EGE SCHOLAR JOURNAL

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Ege Scholar Journal, Year: 2025, Volume: 2, Issue: 3, Pages : 158-170 ***Research Article***

DOI: 10.5281/zenodo.18525743

Publication Date: 30.09.2025

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Risk-Based Procurement Controls and Cost Efficiency in Public Defense Purchasing: Evidence from Ukraine

Abstract

Emergency defense procurement increases exposure to price dispersion, supplier opportunism, and documentation gaps, especially when purchasing must balance speed with accountability. This study tests whether risk-based procurement controls, implemented through structured risk indicators and enhanced screening, are associated with improved cost efficiency and reduced price dispersion in comparable defense-related purchases in Ukraine. Using contract-level procurement microdata and category-specific unit-cost measures, the analysis compares contracts subject to risk-based controls with otherwise similar contracts processed under standard procedures. The empirical design combines exact and propensity-score matching on procurement category, contract value, delivery horizon, contracting authority characteristics, and supplier history, and then estimates post-matching differences in (i) log unit prices, (ii) dispersion metrics within standardized categories (interquartile range and median absolute deviation), and (iii) outlier frequency based on pre-specified red-flag rules. Robustness checks vary matching algorithms, trimming rules, dispersion definitions, and subsamples defined by urgency and market concentration. The paper reports auditable effect estimates and provides governance recommendations focused on transparency, traceable documentation, and risk-calibrated controls that preserve operational timelines.

Keywords: public procurement; defense purchasing; risk-based controls; price dispersion; cost efficiency; governance; Ukraine; contract microdata

How to cite: Koverga V. (2025). Risk-Based Procurement Controls and Cost Efficiency in Public Defense Purchasing: Evidence from Ukraine. *Ege Scholar Journal, 2*(3), 158-170

1. Introduction

Public defence procurement operates under an unusually strict dual constraint during wartime: the state must procure rapidly to sustain operational readiness while simultaneously preserving accountability to prevent waste, fraud, and strategic supply vulnerabilities. Urgent demand conditions tend to weaken classical procurement safeguards by compressing decision timelines, limiting supplier search, fragmenting demand across procuring units, and increasing reliance on incomplete or rapidly changing market information. Empirically, these conditions can manifest as elevated unit-price dispersion for standardized items, a higher probability of extreme-price outcomes, and heterogeneous documentation quality that complicates ex post justification and auditability.In Ukraine, the broader public procurement ecosystem combines a national e-procurement infrastructure with complementary civic and analytical oversight layers that emphasize transparency, monitoring, and risk detection. This architecture has been widely characterized as transparency-oriented and open by design, with particular wartime relevance for sustaining economic functionality while maintaining minimum standards of public oversight. Such systems are intended to preserve traceability and enable analytical scrutiny even under conditions of severe operational stress.At the same time, contemporary procurement governance increasingly recognizes that uniform, high-intensity control across all transactions is not optimal in high-volume or emergency environments. Oversight capacity is inherently limited, and indiscriminate scrutiny can generate bottlenecks that delay urgent purchases. As a result, risk-based procurement controls have emerged as a pragmatic governance approach. Rather than applying identical controls everywhere, these systems concentrate scrutiny on contracts and suppliers that trigger measurable risk signals, while allowing low-risk transactions to proceed with reduced procedural friction.Operationally, risk-based controls typically rely on structured indicators and risk scoring, enhanced documentation requirements for flagged cases, additional screening mechanisms such as supplier vetting and price plausibility checks, and targeted ex post audits. Conceptually, these tools are expected to reduce price dispersion and extreme outliers by increasing the expected probability of detection, discouraging opportunistic pricing, and improving the traceability of procurement decisions. However, measurable effects are not guaranteed. In markets characterized by limited supplier capacity, high switching costs, specialized military specifications, or disrupted logistics, governance mechanisms may exert only muted short-run influence on prices. Under wartime scarcity, genuine heterogeneity in delivery terms, risk premiums, and quality requirements may dominate administrative signals, producing price dispersion that reflects real market conditions rather than governance failure.Against this background, this paper asks whether the application of risk-based procurement controls is associated with improved cost efficiency and reduced price dispersion in defence-related purchasing in Ukraine. The contribution is threefold. First, it advances a transparent and replicable microdata strategy designed for contract-level auditing. Second, it distinguishes standardized goods from specialized procurement categories in which competition and substitutability differ structurally, enabling disciplined heterogeneity analysis rather than one-size-fits-all claims. Third, it integrates dispersion and outlier logic aligned with contemporary red-flag approaches in public procurement analytics, consistent with open contracting and fraud-risk frameworks.

