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# Where does corruption risk sit? Core–periphery structure and clustering of single bidding in Ecuador's subnational public procurement networks

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## Abstract

Single bidding, the award of a competitive tender that attracted only one offer, has become a widely used proxy for corruption risk in public procurement. Recent work on European Union markets showed that this risk concentrates in the core of some national procurement networks and in the periphery of others, and that it clusters in groups of buyers and suppliers. This study tests whether these regularities hold at the subnational scale of a Latin American country. Using Open Contracting Data Standard records from Ecuador's National Public Procurement Service, it analyses 46,279 contracts awarded through competitive procedures between 2015 and 2021, linking 2,838 public buyers and 15,856 suppliers. Buyer–supplier networks were built nationally by year and for 21 provinces. A strength-based k-shell decomposition identified market cores, and edge communities were detected on line graphs. Both measures were

compared with null models that shuffle single-bid labels within product categories. Single bidding affected 30.2% of procedures and ranged from 20% to 44% across provinces. It was significantly clustered in every national network and in 17 of 21 provinces, at 1.2 to 2.0 times the null expectation. Unlike the cross-country European pattern, the size of the market core was unrelated to provincial risk ($r = -0.19$). Provinces with more single bidding were instead those where single bidding concentrated in the core ($r = 0.53$, $p = 0.014$). The results suggest that subnational procurement markets organise risk in different ways and that audits could prioritise central actors where this concentration is detected.

**Keywords:** Corruption risk; Public procurement; Single bidding; Bipartite networks; Core–periphery structure; Community detection; Open contracting; Ecuador

## Introduction

Public procurement is the point at which state budgets meet private firms, and for that reason it is one of the main channels through which public resources can be diverted. Measuring corruption in this setting has always been difficult. Perception surveys capture opinions rather than behaviour and are often weakly related to measured irregularities (Olken 2009). Conviction data reflect the capacity and independence of courts as much as the incidence of corruption. Over the last decade, a different strategy has gained ground: scoring individual contracts with objective "red flags" derived from administrative records, the most robust of which is whether a competitive tender received a single bid (Fazekas et al. 2016; Fazekas and Kocsis 2020). Single bidding does not prove wrongdoing, but at aggregate levels it tracks survey-based governance indicators and responds to institutional factors such as bureaucratic meritocracy (Charron et al. 2017) and political tenure (Coviello and Gagliarducci 2017).

Contract-level indicators also make it possible to ask where in a market corruption risk is located. Procurement markets can be represented as bipartite networks in which public buyers

are linked to the firms that win their contracts. Network studies of these markets have documented how favouritism reshapes the structure of contracting relationships (Fazekas and Tóth 2016), how high-risk buyers rewire their supplier ties after a change of government (Fazekas and Wachs 2020) and how local social capital relates to corruption risk in towns (Wachs et al. 2019). Wachs et al. (2021) extended this line of work to more than four million contracts from 26 European Union member states. They reported three regularities. First, countries whose markets were more centralised, measured by the share of contracts awarded between core buyers and core suppliers, had higher single-bidding rates. Second, single bidding was significantly clustered within communities of contracting relationships in every country. Third, the location of risk varied: in some countries single bidding was over-represented among core actors, while in others it was more common in the periphery.

These findings come from cross-national comparisons of high-income democracies with mature procurement regulation. Whether they hold within a single middle-income country, where markets are smaller, more local and governed by the same national rules, is an open question. The subnational scale is relevant for two reasons. Corruption risks are known to vary considerably across regions of the same country (Charron et al. 2017), and anti-corruption agencies usually allocate audits within national borders rather than across them. Wachs et al. (2021) themselves identified regional disaggregation as a natural extension of their framework.

Latin America offers a strong case for such an extension. Large corruption schemes in the region have involved networks of politicians, firms and intermediaries (Ribeiro et al. 2018; Luna-Pla and Nicolás-Carlock 2020), and network methods have been applied to co-bidding in Brazilian municipalities (Lyra et al. 2021) and to local construction contracts in Guatemala (Waxenecker and Prell 2024). A systematic review of data-driven detection methods concluded that network analysis is particularly useful when labelled cases of fraud are scarce, which is the usual situation (Lyra et al. 2022). Ecuador adds a distinctive feature to this picture. Its

National Public Procurement Service (Servicio Nacional de Contratación Pública, SERCOP) runs a centralised electronic platform and publishes procurement records in the Open Contracting Data Standard (OCDS). Recent studies have used these data to build graph databases of electronic reverse auctions (Fortuny et al. 2023) and to predict early corruption risk with machine learning (Fuertes et al. 2025). To the authors' knowledge, no study has yet described the network distribution of corruption risk across Ecuadorian provinces.

This article replicates and adapts the framework of Wachs et al. (2021) to Ecuador and addresses three questions. (1) Are Ecuadorian procurement markets centralised, and is single bidding over- or under-represented in their cores? (2) Is single bidding clustered within communities of buyers and suppliers beyond what product-market composition would produce? (3) Do these structural features vary across provinces, and are they associated with provincial levels of risk? The analysis covers 46,279 contracts awarded through competitive procedures between 2015 and 2021. The main contribution is empirical, but the study also makes a methodological point: core definitions calibrated on large national markets can leave sparse regional networks with almost no core, so a quantile-based rule and an explicit sensitivity analysis are proposed.

The remainder of the article is organised as follows. The next section describes the data and the construction of the single-bidding indicator. The methods section presents the network measures and null models. The results section reports national and provincial patterns, and the discussion relates them to the European evidence and to anti-corruption practice.

# Data

### *Source and coverage*

The data come from SERCOP's bulk OCDS publication as distributed by the Open Contracting Partnership's data registry (Open Contracting Partnership 2025). The files were retrieved on 2

October 2025 and contain one compiled release per contracting process, with information on the tender, the buyer, the awards, the suppliers and, where available, the signed contracts. The study period is 2015–2021, defined by the year in which each call for tenders was opened. Each record includes the buyer's and suppliers' identifiers, which combine the Ecuadorian taxpayer number (Registro Único de Contribuyentes, RUC) with an internal SERCOP code, as well as party addresses at the province and canton level, the procurement method, the main procurement category, Central Product Classification (CPC) codes for items, tender and award values, and the number of tenderers.

