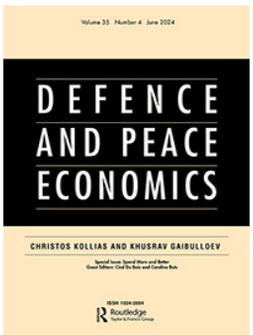

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ARTICLE

The Spectrum of Strategic Autonomy in EU Defence Supply Chains

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ABSTRACT

The Strategic Compass aims to strengthen the resilience of defence-industrial supply chains and complements the long-term strategic ambition of enhancing the EDTIB. Impetus for restructuring the EU's supply chains may be provided by the 2022 Russian invasion of Ukraine, the associated increase in defence budgets, and the promotion of joint projects and cross-border M&A. Since the prospect of achieving strategic autonomy also depends on how 'local' current supply chains are, we offer an in-depth investigation of three dimensions related to foreign dependency (company ownership, tender success, supply chain participation). Despite mean scores of non-EU ownership in the range of 25-30% for the EU's largest defence firms, foreign ownership does not necessarily threaten the EU's security of supply. Nevertheless, the participation of non-EU firms concerning M&A with high relevance for the EU defence industry increases, as does the share of defence-related EU tenders that are won by non-EU firms. An assessment of four multinational military aircraft programmes further exemplifies that the EU's defence R&D and production capabilities may critically depend on outside suppliers. We thus find that the importance of non-EU actors for the EU's defence industry is large and may not easily be mitigated, particularly if commodity imports are considered.

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Defence industry; EU strategic compass; European Defence Technological and Industrial Base (EDTIB); supply chain dependency; industrial policy

JEL CLASSIFICATION
L60; L64; F50

Introduction

On 21 March 2022, roughly one month into Russia's invasion of Ukraine, the Council of the EU adopted a new action plan: the so-called 'Strategic Compass'. Described as an '*ambitious but achievable plan to strengthen* [the EU's] *security and defence policy by 2030*' (EEAS, 2022), it aims to enhance and integrate defence investments, boost international partnerships, and improve the EU's threat assessment and crisis responsiveness.

Many of the objectives and propositions of the Strategic Compass directly target the EU's security and defence industry – more precisely, the European Defence Technological and Industrial Base (EDTIB). To improve the EU's security of supply and strengthen the resilience of critical supply chains in the defence realm, the proposed measures include higher investments in key technologies, selective protectionism, and the reduction of foreign dependence (EEAS, 2022). By securing the EU's access to critical components, technologies, resources, and services (such as Maintenance,

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Repair and Operations (MRO)), the Strategic Compass complements the EU's long-term strategic aim of enhancing the EDTIB.

Recent events, including the COVID-19 pandemic and the 2022 Russian invasion of Ukraine, have underlined the vulnerability of the EU's global supply chains and its dependence on foreign partners. Enhancing the EU's strategic autonomy in the security and defence realm via stronger and more resilient supply chains, as targeted by the Strategic Compass, therefore appears imperative. However, for this strategy to be successful, various obstacles may have to be overcome. For example, import diversification could be hindered by a scarcity of available sources, and foreign control of EU suppliers may result in competing economic or strategic interests. To assess the prospects of enhancing the EU's strategic autonomy, it must be understood how 'local' its current defence-related supply chains are.

This article aims to study the dependency of the EU's defence-industrial supply chain along three dimensions, thereby providing a detailed insight into the wide spectrum of strategic autonomy. We investigate the following dimensions: (1) non-EU ownership of EU defence firms, (2) non-EU success in EU security and defence tenders, and (3) non-EU participation in the supply chain of collaborative EU defence programmes. For each dimension, we evaluate the implications for strengthening the resilience of EU defence-industrial supply chains. The remainder of our multi-approach article is structured according to these three dimensions. A concluding section combines our findings, discusses opportunities for future research, and provides a complementary analysis on foreign dependence in terms of commodities.

Dimension 1: Ownership of Leading EU Defence Firms

As a starting point of our assessment of strategic dependencies, this first dimension investigates the degree of non-EU ownership in the EU's leading defence firms.

Overview and Research Question

The EU defence industry is not 'large' compared to civilian sectors such as food, automotive, energy, insurance, banking, retail, telecommunications, or pharmaceuticals,[1] but its importance may not be judged solely on economic grounds. Rather, the ability to equip armed forces is related to perceived sovereignty and national security (Barrinha 2010). In conflict periods, defence industries can be tied to the very survival of states (Taylor 1990). Reasons for national interest in defence industries may be found, inter alia, in the protection or promotion of technologies, know-how, and employment against non-friendly states (Barrinha 2010; Fiott 2015). Foreign ownership then adds a notable layer of complexity.

Since the early 1990s, the EU defence industry has experienced considerable cross-border integration in terms of ownership as well as control, both within the EU and with outside partners. These developments have received much attention (e.g. Hartley 2017; Smith 2013; Markowski and Wylie 2007; Guay 2005; van Scherpenberg 1997), but the resulting impact on ownership structures of EU defence firms has rarely been assessed empirically. While some studies address the topic (e.g. Braddon and Bradley 2005; Belin and Masson 2017; Belin, Fawaz, and Masson 2019; Curic, Pena, and Rico 2022) an in-depth analysis of ownership data exclusively for EU defence firms has not yet been conducted. Since this analysis is paramount in view of strategic autonomy, we subsequently determine to which degree the EU's leading defence firms are controlled by non-EU owners.

Data and Methodology

We first identify 50 leading EU27 defence firms and collect data on their total and defence revenue.[2] We base our compilation on the Stockholm International Peace Research Institute (SIPRI, 2021), Defense News (2021), corporate and governmental sources. For each firm, we then obtain ownership

information from the *ORBIS* database maintained by *Bureau van Dijk*. This data includes, inter alia, the name, shareholding, country of origin, and type[3] of the owners. To our knowledge, this data has previously only been applied by Belin and Masson (2017) and Belin, Fawaz, and Masson (2019) to assess ownership structures of the EU defence industry. In contrast to these authors, we base our analysis on an exclusive EU sample which allows for a more in-depth analysis of patterns related to national links, cross-shareholdings, and firm types.[4]

Five firms in our sample are trans-European (*Airbus*, *Eurenco*, *GDELS*, *KNDS*, *MBDA*). Most of the remaining firms originate in Germany (15), France (9), Italy (4), Belgium (4), Spain (3), and Sweden (3). Looking at these countries' industry structure, we can presume that our sample covers the lion's share of these countries' national DTIBs. The number of non-negligible owners per firm[5] ranges from one (e.g. *Navantia*, *Damen*) to more than 80 (e.g. *Indra Sistemas*, *MTU Aero Engines*), with a mean value of about 20. Unsurprisingly, it is significantly higher for publicly listed firms than for state- or family-owned firms.

Results and Discussion

Main Findings for Non-EU Ownership

After constructing our dataset, we calculate mean and median scores of EU and non-EU ownership. To account for size differences, we also report weighted samples based on total and defence revenues. Our empirical results in Table 1 show that non-EU shareholders own, on average, more than 30% of the leading EU defence firms. The differential between mean and median scores indicates that the skewness of EU ownership in our dataset is reduced in the weighted samples. If weights are applied according to defence revenues, mean non-EU shareholding falls to 25%, which reflects higher degrees of non-EU ownership among the smaller firms in the dataset.

Non-EU ownership is mainly distributed among owners from the U.S, the U.K, and (to a much lesser extent) other Western countries such as Canada, Norway, and Switzerland. Systemic or geopolitical rivals to the EU (Russia, China) play virtually no role in the ownership of its largest defence firms. Additional industry research confirms that owners from these countries only control a few smaller players.