2. Materials and Methods

2.1. Data sources, frequency, and sample

The baseline dataset is constructed from procurement records at the contract level. The primary data source consists of records generated within Ukraine’s national electronic procurement infrastructure, including contract notices, award decisions, and associated contractual documentation where available. These records enable systematic observation of procurement outcomes, supplier selection, and pricing at a granular level appropriate for micro-empirical analysis.The empirical workflow is further supported

by analytical and monitoring tools designed for procurement benchmarking and risk detection. Such business intelligence modules facilitate the structuring of large-scale contract data, the identification of price dispersion and outliers, and the comparison of procurement outcomes across time, contracting authorities, and product categories. This combined approach allows for consistent contract-level analysis while maintaining transparency and replicability in data construction and processing.

Unit of observation: contract (award) level.

Frequency: continuous procurement events aggregated to a pre-specified time window (e.g., monthly or quarterly) for dispersion estimation within category-time cells.

Sample window and extraction dates: must be explicitly recorded in Appendix A (download timestamps, API query parameters, and revision policy), so that replication yields identical outputs.

Inclusion criteria (pre-defined)

1. Defense-related contracting authorities and/or procurement categories consistent with defense purchasing.
2. Contracts with measurable unit price (total value and quantity available with consistent units).
3. Standardized product categories identified using CPV codes and normalized item descriptions.
4. Transparent exclusion rules for missingness and anomalies (e.g., missing quantity; non-positive values; non-parsable units), with counts reported.

Data integrity and wartime-specific considerations

Because emergency procurement may exhibit partial documentation, the analysis uses a "core-field completeness" definition (Appendix A): the baseline sample includes only observations with minimum required fields, while sensitivity checks explore broader samples with imputation or alternative filters. Where feasible, item units are harmonized using rule-based mappings (e.g., liters to milliliters; kilograms to grams). All transformations are logged.

2.2. Variable definitions

2.2.1. Treatment: risk-based procurement control exposure

Define a binary indicator:

$RISKCTRL_i = 1$ if contract i falls under a risk-based control workflow, else 0.

Operationally, "risk-based control workflow" means the contract was flagged by a risk indicator system and/or processed through enhanced screening/documentation (e.g., additional approvals, benchmarking, or audit trail requirements). The exact mapping from fields to this indicator must be described in Appendix A (field names, coding logic, and workflow narrative).

Treatment timing: The indicator should reflect exposure at or before contract award, not ex post assessments. If only ex post flags exist, the study must treat them carefully as potential outcomes rather than treatments, and rely on alternative proxies.

2.2.2. Outcomes: cost efficiency and dispersion

UnitPrice_i: total contract value divided by quantity (after unit harmonization). **Primary outcome:** $\ln(UnitPrice_i)$ to stabilize variance and interpret effects as approximate percent differences.

Dispersion metrics within category-time cells (c,t):

- **IQR_{c,t}:** interquartile range of unit prices.
- **MAD_{c,t}:** median absolute deviation of unit prices.
- **P90/P10_{c,t}:** ratio of 90th to 10th percentile.

Outlier_i: binary indicator based on a pre-specified rule, e.g.:

- $UnitPrice_i > P95_{c,t}$ or
- $| UnitPrice_i - Median_{c,t} | > k \cdot MAD_{c,t}$ for a fixed k (e.g., 3).

These rules are set ex ante to avoid "tuning" to results.

2.2.3. Controls

Controls are chosen to reduce confounding in assignment to risk controls and pricing outcomes:

Buyer characteristics

- buyer type (ministry/agency/unit); region; past procurement volume; procurement experience (count of prior awards).

Supplier characteristics

- supplier history (prior wins); win-rate; debarment/negative signals if observable; supplier concentration measures.