Two features of the publication shaped the analytical sample. First, most records (86% of award–supplier rows) correspond to purchases through the electronic catalogue, in which public entities buy from framework agreements without a competitive call. These purchases carry neither a call date nor a meaningful number of bidders and were excluded. Second, the number of competitive procedures varies across years of the study period. Annual counts range from 7,200 to 10,915 procedures in 2015, 2016, 2019 and 2020 and are lower in 2017 (2,788) and 2021 (5,451). The publication contains only 465 competitive procedures for 2018, a figure that is difficult to reconcile with the activity of the national system; that year is therefore reported but not interpreted.

### *Analytical sample*

The sample includes the procedures in which suppliers compete openly or by invitation: electronic reverse auction (subasta inversa electrónica), minor-value procedures (menor cuantía), quotation (cotización), open tender (licitación), insurance tender, short-list consultancy, public competition and the selection procedure for social communication services. Direct awards, special regimes, contracts between public entities and catalogue purchases were excluded because competition is absent or limited by design. Within the competitive

procedures of 2015–2021, the number of tenderers was recorded for 99.9% of rows, the supplier for 99.5%, the buyer's province for 94.6% and the CPC code for 99.7%. The reported number of tenderers matched the length of the tenderer list in every record.

Supplier identifiers were harmonised by RUC; only 0.9% of suppliers appeared under more than one internal code. Each observation is an award to a supplier within a procedure, referred to as a contract. The final 2015–2021 sample contains 46,279 contracts from 46,230 procedures, 2,838 buyers and 15,856 suppliers. Table 1 summarises the sample by procedure type.

**Table 1 Competitive procedures by type, 2015–2021**

| Procedure type | Procedures | Share (%) | Single bid (%) | Median bidders |
|---|---|---|---|---|
| Electronic reverse auction | 31,370 | 67.9 | 23.3 | 3 |
| Minor-value procedure | 9,559 | 20.7 | 52.3 | 1 |
| Quotation | 2,596 | 5.6 | 24.5 | 3 |
| Insurance tender | 875 | 1.9 | 23.2 | 2 |
| Short list (consultancy) | 763 | 1.7 | 55.8 | 1 |
| Open tender | 531 | 1.1 | 17.5 | 4 |
| Social communication (selection) | 495 | 1.1 | 64.0 | 1 |
| Public competition | 41 | 0.1 | 9.8 | 3 |
| **Total** | **46,230** | **100.0** | **30.2** | **3** |

Single bid is the share of procedures that received exactly one offer; median bidders is the median number of offers per procedure.

### *Single bidding as a risk indicator*

A contract is flagged when the procedure received exactly one offer. The indicator follows the European literature (Fazekas and Kocsis 2020; Wachs et al. 2021) and is used here as a proxy for restricted competition, not as evidence of corruption in any individual case. A single bid can result from a niche market, a poorly designed call or a lack of local suppliers. For this reason, all comparisons are made against null models that preserve the product composition of each market.

Two checks were performed to see whether single bidding behaves as a risk marker in Ecuadorian data. For the 14,782 procedures with a usable reference budget, the ratio of the awarded value to the reference budget was regressed on the single-bid flag with fixed effects for procedure type, year and procurement category and with standard errors clustered by buyer. Single-bid awards were 0.65 percentage points closer to the reference budget (SE = 0.25, $p = 0.010$), which is consistent with weaker price competition. The second check concerned the length of the bidding period, a common red flag in Europe. Here the relationship ran in the opposite direction: longer periods were associated with higher odds of single bidding (logit coefficient 0.085 per day, $p < 0.001$, N = 14,042), and the median period was 11 days for both groups. Because minimum periods are set by procedure type in Ecuadorian regulation, short advertising periods may not carry the same signal as in Europe. The price check supports the use of single bidding, but the evidence of validity remains partial.

# Methods

### *Network construction*

For each unit of analysis, a weighted bipartite network was built in which nodes are buyers and suppliers and an edge links a buyer to a supplier when at least one contract was awarded between them. The edge weight is the number of contracts. Two sets of networks were analysed: national networks for each year from 2015 to 2021, and provincial networks that pool the seven years for the 21 of Ecuador's 24 provinces with at least 400 contracts. Provinces are assigned by the buyer's registered address. Galápagos, Santa Elena and Santo Domingo de los Tsáchilas fell below the threshold and were excluded; the 21 provincial networks cover 43,355 contracts, 93.7% of the sample. Pooling years gives provincial markets enough contracts for stable estimates, at the cost of mixing relationships formed at different times.

### *Core–periphery structure*

Market cores were identified with a strength-based k-shell decomposition, following the adaptation of Wachs et al. (2021) and the weighted k-shell method of Garas et al. (2012). The classic k-core of a graph is the maximal subgraph in which every node has degree at least k (Seidman 1983; Batagelj and Zaveršnik 2011), and k-shell indices are informative of node centrality in complex networks (Kitsak et al. 2010). In the weighted version, nodes are removed iteratively in increasing order of their strength, the number of contracts with nodes that remain in the network, and each node receives the largest strength threshold it survives as its core number.

Wachs et al. (2021) classified buyers as core members when their core number exceeded the average buyer strength and suppliers when it exceeded twice the average supplier strength. In the Ecuadorian provincial networks this rule left the core empty or with one or two suppliers in most provinces, because supplier strengths are low and homogeneous. The main analysis therefore defines the core as the buyers and suppliers in the top decile of the core-number distribution of their own side. The original rule is reported for the national networks, and the sensitivity of provincial results to thresholds between the top 20% and the top 5% is shown in Fig. 6. Market centralisation is measured as the core share, the proportion of contracts awarded between a core buyer and a core supplier (Borgatti and Everett 2000; Csermely et al. 2013).

To assess whether risk concentrates in the core, the observed single-bid rate among core contracts is compared with a null model in which single-bid labels are randomly permuted among contracts with the same two-digit CPC code, keeping network structure and core membership fixed. The ratio of the observed rate to the mean of 1,000 permutations is reported, together with a one-sided permutation p value. Values above one mean that single bidding is over-represented in the core; values below one mean that it is more common in the periphery.

