Development and examination of a proliferation trade risk metric

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Abstract:

A Proliferation Trade Risk metric has been calculated for each country represented in a publicly-available global trade dataset. This metric, comprising both direct and indirect proliferation trade risk components, represents the risk that each country's proliferation-relevant exports will go to a designated set of proliferation threat countries. This metric can serve to prioritize non-proliferation export control capacity building engagement. Further, within such engagement, the decomposition of the proliferation trade risk metric can identify specific industrial sectors and trade relationships of greatest importance for outreach and enforcement measures. Finally, these supply-side perspectives can be complemented by threat-based profiles identifying the most important suppliers to each threat country.

Keywords: export controls; trade analysis; non-proliferation; outreach; capacity building, risk management

1. Introduction

In 2018, the US National Nuclear Security Administration's International Nonproliferation Export Control Program (INECP) replaced the qualitative trade-based metrics used in its engagement planning process using the publicly available trade data that underlies the Strategic Trade Atlas developed jointly with the European Commission's Joint Research Centre.[1] [1,2]. A Proliferation Trade Risk metric was developed which can be calculated from the BACI data given a set of proliferation threat countries and a set of proliferation-relevant goods. Proliferation Trade Risk was calculated using six countries identified as WMD threats by the 2019 National Intelligence Strategy [3], the 2017 National Security Strategy [4], and the 2018 Nuclear Posture Review [5]. Specifically, these were China, Iran, North Korea, Pakistan, Russia, and Syria, but the methodology can be used for other sets of countries or goods of concern as appropriate for various threat assessments. At the time this metric was developed, it was computed using BACI data for the year 2016 but has since been computed for each year between 1995 and 2016 inclusive.

The Proliferation Trade Risk metric is demand-driven, meaning that trade flows are scored based on their importance to the recipient of the trade rather than the supplier, as will be shown in the Methodology section of this paper below. This can have surprising results, where trade flows seeming small to a supplier may represent significant proliferation trade risk because they constitute a large fraction of a threat country's imports of that commodity, or a large fraction of the imports into an intermediary which is also an important direct supplier of that commodity to one or more threat countries. Once computed, the analysis can support engagement prioritization decisions, and deconstructing the components of the metric can suggest highest risk trade flows and industrial sectors on which to focus risk reduction efforts.

2. Methodology

Given a set of designated proliferation threat countries of concern, a Proliferation Trade Risk (PTR) score can be computed for each country in the BACI dataset. The Proliferation Trade Risk score for each country is a measure of the risk that the country's proliferation-relevant exports[2] will go to a threat country, directly or indirectly. As such, it comprises two terms: Direct Proliferation Trade Risk (D) and Indirect Proliferation Trade Risk (I). Note that proliferation-relevant trade represents the types of goods most likely to include export-controlled items, but it does not necessarily indicate trade in controlled items. For example, trade in commodities classified as pumps is most likely to include export-controlled pumps, but most pumps are not export controlled. The intent is not to identify specific trade flows of proliferation interest, but to identify the regular trading relationships with the greatest proliferation risk.

1 This BACI dataset, which is used extensively in academic trade analyses, is a statistical elaboration of UN COMTRADE that reconciles import and export declarations to enhance the completeness and reliability of the data. http://www.cepii.fr/cepii/en/bdd_modele/presentation.asp?id=1

2 Proliferation-relevant trade excludes goods classified under Harmonized System (HS) chapters unlikely to correspond to proliferation-relevant commodities, such as agricultural products, wood products, fossil fuels, apparel, etc. While proliferation trade risk can be calculated using any basket of goods, this analysis used trade classified under HS Chapters 28 and 29 (chemicals), 75 (aluminium), 76 (nickel), 81 (other/exotic base metals), 84 (machinery), 85 (electronics), and 90 (measurement and test equipment). These selections are configurable and easily modified as needed.

2.1 Direct Proliferation Trade Risk (D)

The Direct Proliferation Trade Risk posed by a supplier country is a measure of the risk that the country's proliferation-relevant exports will go directly to a threat country. It is a demand-driven metric calculated as the sum of the fraction of each threat country's proliferation-relevant imports that come from the supplier.

$$D_{supplier} = \sum_{threat\ countries} \frac{v_{supplier,\,threat\ country}}{V_{threat\ country}} \quad (1)$$

where

$v_{supplier,threat\ country}$ is the value of proliferation relevant trade exported from the supplier to the threat country and $V_{threat\ country}$ is the total value of proliferation relevant trade imported by the threat country.

