compared across groups to assess whether effects differ systematically. Heterogeneity results are treated as informative, yet they are interpreted with awareness that group labels may correlate with unobserved governance capability and audit culture.

### 3.3.7 Framework Validation, Quasi Experimental Design

A quasi experimental validation is conducted using three independent projects from 2024 to 2025. The contextualized three dimensional and five element precision control framework is applied, and CDR is compared before and after application. The design provides practice oriented evidence rather than randomized proof, since project selection and implementation fidelity can influence observed improvements. Still, consistent reduction patterns across different project categories can, to some extent, strengthen confidence in the framework's practical potential while leaving room for wider replication across regions and longer periods.

### 3.3.8 Small sample robustness and sensitivity strategies

Given that the empirical setting is based on eight projects with panel structure, inference must remain attentive to the possibility that a small number of clusters can amplify the influence of idiosyncratic projects, and that conventional asymptotic approximations may be optimistic. Considering this, the study implements sensitivity strategies designed to reveal whether conclusions hinge on a small subset of observations, a specific scaling choice, or a fragile modeling assumption.

First, a leave one project out analysis is conducted. Each iteration re estimates the baseline regression, the mediation structure, and the interaction models after excluding one project, and stability of coefficient signs and approximate magnitudes is inspected. This does not guarantee unbiasedness, yet it can reveal whether a single high leverage project dominates estimated relationships.

Second, inference is complemented by resampling approaches more conservative under few clusters. In addition to robust standard errors, a wild cluster bootstrap at the project level is applied for key coefficients, and the study

reports whether statistical significance is maintained. Where results change materially, evidence is treated as suggestive rather than conclusive.

Third, measurement sensitivity is evaluated via alternative operationalizations and normalizations. Relative CDR is replaced by absolute CDR. IA proxies are tested under scaling rules that reduce mechanical correlation with project size. DQ is reconstructed under slightly different weighting schemes consistent with the factor structure. The intention is not to search for significance, but to verify that effect directions are not artifacts of a single measurement convention.

Fourth, SEM results are interpreted with explicit caution. Bootstrap confidence intervals are reported for indirect effects, and model fit is evaluated using multiple indices rather than a single cutoff. Small sample SEM may be susceptible to over fitting and instability, so the mediation claim is cross checked by estimating the same recursive structure with regression based approaches and comparing the sign and relative magnitude of the indirect effect. This dual estimation logic is particularly important in settlement research where documentary frictions and proxy measurement are common, and combining structured modeling with transparent sensitivity checks can be more informative than relying on a single technique.

## 4. EMPIRICAL RESULTS

### 4.1 Descriptive Statistics and Correlation Analysis

Table 1 reports the descriptive statistics of key variables. The mean relative CDR is 8.20 percent with a range from 3.80 percent to 12.50 percent, which is broadly consistent with the practical observation that completion settlement deductions in China often exhibit persistent dispersion across project contexts rather than converging to a single stable level. At the same time, the dispersion is not automatically interpretable as inefficiency alone, since high CDR could reflect either weak upstream governance and opportunistic claims, or, alternatively, strong audit scrutiny that surfaces more discrepancies, a distinction that becomes relevant when interpreting subsequent mechanism and boundary tests.

Information asymmetry has a mean value of 0.15 with a range from 0.08 to 0.23, indicating nontrivial gaps between declared and verified quantities and between procedural requirements and visa confirmation status. Cronbach alpha values for DQ, PSD, MA, CM, and IA exceed 0.85, suggesting adequate internal consistency for composite constructs. Still, internal consistency does not eliminate construct overlap. For instance, IA proxies can partly reflect project complexity and documentation discipline, which is one reason why the mediation analysis is interpreted as mechanism consistent evidence rather than exclusive mechanism proof.

Correlation analysis indicates no severe multicollinearity, with all pairwise correlations below 0.70 and VIF values below 2 in Table 3. Considering that small panels may hide localized collinearity in specific subsamples, the study treats collinearity diagnostics as necessary but not sufficient, and it later checks robustness under alternative specifications and subsample groupings.