***Clustering of single bidding***

Since corruption risk is an attribute of contracting relationships, communities were detected among edges rather than nodes. Each bipartite network was transformed into its line graph, in which edges become nodes connected when they share a buyer or a supplier (Evans and Lambiotte 2009; Ahn et al. 2010), and the Louvain algorithm (Blondel et al. 2008) was applied to maximise modularity (Newman 2006; Fortunato 2010). Every contract inherits the community of its buyer–supplier edge. Because Louvain partitions vary between runs, the algorithm was run ten times with fixed random seeds for each network; the median clustering ratio and median p value across runs are reported, and the range across runs is given in Additional file 1.

Clustering of single bidding is measured, as in Wachs et al. (2021), by the weighted coefficient of variation of single-bid rates across communities:

$$\sigma_{SB}^{W} = \sqrt{\frac{\sum_{c \in C} |c| \, (sb_c - \mu_{SB}^{W})^2}{\frac{|C|-1}{|C|} \sum_{c \in C} |c|}}, \qquad \mu_{SB}^{W} = \frac{\sum_{c \in C} |c| \, sb_c}{\sum_{c \in C} |c|}$$

where C is the set of communities, |c| the number of contracts in community c and sb_c its single-bid rate. The clustering ratio divides the observed coefficient σ/μ by its mean over 1,000 permutations of single-bid labels within two-digit CPC codes. A ratio above one indicates that risky contracts are more concentrated in some communities than product composition alone would produce.

***Robustness checks***

Procedure type is a strong determinant of single bidding in Ecuador (Table 1). Minor-value procedures, short lists and social communication selections had single-bid rates above 50%, partly because of their invitation rules. A null model that permutes labels only within the same CPC code may therefore attribute to network position what is a consequence of procedure mix.

Both measures were recomputed with a stricter null model that permutes labels within CPC-by-procedure strata. The core analysis was also repeated for electronic reverse auctions alone, which account for 68% of procedures and have the most homogeneous rules. Cross-provincial associations are reported with Pearson and Spearman coefficients; with 21 units, they should be read as descriptive. All analyses were performed in Python with igraph; random seeds are fixed, and the code reproduces every table and figure (see Availability of data and materials).

### *Use of generative AI*

The authors used Claude (Anthropic), a large language model, to support the writing of data processing and analysis code and the drafting of the manuscript. The authors designed the study, verified the code, results and references, revised the text and take full responsibility for the content of the article.

## Results

### *Levels of single bidding*

Single bidding affected 30.2% of competitive procedures in 2015–2021. The share fell from 38.3% in 2015 to between 25.7% and 28.0% in 2019–2021 (Fig. 1a). Differences by procedure type were large (Fig. 1b): single bidding ranged from 17.5% in open tenders and 23.3% in reverse auctions to 52.3% in minor-value procedures and 64.0% in social communication selections. Services had a higher rate (41.3%) than goods (24.8%) and works (24.9%). Overall, 56.3% of contracts went to suppliers registered in the same province as the buyer, which reflects the local character of many of these markets.

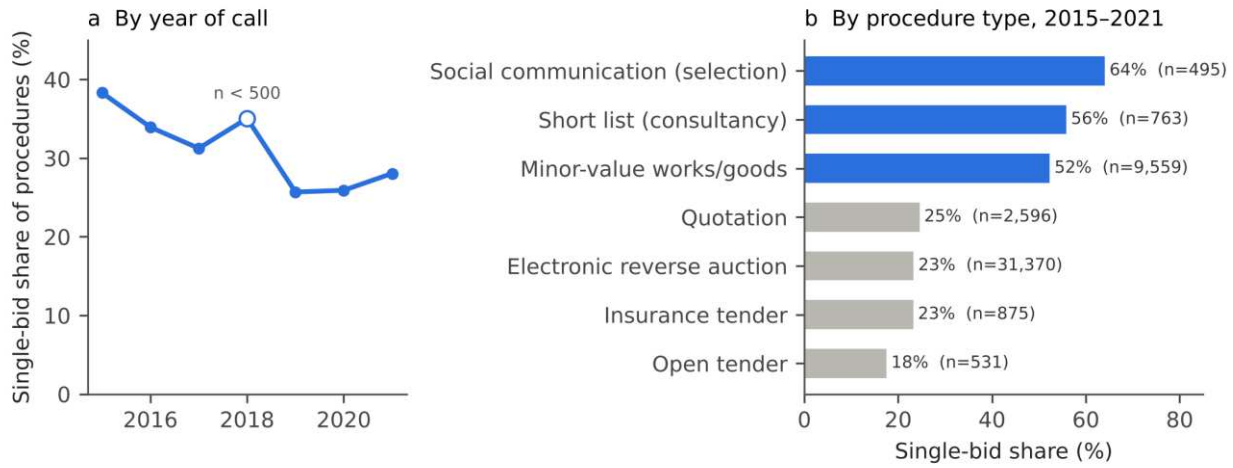



**Fig. 1 Single bidding in Ecuadorian competitive procurement.** a Share of procedures with a single bid by year of call, 2015–2021. The open marker identifies 2018, when the bulk publication contains fewer than 500 procedures. b Share by procedure type for procedures with at least 100 cases; blue bars mark procedures above 50%. Source: SERCOP OCDS publication; authors' calculations.

Provinces differed substantially (Fig. 2). Four coastal provinces, Los Ríos (44.3%), Manabí (40.7%), Esmeraldas (39.4%) and El Oro (39.0%), had the highest rates, followed by the Amazonian provinces of Morona Santiago and Napo (37.0% and 36.9%). The lowest rates were found in the central highlands: Cotopaxi (20.2%), Tungurahua (21.0%) and Cañar (22.0%). The two largest markets, Pichincha and Guayas, were close to the average.