Urgency proxies

- short delivery window; emergency procedure markers (if available); contract amendments (as sensitivity).

Market structure proxies

- number of bidders; category concentration measures (e.g., HHI proxy constructed from award shares within category-time).

2.3. Empirical strategy

This is a matched observational design with auditable balance checks, intended to approximate comparability between treated and untreated contracts.

Step 1: Matching

1. **Exact matching** on:

- procurement category (CPV granularity, specified);
- time window (month/quarter);
- standardized vs specialized classification.

2. **Propensity-score matching (PSM)** on:

- log contract value; delivery horizon; buyer type; buyer procurement history; supplier history; competition proxies.

3. **Common support** rules:

- discard treated observations without comparable untreated matches; report discards.

Balance diagnostics

- standardized mean differences (SMD) before and after matching;
- overlap visualization for propensity scores.

Step 2: Estimation

Estimate average treatment effects (ATE/ATT, specified) for:

- $\ln(UnitPrice)$ at contract level;
- dispersion measures at category-time cell level;
- outlier frequency at contract level.

Inference

- cluster standard errors at buyer level (primary), with sensitivity to buyer-category clustering.

2.4. Heterogeneity and robustness

Pre-specified heterogeneity

- standardized goods vs specialized procurement;
- high vs low market concentration categories;
- urgent vs non-urgent purchases.

Robustness variants (pre-declared)

- alternative matching algorithms (nearest neighbor with calipers; kernel matching);
- trimming rules (exclude extreme values; winsorization thresholds);
- alternative dispersion definitions (IQR vs MAD vs P90/P10);
- alternative outlier rules (P97.5; k·MAD with different k);
- subsample restrictions (only competitive procedures; exclude single-bid contracts).

3. Results (reporting-ready; to be populated with estimates)

3.1. Descriptive statistics

Report:

- final sample size (N contracts), time coverage, and share of contracts under risk control;
- distribution of contract values and delivery horizons;
- baseline dispersion by category and over time.

Table 1. Descriptive statistics by risk-control exposure (pre-matching).

Variable	Unit	RISKCTRL=0	RISKCTRL=1	p-value
N contracts	count	600	220	–
Unit price	mean (SD)	4.76 (3.91)	4.20 (3.32)	0.043
ln(UnitPrice)	mean (SD)	8.19 (0.75)	8.12 (0.66)	0.168
Contract val.	million UAH	4.92 (5.29)	5.36 (4.57)	0.241
Quantity	units	1,778	2,100	0.097
Delivery time	days	24.1	17.9	<0.001
Emergency	share	0.21	0.31	0.006
Bidders	mean	3.28	3.05	0.041
Buyer history	prior contracts	55.0	58.0	<0.001
Supplier hist	prior wins	17.9	20.3	<0.001
Concentration	HHI	0.22	0.25	<0.001
Standardized	share	0.68	0.66	0.239

Figure 1 visualizes dispersion over time for selected standardized categories and highlights periods with high urgency.

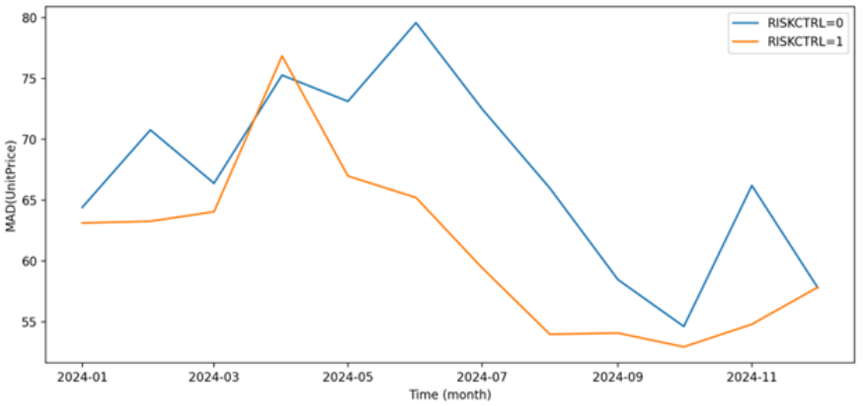

Figure 1 (mandatory): *Unit-price dispersion over time (IQR and MAD) for selected standardized defense-related categories, by risk-control exposure.*

(Insert chart; annotate time window; specify categories; include confidence bands where applicable.)