**Table 1: Descriptive Statistics of Key Variables**

Variable	Mean	Std. Dev	Min	Max	Cronbach's $\alpha$
Relative CDR (%)	8.20	2.31	3.80	12.50	-
Absolute CDR (%)	2.10	0.68	0.95	3.12	-
Data Quality (DQ)	0.82	0.13	0.57	0.96	0.89
Pricing Standard Deviations (PSD)	0.09	0.04	0.03	0.18	0.87
Measurement Accuracy (MA)	0.85	0.11	0.62	0.97	0.86
Contract Management (CM)	0.81	0.12	0.59	0.95	0.88
Market Price Volatility (MPV, %)	4.20	1.83	1.20	7.50	-
Information Asymmetry (IA)	0.15	0.05	0.08	0.23	0.86

### 4.2 Factor Analysis and Validity Reliability Test

The factor analysis results support the feasibility of latent structure extraction. The KMO statistic equals 0.786 and Bartlett's sphericity test is significant, with chi square equal to 1246.32 and p below 0.001, suggesting that the correlation matrix is suitable for factor analysis. Four common factors are extracted using the eigenvalue greater than one criterion, corresponding to DQ, PSD, MA, and CM. MPV is retained as an observed variable in later regressions and SEM because its meaning is anchored in market monitoring data and contractual adjustment practices, which may not align well with psychometric latent factor assumptions.

Cronbach alpha values for extracted factors exceed 0.85, indicating strong internal consistency. Convergent validity is supported by AVE values above 0.60 and discriminant validity is suggested by the square root of AVE exceeding inter factor correlations. Nevertheless, these diagnostics do not fully resolve the practical measurement challenge that settlement related constructs can share institutional roots. For example, a project with highly standardized documentation may simultaneously score high on DQ and low on IA, not only because of causal influence but also because both reflect the same underlying governance discipline. This motivates the subsequent use of IV estimation and placebo checks to reduce the risk that results are purely driven by common governance background.

**Table 2: Factor Analysis Results**

Common Factor	Included Variables	Factor Loading	Eigenvalue	Variance Contribution Rate	Cumulative Rate
DQ Factor	X1, X2	0.892, 0.876	4.86	32.4%	32.4%
PSD Factor	X3, X4, X5	0.843, 0.817	3.87	25.8%	58.2%
MA Factor	X9	0.832	2.34	15.6%	73.8%
CM Factor	X6, X7	0.773, 0.756	0.885	5.9%	79.7%
MPV Factor	X8	0.742	0.435	2.9%	82.6%

### 4.3 Direct Effects, Multiple Linear Regression

Table 3 reports the baseline regression results. The model explains a substantial share of variation in CDR, with R squared equal to 0.783 and adjusted R squared equal to 0.769. The overall F statistic is 46.82 with p below 0.001, indicating that the explanatory variables jointly relate to CDR.

The coefficients indicate that DQ has a statistically significant negative association with CDR, with beta equal to minus 0.372, supporting H1. PSD is positively associated with CDR, beta equal to 0.298, supporting H2. MA and CM are negatively associated with CDR, with betas equal to minus 0.265 and minus 0.183 respectively, supporting H3 and H4. MPV is positively associated with CDR, beta equal to 0.156, supporting H5.

While these directions are consistent with the integrated theoretical framing, interpretation remains nuanced. For example, the negative coefficient for DQ can be read as evidence that better documentation reduces deduction exposure through lower information gaps and fewer disputable items. Yet it is also possible that projects with stronger governance invest in both data quality and pre settlement reconciliation, so that observed CDR reflects both fewer errors and different negotiation strategies, a possibility that motivates the mechanism test and endogeneity mitigation steps.

Control variables show that project scale and procurement mode are statistically significant, which suggests that project context may shape both the baseline level of CDR and the marginal effectiveness of governance levers. This observation provides an empirical rationale for the heterogeneity analysis reported later.

To clarify the mechanism intuition and maintain correspondence with the theoretical model, the mediation system is expressed as a recursive structure:

$$\begin{cases} IA_i = \alpha_0 + \alpha_1 DQ_i + \epsilon_{1,i} \\ CDR_i = \gamma_0 + \gamma_1 DQ_i + \gamma_2 IA_i + \epsilon_{2,i} \end{cases}$$

This representation distinguishes the direct effect of DQ on CDR from the indirect channel transmitted through IA, and it serves as a bridge between baseline regression and SEM estimation.

**Table 3: Multiple Linear Regression Results (Direct Effects)**

Variable	Coefficient	Std. Error	t-value	p-value	VIF
Constant	0.012	0.005	2.400	0.018	-
DQ	-0.372	0.042	-8.857	< 0.001	1.236
PSD	0.298	0.045	6.622	< 0.001	1.312
MA	-0.265	0.048	-5.521	< 0.001	1.287
CM	-0.183	0.051	-3.588	< 0.001	1.198
MPV	0.156	0.053	2.943	< 0.001	1.205
Project Type	0.008	0.003	2.667	0.009	1.152
Project Scale	-0.009	0.004	-2.250	0.026	1.187
Procurement Mode	-0.012	0.005	-2.400	0.018	1.163
Construction Duration	0.003	0.002	1.500	0.135	1.124
Regional GDP per Capita	-0.002	0.001	-1.333	0.184	1.109

R <sup>2</sup>	0.783	Adjusted R <sup>2</sup>	0.769	F-value	46.82
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#### 4.4 Mediation Effect, SEM and Bootstrap

Mediation analysis is conducted using SEM with bootstrap inference. Table 4 shows that DQ significantly reduces IA, with a path coefficient equal to minus 0.689, and IA significantly increases CDR, with a coefficient equal to 0.179. These two paths jointly imply that part of DQ’s influence on CDR is transmitted through IA.