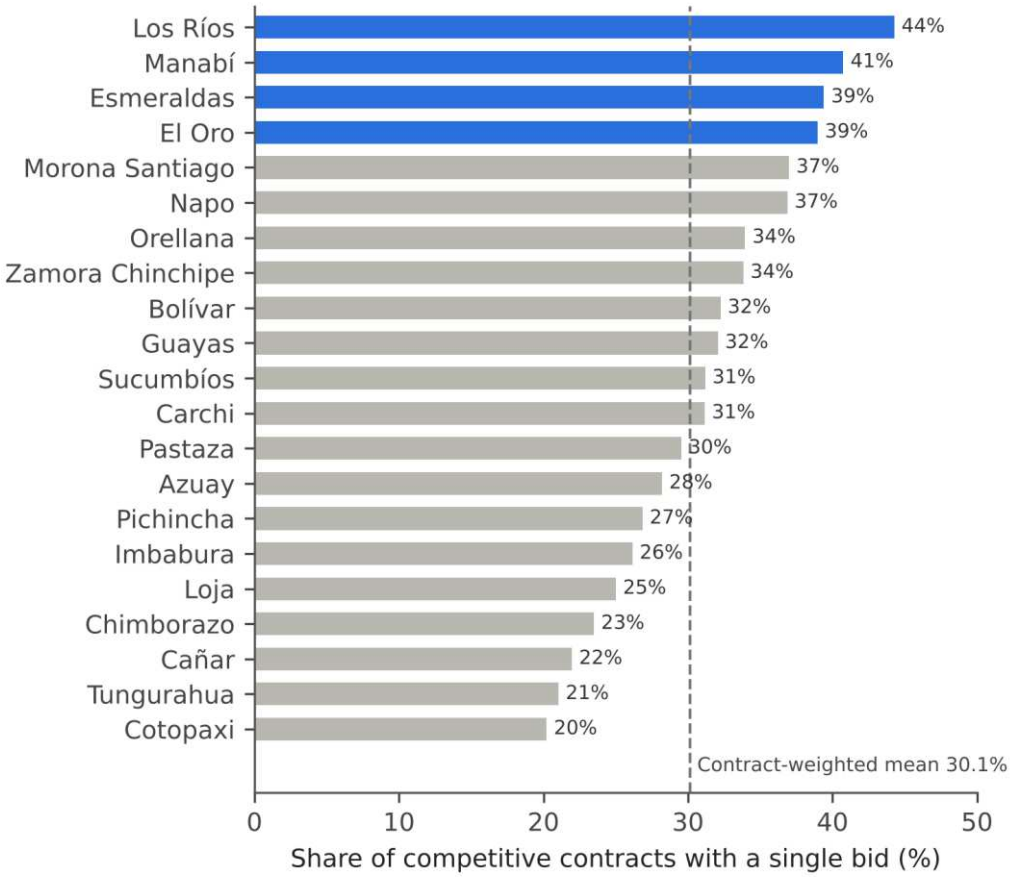



**Fig. 2 Single-bid share of competitive contracts by province of the buyer, 2015–2021.** Provinces with at least 400 contracts. The dashed line marks the contract-weighted mean of the 21 provinces; blue bars mark rates above 38.5%.

### *National networks*

The national networks are sparse and modular. Modularity of the edge partitions ranged from 0.86 to 0.92 between 2015 and 2021. Single bidding was clustered in every year (Table 2). With the CPC null model, the clustering ratio ranged from 1.22 to 1.39 ($p < 0.001$ in all years); with the stricter CPC-by-procedure null, it ranged from 1.15 to 1.25 ($p < 0.001$). These ratios are lower than those reported for European countries, which ranged from about 2 to 8 (Wachs et al. 2021).

The core results depended on how the core was defined. Under the original rule, the core was small, holding between 4.9% and 13.4% of contracts, and single bidding was over-represented

in it in every year, significantly so in 2016, 2017, 2019 and 2020 (ratios of 1.13 to 1.55, $p \leq 0.002$). Under the top-decile rule, which places roughly a quarter to a third of contracts in the core, the ratio stayed between 0.95 and 1.04 and was never significantly above one. At the national level, risk is therefore concentrated among the very largest contracting pairs but not across the wider set of central actors. As the provincial results show, this near-neutral national figure combines provinces where the core is riskier than expected with provinces where it is safer.

**Table 2 National buyer–supplier networks by year, 2015–2021**

| Year | Contracts | Buyers | Suppliers | Single bid (%) | Modularity | Clustering ratio, CPC null (p) | Clustering ratio, CPC×procedure null (p) | Core share, original rule (%) | Core ratio, original rule (p) | Core ratio, top decile (p) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2015 | 7,209 | 1,477 | 4,366 | 38.3 | 0.89 | 1.34 (<0.001) | 1.24 (<0.001) | 6.3 | 1.07 (0.105) | 0.96 (0.973) |
| 2016 | 10,312 | 1,693 | 4,824 | 33.9 | 0.86 | 1.39 (<0.001) | 1.25 (<0.001) | 13.4 | 1.13 (<0.001) | 0.98 (0.916) |
| 2017 | 2,790 | 951 | 1,994 | 31.2 | 0.92 | 1.22 (<0.001) | 1.17 (<0.001) | 4.9 | 1.55 (<0.001) | 1.04 (0.164) |
| 2018[a] | 467 | 281 | 417 | 34.9 | 0.96 | 1.08 (<0.001) | 1.05 (0.003) | 0.9 | 1.31 (0.315) | 1.00 (1.000) |
| 2019 | 10,917 | 1,791 | 5,706 | 25.7 | 0.88 | 1.39 (<0.001) | 1.22 (<0.001) | 9.7 | 1.14 (0.002) | 0.95 (0.964) |
| 2020 | 9,127 | 1,536 | 4,661 | 25.9 | 0.86 | 1.30 (<0.001) | 1.15 (<0.001) | 13.3 | 1.13 (<0.001) | 1.00 (0.573) |
| 2021 | 5,457 | 1,269 | 3,217 | 28.0 | 0.87 | 1.25 (<0.001) | 1.16 (<0.001) | 7.2 | 1.08 (0.150) | 0.96 (0.892) |

Ratios divide observed values by the mean of 1,000 permutations of single-bid labels; p values are one-sided tests of values above the null. The original rule follows Wachs et al. (2021); the top-decile rule is the one used for provinces. [a] 2018 is based on fewer than 500 procedures and is not interpreted.