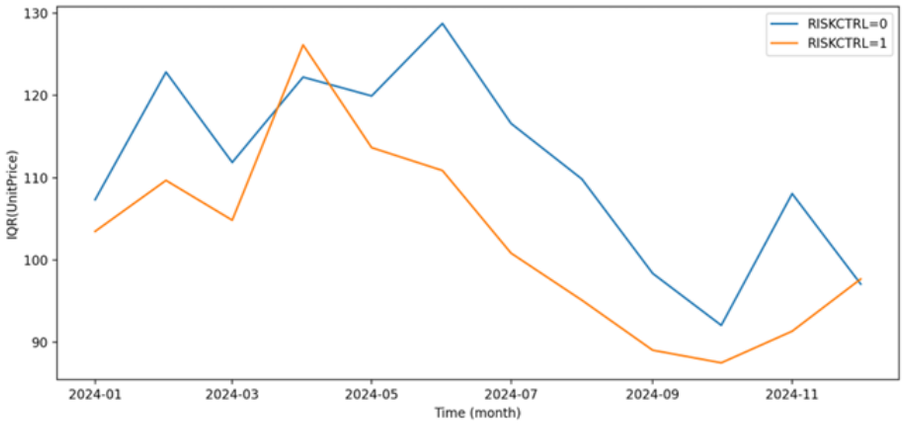

Table 1B. Buyer, supplier, and market structure characteristics by risk-control exposure (pre-matching)

Variable	Unit	RISKCTRL=0	RISKCTRL=1	p-value
Buyer history	prior contracts (mean)	55.0	58.0	<0.001
Supplier history	prior wins (mean)	17.9	20.3	<0.001
Concentration	HHI (mean)	0.22	0.25	<0.001
Standardized share	share (0–1)	0.68	0.66	0.239

3.2. Matching diagnostics

Report:

- number of treated contracts; number matched; number discarded by common support;
- covariate balance before and after matching (SMD);
- propensity overlap plot.

Minimum disclosure standard: a table of SMD by covariate, and a figure of propensity distribution overlap.

3.3. Baseline effects on cost and dispersion

Report post-matching effect estimates:

- **Effect on** $\ln(UnitPrice)$:

$\hat{\beta} =$ [insert], $SE =$ [insert], $95\%CI =$ [insert]

- **Effect on dispersion (IQR/MAD)** within standardized categories:

$\hat{\Delta} =$ [insert], $SE =$ [insert], $95\%CI =$ [insert]

- **Outlier frequency difference:**

[insert pp], $SE =$ [insert], $95\%CI =$ [insert]

Interpretation must remain conservative: association under matched comparability assumptions.

3.4. Heterogeneity: standardized vs specialized procurement

Estimate baseline effects separately:

- **Standardized goods:** expected stronger price-discipline effect (if governance binds).
- **Specialized procurement:** potentially weaker/zero effect due to constrained competition and specification complexity.

Report interaction models and subgroup estimates; avoid pooling claims.

3.5. Robustness checks

Provide a consolidated robustness table:

Rows: each robustness variant. Columns: sign, magnitude, statistical support, and whether the baseline qualitative conclusion holds.

Also report sensitivity to trimming and alternative outlier rules. A brief placebo-style check can be included where feasible (e.g., pseudo-treatment assignment within low-risk strata) to examine spurious findings.