Our results further show that non-EU ownership is strongly influenced by firm type. All publicly traded firms in the dataset display some degree of non-EU ownership. Those with 100% EU ownership are mostly state-owned (e.g. *Navantia*, *Polska Grupa Zbrojeniowa*), family-owned (e.g. *Damen*, *Diehl*, *Lürssen*) or a combination of both (e.g. *KNDS*).[6] If state- and family-owned firms are excluded, mean EU ownership falls to about 52% (unweighted sample) and 68% (weighted with defence revenue). Subsectors may also play a role: for example, mean EU ownership is significantly higher for naval shipyards than for the remaining firms in the dataset (92% vs. 72%, samples weighted with defence revenue).

Table 1. Ownership of the largest EU27 defence firms by origin (2021).

	Ø ownership in %			Median ownership in %		
Weight	None	Total revenue	Defence revenue	None	Total revenue	Defence revenue
EU27	67.8	71.6	75.0	86.5	73.4	75.6
U.S.A	11.7	18.1	15.9	0.0	19.5	16.5
U.K	10.2	6.0	5.9	0.0	7.1	6.2
Other non-EU27	10.3	4.3	3.2	0.0	0.0	1.7
Obs.	50	49	34	50	49	34

Source: Own analysis based on Bureau van Dijk (2022), SIPRI (2021), Defense News (2021), corporate and governmental publications. *Notes*: Numbers are approximate as the exact distribution of minor shareholdings is not always known. For several firms, revenue data could not be obtained (as indicated by the number of observations). In column 5, the median for a combined "non-EU27" subgroup would account for the remaining 13,5%.

Table 2. Ownership patterns within national subsamples.

	Ø ownership in % (weight: defence revenue), lower bound*					
Subsample	France	Germany	Italy	Spain	Sweden	Trans-European
France	61.6	2.8	1.6	1.9	<0.1	n/a
Germany	0.4	26.4	0.1	1.1	<0.1	n/a
Italy	<0.1	3.3	38.4	0.4	<0.1	n/a
Spain	<0.1	0.2	<0.1	74.5	<0.1	n/a
Sweden	0.7	2.8	<0.1	<0.1	64.4	n/a
U.S.A	11.1	23.8	18.8	17.7	15.3	18.1
U.K	4.8	5.1	3.4	4.9	15.1	8.6
Obs.	7	8	3	3	3	4

Source: Own analysis based on Bureau van Dijk (2022), SIPRI (2021), Defense News (2021), corporate and governmental publications. *Notes*: n/a=not available. *Remaining shareholdings (not displayed): other EU/non-EU owners and minor shareholders (for whom the exact distribution is not always known; numbers are thus lower-bound estimates).

As our results may be linked to differences among EU Member States, we further separate the dataset into national subsamples. Like Belin and Masson (2017) and Belin, Fawaz, and Masson (2019), we find varying degrees of national linkages, although our larger EU database sometimes produces different results. After applying weights based on defence revenues, we find that national owners hold, on average, about 26% of Germany's leading defence firms. Higher levels are found for Italy (38%), France (62%), Sweden (64%), and Spain (75%). Due to the small size of the subsamples, these findings are obviously prone to outliers (e.g. due to state- and family-ownership). Furthermore, cross-shareholdings among the leading EU defence firms are often substantial.[7] Despite these restrictions, the findings in Table 2 nevertheless reflect the well-known differences in the approaches towards *national champions*.

Ownership Vs. Control

Mean scores of non-EU ownership in the range of 25-30% appear substantial, but a distinction should be made between full control by individual non-EU entities and accumulated minority shareholdings. 11 of the 50 firms in our dataset are controlled by individual non-EU firms, including important system integrators (e.g. *GDELS*, *German Naval Yards*) and tier suppliers (e.g. *MTU Friedrichshafen*). Among the largest firms in our dataset, however, non-EU ownership is highly fragmented. As shown in Figure 1, the average shareholding of leading non-EU owners in the 10 largest publicly listed EU defence firms ranges between 0.8% and 4%. A high cumulative degree of non-EU ownership may therefore not equate to foreign 'control' if it is dispersed on numerous smaller shoulders. Furthermore, an average of 9 of the 10 largest non-EU shareholders of these EU defence firms are financial services firms or institutes, investment banks or funds, or insurance companies, and therefore less likely to interfere in strategic decisions.[8]

Given the overall fragmentation of non-EU ownership, we find little reason to be concerned with the '*common ownership problem*' identified by Curic, Pena, and Rico (2022). We do acknowledge that minority shareholders may exert strategic influence on defence firms' business decisions, but a significant impact on the landscape of the EU defence industry appears to be the exception rather than the rule.

Furthermore, foreign investment in important defence firms, sometimes even full takeovers, may be welcomed by national governments – either for economic reasons or as a chance to deepen strategic partnerships. For example, *GDELS* (*General Dynamics European Land Systems*), created by the US defence giant *General Dynamics* to manage several European acquisitions, is now a trusted partner for military modernisation moves in its 'home' countries (a recent example being Spain's *VCR 8 × 8 Dragon* project). *GDELS* exemplifies how defence firms often continue to 'act European' despite operating under non-EU ownership.

Finally, several examples from the EU demonstrate that foreign control of defence firms may be reversed if national governments see their vital interests at stake. Consider *Kockums*, whose sale to

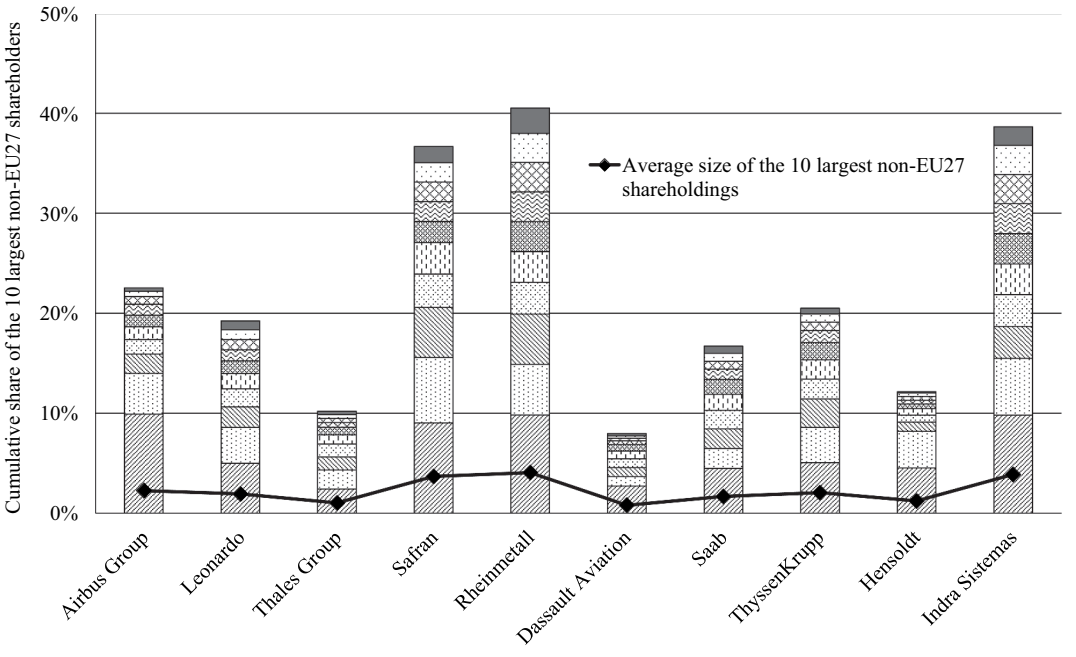

Figure 1. Cumulative ownership of leading EU defence firms by non-EU shareholders. *Source*: Own analysis based on Bureau van Dijk (2022).