### *Provincial networks*

Table 3 reports the provincial results. Provincial markets ranged from 462 contracts in Bolívar to 12,094 in Pichincha, with densities between 0.004 and 0.028 and modularity between 0.74 and 0.91. Single bidding was significantly clustered ($p < 0.05$) in 17 of the 21 provinces under the CPC null and in 16 under the stricter null. The strongest clustering was found in El Oro (2.00 times the null), Guayas (1.95) and Pichincha (1.70). Only Bolívar showed no clustering at all (0.96).

**Table 3 Provincial buyer–supplier networks, 2015–2021**

| Province | Contracts | Buyers | Suppliers | Density | Single bid (%) | Core share (%) | Core ratio (p) | Modularity | Clustering ratio (p) |
|---|---|---|---|---|---|---|---|---|---|
| Los Ríos | 1,231 | 104 | 756 | 0.013 | 44.3 | 21.1 | 1.10 (0.073) | 0.87 | 1.31 (<0.001) |
| Manabí | 2,781 | 211 | 1,624 | 0.007 | 40.7 | 20.8 | 1.20 (<0.001) | 0.84 | 1.46 (<0.001) |
| Esmeraldas | 1,033 | 100 | 650 | 0.014 | 39.4 | 20.2 | 1.10 (0.084) | 0.88 | 1.40 (<0.001) |
| El Oro | 1,673 | 129 | 967 | 0.011 | 39.0 | 23.2 | 1.33 (<0.001) | 0.91 | 2.00 (<0.001) |
| Morona Santiago | 903 | 73 | 546 | 0.018 | 37.0 | 27.9 | 1.02 (0.379) | 0.86 | 1.49 (<0.001) |
| Napo | 678 | 54 | 437 | 0.023 | 36.9 | 35.1 | 1.16 (0.003) | 0.78 | 1.26 (0.006) |
| Orellana | 810 | 59 | 517 | 0.020 | 34.0 | 32.5 | 1.05 (0.235) | 0.75 | 1.18 (0.051) |
| Zamora Chinchipe | 689 | 62 | 402 | 0.022 | 33.8 | 20.0 | 0.86 (0.943) | 0.84 | 1.37 (<0.001) |
| Bolívar | 462 | 56 | 328 | 0.022 | 32.3 | 19.7 | 1.23 (0.023) | 0.85 | 0.96 (0.688) |
| Guayas | 7,111 | 309 | 3,520 | 0.005 | 32.1 | 28.1 | 1.06 (0.010) | 0.84 | 1.95 (<0.001) |
| Sucumbíos | 1,116 | 73 | 676 | 0.018 | 31.2 | 20.9 | 1.01 (0.493) | 0.76 | 1.36 (0.002) |
| Carchi | 626 | 64 | 361 | 0.021 | 31.2 | 28.8 | 1.19 (0.012) | 0.74 | 1.42 (<0.001) |
| Pastaza | 579 | 47 | 359 | 0.028 | 29.5 | 22.1 | 1.10 (0.178) | 0.82 | 1.60 (<0.001) |
| Azuay | 3,167 | 195 | 1,600 | 0.007 | 28.2 | 35.8 | 1.00 (0.512) | 0.81 | 1.46 (<0.001) |
| Pichincha | 12,094 | 480 | 4,368 | 0.004 | 26.8 | 33.8 | 0.97 (0.959) | 0.86 | 1.70 (<0.001) |
| Imbabura | 1,495 | 105 | 890 | 0.013 | 26.2 | 23.8 | 0.91 (0.904) | 0.87 | 1.12 (0.072) |
| Loja | 1,748 | 172 | 965 | 0.008 | 25.0 | 30.5 | 0.88 (0.988) | 0.81 | 1.33 (<0.001) |
| Chimborazo | 1,720 | 107 | 953 | 0.013 | 23.5 | 31.6 | 0.97 (0.712) | 0.88 | 1.24 (0.015) |
| Cañar | 897 | 70 | 523 | 0.019 | 22.0 | 21.7 | 0.93 (0.771) | 0.83 | 1.13 (0.071) |
| Tungurahua | 1,355 | 91 | 829 | 0.015 | 21.0 | 21.7 | 1.09 (0.173) | 0.78 | 1.29 (0.003) |
| Cotopaxi | 1,187 | 79 | 698 | 0.017 | 20.2 | 24.9 | 1.01 (0.506) | 0.83 | 1.30 (0.004) |

Provinces are ordered by single-bid share. Core: top decile of weighted core numbers for buyers and suppliers. Core ratio and clustering ratio are observed values divided by the mean of 1,000 permutations of single-bid labels within two-digit CPC codes; p values are one-sided tests of values above the null.

The location of risk was heterogeneous. Single bidding was significantly over-represented in the core of six provinces: El Oro (1.33), Bolívar (1.23), Manabí (1.20), Carchi (1.19), Napo (1.16) and Guayas (1.06). It was more frequent in the periphery than expected in Loja (0.88; one-sided $p = 0.012$ for under-representation) and in Pichincha (0.97; $p = 0.041$). The remaining provinces did not depart from the null model. Fig. 3 illustrates the core of El Oro: 18 buyers and 128 suppliers connected by 198 contracting pairs and 388 contracts. Just over half of these pairs (52%), which together account for 59% of core contracts, had single-bid rates above the provincial mean of 39%, and the single-bid rate among core contracts reached 51%.