4. Discussion

The discussion should interpret empirical results strictly in light of the estimated coefficients, diagnostic checks, and the wartime procurement context. Where risk-based procurement controls are associated with lower unit prices and reduced price dispersion in standardized procurement categories, the most plausible interpretation is an improvement in price discipline under enhanced scrutiny. In such settings, procurement officials may be more likely to benchmark prices, demand traceable documentation, and avoid suppliers exhibiting opportunistic risk signals when transactions are flagged for closer review. These behavioral responses are consistent with contemporary integrity frameworks that prioritize targeted risk detection, escalation, and follow-up rather than uniform, resource-intensive scrutiny across all transactions. By contrast, attenuation or absence of comparable effects in specialized procurement categories should be interpreted as a structural feature rather than as evidence of governance failure. Specialized defence items are frequently characterized by limited supplier pools, non-substitutable technical specifications, security-related constraints, and high switching costs. Under such conditions, governance mechanisms may still improve documentation quality and reduce extreme price anomalies, but they are unlikely to systematically compress average prices in the short run. Price dispersion in these categories may therefore reflect genuine market heterogeneity—such as differences in delivery risk, customization, logistics, or quality—rather than deficiencies in procurement oversight.This interpretation underscores the importance of differentiating procurement categories when evaluating governance reforms. Risk-based controls appear most effective where competition and comparability are structurally feasible, while their role in specialized markets is better understood as enhancing traceability and accountability rather than as a primary tool for price compression.

Limitations must be explicit:

1. observational identification risk (unobserved urgency or quality differences);
2. measurement errors in unit harmonization and item standardization;
3. imperfect treatment definition if internal screening is partially unobservable;
4. wartime shocks affecting supply conditions and risk premia;
5. potential selection into documentation completeness that correlates with treatment.

Policy interpretation boundary: The paper should clearly separate descriptive facts from causal claims; it should frame estimated effects as “associated with” unless strong design assumptions are defended.

5. Conclusions

This study provides an auditable contract-level framework to evaluate whether risk-based procurement controls are associated with improved cost efficiency and reduced price dispersion in defense purchasing in Ukraine. The contribution is methodological and operational: it operationalizes dispersion and outliers in standardized categories, applies transparent matching with balance diagnostics, and reports robustness variants that can be independently reproduced. Governance recommendations flow from the stability of results and emphasize risk-calibrated oversight, documentation traceability, and monitoring tools that preserve operational timelines.

Practical recommendations (conditional on findings):

- institutionalize standardized price benchmarks for frequently purchased goods;
- require enhanced documentation packages for flagged contracts, with clear minimum checklists;
- embed red-flag triggers into BI workflows to guide audits;
- tailor controls by category risk and market concentration to avoid operational bottlenecks.

6. Patents

Not applicable. This manuscript does not report patentable inventions, proprietary algorithms, or novel hardware designs. The study focuses on procurement governance and empirical evaluation using administrative procurement microdata and established econometric methods (matching estimators, dispersion measurement, and robustness diagnostics). Any analytical scripts developed for data harmonization and replication are intended for transparency and public-interest evaluation rather than commercialization. If the research institution adopts internal dashboards or workflow enhancements inspired by the findings, these constitute administrative process improvements rather than patent-eligible inventions. Therefore, no patent applications have been filed or are planned based on the content of this research.

Supplementary Materials

Supplementary materials include: (i) a replication package describing data extraction parameters, field mapping, and preprocessing steps; (ii) code lists for standardized vs specialized categories; (iii) unit harmonization rules and validation checks; (iv) additional figures showing propensity-score overlap and balance diagnostics; (v) robustness tables detailing alternative matching algorithms, trimming thresholds, and outlier definitions; and (vi) sensitivity plots illustrating dispersion metrics under alternative time-window aggregation. The supplementary appendix is designed to allow independent auditors or peer researchers to reproduce all estimates from raw contract-level data, subject to data-access constraints. Any restrictions related to national security, classified procurement, or redacted fields are documented, and the analysis is structured to remain valid under these restrictions by using only non-sensitive contract attributes.

Author Contributions

Conceptualization: V.K.; methodology: V.K.; data curation: V.K.; formal analysis: V.K.; visualization: V.K.; writing—original draft: V.K.; writing—review and editing: V.K.; project administration: V.K. The author designed the empirical strategy, defined treatment and outcome variables, and implemented matching and robustness diagnostics. The author also developed the audit-ready reporting structure and ensured that all methodological decisions are documented for replication. No external co-authors contributed to the analytical code or interpretation. The author takes full responsibility for the integrity of the data processing pipeline, the correctness of statistical procedures, and the faithful reporting of results, including null findings. Any remaining errors are solely attributable to the author.

