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Using Beneficial Ownership Data for Systematic Risk Assessment in Public procurement. The Example of 6 European Countries

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Abstract
Despite the considerable interest, there is little evidence on the suitability of beneficial ownership data for systematic corruption risk assessment. This paper aims to validate common beneficial ownership risk indicators for proxying public procurement corruption. By implication, it offers practical insights for research, policy, and investigations. It also generates hypotheses regarding the impact of beneficial ownership registers on the organisation of financial crime. We match administrative data of 8 million government contracts with 11 million companies' beneficial ownership records in Denmark, Estonia, Latvia, Slovakia, Ukraine, and the UK. We estimate fixed effects regressions tailored to capture non-linear relationships between company risk indicators of beneficial ownership and corruption risk indicators of public procurement. Correlations among two sets of differently constructed, yet conceptually related risk factors are interpreted as evidence for measurement validity. We find that BO-based risk indicators capturing unusual and outlier BO features - high company frequency of BO, frequent information change, outlier BO age, and no BO data - all perform in line with expected results. However, BO-based risk indicators relating to BO countries, such as sanctioned jurisdictions, largely fail to relate to public procurement corruption risks in line with expectations. Finally, BO-based risk indicators, which have already been widely validated in the literature using different data sources - company age and political connections - also turn out to be valid. Our findings lend support to the systematic use of beneficial ownership-based risk indicators in research, policy, and investigations. Our new risk assessment tools enable investigators to generate new investigative leads and policymakers to track the scale of likely corrupt transactions in public procurement.

Keywords Beneficial ownership · Corruption · Measurement · Public procurement

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Introduction

To avoid the use of corporate structures for money laundering, corruption, and other financial crimes, beneficial ownership (BO) registers have been created in several countries since 2015. These registers contain information on the natural persons who ultimately own or control companies, and other legal entities such as funds and trusts. One of the reasons behind the creation of these registers is that having this information available in a central public register can deter individuals from misusing corporate structures. Given the increasing availability of BO data, there is a need for a better understanding of the quality of these datasets, as well as for evaluating their usefulness for research and policy analysis.

A series of articles has been written on the benefits of BO registers, including their use for systematic risk flagging and investigations (Carbone et al., 2023; Knobel & Seabarron, 2020). However, most of these articles are qualitative, based on small-scale data, or they merely enumerate expected benefits, challenges, and uses of BO data and risk indicators (Gilmour, 2020; Aristodemou, 2024; Ezeigbo et al., 2021). Only a few articles analyse the effects of BO registers on deterring crime in real estate and FDI (Collin et al., 2023; Amberger et al., 2025), or the structure of large-scale ownership networks and financial secrecy (Garcia-Bernardo et al., 2017). While the value of BO data for individual investigations or checking business partners' identity is well-established, there is a paucity of evidence on the systematic suitability of BO datasets for the large-scale risk detection and mapping of financial crimes. It is unclear whether BO datasets, despite their quality issues, can be used for assessing risks across large swathes of the economy, and whether specific fields in these datasets can be used to compute risk indicators (e.g., the number of companies associated with a BO). Moreover, there is a particular lack of analysis using linked BO-public procurement data, despite high corruption risks in public procurement and many papers establishing the importance of ownership risk factors in this field (Fazekas et al., 2018).

To address this evidence gap, the overarching objective of this paper is to lay the groundwork for the emerging literature related to the use of BO data for systematic risk assessment as well as for policy-relevant impact studies. To do so, *this paper validity tests the most common risk indicators of money laundering and corruption in beneficial ownership datasets*. Validity testing is enabled by linking BO data to public procurement data and the risk indicators already validated in the latter.

In this paper, we test the usefulness of BO risk indicators in company datasets for large-scale risk assessment in 6 European countries: Denmark, Estonia, Latvia, Slovakia, the United Kingdom, and Ukraine. The selection of these countries reflects a series of considerations. First, data with sufficient scope and quality must be available to conduct large-scale indicator validity testing (Adcock & Collier, 2001). This means that we needed public access to procurement and BO datasets covering a prolonged and overlapping time period. Second, a diverse set of countries was selected to offer sufficient variation in integrity and prevalence of high-level corruption. Testing the same indicators with the same methods in countries experiencing different levels of corruption allows us to arrive at more generalisable results. Third, the countries selected in the analysed time period followed approximately the same legal frameworks regarding beneficial ownership information and public procurement. These similarities allow us to keep our cases, while separately analysed,

roughly comparable in their fundamental legal and data infrastructures, holding several intervening variables constant.

We define corruption in public procurement as the violation of open and impartial access to government contracts to benefit a favoured company or network of individuals (Fazekas et al., 2023). To test the validity of a wide range of proposed BO risk indicators, we use 2 widely established validity concepts (Adcock & Collier, 2001): content validation (theoretical) and convergent validation (empirical). Theoretically, we conduct content validation, that is, we show that each BO risk indicator is in line with our corruption definition and that they capture theoretically coherent actor strategies pertaining to corruption. Empirically, we conduct convergent validity tests by correlating BO risk indicators with public procurement corruption risk indicators while controlling for as many confounding factors as possible. While these validation concepts are widely established, they are not without limitations. Content validity, while necessary, is insufficient on its own to establish measurement validity; hence, the need for other types of evidence. A major concern with applying convergent validation arises when both the established and new indicators are noisy; in other words, there is no "true" measure of the underlying concept. In such a case, which is close to our empirical setup, low correlation may not mean a lack of validity.

Risky beneficial owners or ownership patterns point to potential corruption and related crimes, as they underpin corrupt rent extraction from government contracts and facilitate hiding corrupt actors. Hence, *content validation* means for us to explain why and how specific BO risk indicators point to likely efforts to hide owners or proceeds in public procurement, or alternatively, how BO patterns reveal that there is a corrupt network at work in public tenders. An example for the former would be a company whose owner looks like a nominee or strawman; hence we expect that corrupt motives would be at work behind using such a company for winning a corrupted tender. An example for the latter case would be a company with a conflict of interest, such as one of the company's owners being a political office holder. In other words, we need to show that an indirect (signs of hiding) or direct (high-risk relationship revealed) link is likely to exist between corruption in the winning supplier and corruption in its contract.

For empirically testing *convergent validity*, we lean on already validated corruption risk indicators in public procurement (Fazekas & Kocsis, 2020). If corruption takes place in a public tender won by a particular company, we expect risks to show up both in the tender itself and the winning bidder (Fazekas et al., 2018). Naturally, public procurement corruption can happen through completely legit and non-risky firms; however, this tends not to be the case. Hence, we claim that corruption is measured from 2 different angles: using 2 different datasets and 2 different sets of risk indicators. The correlation between BO and public procurement data-based risk indicators is hence evidence for convergent validity. Given that there are many confounding factors in public procurement corruption, that is, factors which lead to high-risk features in the data without necessarily corruption taking place, we need to control for several factors, such as market or contract value.

The remainder of the article is structured as follows: first, we start by briefly introducing the institutional framework regulation BO registers in each of our case study countries. Second, we describe in detail the data collection, cleaning, and matching process. Third, we introduce our overarching theoretical framework and outline how and why each of the proposed BO indicators relates to the intent to hide corruption. Fourth, we describe our meth-

odological approach to indicator validation. Fifth, we summarize our main findings and discuss specific results for each variable. Finally, we draw conclusions and policy lessons.

Institutional Background

As BO transparency requirements represent the key source of information for the subsequent analysis, we briefly review the European Union (EU) BO legal framework and a few key details of each country's regulatory framework. This allows for understanding the strengths and weaknesses of the BO data analysed and potential ways to circumvent transparency requirements.

As part of strengthening the regulatory framework against money laundering, the financing of terrorism, and other financial crimes, the EU approved the 4th Anti-Money Laundering (AML) Directive in 2015 (EU Directive, 2015/849). This Directive required each Member State to establish a central register that contained information on the beneficial owners of companies. In this directive, a beneficial owner is defined as the natural person who ultimately owns or controls a company (EU Directive, 2018/843). In response to the rise of new threats to money laundering (e.g., cryptocurrencies), the 5th AML Directive was published in 2018, extending the BO framework. Among others, it required Member States to make the existing central BO registers public. Although there have been considerable advances regarding the creation and publication of central BO registers since 2018, in November 2022, the Court of Justice of the European Union (ECJ) ruled that the publicity of BO data conflicts with privacy rights and therefore these registers should no longer be publicly accessible (Thomas-James, 2023). This ruling reignited the discussion about the importance of balancing transparency with the protection of privacy issues that has been part of the BO scholarly debate since the creation of these registers (Gilmour, 2020; Knobel, 2024). After the publication of this decision, many, albeit not all, EU countries closed access to their BO registers (Martini, 2023). In this article, we could only make use of publicly available BO datasets following the 2022 ECJ ruling.