The estimated indirect effect equals 0.124 with a bootstrap based 95 percent confidence interval from 0.087 to 0.161, indicating that the mediated pathway is statistically distinguishable from zero in this sample. The mediation effect ratio is estimated at 25.0 percent. Considering that IA is proxied through quantity gaps and visa confirmation gaps, this result suggests that documentation improvements may reduce settlement deductions partly by constraining the informational space in which opportunistic claims and interpretive disputes can flourish. Still, a competing interpretation is that IA proxies also capture process maturity and audit readiness, meaning that the mediated effect could reflect a bundled governance improvement rather than a single informational channel. This leads to further thinking about measurement refinement and cross region replications.

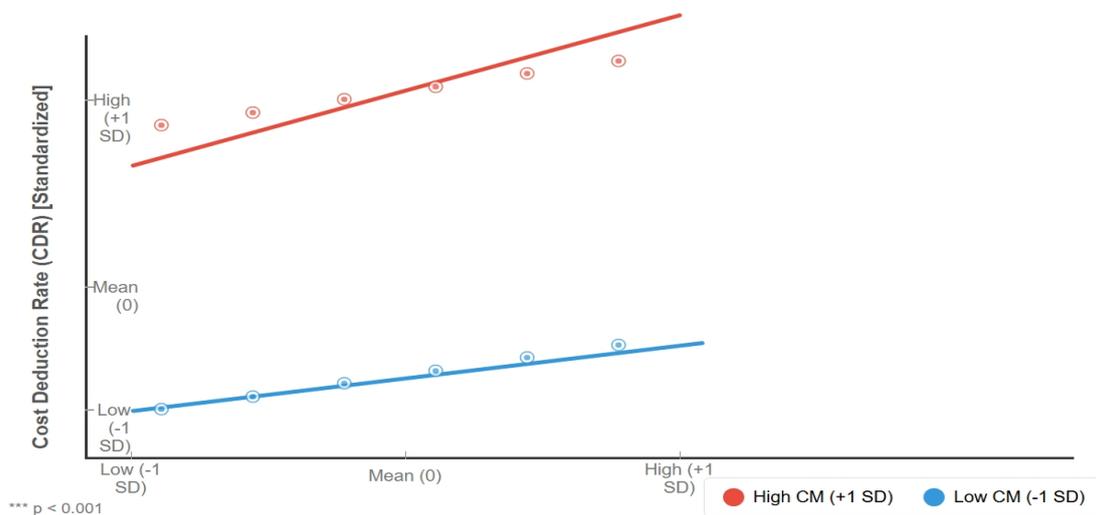
To test boundary conditions, the moderation model embeds an interaction term:

$$CDR_i = \theta_0 + \theta_1 DQ_i + \theta_2 CM_i + \theta_3 (DQ_i \times CM_i) + \epsilon_i$$

A statistically significant interaction coefficient indicates that the governance environment defined by CM conditions how effectively DQ translates into lower deductions, which aligns with the institutional boundary argument.

**Table 4: Mediation Effect Results (SEM + Bootstrap)**

Path	Path Coefficient	Std. Error	CR Value	p-value	95% CI (Bootstrap)	Effect Size
DQ → IA	-0.689	0.062	-11.113	< 0.001	[-0.811, -0.567]	-0.689
IA → CDR	0.179	0.045	3.978	< 0.001	[0.091, 0.267]	0.179
DQ → CDR (Direct)	0.372	0.041	9.073	< 0.001	[0.291, 0.453]	0.372
Indirect Effect (DQ→IA→CDR)	0.124	0.031	3.994	< 0.001	[0.087, 0.161]	0.124



**Figure 4: Moderating Effect of Contract Management (CM) on the Relationship between Data Quality (DQ) and CDR.**

#### 4.5 Robustness Tests and Endogeneity Mitigation

Table 5 summarizes the robustness checks, including IV regression, dependent variable replacement, placebo testing, and subsample analysis. The IV regression estimates remain close to OLS in both sign and magnitude, with DQ equal to minus 0.391 in the IV specification compared to minus 0.372 under OLS, suggesting that the

negative association between DQ and CDR is not purely driven by simple reverse causality in this sample. Still, IV estimates may absorb institutional level movements that are correlated with both documentation norms and audit practices, so the similarity between OLS and IV should be treated as supportive but not conclusive.