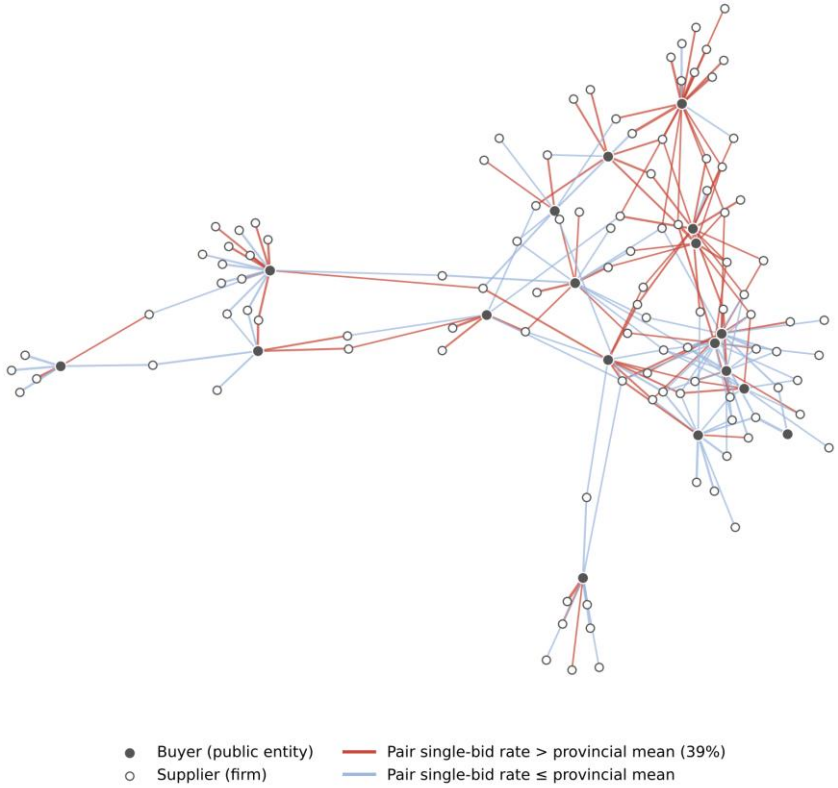



**Fig. 3 Core of the El Oro procurement market, 2015–2021.** Buyers (filled) and suppliers (open) in the top decile of weighted core numbers. Edges link pairs with at least one contract; width increases with the number of contracts. Red edges mark pairs whose single-bid rate exceeds the provincial mean (39%). Layout: Fruchterman–Reingold weighted by contract counts.

### *Centralisation, concentration of risk and provincial risk levels*

The European pattern linking centralisation and risk did not appear across Ecuadorian provinces. The core share was unrelated to the single-bid rate (Pearson $r = -0.19$, $p = 0.40$; Spearman $\rho = -0.29$, $p = 0.20$; Fig. 4a), whereas Wachs et al. (2021) reported a correlation of 0.61 across EU countries. What did predict provincial risk was where the risk sat. Provinces in which single bidding was over-represented in the core had higher single-bid rates overall ($r = 0.53$, $p = 0.014$; $\rho = 0.55$, $p = 0.009$; Fig. 4b). The clustering ratio, modularity, network density and the share of local suppliers were not significantly associated with provincial risk ($|r| \leq 0.27$, $p \geq 0.24$).

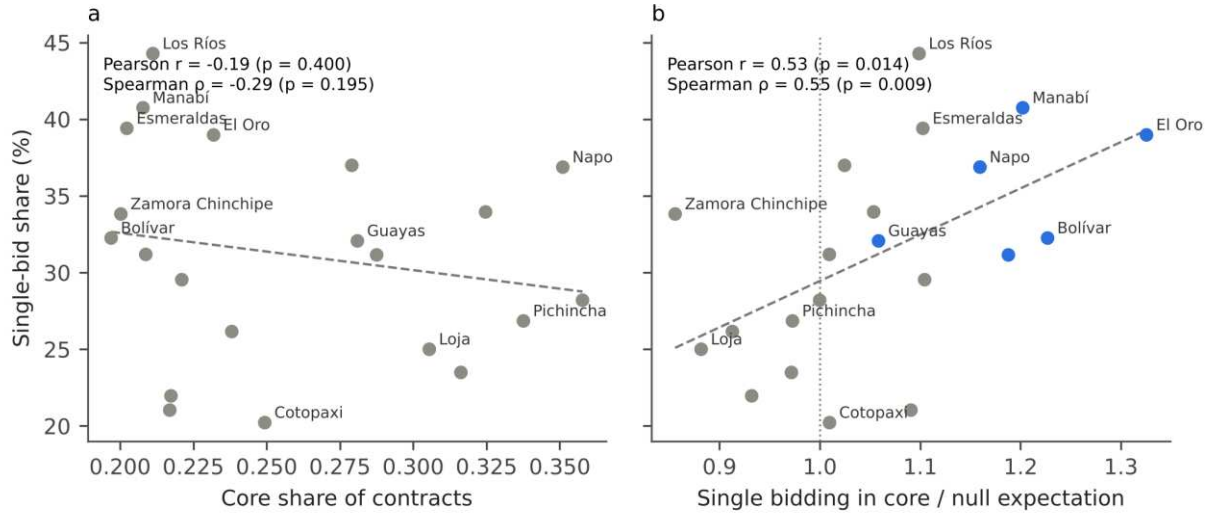



**Fig. 4 Market centralisation, concentration of risk in the core and provincial single-bid rates.** a Core share of contracts against the single-bid share. b Ratio of observed to expected single bidding among core contracts against the single-bid share. Each point is a province (2015–2021); dashed lines are least-squares fits. Blue points in b mark significant core over-representation ($p < 0.05$).

Fig. 5 combines the two dimensions of the risk distribution, in the spirit of the comparative map proposed by Wachs et al. (2021). El Oro stands out with risk that is both concentrated in the core and strongly clustered. Manabí, Carchi, Napo and Guayas share this combination to a lesser degree. Pichincha and Azuay have clustered risk without core concentration. Bolívar shows the reverse profile, with core concentration and no clustering. Loja, Zamora Chinchipe and Imbabura have risk located mainly outside their cores.