Saab was pressured by the Swedish Government following Russia's annexation of Crimea and various violations of Swedish airspace (Lundmark 2014a, 2014b). In times of crisis, national governments in the EU can be expected to employ similar measures if they consider foreign ownership to contrast with their national security concerns.

Defence M&A Intensity

By providing an overall picture of the control of the EU's most important defence firms, the preceding analyses relate to the current EDTIB. This EDTIB partly results from an evolution of mergers and acquisitions (M&A) since the end of the Cold War that led to more convergence. We now complement our analyses by investigating the role non-EU firms in this consolidation process. Specifically, given the focus on strategic autonomy, we want to assess whether a pattern of non-EU M&A involvement can be observed.

To evaluate this question, we individually analyse 7.850 notified M&A cases from the European Commission's *Competition Cases Database* for the years 1990-2020 to determine whether they affected the defence-industrial supply chain.[9] Those M&A which are found to exhibit defence relevance are then further divided into two categories:

- **High defence relevance**: These M&A mostly affect core defence activities of leading defence firms (e.g. the formations of *Eurocopter*, *AgustaWestland* and *EADS*). However, smaller defence firms or subordinate activities of leading companies are also covered (such as *Rheinmetall*'s partial takeover of the specialized infrared systems supplier *AIM*).
- **Peripheral defence relevance**: Firms affected by these M&A have little direct involvement in the defence industry, but their products or services are relevant for the defence-industrial supply chain. Notably, this includes suppliers of raw materials or low-tier parts.

Table 3. Composition of the M&A dataset.

	Location target firm(s)	Location acquiring firm(s)	Number of cases	Share of dataset (in %)
All notified M&A, 1990-2020	Any	Any	7,850	100.0
No defence relevance	Any	Any	7,110	90.6
Peripheral defence relevance	Any	Any	416	5.3
High defence relevance	Any	Any	324	4.1
High defence relevance	EU27	Any	203	2.6
High defence relevance	EU27	Non-EU27	42	0.5

Source: Own analysis based on European Commission (2022a).

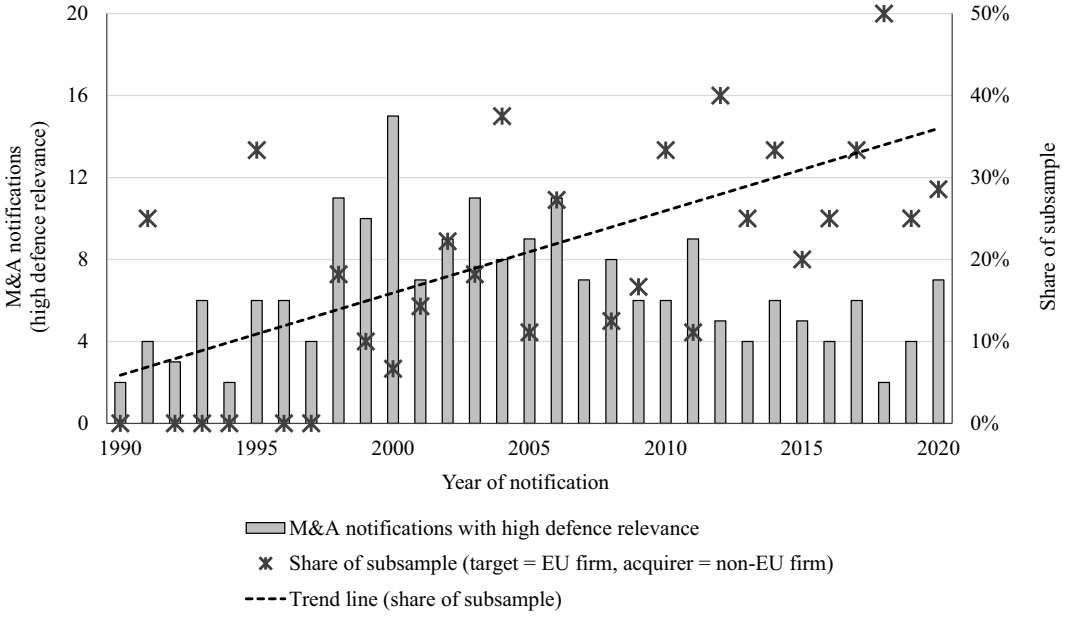

Figure 2. Takeovers by non-EU defence firms among EU M&A with high defence relevance. *Source*: Own analysis based on European Commission (2022a).

The composition of our dataset (Table 3) shows that 740 cases, about 9.4% of all M&A in the observed period, exhibit at least some importance for the defence-industrial supply chain. Of these, 324 (4.1%) fall into the *high defence relevance* category. Excluding cases wherein the acquired firm(s) are located outside the EU27 (e.g. in the US, UK, Norway, Switzerland) leaves 203 M&A in our dataset. These cases form the basis of the subsequent analysis. Most of these M&A happened in the first decennium of the new century (see Figure 2), with 15 M&A in 2000 as an absolute maximum.

Our dataset covers 42 takeovers of EU firms with high defence relevance by non-EU firms.[10] These takeovers are not distributed evenly over the years 1990-2020: whereas the involvement of non-EU partners used to be the exception rather than the rule, Figure 2 shows an increasing trend. While the number of takeovers with high defence relevance was rather low during the most recent decade, the share of takeovers by non-EU partners was relatively high (between 20% and 50%).

Hence, whereas our previous analyses indicated that 'only' about 25-30% of the leading EU27 defence firms are owned by non-EU shareholders, our study of the most recent takeovers in the broader defence industry shows an increasing activity of non-EU players. Moreover, many of the most recent takeovers target high-end technology firms.[11] Given the ever-growing importance of technology for the armed forces, a resilient and competitive industrial base requires the

development of next-generation technologies. While the EU should not fall into the trap of plain protectionism, it needs to be cautious not to lose control and sovereignty of assets and technologies which are crucial to its armed forces.

Dimension 2: Non-EU Involvement in EU Defence Tenders

Public procurement is an additional notable area in which strategic dependency can be revealed. In terms of security of supply, the possibility to fulfil public sector needs by partners within a strategic alliance (e.g. EU27, NATO) may be a crucial advantage.

Overview and Research Question

Public procurement may account for a substantial share of total demand in the EU (European Commission 2022c). Therefore, supplier robustness and trustworthiness are not only crucial for strategic aims, but also for the overall health of the economy. Severe supply chain problems during as well as resulting from the COVID-19 pandemic and the 2022 Russian invasion of Ukraine underline this (Jagtap et al. 2022) – in both cases, the inability to fulfil public sector demand hampered reaching strategic objectives. This, in turn, led to economic issues (Borrell 2022), and vice versa.

In times of uncertainty, international trade may be disproportionally impaired for strategically sensitive sectors. The export bans on commodities to fabricate COVID-19 vaccines (Peters and Prabhakar 2021) as well as the suspension of gas and wheat exports from the Ukraine and Russia can be instructive (Polityuk and Hunder 2022). Another prime example is found in security and defence-related public procurement, which recently gained a prominent place on the political agenda, not least through its central inclusion in the Strategic Compass (Sweeney and Winn 2022). An explicit aim of the Strategic Compass is to build and fortify the EDTIB via increased spending, specifically to reduce dependencies both in the technological and industrial realms (EEAS, 2022).

The politically strategic nature of security and defence spending has been well-established in the literature (see, e.g. Hartley 2000). Notably, extant research demonstrates that public procurement in this sector is driven by geopolitical interests to a larger extent than in other sectors (Kollias and Tzeremes 2022; Mawdsley 2018). Obviously, the success of strategies aiming to foster intra-alliance security and defence procurement crucially depends on (1) alliance partners factually producing the required product or service, and (2) congruent (economic) interests among said partners. It has been argued that these caveats are particularly relevant for the EU27 (Besch 2019; Calcara 2020b).