Each of the 6 countries analysed in this paper has comparable, albeit somewhat different, laws and regulations for BO registers. These establish the scope of the legal vehicles that are obliged to declare their beneficial owners, as well as definitions of direct and indirect ownership that further determine which companies and owners must comply with transparency requirements. Table 1 briefly summarises the main characteristics of each of the registers used in this paper. Since the unit of analysis is public procurement contracts awarded to companies that have BO information available, the discussion concentrates on the BO information of companies, excluding funds and trusts.

Data

This paper analyses administrative datasets of public procurement contracts matched with BO registers in 6 countries: Denmark, Estonia, Latvia, Slovakia, Ukraine, and the UK, for 2009–2022 (exact time period varies by country). Below, we describe the BO and procurement datasets used and how they were matched.

Table 1 Beneficial ownership registers characteristics

	Denmark[1]	Estonia[2]	Latvia[3]	Slovakia[4]	Ukraine[5]	UK[6]
Name	Central Business Register (CVR)	e-business register	Registry of Enterprises	Public Sector Partners Register (RPVS)	Unified State Registry (USR)	People with significant control register (PSC)
Launch date	May 2017	2018	2017	2017	September 2015	April 2016
Sector	Full economy	Full economy	Full economy	Procurement	Full economy	Full economy
Authority	Danish Business Authority	Commercial Register	Ministry of Justice	Ministry of Justice	Ministry of Justice	Companies House
Laws involved	Act amending the Companies Act, the Certain Commercial Undertakings Act, the Corporate Funds Act and various other acts	Money Laundering and Terrorist Financing Prevention Act	Law On the Enterprise Register of the Republic of Latvia	Act on the Register of Public Sector Partners (ARPSP)	On State Registration of Legal Entities, Individual Entrepreneurs and Public Associations	Small Business Enterprise and Employment Act

[1]https://danishbusinessauthority.dk/sites/default/files/2023-10/consolidated-act-certain-commercial-undertakings-01022021_WA%20%282%29.pdf

[2]https://www.riigiteataja.ee/en/eli/517112017003/consolide

[3]https://likumi.lv/ta/id/72847-par-latvijas-republikas-uznemumu-registru

[4]https://www.justice.gov.sk/sluzby/register-partnerov-verejneho-sektora/

[5]https://zakon.rada.gov.ua/laws/show/755-15#Text

[6]https://www.gov.uk/government/collections/small-business-enterprise-and-employment-bill

Beneficial Ownership Data

Two data sources, the Open Ownership Register[1] and national BO registers, were used to collect BO data. Countries' BO datasets differ in information content to some degree. All datasets contain the companies' unique IDs, the full name of the BO, and the BO's nationality. The Latvian and UK datasets have BOs' dates of birth too. This information allowed us to calculate the BOs' age when the company bid for a contract. Only Estonian beneficial ownership data contains information about the BO's unique identifier. Partial identification is available for all other countries. Denmark and the UK datasets provide a historical perspective on who the BOs of companies were before the register was created. Additionally, Denmark's dataset contains information about the type of ownership (shareholding or voting rights) and the exact period of ownership. Danish data also has information on the percentage of shares controlled by a natural person.[2] Neither Ukrainian nor Slovakian data contains information about when a person becomes a company's controller.

[1] The Open Ownership Register closed at the end of November 2024, nonetheless the bulk data is still available at https://bods-data.openownership.org/.

[2] This data was not used for the analysis.

Although Ukraine was the first country to open its beneficial ownership register to the public, it has the most significant limitations among the countries analysed. First, Ukraine closed access to the data in machine-readable format because of the Russian-Ukrainian war. This was done for security concerns, as the BO dataset contains the complete addresses of registered companies and their owners. Therefore, the last data available for Ukraine is from February 2022. Second, affiliate companies do not register as separate legal entities and do not provide any data to the register. However, they can participate in public procurement procedures.

Neither Latvia's nor the UK's data have information about the companies' names, only company IDs. Hence, UK companies' names had to be additionally collected from companies' warehouse to improve matching to public procurement data, which often only has the names of the winning suppliers but not the IDs.

Public Procurement Data

Public procurement data for Denmark, Estonia, Latvia, Slovakia, and the UK were collected from https://opentender.eu/ and have already been standardised following the same structur e and data quality standards. As Ukraine is not part of opentender.eu, Ukrainian public procurement data was collected from the BI-Prozorro module and structured to match the other datasets.[3] Denmark has the smallest dataset, with only 55,000 contracts, covering the period between 2006 and 2022. In contrast, Ukraine's procurement data comprises 7.6 million contracts, covering only the period from 2016 to 2022. Additionally, only Ukrainian procurement data contains almost all bidders' IDs, allowing high-quality data matching. However, due to the war, some procurement procedures were closed in 2022, and data were removed from the public domain. This caused the absence of key details about the procurement procedure and did not allow for calculating all corruption risk indicators for the Ukrainian data. The datasets of the rest of the countries have a limited number of bidder/supplier IDs. The UK procurement data has the lowest availability of bidder IDs.

Data Matching Process and Scope of Datasets Used for the Analysis

To match procurement and BO datasets, procurement data needed considerable pre-processing. First, all contracts without bidder names were removed. Second, foreign bidders were removed from the Danish, Estonian, Latvian, and UK datasets, as these BO registers do not contain information about foreign companies. Finally, procurement datasets were filtered from the year when the BO register started operating, dropping contracts from earlier years. As the Slovakian BO register has information for foreign firms, we did not remove foreign suppliers. Also, since the Slovakian and Danish BO data are historical, we did not have to drop public procurement data from before the creation of the register.

Any citizen or tax resident in Ukraine can register as an Individual Entrepreneur, which is a form of sole proprietorship. Because of this, they are allowed to participate in public procurement processes and are not required to provide BO information. Therefore, contracts of individual entrepreneurs or sole traders were removed from the Ukrainian procurement dataset. Additionally, Ukraine has a low threshold for reporting procurement data; therefore,

[3] https://bipro.prozorro.org/qlikview/FormLogin.htm.

bids with a tender price lower than 250,000 UAH (about 5600 EUR) have been removed from the datasets.

In Slovakia, submission of BO information is mandatory only for private companies participating in public procurement processes and for companies winning contracts of at least 100,000 EUR (Labant & Šípoš, 2017). Therefore, contracts of a lower value were removed.

In all countries, publicly listed joint-stock companies are not obliged to provide information about their BOs. Hence, we removed publicly listed companies from the dataset because their BO data was not available.

The first step in the matching process for all countries was matching by company ID. Matching by company names, the second step, was applied for Denmark, Slovakia, and the UK to improve matching rates. Elementary text pre-processing was done before matching, such as lowercasing names. For Slovakia and the UK, non-alphanumeric characters were removed. Companies' names in the UK have different forms of writing depending on the company's type (for example, Ltd or Limited). Therefore, company types were removed. This allowed us to improve the percentage of matching significantly. However, this also increased the possibility of mistakes.

Matching rates and data scopes considerably vary by country (Table 2). Estonia and Ukraine have the highest matching rates because of recent transparency reforms in the Ukrainian public procurement system and the Estonian well-structured BO and procurement datasets with company IDs. In contrast, the UK has the lowest coverage by bidder IDs in its procurement dataset, hence the comparatively low matching rate.

One company in the matched dataset may have more than one beneficial owner. Therefore, to work with the contract-level procurement data, BO data was aggregated to the company level. For numerical variables, minimum or maximum values were used.

Theoretical Framework and Indicators

This section starts by briefly outlining our overarching conceptual framework; then it introduces public procurement corruption risk indicators, which serve as the dependent variable in our models. Given that the procurement risk indicators have already been validity tested (OLAF, 2017; Fazekas et al., 2023), they can be treated as a reference point for BO-based risk indicators. Then, this section discusses BO data-based risk indicators, which are feasible to calculate given commonly available BO datasets (Carbone et al., 2023; Jofre & Knobel, 2025; Bosisio et al., 2021). It not only defines each indicator but also discusses

Table 2 Description of the matched dataset used in the analysis

Country	Matched years	No. of companies in BO register	No. of bid IDs	No. of bids with BOs	% of bids with BOs
Denmark	2016–2021	429,513	23,277	7295	31.3
Estonia	2018–2022	275,985	42,376	32,220	76
Latvia	2017–2021	154,418	138,513	64,890	46.8
Slovakia	2009–2021	11,052	63,699	38,834	61
Ukraine	2016–2022	2,045,940	7,603,582	5,011,844	65.9
The UK	2016–2021	8,317,840	126,282	40,045	31.7

the underlying corrupt phenomena, i.e., why they signal the risk of corruption and money laundering rather than other phenomena. Hence, we carry out a content validation exercise (Adcock & Collier, 2001).