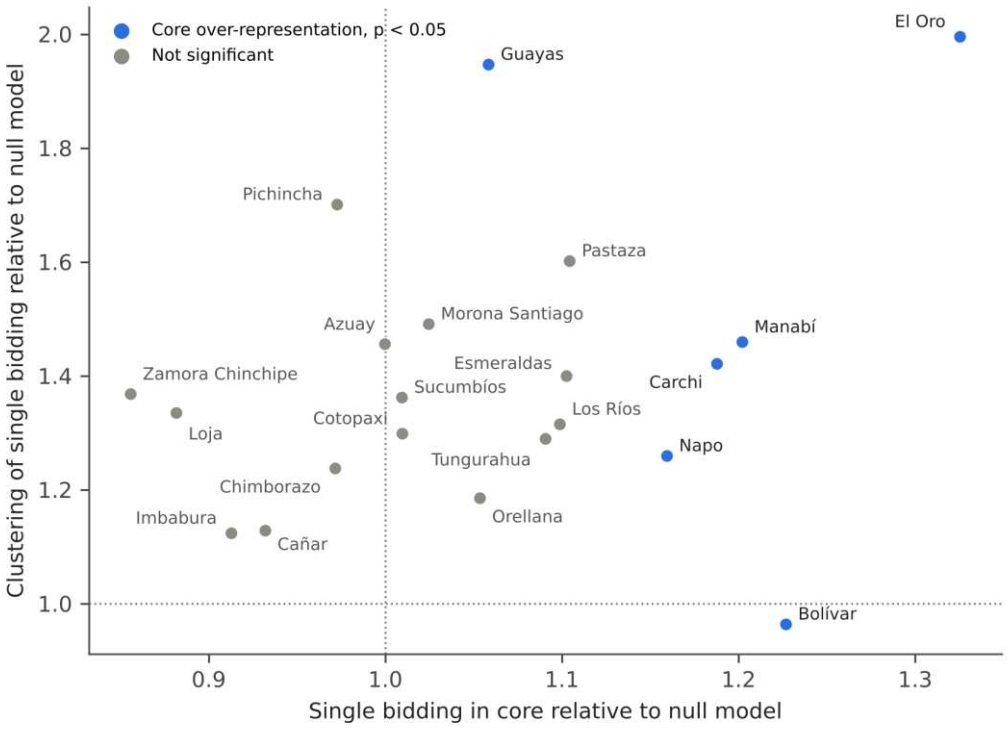



**Fig. 5 Core concentration against clustering of single bidding, by province, 2015–2021.** Both axes are ratios of observed values to the mean of 1,000 permutations of single-bid labels within two-digit CPC codes; dotted lines mark the null expectation. Blue points mark significant core over-representation ($p < 0.05$).

### *Robustness*

The provincial core results are partly sensitive to the threshold used to define the core (Fig. 6). The number of provinces with significant over-representation ranges from three to six depending on the threshold. Four provinces keep ratios above one under every definition: El Oro (1.16–1.39), Napo (1.13–1.41), Bolívar (1.12–1.33) and Manabí (1.08–1.21). Imbabura stays below one under all of them (0.90–0.93). Other provinces, such as Cotopaxi, Guayas and Pichincha, move from below to above one as the core is narrowed. Read together, the sensitivity analysis suggests that in these markets single bidding is concentrated among the most central pairs rather than across the broader core.

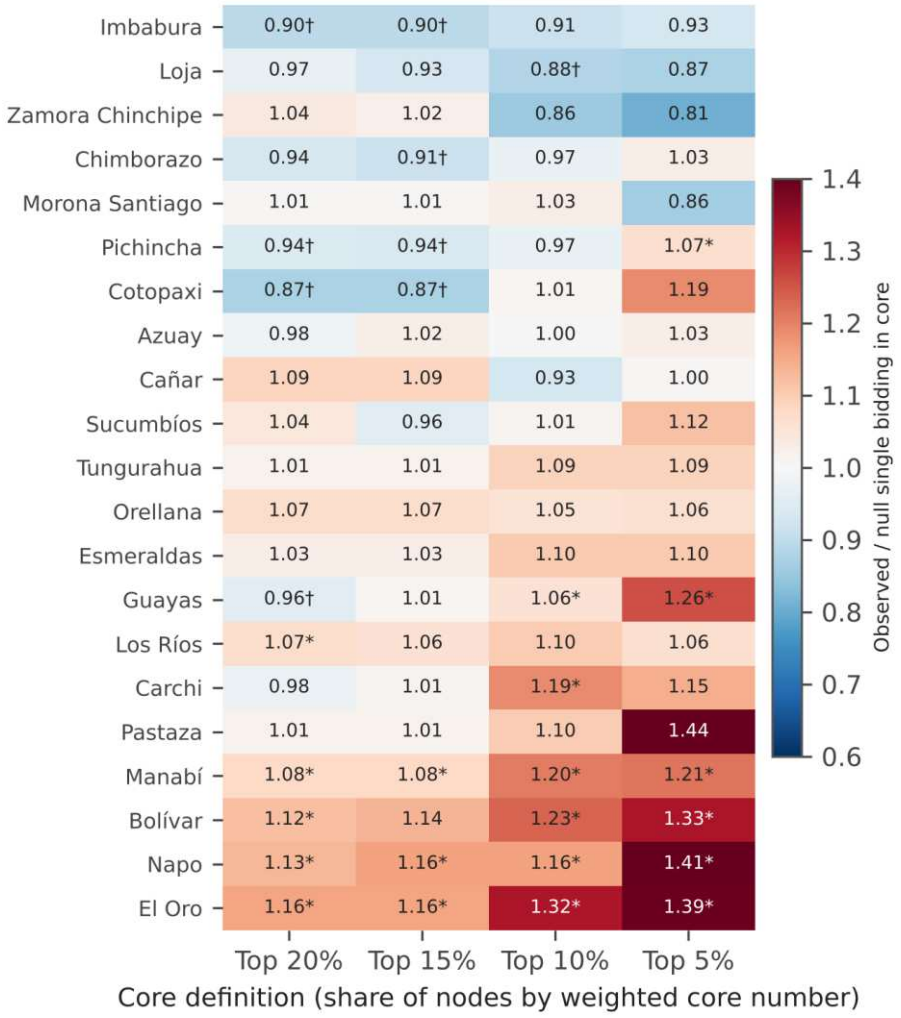



**Fig. 6 Sensitivity of core over-representation of single bidding to the core definition.** Cells show the ratio of observed to expected single bidding among core contracts when the core includes the top 20%, 15%, 10% or 5% of buyers and suppliers by weighted core number. * over-representation $p < 0.05$; † under-representation ($p > 0.95$ in the one-sided test). Provinces are ordered by their mean ratio.