To provide empirical benchmark data for the Strategic Compass, we map recent EU27 public procurement award practices. Focusing on the period from 2016 onwards, this section performs an econometric analysis of EU27 security and defence-related public procurement procedures to assess the importance of, and thus reliance on, non-EU 27 suppliers.

Data and Methodology

To investigate security and defence-related public procurement procedures of the EU27, we use data from the EU's *DIGIWHIST* project (2022). A key deliverable of the project was to set-up and host the *OpenTender.eu* platform, which contains data on tenders from 33 issuing countries, including the EU27. This dataset was compiled by scraping *Tender Electronic Daily* (TED), as well as national public procurement portals (Hrubý et al. 2018). The strength of this platform stems from the richness of the individual tender data, including on the entire public procurement cycle: from the selection of the number of technical criteria to the full contact details of the winning bidder.

Since *OpenTender.eu* does not cover all national public procurement portals, and since national data strongly varies in quality and completeness (Hrubý et al. 2018), our analysis solely covers tenders included in the TED subsample. Thereby, we safeguard comparability between the EU27 and maximise data representativeness. Focusing on the TED subsample likely excludes defence

Table 4. TED tender attrition to arrive at final sample.

	Number of TED tenders	Share of dataset (in %)
All TED tenders	4,212,180	100.0
EU27 TED tenders	3,794,071	90.1
EU27 TED tenders since 2016	2,044,919	48.5
Defence-related EU27 TED tenders since 2016	12,604	0.3

Source: Own analysis based on eu (2022).

procurement that is exempt from reporting requirements and/or subject of government-to-government agreements, but an analysis of this sample allows going beyond case studies to quantitatively determine factors of influence in public procurement awards. The starting point of our analysis (2016) is arguably significant for EU27 security and defence procurement due to this year's State of the Union address by former Commission President Juncker, which stressed the need of a more integrated defence approach (Juncker 2016), and the subsequent communication of the European Defence Action Plan (EDAP). Moreover, as we aim to assess current procurement practices, our focus on a recent period is justified.

To classify public procurement procedures thematically, the *Common Procurement Vocabulary* (CPV) is used. The CPV consists of 45 tender subjects ranging from agricultural machinery to R&D services (Regulation (EC) 2195/2002, 2002). For our analysis, we focus on tenders classified under CPV code 35 ('Security, fire-fighting, police and defence equipment'). As shown in Table 4, this (broad) definition of security and defence-related procurement narrows the final sample for our econometric investigation down to 12,604 EU27 TED tenders for the period ranging from 2016 to 2020 (about 0.3% of the entire TED database).

We analyse our final dataset by means of logistic modelling. This explorative approach allows us to gain valuable insights by uncovering determinants of non-EU27 bidding success in EU27 security and defence-related tenders.

Our structural logistic model, with the dependent binary variable $EU27\ Winner_i$, is presented in the following formula[12]:

$$EU27\ Winner_i = Constant + \beta_1 Bids_i + \beta_2 Tender\ Value_i + \beta_3 Award\ Criteria_i + \beta_{4-7} Year_i + \beta_{8-34} Buyer\ Country_i + \varepsilon_i$$

with *i* denoting the individual security and defence-related tender.

The dependent variable equals 1 when a tender is won by an EU27 bidder, and 0 otherwise. Therefore, the estimated signs indicate whether the various independent variables constitute markers for dependency (-) or independency (+). In essence, the investigation assesses the effect of (1) tender competition levels, proxied by the number of received bids, (2) tender value, and (3) tender complexity, proxied by the number of award criteria, on the probability of an EU27 bidder winning a certain security and defence-related tender. The model is run with controls for the issuing country and the year in which the tender was issued. Table 5 gives an overview of the dependent and independent variables.

Table 5. Overview of logistic model variables.

Variable	Description
$EU27\ Winner_i$	Binary variable (equals 1 if the tender was won by an EU27 bidder)
$Bids_i$	Number of bids received in response to the tender
$Tender\ Value_i$	Value of the tender (in tens of millions of euros)
$Award\ Criteria_i$	Number of award criteria of the tender
$Year_i$	Year in which the tender was issued

Source: Own analysis based on eu (2022).

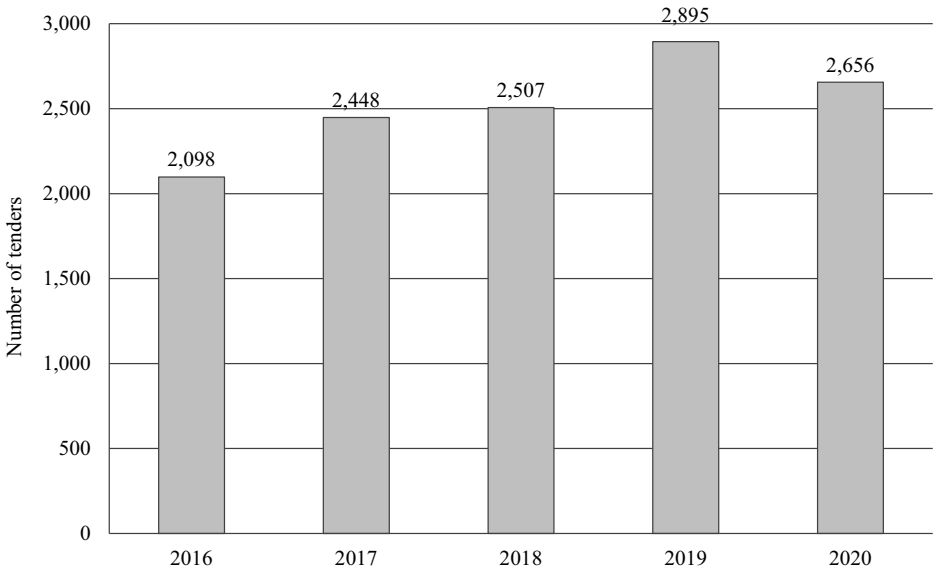

Figure 3. Annual number of security and defence-related EU27 TED tenders. *Source*: Own analysis based on OpenTender.eu (2022).

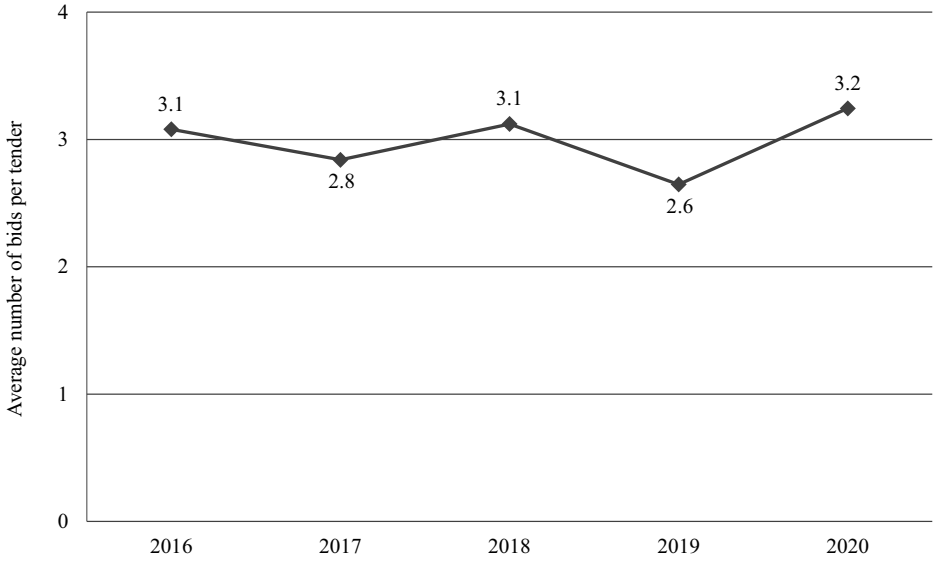

Figure 4. Number of bids for security and defence-related EU27 TED tenders. *Source*: Own analysis based on OpenTender.eu (2022).