Given that corruption is a deliberately hidden phenomenon, we expect corrupt actors to weigh their options in response to the introduction of a BO register: (i) continue corrupt transactions unchanged and reveal their identities in the register; (ii) continue corrupt activities but better hide their identities; or (iii) stop participating in corruption altogether. While we do not make strong assumptions about the motivations and calculus of corrupt actors, we expect them to make boundedly rational choices among these options (Aristodemou, 2024; Gilmour, 2020; Winter, 2019).

Based on the widely documented instances of circumventing BO registers (Transparency International, 2019; Bosisio et al., 2021; Knobel, 2019), we posit that direct evidence of risky connections, such as a political officeholder owning a company winning a government contract, is relatively easy and comparatively cheap to hide. It can be done, for example, through the appointment of a nominee (FATF & EGMONT, 2018), or registering the company abroad where BO transparency regulations are easy to circumvent or exploiting loopholes such as hiding behind a trust (Knobel, 2017). By implication, we expect BO data to carry little direct evidence for corruption risks and instead indirect signs to be more indicative. Moreover, indirect evidence, indicative of the intent to conceal information, is more likely to correlate with public procurement corruption risks (Carbone et al., 2023; Jofre & Knobel, 2025; Annex F). Such tell-tale signs for circumventing transparency regulations could include missing values, data errors, unreasonable values, and unusual records in the BO registers. The following indicator-by-indicator discussion outlines, specifically for each scheme, how they relate to circumventing regulations and offer proxy indicators for corruption.

Nevertheless, we do not mean that there is no chance of direct evidence for corruption risks in BO datasets at all. It may well be that the risk of punishment is perceived to be so low by corrupt actors (e.g., they think that their political connections would block any investigation or court case against them) that they do not care to hide obvious risky connections visible in BO datasets. It may also be the case that linking data from different administrative datasets (either in other countries or different datasets) can reveal direct signs of corruption that are not anticipated by corrupt actors (U4, 2023).

Dependent Variable: Public Procurement Corruption Risk Index (CRI)

To proxy corruption in public procurement, we use the Corruption Risk Indicator (CRI), a composite indicator that identifies risk factors of high-level corruption (Fazekas & Kocsis, 2020). The methodology behind this indicator reflects the conceptualisation of corruption as the violation of open and impartial access to government contracts to benefit a favoured company or network of individuals (Fazekas et al., 2023). The CRI is composed of several individual risk indicators or "red flags": (1) single bid submitted in a tender; (2) non-open procedural type; (3) short advertisement or submission period; (4) no call for tenders published; (5) supplier registered in a tax haven; (6) short decision period; and (7) buyer's spending concentration (Table 3). The CRI is constructed so that a higher indicator value signals a higher risk of corruption in a procurement contract. In line with the above definition of corruption, the red flags that make up the CRI approximate a range of strategies

Table 3 Descriptive statistics for the Corruption Risk Index by country

Descriptive	Denmark	Estonia	Latvia	Slovakia	Ukraine	UK
count	23,134	41,373	138,345	63,699	1,254,401	126,282
mean	0.34	0.35	0.25	0.23	0.27	0.38
std	0.18	0.23	0.24	0.21	0.32	0.22
min	0	0	0	0	0	0
25%	0.25	0.2	0.01	0.03	0	0.2
50%	0.33	0.33	0.17	0.2	0.03	0.4
75%	0.5	0.5	0.42	0.33	0.67	0.51
max	1	1	1	1	1	1

corrupt groups use to bias the tendering process and achieve favouritistic tendering results. Taken together, the indicators composing the CRI represent a robust measure of potential corrupt contracting spanning across many widely documented corrupt scenarios. For a full description of these public procurement corruption risk indicators used in the analysis, see Fazekas et al. (2024), while further theoretical background and evidence for indicator validity can be found in Fazekas and Kocsis (2020).

Independent Variables: Beneficial Ownership Risk Indicators

Following a comprehensive literature review and verifying whether BO datasets in the six countries enable indicator calculation, eight BO-risk indicators were selected for in-depth analysis. These indicators not only indicate alleged corruption but also money laundering and other financial crimes, according to the literature (Carbone et al., 2023; Jofre & Knobel, 2025; Bosisio et al., 2021) and corruption investigation cases (Annex F). Still, our discussion narrows in on corruption in public procurement to remain succinct and focus on validity testing. The nine indicators fall into three broad categories:

1. unusual and outlier BO features (high company frequency of BO, frequent BO information change, outlier BO age, and no BO data);
2. BO country (foreign BO, BO from sanctioned countries); and.
3. BO-risk indicators which have already been validated, as they are available from established sources other than BO registers (company age and owners' political connections).

Number of Companies Owned by the Same Beneficial Owner

The first BO-risk indicator we discuss is the number of companies that are owned by the same person (Table 4). Although there are legitimate reasons why one person can own several companies, like being a known millionaire/billionaire of the country, this can also be a signal that the owner is a nominee or strawman and that the underlying personal data is fraudulent (Carbone et al., 2023; Taylor, 2022). If a powerful, corrupt group decides to put nominees to front its companies winning public contracts, it might want to spread the risks of detection by setting up a great number of companies and bidding independently with them in public tenders (Bosisio et al., 2021). Given the high set-up cost of identifying and controlling nominees, it is preferable for the corrupt group to use one or a small set of nominees rather than a new nominee for each company. This gives rise to our BO-risk indicator, an unusually high number of companies registered by the same person. The ease

Table 4 Descriptive statistics of the indicator: Number of companies owned by the same beneficial owner, by country

Descriptive	BO freq DK	BO freq EE	BO freq L	BO freq SK	BO freq UA	BO freq UK
count	7295	31,217	57,057	32,067	1,234,966	21,381
mean	14	5	3	2	7	4
std	18	8	4	2	32	24
min	1	1	1	1	0	1
25%	4	2	1	1	1	1
50%	8	3	2	1	1	2
75%	17	7	4	3	3	4
max	202	311	122	16	495	1324

with which fake identities can be used for setting up companies and the lack of verification of personal information make this corruption scheme low risk for corrupt groups (Global Witness, 2019). As this indicator aims to track unusually high company frequency, when aggregating from the individual to the company level (note that one company can have multiple beneficial owners), we took the highest value among the company's owners as the aggregate company value.

Frequent BO Information Change

A high number of changes in a company's BO information, especially an outlier number of changes, is our second risk indicator (Table 5). Frequent changes in ownership structure could indicate the intent to avoid regulatory scrutiny (European Banking Authority, 2021), for example, by changing owners just for the period when the company's owners are checked for bid assessment. It could also represent a change in ownership structure to evade sanctions levied at some of the true owners, or circumventing conflict of interest rules preventing political office holders from owning a company winning government contracts. Given the speed and low cost of BO registry changes, this is a flexible and relatively low-cost evasion technique for corrupt groups that can be deployed if and when needed (Bosisio et al., 2021). Nevertheless, the number of BO data changes is only a crude proxy for these tactics, as one or a few changes could achieve corrupt goals on their own if the corrupt group is skilled and careful. If the corrupt group is incompetent or faces considerable infighting within the group, our indicator might be closer to corrupt behaviours.

Changes in ownership to evade sanctions represent a typical manoeuvre performed by corrupt and high-profile actors. For example, Arkady Rotenberg, a close friend of Vladimir Putin and owner of two of Russia's biggest construction contractors, changed the owner-

Table 5 Descriptive statistics of the indicator: Frequency of BO information change, by country

Descriptive	BO changes frequency DK	BO changes frequency EE
count	7295	31,217
mean	1	1
std	0	0
min	1	1
25%	1	1
50%	1	1
75%	2	1
max	11	7

ship of one of his firms, Milasi Engineering, to his son to evade sanctions after the annexation of Crimea in 2014.[4] Similarly, Alexey Mordashov used this technique to transfer the ownership of several of his companies (Nordgold and TUI) to his wife after being targeted with EU sanctions in relation to the invasion of Ukraine.[5] This risk indicator could only be calculated for the Danish and Estonian BO datasets due to data constraints.

Missing BO Data

A straightforward indication of the intent to circumvent transparency rules and potentially hide corruption is when a company's owner does not comply with BO reporting requirements. Hence, missing BO information is our third BO-risk indicator. When a company bids for a government contract, oftentimes ownership information and various declarations by the owners are required, which could be checked against a BO register. However, when the company fails to submit the information on its BOs, it can submit incomplete or misleading documentation to the bid evaluation committee to avoid proper scrutiny or hide a conflict of interest. Given that imposing substantial fines or more costly administrative sanctions (e.g., suspending the company's registration until BO information is corrected) is very rare in Europe (Russell-Prywata, 2023), this strategy for hiding the true owners is of relatively low cost. In addition, if the procurement assessment board can be bribed or influenced through connections, checking tender documentation can also be avoided, making this strategy effective according to the literature (Amberger et al., 2025; European Banking Authority, 2021; Bosisio et al., 2021; Jofre et al., 2021; Szakonyi & Martini, 2021; Global Witness, 2019).