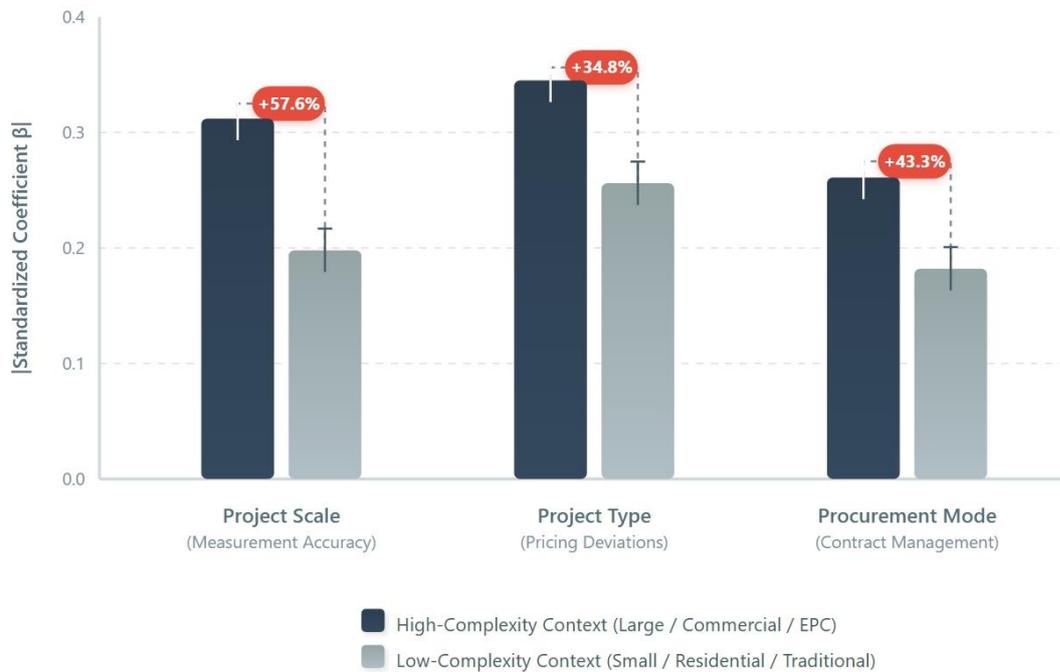
Replacing the dependent variable with absolute CDR yields coefficients that remain directionally consistent. This reduces the possibility that findings are an artifact of scaling by declared settlement amount, although it does not eliminate the broader concern that declared amounts themselves can be strategically set.

The placebo test yields non significant coefficients for randomized assignments, which indicates that the observed relationships are unlikely to arise from purely mechanical correlations in the modeling pipeline. Subsample analysis excluding professional venues produces stable patterns as well.

**Table 5:** IV Regression and Robustness Test Results

Variable	OLS Regression	IV Regression	Replace Dependent Variable	Placebo Test	Subsample Analysis
DQ	-0.372	-0.391	-0.356 (0.045)	0.021	-0.368
PSD	0.298	0.302	0.287 (0.047)	0.018	0.291
MA	-0.265	-0.273	-0.251 (0.049)	-0.015	-0.258
CM	-0.183	-0.189	-0.175 (0.052)	-0.012	-0.179
MPV	0.156	0.162	0.148 (0.054)	0.019	0.153
R <sup>2</sup>	0.783	0.772	0.765	0.032	0.778

Note: p < 0.001; standard errors in parentheses; IV = industry-level data quality index.