Results and Discussion

As shown in Figure 3, the annual number of the 12,604 security and defence-related EU27 TED tenders covered by our analysis has increased during the investigated period (from about 2,100 in 2016 to almost 2,700 in 2020). During the same period, the average value of these security and defence-related tenders rose from about 2.1 to 3.3 million euros.[13] The growing market size (at least in nominal terms) underlines its ongoing relevance as a strategic sector of interest.

Table 6. Leading countries of provenance of winning non-EU27 bidders.

Country of provenance of winning bidders	EU27 TED defence tenders won since 2016
U.S.A	177
U.K	102
Switzerland	36
Norway	24
Israel	18
China	16
Canada	14
Brazil	11
U.A.E	7
Lebanon	7

Source: Own analysis based on eu (2022).

Figure 4 highlights that average competition remained largely constant over the investigated period with about three received bids per tender. Due the nature of the sector, the minimum viable size of a firm is quite elevated, and scale advantages are widespread (Hartley 2000). As a result, competition is limited. The low average number of received bids impacts the tender issuers' leeway to integrate certain demands in their tender documents: overly ambitious tenders might quickly receive only a single bid, or none at all.

Our main interest is the dependency of EU27 tender issuers on non-EU27 bidders. In numerical terms, 448 tenders were won by non-EU27 bidders, while the remaining 12,156 tenders were fulfilled by bidders from the EU27. From Table 6, which displays the most common countries of provenance of winning non-EU27 bidders, it appears that EU27 countries are mostly dependent on members of common (strategic) alliances (e.g. the EEA and/or NATO). Nevertheless, countries such as Israel, China, and Brazil are likewise represented among the top 10. Of course, the importance and intricacy of the individual tenders likewise play a role.

To determine the factors that significantly influence the likelihood of a non-EU27 bidder winning a security and defence-related tender issued by an EU27 country, we apply our above-presented explorative logistic regression model to 5,228 of the 12,604 security and defence-related EU27 TED tenders.[14] Table 7 presents the regression results.

A *first* relevant insight is that, as the number of bids for a tender grows, the probability of having an EU27 winner significantly increases (by 7.9% in terms of likelihood per additional bid). More choice is advantageous in public procurement procedures, as it increases the leverage of the issuer vis-à-vis the individual bidders (Graeus 2016). The fact that non-EU27 bidders are comparatively

Table 7. Logistic regression estimates of determinants in EU27 wins in defence-related EU27 TED tenders since 2016.

	EU27 Winner
Bids	0.0761***
	(0.0278)
Tender Value	−0.1434***
	(0.0382)
Award Criteria	0.0830
	(0.0751)
Constant	3.6360***
	(0.4186)
Observations	5,228
Pseudo R^2	0.2592
Year FE	Yes
Buyer Country FE	Yes

Source: Own analysis based on eu (2022).
Notes: Standard errors in parentheses.
*** p <0.01, ** p <0.05, * p < 0.1.

more successful in less competitive tenders could signal a lack of internal EU27 options for these tenders.

Second, as tender value increases, it becomes less likely that an EU27 bidder wins a certain tender: an increase by 10 million euros is associated with a 13.4% drop in the probability of an EU27 bidder winning that tender. While the role of non-EU27 bidders might be limited in numerical terms, their weight in terms of value could thus be more pronounced. We ran a t-test to verify whether, in a univariate setting, there is a significant difference in average values of tenders won by EU27 and non-EU27 bidders. We find that the difference is indeed significant and quite large: the average tender won by a non-EU27 bidder is 3.7 million euros larger than those won by an EU27 bidder. This adds plausibility to the proposition that EU27 countries must rely on external suppliers for certain products or services due to a lack of EU27 production capabilities or capacities.

Third, there are considerable differences among EU Member States in their tendency to attribute security and defence-related tenders to non-EU27 bidders. Tenders issued in Finland, Denmark, and Luxembourg have the lowest probability of having an EU27 bidder as a winner, while those originating in Poland, the Czech Republic and Bulgaria have the highest likelihood in that respect. However, it should again be noted that our analysis solely includes tender data from the TED-database, and by consequence leaves out purchases which are performed under reporting exceptions and/or part of specific government-to-government agreements. Finally, the probability of having an EU27 bidder winning a security and defence-related public procurement tender significantly decreases over time in our sample, which suggests that the prominence of non-EU bidders is becoming more salient.[15] In view of attaining the aims of the Strategic Compass, it could be important to reverse this trend.[16]

The above analysis paints a mixed picture concerning the pursuit of the Strategic Compass' aims in terms of public procurement realities. While only a limited share of tenders is won by non-EU27 bidders (in absolute numbers), this dependency has been growing – particularly in areas of the security and defence market that tend to be characterised by high-value contracting and few suppliers. Reversing this trend would likely prove challenging, not least because the identified asymmetries across the region might hinder the implementation of EU-wide strategies.

Dimension 3: Supply Chain Participation

For our third dimension, we turn to the supply chain of EU defence projects, focusing on large cross-border cooperations.

Overview and Research Question

From a governmental point of view, cooperation in defence production is usually a second-best option borne out of financial or technological constraints (Kapstein 1992). While the empirical evidence for efficiency gains in cross-border projects is mixed,[17] additional advantages from cooperation may include the retention of sovereignty at the EU level. Jones (2006) identifies two channels: *first*, cooperation can permit EU defence firms to compete with larger US rivals. *Second*, cooperation may lower the dependence of EU Member States on outside suppliers (notably the US) in terms of armaments supply.[18] We argue that the achievable level of EU autonomy in defence production hinges on the foreign dependence of EU supply chains. Therefore, we intend to assess to which level leading EU defence programmes rely on non-EU suppliers.

The literature on the consequences of collaboration and imports for defence supply largely rests on the *final equipment* level. The supply chain has received significantly less attention (exceptions include the recent work of Matthews and Al-Saadi 2021). Sovereignty and control matter for the supply chain. Nations relying on other (dominant) powers for regular, unrestricted access to spare parts and other defence resources may become dependent and thus reduce their security of supply (Jones 2006). Varying incentives between policymakers and firms may also affect supply chains:

Bellouard and Fonfría (2018) argue that private system integrators, driven by short-term corporate incentives (e.g. cost and risk reduction), may prefer choosing external suppliers over improving EU security of supply (unless prohibited by contractual obligations).

The significance of (non-)sovereignty for EU defence supply chains provides a background for our subsequent analysis. We assess the level of non-EU involvement in EU defence projects through an analysis based on a subset of large trans-European collaborations, arguably the most complex group of defence projects in terms of negotiating and managing the supply chain.

Data and Methodology

We focus on the largest cooperative European military aircraft programmes which have already reached serial production: the *Eurofighter Typhoon*, the *A400M*, the *Tiger*, and the *NH90*. This choice is motivated by theoretical considerations and data availability. First, given that multinational approaches are becoming more and more prevalent in the EU aircraft industry, it appears adequate to focus on these difficult to manage cross-border projects. Second, the applied database (see below) is seemingly less complete with respect to largely domestic programmes. However, we note that domestic programmes (e.g. *JAS 39 Gripen*, *Rafale*) may also be dependent on imported parts.