While this indicator is straightforward conceptually, it is hard to measure because there is a wide range of exceptions to BO transparency requirements (see institutional background section above), and because data matching errors might lead to missing BO information in our database, even if it is de facto available. Moreover, it is also possible that BO data is missing because of an error in submitting information or because the company is not able to identify a BO. Hence, this indicator was calculated using the lack of matched BO-procurement data, with some modifications to account for these potential biases. Whenever possible, we removed sole entrepreneurs and joint stock companies without BO requirements to improve the matching rates. In Ukraine and the UK,[6] BO data contains a specific notification of being unable to identify or locate a BO, which we used as the 'no BO' information flag in the analysis.

Age of Beneficial Owners

A further indication of hiding the true BOs and instead using a nominee is the anomalous age of a beneficial owner, which is our fourth BO-risk indicator. Although there is nothing illegal about having a minor or an elder as the ultimate BO of a company, there has

[4] https://www.forbes.com/sites/giacomotognini/2022/03/09/evading-sanctions-a-how-to-guide-for-russian-billionaires/.

[5] https://www.reuters.com/article/business/germany-investigates-ownership-change-at-tuis-top-russian-shareholder-idUSKCN2LF0W1/.

[6] https://zakon.rada.gov.ua/laws/show/755-15#Text and https://www.gov.uk/government/collections/small-business-enterprise-and-employment-bill.

been extensive documentation of corruption risks involving minors and elders as nominees (Bosisio et al., 2021; European Banking Authority, 2021; Carbone et al., 2023; Global Witness, 2019; FATF-Egmont Group, 2018; OCCRP, 2022). For example, in Mexico, elders from rural provinces were asked to give their personal information to be declared as legal representatives of shell companies used to divert public funds in exchange for some small economic compensation in a national corruption scheme brought to light thanks to the famous journalistic investigation *La Estafa Maestra* (Castillo et al., 2017). In these contexts, the young and old age of BOs serves as a proxy for the ease with which corrupt groups can influence and control nominee BOs, such as using a vulnerable elderly nominee.

This indicator could only be calculated in Latvia, Slovakia, and the UK. Aggregating from the individual to the company level, both the age of the oldest and youngest beneficial owner of the company were used (Table 6).

Beneficial Owner with a Foreign Nationality

BOs from foreign countries typically represent additional challenges to verifying the individual's true identity and personal information, such as their address. Such additional hurdles might open the door for using a nominee or a non-existent person as BO for a company that bids in public tenders. If the true owners face conflict of interest restrictions or have other risky features in the country of the tender (e.g., being barred from managing a company), hiding behind a foreign nominee could enable corrupt contracting at relatively low cost for the corrupt who have the necessary infrastructure and connections in the foreign country to organise the fake or unverifiable identity registration.

According to FATF recommendations related to beneficial owners, it is important that countries have a risk-based approach to foreign-created legal entities that have considerable links to the country in question, such as winning public procurement contracts. This includes having access to up-to-date and verified information regarding the ultimate BOs of legal entities, to avoid the use of nominee arrangements (FATF & EGMONT, 2018). The World Bank also considers that multijurisdictional splitting, the case where networks of legal structures split their ownership and asset administration, through the use of bank accounts and intermediaries located in different jurisdictions, could be done to avoid the imposition of sanctions and detection of illicit activities (World Bank, 2022).

This BO-risk indicator takes all foreign countries as a potential source of corruption risk, while subsequent BO country-based indicators will only focus on specific groups of countries that represent particular risks (Table 7). In this sense, this indicator is rather broad-based, hence potentially noisy, compared to the more specific BO country-based indicators.

Table 6 Descriptive statistics of the indicator: Age of beneficial owners, by country

Descriptive	BO age LV	BO age SK	BO age the UK
count	8792	32,067	21,381
mean	58	54	54
std	10	9	12
min	26	15	0
25%	51	48	47
50%	58	55	55
75%	68	61	63
max	86	92	93

Table 7 Descriptive statistics of the indicator: Foreign BO by country group (Nationality)

Category	Denmark	Estonia	Latvia	Slovakia	Ukraine	UK
Domestic	7224	27,264	56,862	33,974	1,205,096	19,384
No data	15,839	10,156	73,623	25,610	20,248	108,840
Foreigners:	210	4906	9095	16,348	38,786	2935
Sanction countries	0	0	189	924	4296	184

Still, given the complexity of individual national rules, we argue that such a generic risk factor could already be informative.

When aggregating from the individual to the company level, we flagged companies as risky whenever at least one of the company's BOs is a foreigner compared to the country where the public tender takes place.

Beneficial Owner from a Sanctioned Country

Building on the arguments underpinning the foreign BO risk indicators, we propose a more specific BO-risk indicator flagging companies with at least one BO from a sanctioned country: Russia, Belarus, and Iran (for a similar approach see: Nicolazzo et al., 2022). Many beneficial ownership regulations include the need to identify and check BOs that appear on a sanctions list. Nonetheless, there is sometimes a lack of verification of this information by the authorities in charge of public BO registers (Russell-Prywata et al., 2023). Given that individuals from sanctioned countries are more likely to carry out corrupt acts, even before the imposition of sanctions (Bosisio et al., 2021; Baquero et al., 2021; European Banking Authority, 2021; FATF-Egmont Group, 2018), in pursuance of their home country's strategic interests, we consider them as an indication of potential corruption.

Company Age

If a company wins a big procurement contract the same year it was founded, it could signal corruption risks given the lack of experience and skills of the company in question (Fazekas et al., 2017). By extension, the age of a company when it wins a government contract can be considered a risk factor if it is too small, with risks increasing as the company is younger.

It is a risk factor that can be calculated with the data in some BO datasets, which is relevant for us, even though such information has already been widely available from company registers. This BO risk can be calculated only for the BO data of Denmark and Slovakia (Table 8). It is important to state that Slovakia's BO data has the entry date to the electronic BO register, which in some cases is later than the actual company registration, which gives a negative number in some cases.

Beneficial Owner is a Politically Exposed Person

A widely documented and used corruption risk indicator is when a government supplier has a political connection, that is, at least one of its BOs being flagged as a Politically Exposed Person (PEP) (Bosisio et al., 2021, FATF, 2013, Haberly, 2020, ICIJ 2021, van der Does de Willebois et al. 2011). Political office holders owning a company bidding in public tenders can use their connections and knowledge of the inner functioning of government to secure

Table 8 Descriptive statistics of company age, by country

Descriptive	Company age DK	Company age SK
count	7295	35,914
mean	19	15
std	13	6
min	0	−4
25%	10	11
50%	17	17
75%	28	20
max	90	62

Table 9 Number of contracts with the supplier having a PEP link, Ukraine

BO PEP	Count
PEP	7838
Not PEP	1,246,563

favoured treatment for their firms. Hence, companies with a PEP BO are expected to engage in high corruption risk tenders more often.

This indicator could only be calculated for Ukraine, as there was already an established PEP list (Table 9). Ukraine does not have an official register of PEPs; however, we had access to the data of the Anti-Corruption Action Centre, which maintains a reliable register of PEPs in the country.[7]

Methods

Following theoretical content validation in the previous section, we empirically test convergent validity, building on the framework of Adcock and Collier (2001). This means that we are looking for conditional correlations between recently proposed BO-based company risk indicators and the already validated Corruption Risk Index (CRI) in public procurement. We conduct fixed effects linear regressions on the contract level for each country, with the public procurement-specific CRI as the dependent variable and the BO-risk factors as independent variables (IVs) of interest. As a robustness test, we also run the same models but with the binary risk factor single bidding, which is less complex, albeit less comprehensive than the composite CRI (Annex D). Each BO indicator is tested on its own while controlling for a range of confounding factors. Control variables are the following: fixed effects for tender year, the main product market (using Common Procurement Vocabulary: 2-digit CPV codes), the tender price, buyer type, and buyer location (NUTS code). Taken together, these control variables account for structural and market conditions determining background risk levels, such as the expected rate of single bidding even in the absence of corruption. We run country-by-country models to fully consider country-specific risk patterns and data systems. Hence, correlations among BO and procurement risk indicators can be interpreted within very narrowly defined, local market realities, holding a host of confounders constant, reliably pointing to indicator validity.