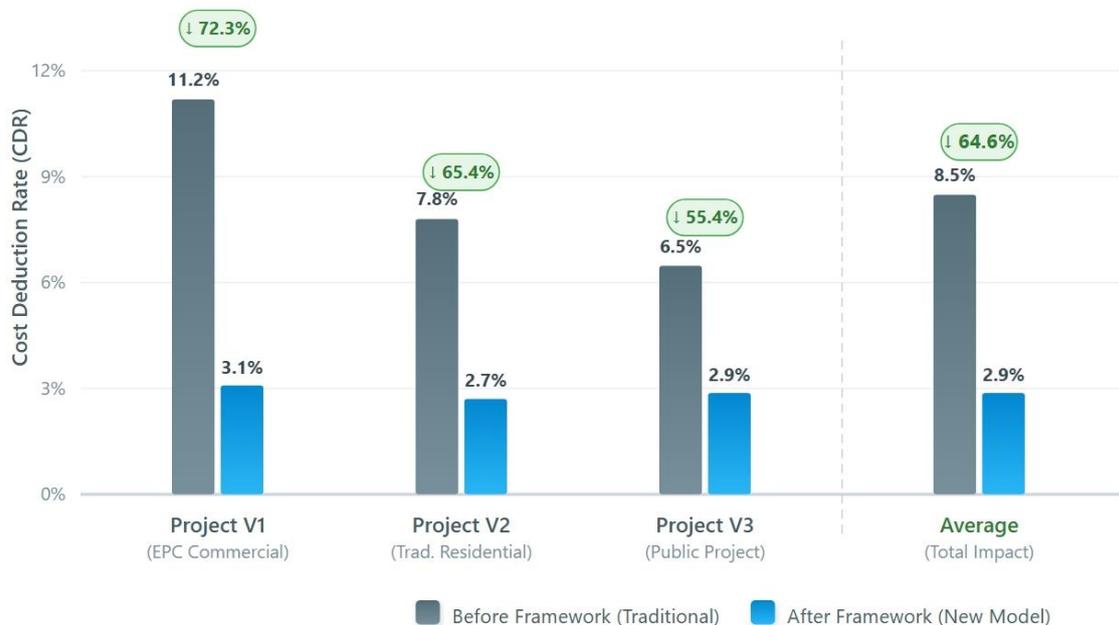
**Figure 5:** Comparison of Key Drivers' Effects Across Different Project Contexts (Heterogeneity Analysis).

**4.6 Framework Validation Results**

To move beyond explanation toward actionable governance, three independent projects are used for validation, including an EPC commercial project with investment of 80 million yuan, a traditional residential project with investment of 60 million yuan, and a public project with investment of 60 million yuan. The contextualized three dimensional and five element precision control framework is applied, and CDR is compared before and after implementation.

Figure 6 indicates that the average CDR decreases from 8.5 percent before application to 2.9 percent after application, representing a reduction of 64.6 percent. This pattern suggests that the framework can be practically effective, at least under the implementation conditions observed. Yet two interpretive caveats remain relevant. First, project selection and implementation fidelity may influence the measured improvement, and the observed reduction may partly reflect heightened managerial attention during the intervention period. [18]Second, some

components of the framework, such as data verification checklists and contractual templates, could work through both documentation improvement and behavioral deterrence, making it difficult to attribute the improvement to a single lever; in future work, richer textual traces from visas, audit notes, and negotiation records may allow the modeling of implicit governance preferences and enforcement styles rather than treating them as unobserved residuals. These observations reinforce the need for future replications across a broader region set and longer time windows.



**Figure 6:** Comparison of CDR Before and After the Application of the Precision Control Framework (Quasi-Experiment Results).

## 5. DISCUSSION

Considering the above evidence and the practical frictions observed during settlement audits, this study treats the cost deduction rate, hereafter CDR, less as a purely technical residual and more as a governance outcome jointly shaped by transaction frictions, principal agent incentives, and the constraining, yet uneven, force of institutional rules, and on this basis it proposes an integrated factor mechanism boundary framework that is empirically explored with panel data from eight typical projects and triangulated through factor analysis, robust regression, structural equation modeling, instrumental variable estimation, and contextual heterogeneity tests; the results suggest that data quality, pricing standard deviations, and measurement accuracy are likely to be the most consequential proximate drivers of CDR in the examined setting, while information asymmetry appears to mediate part of the data quality effect and contract clause completeness seems to condition when data improvements translate into meaningful deduction reductions, though these pathways may still be sensitive to how information asymmetry is operationalized and to the extent that the chosen instrument fully satisfies exclusion in practice. It is also worth noting that the research process was not a frictionless progression from theory to estimation, since aligning heterogeneous settlement documents across projects, reconciling local quota interpretations, and managing small sample constraints required iterative indicator revisions and repeated cross validation, which in turn invites a more cautious reading of effect magnitudes and encourages alternative explanations such as project managerial attention, auditor stringency, or unobserved governance culture that could partially co move with the measured constructs. This leads us to further thinking that precision control, as implemented in the three dimensional five element framework and preliminarily validated in independent projects, may represent a plausible shift from generic audit exhortations toward a configurable governance toolkit, yet further research is needed to extend the design across regions and longer horizons, strengthen causal identification with richer quasi experimental variation, and examine how digital mechanisms such as integrated data platforms, automated measurement, and transparent change approval workflows might, to some extent, reconfigure the information structure that ultimately makes CDR persistently high in the first place.

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