The four selected systems are all European by design but differ in terms of management and industrial organisation. The *A400M* and *Tiger* are delivered by *Airbus* in close collaboration with the aerospace industries of all partner nations. Development and production of the *Typhoon* are coordinated by *Eurofighter Jagdflugzeug GmbH*, headquartered in Germany and controlled by the leading aerospace firms of its partner nations: *Airbus* for Germany and Spain (46%), *BAE Systems* for the UK (33%), *Leonardo* for Italy (21%).[19] *NHIndustries*, responsible for the *NH90*, is likewise owned by defence firms from its original partner nations: *Airbus* for Germany, France and Spain (62.5%), *Leonardo* for Italy (32%), *Fokker Technologies* for the Netherlands (5.5%, now part of *GKN Aerospace* of the UK).

In simplified terms, the prime contractors of these programmes (*Airbus*, *Eurofighter Jagdflugzeug*, *NHIndustries*) subcontract individual subsystems and parts to various tier-1 suppliers, who involve other lower-tier suppliers besides their own in-house contribution.[20] Subsystems and final assembly then take place at dedicated sites. In case of foreign sales, supply chains and assembly sites may deviate from the core programme, depending on the foreign industry's negotiated participation. Additional consortia may be implemented at the subsystems level: for example, the *Typhoon*'s *EJ200* engine is supplied by *Eurojet Turbo GmbH*, a four-nation partnership involving *MTU Aero Engines* (33%), *Rolls-Royce* (33%), *Avio Aero* (21%) and *ITP Aero* (13%).

Importantly, defence-industrial participation in collaborations is not simply allocated based on economic efficiency considerations. Rather, partner nations usually demand work shares for their domestic industries equivalent to their financial contribution ('*juste retour*').[21] This applies to the *Typhoon* and the *NH90*, which are based on ad-hoc interstate agreements (Calcara 2020a). Procurement of the *A400M* and *Tiger* is coordinated by *OCCAR*, whose *global balance* approach permits larger deviations from *juste retour*.[22] As highlighted by Matthews and Al-Saadi (2021), contractual work shares in defence consortia often determine the sourcing of parts and components, which creates inefficiencies as it raises the complexity of coordination and may rule out cheaper or more capable alternatives. Furthermore, as pointed out by Calcara (2020b), even cooperating countries may be unwilling to share specific defence technologies.

Complex aerospace and defence programmes, especially those with many partner nations, often involve a vast number of firms. Eurofighter Jagdflugzeug (2022) reports that over 400 tier-1 suppliers engage in the *Typhoon* supply chain. Anecdotal evidence suggests that the total number of suppliers involved in major EU defence programmes (at all tier levels) may be in the thousands,[23] of which most are SMEs. However, this information is usually confidential and not directly available. We thus base our analysis on the *Airframer Supply Chain Directory* (maintained by Stansted News Limited),

which compiles data on tier suppliers of aerospace programmes from public sources. Per programme, this database groups suppliers into categories (e.g. avionics, weapons systems, engines) and offers information on their exact contribution. For our selected systems, the number of registered suppliers ranges from 38 (*Tiger*) to 261 (*A400M*). By adding the origin of each supplier (based on our own research), we obtain a dataset that enables us to approximate the share of non-EU27 suppliers in the selected programmes.[24]

To our knowledge, the *Airframer Supply Chain Directory* is the most extensive publicly available source on aerospace supply chains. Nevertheless, some limitations should be noted. *First*, we may not cover consortia outside the aerospace sector (e.g. *ASCOD*, *Boxer*, *FREMM*), as no comparable database exists for sectors such as land systems and naval shipbuilding. *Second*, due to global sourcing, 'EU' parts may have high degrees of non-EU origin, and vice versa (we assess resource dependency in our concluding section). *Third*, the database does not report the value or production share of the suppliers' contribution. This restricts our analysis to the *number* of tier suppliers per country and category. Since the list of suppliers is inevitably incomplete, we may also not rule out some degree of sample selection. However, robustness checks indicate that all major subsystems and parts are covered by the dataset, and that tier-1 suppliers dominate the data. For example, the *weapons systems* category of the *Typhoon* almost exclusively lists leading defence firms such as *BAE Systems*, *Cobham*, *General Dynamics UK*, *Hensoldt*, *Leonardo*, *MBDA*, *Raytheon*, *Thales*, and *Ultra Electronics*.

Results and Discussion

The results of our analysis are summarised in Table 8. The distribution by origin indicates that US and U.K firms form the largest groups of non-EU tier suppliers in our dataset. The overall share of non-EU suppliers is substantially smaller for the *Tiger* and *NH90* (26-28%) than for the *A400M* and *Typhoon* (44-51%). This is not surprising given that the U.K is a major partner nation in the two latter consortia (which significantly predate the 'Brexit'). If the EU and U.K are grouped together, the share of external suppliers lies in the range of 20-30% for all four programmes. This significant participation of non-EU suppliers reflects the interconnectedness of the EU defence industry with other (Western) defence industries. The participation of non-EU suppliers extends to some of the most critical parts of military aircraft (such as avionics, engines, or weapons systems). Besides the EU, UK, and US, the most common regions of origin are Switzerland (*A400M*, *Tiger*) and Turkey (*A400M*).

Besides the UKs participation in the *A400M* and *Typhoon*, there exist at least two further reasons for the high share of non-EU suppliers. In certain areas, non-EU suppliers may be indispensable (either as consortium partners or as outside suppliers) due to specific know-how or industrial capabilities. A second explanation, which appears more relevant in the selected cases, is found in takeovers. By acquiring EU firms (or via Brexit), non-EU firms can become (prime) suppliers in these

Table 8. Origin of registered suppliers of collaborative European military aircraft programmes.

	Eurofighter Typhoon	A400M	Tiger	NH90
France	9	60	14	11
Germany	28	35	7	9
Italy	16	4	0	3
Spain	9	27	5	6
Trans-European	3	4	2	3
Other EU27	6	17	0	4
U.K	31	37	1	4
U.S.A	40	57	1	7
Other non-EU27	4	20	8	3
Total number of registered suppliers	146	261	38	50
Share of non-EU27 (incl. U.K)	51%	44%	26%	28%
Share of non-EU27 (excl. U.K)	30%	30%	24%	20%

Source: Own analysis based on Stansted News Limited (2022).

collaborative programmes (Matthews and Al-Saadi 2021), e.g. the remnants of *Fokker Technologies* have been integrated into *GKN*.

Despite the scarcity of empirical data, our findings are in line with some earlier observations. For example, Gutierrez (2013) reports that US firms accounted for about 20% of the global *A400M* supply chain in 2013, and European firms (including those from Switzerland and the UK) for 77%. This corresponds to our findings (22% and 72%, respectively).[25] A list of approved suppliers published by Airbus (2021), not tied to any specific programme, presents a comparable picture.[26] These observations further corroborate the representativity of our data.

While some EU system integrators may pursue counterbalancing strategies (such as vertical integration[27]), we expect non-EU suppliers to remain crucial for future collaborative defence systems in the EU. *First*, EU suppliers may be unable to contribute certain parts and technologies (either generally, or in terms of cost-effectiveness[28]). *Second*, non-EU countries – particularly the US and the U.K – will remain partners in core defence programmes of EU Member States. For example, the U.K has re-joined the *Boxer* programme and leads the next-generation combat aircraft consortium *Tempest*. A similar point can be made for several U.S projects, e.g. the *F-35 Lightning II*. *Furthermore*, as presented before, U.S and U.K firms retain direct ownership over numerous EU defence firms. Finally, while our analysis observes mostly the tier-1 level, foreign dependence may be much higher at lower levels of the supply chain – particularly for raw materials. These dependencies are assessed in the concluding section.