As some of the variables of interest and control factors have relatively high missing rates, we typically transform them into deciles with an additional missing category. This enables

[7] https://web.archive.org/web/20201020225836/https://pep.org.ua/en/article/1.

us to retain all relevant observations in the model while explicitly accounting for the impact of missing values. This is crucial for risk indicator development, given that the lack of information can signal corrupt intent. In addition, we expect non-linear relationships whereby a wide range of indicator values have little to no bearing on risks, while beyond a certain threshold, risks jump. To model such effects, turning our key predictors of interest in the BO data into deciles is useful, as it can trace null effects and sudden jumps by decile. Even though linear regressions are not adept at capturing non-linear associations and thresholds, the use of deciles and the careful assessment of each category's coefficients allow us to sufficiently model the expected non-linear relationships.

Results

This section presents the main results concerning the relationships between BO-risk indicators and CRI. First, we offer a high-level overview of each BO-risk indicator; second, we highlight some typical relationships to provide a detailed interpretation reflecting our theory. Table 10 summarises the results from the OLS regressions for each BO indicator in each country (for full regression details, see Annex C). Additionally, we also report simple linear correlation coefficients in Annex A as a reference. Whenever the BO-risk indicator derives from a continuous distribution, such as the number of companies a BO owns, we look for extreme values and outliers that would indicate likely wrongdoing. We sliced continuous distributions into deciles and verified which category increases CRI in the regressions. This approach reflects on the expectation that a wide range of indicator values are plausible, hence low risk (e.g. a person owning 2–3 or even more companies), while unusually high or low values could indicate deliberate hiding or obfuscation (e.g. a person owning hundreds of companies, like in the cases 1 and 2 in Annex F). In the case of binary indicators, no such approach was needed, since we could simply test them as they are. Not all tests were

Table 10 Summary of main results: BO features impacting public procurement corruption risks

Risk Indicator	Denmark	Estonia	Latvia	Slovakia	Ukraine	UK
Company frequency by BO	Yes (top 10%: 31-202)	Yes (top 20% 8 - 312)	Yes (top 10% 7-122)*	n/a	Yes (top 10%: 8-495)	Yes (top 10%:9-1324)
BO information change frequency	Yes (top 1%: 4 - 11)	Yes (top 1%: 3 - 7)	n/a	n/a	n/a	n/a
No BO data	No	No	Yes	Yes	Yes	Yes
BO age in years (max)	n/a	n/a	Yes (top 10% 71-86)	Yes (top 1 % 78-92)	n/a	Yes (bottom 10%: 0-37)
BO country: Foreign	No	No	No	Yes	No	No
BO country: Sanctions	n/a	n/a	No	No	No	Yes (residence)
Company age in years	Yes (bottom 10%: 0-4)	n/a	n/a	Yes (bottom 3%: 0-2)	n/a	n/a
BO PEP	n/a	n/a	n/a	n/a	Yes	n/a

Notes* 1 outlier was removed

possible (see n/a values in Table 10) due to a lack of data. This typically means that the necessary variable was missing in the BO dataset (e.g., many BO datasets do not record the company foundation year, hence the company age risk indicator cannot be calculated). N/a can also mean that while the underlying data is theoretically available, in practice, there was little to no variation for conducting meaningful statistical tests (e.g., only a handful of public procurement suppliers with owners linked to sanctioned countries).

While, unfortunately, not all hypothesized relationships could be tested in all countries, an overwhelmingly positive and varied picture of BO-risk indicator validity emerges in Table 10. First, BO-risk indicators capturing unusual and outlier BO features—high company frequency of BO, frequent information change, outlier BO age, and no BO data—all perform very well, as expected in the literature (Carbone et al., 2023; Jofre & Knobel, 2025). The no BO data indicator occasionally works in the opposite direction, which may indicate matching quality issues rather than a lack of indicator validity. Second, BO-based risk indicators relating to BO countries, such as sanctioned jurisdictions, largely fail to relate to public procurement corruption risks in line with expectations, even though there are notable examples where we find the hypothesized relationship. This may indicate that using domestic nominees is preferred by corrupt groups compared to relying on foreign jurisdictions. Nevertheless, the fact that a large number of BOs from high-risk jurisdictions can still be found among public procurement winners with high corruption risks is notable. Finally, BO-based risk indicators, which have already been widely validated using different data sources - company age and political connections - also turn out to be valid in our regressions. This provides further evidence of the value of BO datasets and the robustness of our methodology.

Detailed Results by BO risk Indicator

Regarding the *company frequency by BO indicator*, we expect that unusually high values indicate elevated corruption risks in public procurement, (Bosisio et al., 2021, FATF-Egmont Group 2018, Global Witness, 2019), unless the individual is a known billionaire, which is expected to be rare. This is exactly the relationship we find in all countries where such information is reliably available, that is, in Denmark, Estonia, Latvia, Ukraine, and the UK. Taking the example of the UK (Table 10), we find that a low to moderate number of companies owned by the BO of the public procurement supplier are associated with average CRI after controlling for a host of confounders. However, when the number of companies is very large or an outlier, we find a distinct jump in procurement risks. The riskiest interval of this indicator corresponds to the top 10% of values, ranging from 9 to 1324 companies owned by the very same person (Fig. 1). This risk indicator corresponds to other documented cases of corruption in public procurement, as seen in cases 1 and 2 of Annex F. The UK has the most extreme outliers for this indicator, while other countries also have implausibly high values, going up to 100–300 companies per individual. This risk indicator, however, could not be reliably calculated for Slovakia, where not all companies are required to provide information about their beneficial owners[8] only companies that have government contracts worth more than 100 thousand EUR.

Regarding *the indicator on BO information change frequency*, we expect that multiple changes in the data for a company's BOs relate to higher public procurement corruption

[8] https://transparency.sk/wp-content/uploads/2017/06/Register-of-beneficial-ownership_study2017.pdf.

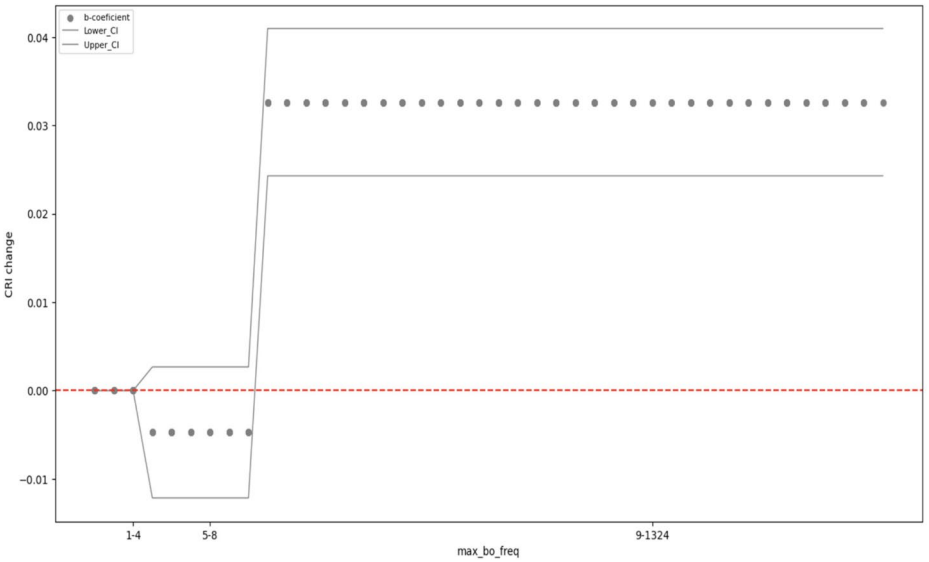

Fig. 1 CRI and the number of companies owned by the same BO in the UK

risks. This is because changes in BO administrative records may obfuscate real ownership, for example, around checks on the company bidding for a contract. For more on this expectation see European Banking Authority (2021) and Bosisio et al. (2021); and also consult documented cases 3 and 4 in Annex F. Although we could only calculate this indicator in Denmark and Estonia, both countries' results point to the hypothesized positive relationship. In Estonia, the range of risky values falls between 3 and 7 changes, corresponding to the top 1% of the BO information change distribution (Fig. 2). In Denmark, high-risk BO indicator values are rather similar, 4 to 11 changes, again corresponding to the top 1% of the continuous distribution.