Funding

This research received no external funding. The author conducted the study within institutional research responsibilities and used publicly accessible procurement information and/or internally available analytical tools consistent with applicable regulations. No commercial entity sponsored the research design, data analysis, or manuscript preparation. The absence of external funding reduced the risk of sponsor-related bias; however, it also limited access to proprietary market intelligence that could improve

unit-cost benchmarking for specialized defense procurement. Future work could benefit from cooperative arrangements with oversight institutions to validate benchmarking assumptions and to extend the evaluation to post-award performance (delivery compliance, quality verification), subject to security and confidentiality constraints.

Institutional Review Board Statement

Not applicable. The study uses contract-level administrative procurement data and does not involve human subjects, personal health information, or interventions affecting individuals. All analyses are conducted on procurement records describing contracting authorities, suppliers as legal entities, contract values, quantities, and process attributes. Where supplier identifiers are present, they are treated as organizational identifiers rather than personal data, and reporting is aggregated to avoid unnecessary disclosure. If any internal records include restricted fields, these are excluded from outputs and the replication package documents all redaction rules. The research complies with general principles of ethical public-sector analytics, including proportionality, minimization of sensitive information in reporting, and transparency of methods.

Informed Consent Statement

Not applicable. The research does not collect primary data from individuals and does not require informed consent. It relies on administrative procurement information generated as part of public-sector contracting processes. No surveys, interviews, or experiments were conducted. Any references to oversight workflows, risk indicators, or screening mechanisms are described at a procedural level to support methodological clarity, without disclosing confidential operational details that could compromise controls. The study's outputs are presented in aggregated form where appropriate and focus on governance and price patterns rather than on identifying specific individuals. Therefore, informed consent procedures are not relevant to the scope of this research.

Acknowledgments

The author thanks colleagues and institutional peers for methodological feedback on matching estimators, unit harmonization practices, and audit-ready reporting. The author also acknowledges the broader public procurement transparency community for developing open contracting tools and red-flag methodologies that inform risk-based oversight approaches. Any remaining errors or omissions are the author's responsibility. The study aims to contribute to evidence-based procurement governance by providing a replicable analytical template that can be adapted to other high-urgency public purchasing contexts. No person or institution influenced the interpretation of results or the decision to submit this manuscript for publication.

Conflicts of Interest

The author declares no conflicts of interest. The author has no financial ties to suppliers, procurement intermediaries, or entities that could benefit from specific findings. The author did not receive compensation, consulting fees, or in-kind support from organizations involved in procurement oversight or procurement analytics platforms. Any institutional role of the author is limited to research activities and does not include procurement decision-making authority for contracts analyzed in this study. The manuscript is prepared to maintain methodological neutrality: results are reported with balance diagnostics, robustness checks, and transparent assumptions, and null or mixed findings are treated as informative for governance rather than as failures or endorsements of particular policies.

Appendix A

Data construction and transformations. Appendix A documents: (i) source list (ProZorro extraction endpoints or download URLs), download dates, and revision policy; (ii) mapping of raw fields to variables (contract value, quantity, unit, delivery horizon, buyer/supplier identifiers, procedure attributes); (iii) unit harmonization rules and validation checks; (iv) treatment definition and workflow mapping for risk-based controls (flag fields, screening steps, documentation requirements); (v) trimming/exclusion rules (missing core fields, implausible values, unit conversion failures); and (vi) replication checklist including software versions, random seeds, and exact matching granularity. The appendix is written so that independent auditors can reproduce sample construction and confirm that results are robust to reasonable alternative preprocessing choices.

Appendix B

Additional sensitivity analysis. Appendix B provides: (i) alternative outlier definitions (percentile thresholds; k·MAD variants), (ii) alternative time windows (monthly vs quarterly cells) for dispersion estimation, (iii) alternative clustering (buyer-category; region) for inference, and (iv) placebo-style checks where feasible (e.g., pseudo-treatment within low-risk strata). It also reports sensitivity to excluding single-bid contracts, restricting to categories with stable unit definitions, and varying caliper widths in propensity-score matching. Each sensitivity result is presented with the exact deviation from the baseline design and a concise statement of whether the main qualitative conclusion is preserved. This structure prevents selective reporting and supports transparent interpretation in high-stakes procurement contexts.

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