Concluding Remarks

Combined Assessment and Opportunities for Future Research

Recent events have highlighted the risk of strategic dependency and the costs of supply chain disruptions. This conclusion is not different for the defence-industrial supply chain, especially considering the heightened risk of geopolitical conflicts, trade conflicts, but also pandemics. Our analyses of three separate dimensions related to foreign dependency (company ownership, tender success, supply chain participation) deliver several implications for strengthening the resilience of EU defence-industrial supply chains.

The largest EU defence firms are, on average, to about 25-30% in the hands of non-EU owners, but these foreign shareholdings are typically dispersed over many investment funds, financial services firms etc. and therefore less critical from a strategic perspective. Ownership by systemic or geopolitical adversaries is virtually non-existent. While several strategically important firms have become subsidiaries of non-EU defence firms (mostly from the US and UK), this does not necessarily threaten the EU's security of supply with defence material. Nevertheless, we observe a rising tendency in (1) the participation of non-EU firms concerning M&A with high relevance for the EU defence industry, and (2) the share of defence-related EU tenders that are won by non-EU firms. Our assessment of four multinational military aircraft programmes further exemplifies that the EU's defence R&D and production capabilities may critically depend on outside suppliers.

If the EU seeks to strengthen its defence-industrial supply chains, as stated in the Strategic Compass, it must therefore not relinquish control and sovereignty over the production capabilities, technologies, processes, and resources that are essential to its military forces. However, while efforts are clearly being made to accommodate for the goals of the Strategic Compass, a move towards true strategic autonomy seems not feasible, at least in the short run. It appears unlikely that substantial improvements will be made in the coming years in each of the three dimensions discussed in this article, and it goes without saying that any serious pursuit of strategic autonomy would come at significant economic costs.

Several complementary analyses, which would exceed the scope of this article, offer promising opportunities for future research. Concerning Dimension 1, it could be investigated to which degree the differences between EU Member States in non-EU ownership of their leading defence firms reflect heterogeneous defence-industrial strategies and safeguards (such as takeover and foreign direct

investment rules). For example, whereas the French Government holds 'golden shares' in *Thales* and *Nexter* (even after its integration into *KNDS*), nine EU Member States have not even established screening mechanisms for industries related to defence and national security (European Commission 2022b). As for Dimension 2, the salience and success rate of certain non-EU countries in EU27 tendering, notably for higher-value contracts, could be further investigated via gravity model regression analyses for international trade flows. In Dimension 3, our findings for non-EU participation in defence supply chains mainly reflect the tier-1 level of four multinational aircraft programmes and may thus not be extrapolated on the entirety of EU defence systems. Additional research based on (1) national aircraft programmes, (2) other defence-industrial segments (e.g. naval, land) and (3) lower-tier levels could further test our results. Furthermore, the development of non-EU participation in EU defence supply chains could be observed over time, as some indicators point at a growing dependence on non-EU suppliers.[29]

A Note on the EU's Foreign Dependence in Terms of Commodities

The main analyses of this article focus on the industrial dimensions of the Strategic Compass. These dimensions cannot be discussed without mentioning commodity dependency: the EU's defence-industrial supply chain relies heavily on imports from non-EU countries for many critical resources, which are often only provided by an extremely limited number of countries and suppliers. Therefore, we conduct a complementary analysis for the EU's commodity dependency for those resources that are specifically relevant for the defence industry.

First, we construct a list of 40 critical commodities[30]: 29 metals, 4 precious metals, 4 non-metals, 2 mineral fuels (crude oil and natural gas), plus the combined group of rare earth elements (REE).[31] For each commodity, we then collect data on the following indicators[32]:

- Global and EU27 production (in 2020 and 2000, quantity by country),
- EU27 imports from non-EU sources (2020, quantity by origin),
- Import reliance at the EU level for two different stages (extraction and processing).[33]

The combined analysis of the collected data delivers several important insights on the EU's commodity dependence. Global raw material production has increased significantly between 2000 and 2020 for most commodities in our dataset – on average by about 180% (median: 80%). For 22 of the 40 commodities, concentration of global production[34] was lower in 2020 than in 2000, which suggests that the overall rise in production was often associated with an increase in the (relative) importance of new sources. However, we find that the higher diversity of global production has oftentimes not improved the EU's supply situation in terms of defence-related raw materials. This has several reasons.

First, for most commodities, the EU27 made only a small difference to the rise in global output between 2000 and 2020. EU production expanded by barely 5%, compared to an average gain of roughly 180% for non-EU production. *Second*, not all global sources are equally accessible to EU customers. Besides technical aspects (such as transport infrastructure), certain producers may withhold quantities to first satisfy their own demand and that of their strategic partners. Some of the largest deposits of critical raw materials are located within the borders of (actual or potential) systemic rivals. China, for example, was the largest global producer of 20 out of the 40 assessed commodities. *Third*, dependence on certain suppliers such as China may even be high for resources that originate elsewhere. Lithium, for example, is primarily sourced in Chile, but processed mainly in China (Koch and Volkery 2022). *Fourth*, for several key commodities, Russia's invasion of Ukraine has directly affected the EU. Russia has been an important supplier of crude oil and gas as well as the largest (non-EU) source of vanadium, tungsten, palladium, selenium, and nickel, and the second largest source of phosphate and aluminium. Furthermore, Ukraine is an important supplier of iron ore and titanium to the EU. *Fifth*, diversification of EU supply will become even more complicated considering the high projected growth of demand for several critical commodities. Annual EU demand for cobalt, for example, could quadruple until 2030 (Alves Dias et al. 2018). *Sixth*, even if

the EU enjoys a low degree of import reliance at the extraction phase, local production is often very concentrated and therefore vulnerable.

Studying the recent evolution and looking forward provides reasons for concern. While for several critical raw materials new global sources have become available during the last 20 years, demand has increased disproportionally. This raises the question whether the EU can succeed in further diversifying the supply chain and ensuring sufficient raw materials for the future. There is certainly a will to do so, but the reality for several defence commodities renders adequate diversification impossible, at least in the near term.