Concerning the *no BO data indicator*, according to the literature, we expect that having no beneficial owner information is associated with higher public procurement corruption risks, as not fulfilling reporting requirements can effectively hamper scrutiny (Amberger et al., 2025; Bosisio et al., 2021; Jofre et al., 2021). For related proven cases see Annex F, cases 5 & 6. This hypothesized relationship could be identified in 4 out of 6 countries: Latvia, Slovakia, Ukraine, and the UK (Fig. 3). In Ukraine, after the passing of legislation that makes it possible to ban a bidder from participating in public procurement due to the lack of submitting information about its beneficial owners, we see a decrease in the number of companies with no BO information, which can explain the strong relationship we see between having no BO data and higher risks in CRI. In all of our countries, the no BO information indicator is most likely a noisy measure of actually neglecting legal requirements. This is due to a number of potential data errors and complications. Public procurement datasets have a limited number of bidder ID codes that make the matching less accurate, for example, in the UK. A further problem is posed by subsidiaries of publicly listed companies from abroad. While we could identify domestically listed companies and hence remove them from the analysis (listed companies do not have to submit BO data), if the ultimate owner company

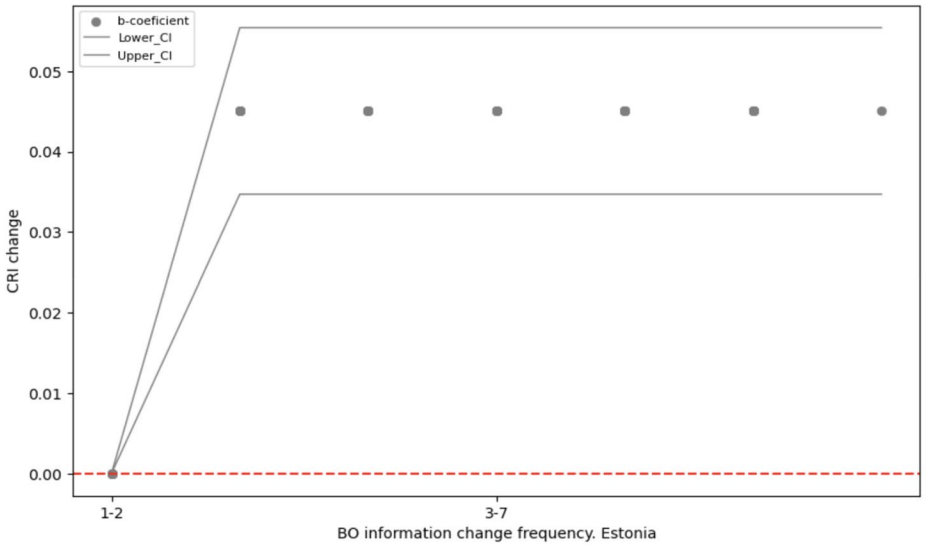

Fig. 2 CRI and the number of changes to BO data in Estonia

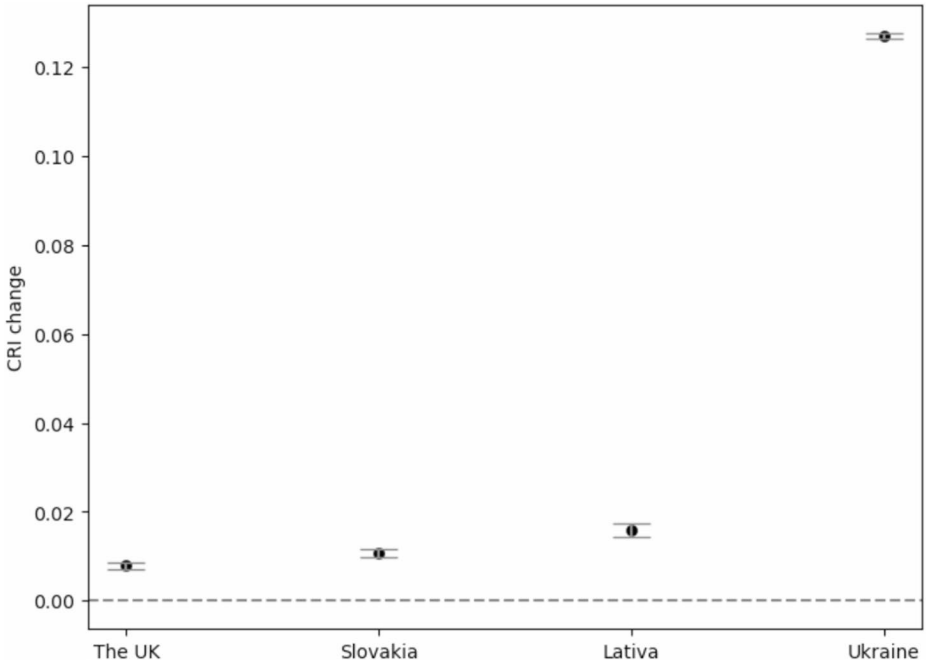

Fig. 3 CRI and no beneficial owner data in selected countries

is listed abroad, we could not reliably identify the relevant domestic subsidiaries, so they remain in the analysis even though they have legitimate reasons for not submitting BO data.

Regarding *the age of the BO*, we expect that extremely young or old owners would be related to higher corruption risks, as these individuals are more likely to be nominees or strawmen (Bosisio et al., 2021; Global Witness, 2019; OCCRP, 2022; cases 7 & 8 in Annex F). We saw such relationships in all the countries where we have the necessary data: Latvia, Slovakia, and the UK. Nevertheless, the particular age group related to the higher risk of corruption in public procurement changes by country. In the UK, BOs younger than 37 years (i.e., the bottom 10% of the age distribution) are riskier (Fig. 4-Panel A), while in Latvia, BOs older than 71 years (i.e., the top 10%) are related to higher public procurement risks (Fig. 4-Panel B). Slovakia is similar to Latvia, showing higher risks among older BOs.

Now we turn to *BO country*, *either citizenship or residency*. Regarding foreign BOs, the expectation is that foreign BOs might escape scrutiny by virtue of being foreigners, e.g., making identity checks harder (Bosisio et al., 2021; Baquero et al., 2021; European Banking Authority, 2021; FATF-Egmont Group, 2018). However, this indicator is likely very noisy, grouping a range of more and less risky countries under one category. In line with this, foreign BOs are not associated with higher corruption risks in 4 out of 6 countries, with Slovakia being the exception, where foreigners are of higher risk across the board. For Latvia, both foreign nationality and residence are risky vis a vis single bidding. For the UK, some nationalities/residencies are risky, but all foreigners as a category are not risky because a significant group of foreigners are from well-developed, low-risk countries.

We also analysed a specific hypothesis relating to a narrower category of BO countries (citizenship or residence), namely sanctioned countries. In most countries, we did not find empirical support. The only country where the empirical material partially confirms the hypothesis of higher risks associated with sanctioned countries such as Russia, Belarus, Iran is the UK (Fig. 5). Unfortunately, due to the too low number of observations, we could not test many of the BO country-based indicators; data was especially sparse in Estonia. Nevertheless, it must be noted that specific country nationals or residents may be risky in selected contracting countries, as for example Chinese citizens or residents appear to be associated with higher public procurement risks in the UK.

In this paper, we also tested ownership-based indicators already established in the literature (Carbone et al., 2023; Jofre & Knobel, 2025). With regards to the relationship between the *age of the company* at the time of receiving the contract and corruption risks in public procurement, we expect to see very young companies to have a higher CRI, in line with actual instances of corruption (cases 15–17, Annex F). This is exactly what we see in both countries where we had the necessary information to calculate this indicator: Denmark and Slovakia. In Denmark, companies younger than 4 years, i.e., those in the bottom 10% of the company age distribution, display considerably higher public procurement corruption risks (Fig. 6). For Slovakia, the interval for heightened corruption risks corresponds to less than 2 years, that is, the bottom 3% of the distribution.

Regarding *Politically Exposed Persons (PEPs)* or companies with political connections, we expect that PEP BOs display higher corruption risks in public procurement. (van der Does de Willebois et al. 2011). This is precisely the empirical relationship we find in Ukraine, the only country where the necessary political connections data is available (Fig. 7). These findings coincide with several well-documented cases (cases 18–24, Annex F). Some of the country's high-profile PEPs, like Rinat Akhmetov, Mykola Zlochevskyi,