The stricter null model, which permutes labels within CPC-by-procedure strata, increased the number of provinces with significant core over-representation from six to nine; Esmeraldas, Los Ríos and Pichincha were added. Clustering remained significant in 16 provinces. Province-level results for both null models, the reverse-auction subsample and the variation across Louvain runs are reported in Additional file 1. Restricting the analysis to electronic reverse auctions confirmed core over-representation in El Oro (1.43), Guayas (1.32) and Manabí (1.17), while Napo and Bolívar fell just short of significance ($p = 0.06$). In this subsample

Azuay, Los Ríos, Pastaza, Pichincha and Tungurahua also showed significant over-representation, and Loja and Zamora Chinchipe remained below one. The main contrast between provinces whose central actors concentrate single bidding and provinces where it lies in the periphery is therefore not an artefact of procedure mix.

## Discussion

This study adapted a network framework developed for European procurement markets to the provinces of a Latin American country. Two of the European regularities held in Ecuador, and one did not.

Single bidding was clustered. In every national network and in most provinces, risky contracts were concentrated in particular communities of buyers and suppliers, beyond what the product composition of each market would produce. The magnitude of clustering, about 1.2 to 2.0 times the null where it was significant, was smaller than in the European markets studied by Wachs et al. (2021). Part of this difference may be methodological, since Ecuadorian provincial markets are much smaller and the stricter null models used here absorb procedure-specific effects. Clustering nonetheless has a practical implication: when an irregular contract is found, the buyers and suppliers in the same community are reasonable candidates for follow-up review.

The location of risk also varied. As in Europe, some markets had single bidding over-represented in the core and others in the periphery. The novelty is that this variation appears within a single country, under the same procurement law and the same electronic platform. Differences in regulation therefore cannot explain it. More plausible candidates are local factors such as the size and diversity of supplier markets, the capacity of buying entities and local political competition, which previous research has linked to corruption risk (Charron et al. 2017; Coviello and Gagliarducci 2017; Wachs et al. 2019).

The regularity that did not hold is the link between centralisation and risk. In European countries, larger cores went together with higher single-bidding rates. Across Ecuadorian provinces, core size was unrelated to risk. What distinguished high-risk provinces was that their single bidding was concentrated in the core. Provinces such as El Oro and Manabí did not have more centralised markets than Pichincha or Loja, but their most central buyers and suppliers concentrated a disproportionate share of uncontested contracts. This pattern is consistent with the state capture view, in which corruption is organised around a limited set of stable relationships between powerful buyers and favoured firms (Fazekas and Tóth 2016). It also suggests that, at the subnational scale, structural concentration by itself is a weaker warning sign than the combination of concentration and risk.

These findings have implications for audit strategy. A control body with limited resources faces different problems in different provinces. Where risk sits in the core, as in El Oro, Manabí or Napo, a small number of high-volume relationships may account for much of the exposure, and targeted reviews of central buyers are likely to be efficient. Where risk sits in the periphery, as in Loja or Imbabura, it is spread over many small buyers and occasional suppliers, and broader preventive measures such as training, standard tender documents or automated red flags may be more appropriate. Network indicators of this kind could complement the contract-level early-warning models already developed for Ecuador (Fuertes et al. 2025) and broader technological approaches to integrity (Adam and Fazekas 2021).

The study has several limitations. The analysis covers 2015–2021, and the number of procedures varies across years, with 2018 particularly thin; the results therefore describe the period as a whole rather than year-to-year change. Single bidding is a proxy, and its validation in Ecuadorian data is partial: it is associated with weaker price competition, but not with shorter bidding periods. Core results depend on the threshold used to define the core, which is why the sensitivity analysis is reported in full. Provincial networks pool seven years and assign

contracts by the buyer's address, which ignores markets that cross provincial borders. Finally, the cross-provincial correlations rest on 21 observations and describe associations rather than causal effects.

Future work could follow the structure of provincial markets year by year within the period, as done for government turnover in Europe (Fazekas and Wachs 2020), and extend the analysis to later years as validated records become available. Composite risk indices that combine single bidding with price, timing and supplier-history indicators would strengthen measurement (Fazekas et al. 2016). Validation against audit findings of the Comptroller General's Office or judicial cases, in the spirit of studies that used audit reports in Brazil (Ferraz and Finan 2008), would test whether network signals anticipate detected irregularities.

## Conclusions

Corruption risk in Ecuadorian public procurement is unevenly distributed in a way that national averages hide. Single bidding affected three in ten competitive procedures between 2015 and 2021, was clustered in communities of buyers and suppliers in nearly every province, and was concentrated in the core of some provincial markets and in the periphery of others. Unlike in the European cross-country evidence, the size of a market's core did not predict its risk; the concentration of single bidding among central actors did. Network measures computed from open contracting data offer a low-cost way to tell these situations apart, and the method can be applied to any country that publishes OCDS records with bidder counts and stable party identifiers.

## Supplementary Information

Additional file 1: Supplementary tables. Table S1: provincial results under the alternative null model and for electronic reverse auctions. Table S2: core over-representation for alternative

core thresholds with permutation p values. Table S3: range of clustering ratios across ten Louvain runs. Table S4: validation regressions for the single-bid indicator.

## Abbreviations

CPC: Central Product Classification; OCDS: Open Contracting Data Standard; RUC: Registro Único de Contribuyentes (taxpayer identification number); SERCOP: Servicio Nacional de Contratación Pública (National Public Procurement Service)

## Declarations

### *Availability of data and materials*

The source data are publicly available from the Open Contracting Partnership data registry, https://data.open-contracting.org/en/publication/110. The processed dataset and code supporting the conclusions of this article are available in the GitHub repository, https://github.com/carluiredro/ecuador-procurement-networks.

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The authors declare that they have no competing interests.


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### *Authors' contributions*

All authors contributed equally to this work. LRV, JMP and CRO jointly conceived and designed the study, processed and analysed the data, interpreted the results and wrote the manuscript. All authors read and approved the final manuscript.


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## Supplementary Files

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