Notes

1. Authors' analysis of the revenue of the EU's largest civilian and defence firms, based on data compiled from Forbes (2022) and SIPRI (2021).
2. Airbus, Arquus, BAE Systems Bofors, BAE Systems Hägglunds, Chantiers d'Atlantique, Constructions Mécaniques de Normandie, Czechoslovak Group, Damen Shipyards Group, Dassault Aviation, Diehl, Dynamit Nobel Defence, Elettronica, Eurenco, ESG Elektroniksystem und Logistik, EXPAL Systems, FFG Flensburg, Fincantieri, FN Herstal, Fokker Technologies (now part of GKN Aerospace), Framatome, GDELS, German Naval Yards, Hensoldt, Heckler & Koch, Indra Sistemas, Iveco Defence Vehicles, John Cockerill, KNDS, Leonardo, Lürssen, MBDA, MTU Aero Engines, MTU Friedrichshafen (now part of Rolls-Royce Power Systems), Naval Group, Navantia, OGMA, Patria Group, Polska Grupa Zbrojeniowa, Ratier-Figeac, Renk, Rheinmetall, Rohde & Schwarz, Saab, SABCA, Safran, Sonaca, Thales Group, ThyssenKrupp, Vodochody Holdings, ZF Friedrichshafen. These 'leading' defence firms are selected based on their defence revenue. Several other EU defence firms could have been included instead of the smallest firms in our sample, but as we assign weights based on the firms' defence revenues, the impact on our main results would be negligible.
3. For example: governmental, private firm, financial institute, bank, investment fund, family-owned.
4. Belin and Masson (2017) and Belin, Fawaz, and Masson (2019) cover 61 and 63 firms, distributed as follows. Trans-European: 3/3, UK: 9/9, other EU: 15/17, US: 34/34. While we do not cover UK and US firms, our analysis applies a larger EU sample (50 firms).
5. Defined by *Bureau van Dijk* as having a shareholding of 0,01% or higher.
6. It is highly probable that state- and family-owned firms in our sample were at least partly owned by non-EU shareholders if such investment were possible. By contrast, EU ownership scores of 0% indicate that a firm has become a wholly-owned subsidiary of a non-EU firm (e.g. *GDELS*, *BAE Systems Bofors & Hägglunds*).
7. These explanatory factors for varying degrees of national ownership (state- and family-ownership, cross-shareholdings) are also discussed by Belin and Masson (2017) and Belin, Fawaz, and Masson (2019).
8. However, there have been exceptions. *Cevian*'s lobbying for a streamlining of *ThyssenKrupp*'s activities, for example, nearly resulted in a divestment of *ThyssenKrupp Marine Systems*.
9. Our analysis is restricted to larger M&A with an EU dimension (i.e. those that met the turnover thresholds set by the EU Merger Regulation) and to those that were referred to the Commission by national competition authorities. While defence M&A investigated by national competition authorities are not covered, we consider our dataset as sufficiently large and representative for the most important defence M&A within the EU.
10. This subsample only covers cases in which the acquiring firm(s) are located exclusively outside the EU27. Were cases with an additional involvement of an EU27 acquirer considered (e.g. a joint venture between an EU and a US firm), the size of the subsample would increase from 42 to 71 cases.
11. Such as the 2020 acquisition of the *Asteelflash Group*, Europe's second largest electronic manufacturing firm with defence and aerospace applications, by a Shanghai-based subsidiary of the semiconductor producer *ASE*.
12. Logistic modelling is suited to deal with binary dependent variables (Cameron and Trivedi 2005).
13. Based on 9,596 observations (for 3,008 tenders, value data was unavailable).
14. For the remaining 7,376 tenders, data was lacking (notably for the variables $Tender\ Value_i$ and $Award\ Criteria_i$).
15. Based on data gathered from the SIPRI Arms Transfers Database (2022), we determined that the portion of defence imports by the EU27 that is sourced in non-EU27 countries increased from 42.5% in 2016 to 74.6% in 2020.
16. To test the robustness of our findings for extremely protectionist policies, we ran the logistic model on a subsample of tenders ($n = 1{,}586$) which are covered by the Agreement on Government Procurement by the World Trade Organization. The results demonstrate that the significance of the variables of interest (tender size and number of bids) remains, and coefficient sizes increase.
17. Braddon and Hartley (2013) and the NAO (2004, 2001) claim higher delays and cost overruns in collaborative EU defence projects, but Hartley and Braddon (2014) find no inverse relationship between the number of partner nations and development time.

18. Concerning additional explanations for EU defence collaboration, an overview of the various research strands is given by Calcara (2018).
19. See Matthews and Al-Saadi (2021) for additional information on the organisation of the *Typhoon* consortium.
20. See Gutierrez (2013) for a presentation of the global supply chain of the *A400M*. This subcontracting process may also apply to R&D: Bellouard and Fonfría (2018) state that about 70% of all R&D in military aircraft is typically subcontracted. According to Hayward (2001), much of the globalisation of modern defence supply chains takes place at lower-tier levels, where it involves commercial technology and is difficult to observe.
21. Disagreement over industrial participation can be a major reason behind project withdrawals (Calcara 2020b).
22. See Keohane (2002); Barrinha (2010); Kleczka, Buts, and Jegers (2020); Matthews and Al-Saadi (2021).
23. According to *Airbus* data presented by Gutierrez (2013), the equipment list of the *A400M* covers more than 4,000 individual parts, of which only about 60% are installed at the sites of *Airbus* and its subsidiaries.
24. Several decisions had to be made during data collection. First, if firms are listed multiple times as suppliers for the same programme, they are counted repeatedly if their contributions can be clearly differentiated. For example, *Thales* is a tier-1 supplier for five separate avionics and airframe systems of the *Tiger*. Second, as will be presented in more detail later, the distinction between EU and non-EU suppliers is not always clear. EU firms are not counted as non-EU suppliers if they were acquired only recently (for example: *CESA*, part of *Héroux-Devtek* of Canada since 2018, is counted as a Spanish supplier).
25. This data is also evaluated by Linnenkamp (2017). Certain variations between our findings and Gutierrez' (2013) distribution of suppliers within Europe could be explained by the time difference between the separate analyses and by varying treatments of foreign ownership.
26. Based on our evaluation, the approximate distribution of approved *Airbus* suppliers by origin is as follows. EU27: 57%, U.S.A: 18%, U.K: 12%, other countries: 13%. While this approval list also includes civilian *Airbus* programmes, its distribution resembles our findings for the *A400M*.
27. Vertical integration may lessen dependencies for specific parts and materials. Most leading EU defence firms are vertically integrated in certain areas. For example, *Naval Group* and *TKMS* have acquired the naval electronics and defence businesses of *Thales Naval* and *Atlas Electronics*, respectively.
28. For example, it has been argued that Western European defence industries are at a comparative disadvantage vis-à-vis the U.S in terms of military R&D (Hartley 2017; James 2008; Kapstein 1994; Chiang 1992).
29. See footnote 15.
30. For constructing this list of critical resources for the EU's defence-industrial supply chain, we combine the findings of Pavel and Tzimas (2016) with the latest edition of the European Commission's triennial communication on *critical raw materials* (CRMs) (European Commission 2020), with background documents prepared by Latunussa et al. (2020) and Blengini et al. (2020), and with our own research.
31. Metals: aluminium, barium/baryte, bauxite, beryllium, bismuth, cadmium, chromium, cobalt, copper, gallium, germanium, indium, iron ore, lead, lithium, magnesite, manganese, molybdenum, nickel, niobium, rhenium, tantalum, thorium, tin, titanium, tungsten, vanadium, zinc, zirconium. Precious metals: gold, palladium, platinum, silver. Non-metals: boron, fluorspar, phosphate, selenium. Mineral fuels: crude oil/petroleum, natural gas. REE include, inter alia, dysprosium, neodymium, praseodymium, samarium, and yttrium. This selection is largely based on Pavel and Tzimas (2016), with some alterations to account for the European Commission's list (2020) and our own findings.
32. Production data is taken from the *World Mining Data* series of the Austrian Federal Ministry of Agriculture, Regions and Tourism (BMLRT, 2022) and the *Mineral Commodity Summaries* published by the US Geological Survey (USGS, 2022). Import reliance stems from Blengini et al. (2020). Import data is taken from Eurostat (2022) and Latunussa et al. (2020). The import data should be treated with caution: first, it does not always clearly separate raw from refined materials. Sometimes, imports are not reported due to commercial confidentiality rules (e.g. Austria's tungsten imports, see Latunussa et al. 2020). Furthermore, the data is not corrected for the *Rotterdam effect*, which may distort the distinction between imports from outside and within the EU.
33. Following Blengini et al. (2017), import reliance reflects the relation of net imports to apparent consumption for a given year t and commodity i as follows.
$$import\ reliance_{i,t} = \left(import_{i,t} - export_{i,t}\right) / \left(domestic\ production_{i,t} + import_{i,t} - export_{i,t}\right).$$
34. We investigate concentration in the commodity markets via the *Herfindahl-Hirschman-Index*, defined as $HHI_{i,t} = \sum_j^J \left(s_{i,j,t}\right)^2$ for a given year t and commodity i, with s_j denoting the share of country j in global production.

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