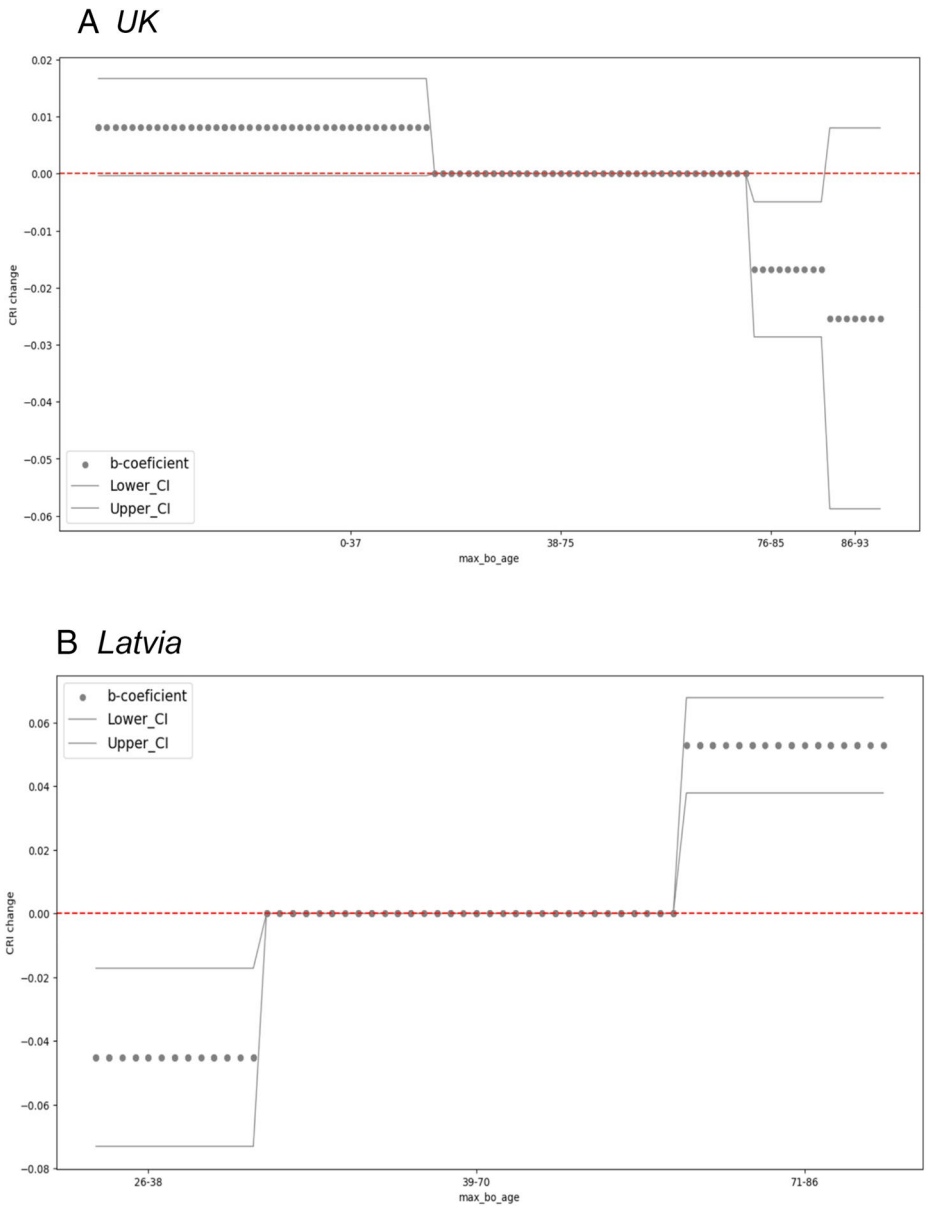

Fig. 4 CRI and the age of the beneficial owner

and Oleksandr Novynskyi, are connected to companies that provide services to the state, specifically in the energy sector (oil, gas, and electricity). Regarding this issue, some journalistic investigations (Nikolov, 2020) show a tendency of overpriced services and unfair procurement competition connected with PEP's companies in Ukraine.

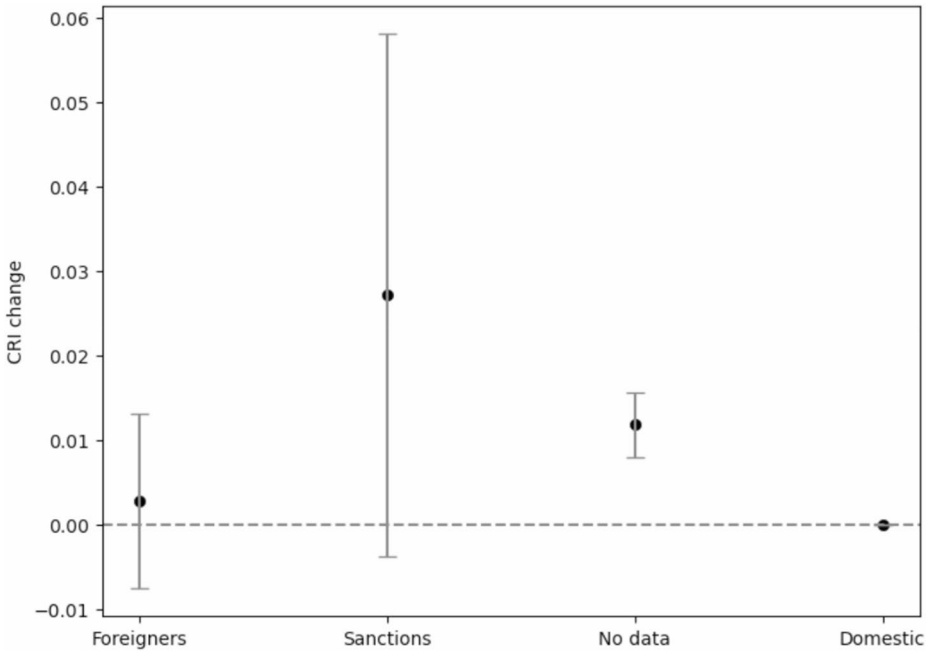

Fig. 5 CRI and the country of residence of beneficial owners in the UK

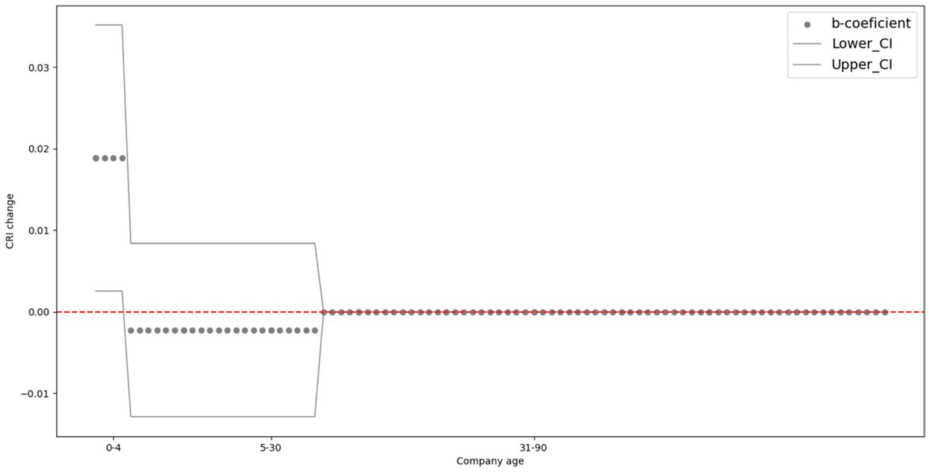

Fig. 6 CRI and company age at time of receiving the contract (years), Denmark

Discussion and Conclusions

The above analysis has amply demonstrated the value of linked beneficial ownership data and the new horizons it opens for analysing risks related to companies, but also to government contracts. We showed at scale, across six different European countries, that some, albeit not all,

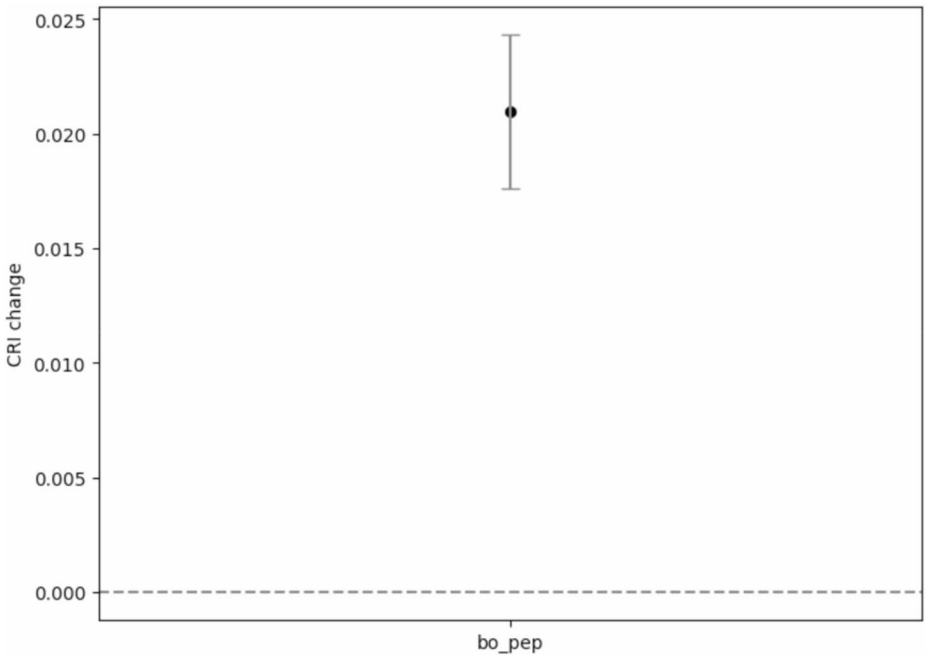

Fig. 7 CRI and BOs that are Politically Exposed Persons in Ukraine

theoretical expectations for BO data-based risk indicators are valid proxy indicators of corruption. In particular, indicators that relate to BO features, other than country, and indicators related to the company (e.g., company age at the time of winning the contract) are promising. The prime indicator types motivating BO registry creations, related to foreign and high-risk jurisdictions, turned out to be only moderately valid. This result may be driven by corrupt actors switching from hiding behind secrecy jurisdictions to using brokers and nominees.

One of our key contributions lies in demonstrating that, despite quality issues, certain variables in BO datasets are valid for systematically detecting both direct and indirect risks of corruption in public procurement. Two widely used validity concepts from the literature (Adcock & Collier, 2001) were employed to establish this. To conduct content validation, we showcased several corruption schemes (Annex F) that align theoretically with our definition of corruption as the violation of open and impartial access to government contracts to benefit a favored company or network of individuals (Fazekas et al., 2023). We also demonstrated the convergent validity of most of our BO-based indicators by showing the correlations between them and previously established public procurement risk indicators (OLAF, 2017).

Considering that most of our BO indicators (companies owned by the same BO, frequent changes in BO, age of BOs), which signal the use of nominees or strawmen, are valid, our findings line up with the existing literature on corrupt actors optimising their monitoring evasion behaviour (Aristodemou, 2024; Gilmour, 2020; Winter, 2019) and the ease with which they can conceal their true identities and circumvent transparency regulations (Transparency International, 2019; Bosisio et al., 2021; Knobel, 2019). This echoes broader findings in the literature that corrupt actors often adapt by shifting from offshore secrecy to

nominees, brokers, and other domestic intermediaries (Harari et al., 2020; Gilmour, 2020; Colin et al., 2023). Nonetheless, direct risks of corruption in public procurement, like BOs that are PEPs, also appear to be valid in the cases when data was available. This suggests that some high corruption risk and exposed actors may not fear sanctions and decide to conduct high risk activities in the open.

These findings have policy implications beyond BO regulations. They demonstrate that, for specific transparency regulations to achieve their objective of deterring financial crime, a multi-pronged approach must be undertaken. One that considers the importance of having up-to-date, reliable data that various actors can use. It also highlights the importance of interconnecting databases to prevent, detect, and investigate instances of corruption in public procurement (Tello-Arista & Fazekas, 2024). In addition to considering indirect approaches to detecting risks of corruption, given the adaptability of corrupt actors to transparency regulations.

One of the underlying goals of BO risk indicator validation is to use them for systematic risk assessment across countries as well as over time within the same country or looking at meso and micro actors such as regions or individual procuring authorities. In order to demonstrate the scale of the uncovered valid BO risk indicators and their relevance, we tabled the share of government contracts going to a flagged supplier (Table 11.). These simple descriptive statistics reveal that Denmark and the UK often, albeit not always, harbour lower BO risks than their lower integrity peers, such as Ukraine. Even though the lack of comparable data and valid indicators across all six countries limits the cross-country comparability of results. Nevertheless, the prevalence of various risk factors ranges from niche (0.03, 0.6, 0.7%, etc.) to widespread (50–60% of contracts). This is hardly surprising as the BO risk indicators capture very different potential corruption schemes, and they suffer from data quality errors to different degrees. Unsurprisingly, the lack of BO data is the most widespread risk factor, which includes both benign administrative errors and corrupt intent to hide information. This finding underlines a point emphasized in prior research: missing or low-quality ownership data is itself a red flag (Open Ownership 2023).

Table 11 Prevalence of validated BO risk features in public procurement

Risk Indicator	Denmark	Estonia	Latvia	Slovakia	Ukraine	UK
Company frequency by BO	4.0%	13.8%	7.7%	n/a	12.3%	1.6%
BO information change frequency	0.2%	3.2%	n/a	n/a	n/a	n/a
No BO data	not valid	not valid	53.2%	39.0%	25.9%	68.3%
BO age in years (max)	n/a	n/a	0.7%	0.6%	n/a	1.7%
BO country: Foreign	not valid	not valid	not valid	5.9%	not valid	not valid
BO country: Sanctions	n/a	n/a	not valid	not valid	not valid	0.2%
Company age in years	3%	n/a	n/a	1.5%	n/a	n/a
BO PEP	n/a	n/a	n/a	n/a	0.6%	n/a

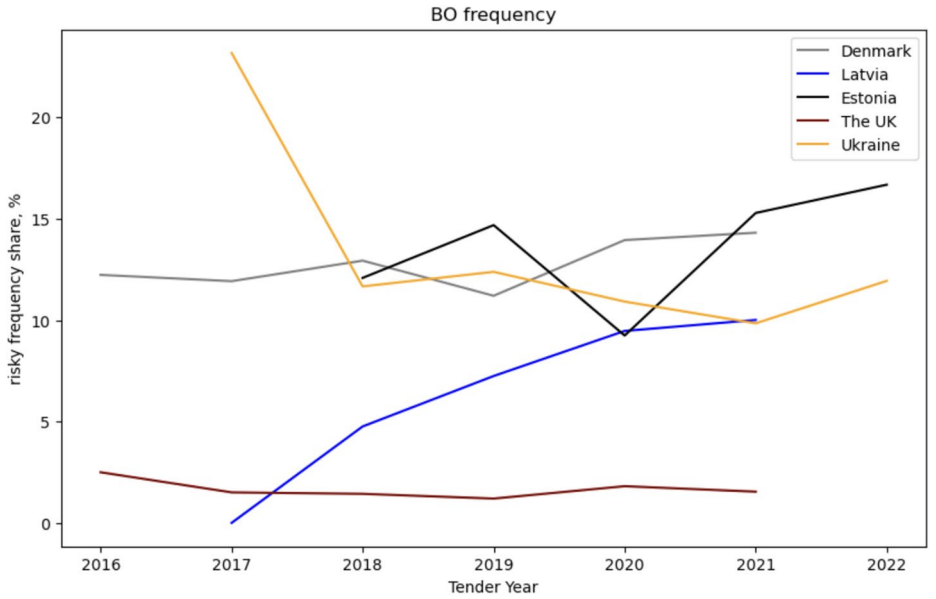

Fig. 8 Company BO frequency risk factor prevalence in public procurement, Denmark, Estonia, Latvia, Ukraine, and the UK

In order to additionally demonstrate the statistically desirable properties of the validated BO risk factors, we also show that they vary over time within the same country (Fig. 8). The UK shows a stable, low prevalence of this BO risk factor, while Ukraine substantially lowers its prevalence over time.

Our results also point out the diversity of BO register and procurement system contexts and the corresponding diversity of risky transactions and features. While the indicator calculation and measurement logics are generic, their country-specific realisations are diverse and context-dependent. This also includes great differences across countries in terms of data quality. Given that missing information can serve as a reliable risk indicator on its own, the relationship between the usefulness of BO datasets and their quality is by no means straightforward. Our results showcase the applicability of BO data for systematic risk assessment, which opens the door for a range of policy and research applications. BO risk indicators can be used to track the impact of policy interventions such as improved identity verification of BOs. Risk factors can also help target preventive measures, such as enhanced compliance checks on risky government suppliers and bidders. Moreover, investigations can be supported by flagging potential nominee BOs rather than taking the data at face value; hence, unblocking investigative leads.

Nevertheless, our parametrisation of the BO-based risk indicators is by no means perfect, calling for research refining and further validity testing these risk indicators, for example, by linking them to proven cases of corruption in the country analysed. Moreover, future research could also identify additional BO-based risk indicators, like the role offshore jurisdictions[9], improving the comprehensiveness of the measurement framework.

[9] Some jurisdictions may be more ready to offer legal services enabling the use of nominee business ownership as some documented cases point at such risks in public procurement (cases 9–14 Annex F).

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Authors' Contributions Conceptualization: ITA, MF; Methodology: MF, AV; Data preparation: AV; Data analysis: MF, AV; Writing: ITA, MF, AV; Funding acquisition: MF.

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Data Availability The dataset used in the analysis is deposited at Mendeley data: https://data.mendeley.com/datasets/s6skkpwzs6/2.

Declarations

Ethics Approval and Consent to Participate The research is exclusively based on publicly available administrative data which have been used and processed in line with the goals of publishing the datasets by the respective governments.

Consent for Publication All authors gave explicit consent for publication.

Conflict of Interest The authors have no competing interests to declare that are relevant to the content of this article.

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