2.2 Indirect Proliferation Trade Risk (I)

The Indirect Proliferation Trade Risk posed by a supplier country is a measure of the risk that the country's proliferation-relevant exports will go indirectly to a threat country via one or more intermediary countries. Intermediate countries are identified in the data as countries receiving proliferation-relevant goods from the supplier and exporting proliferation-relevant goods to threat countries. It is calculated as the sum of the fraction of each intermediary country's proliferation-relevant imports coming from the supplier multiplied by the intermediary country's Direct Proliferation Trade Risk (D), which captures the risk that proliferation-relevant goods exported by that country would go to a threat country.

$$I_{supplier} = \sum_{intermediary\ countries} \frac{v_{supplier,\,intermediary}}{V_{intermediary}} D_{intermediary} \quad (2)$$

Thus, exports from a supplier to a potential intermediary only contribute to Indirect Proliferation Trade Risk if that intermediary also exports proliferation-relevant trade directly to threat countries, and the contribution is proportional to the fraction of the intermediary's imports coming from the supplier and the threat countries' imports coming from the intermediary.

2.3 Computation

The Direct and Indirect Proliferation Trade Risks can quickly and efficiently be calculated using matrix algebra with the BACI dataset. To facilitate computation, we construct a matrix v_{ij} with column *i* and row *j* where each entry is the total value of proliferation relevant trade from export country *i* to import country *j.* The total value of proliferation relevant trade *V* for a given threat country is simply the sum of that country's column in the trade matrix and is represented by a column vector with *N* entries. Using matrix index notation, equations (1) and (2) become

$$\boldsymbol{D} = \boldsymbol{v}[:, \boldsymbol{coc}] \times \left(1 / \boldsymbol{V}[\boldsymbol{coc}]\right)^{\boldsymbol{T}}, \quad (3)$$

$$\boldsymbol{I} = \left(\boldsymbol{v} \times \left(1 / \boldsymbol{V}\right)\right) \boldsymbol{D}, \quad (4)$$

where × denotes element-wise multiplication and *coc* denotes the column indices corresponding to the countries of concern. The direct trade risk vector *D* is then zero for all countries except countries of concern, whereas *I* is fully populated for each country assuming relevant trade. The PTR is given as the sum of *I* and *D*.

2.4 Known issues

While BACI attempts to reconcile incomplete or missing trade reports, the data is inherently noisy. Some countries report many thousands of import and export records per year, while other countries provide only sporadic and sparse reporting. This methodology becomes very sensitive when total reported proliferation-relevant imports into a country are small. Because the total value of proliferation relevant trade is in the denominator, when this value is small, relatively small trade flows can generate large proliferation trade risk scores. In general, this appears to be a strength of the methodology, as it successfully highlights small but unusual trade flows that may indicate import and re-export to threat countries via intermediaries. In addition, trade with intermediary countries with zero Direct Proliferation Trade Risk (D = 0) offers no additional Indirect Trade Risk, even though those intermediary countries may have non-zero indirect trade risk. This "second-order risk" (i.e., the risk of trade flows to threat countries via multiple intermediaries) is currently ignored, but preliminary investigation indicates this has only small impacts on the results.

3. Results

Figure 1 shows the computed Proliferation Trade Risk scores over time, and Figure 2 shows normalized Direct and Indirect Proliferation Trade Risk scores for each country in the BACI dataset for the year 2016. China (CN) had the highest Direct and Indirect Proliferation Trade Risk by far. A cluster of four countries, Germany (DE), South Korea (KR), Japan (JP), and the United States (US), represented the next level of Proliferation Trade Risk.

Excluding these top 5 risks, Figure 3 shows more clearly the raw Direct and Indirect Proliferation Trade Risk scores for the remaining countries for 2016. Of these, the United Arab Emirates (AE), Italy (IT), Turkey (TR), and India (IN) were the top Direct Proliferation Trade Risks, while Malaysia (MY), Singapore (SG), Vietnam (VN), Italy (IT), France (FR), Thailand (TH), the Netherlands (NL), the United Kingdom (UK), and the Philippines (PH) had the highest Indirect Proliferation Trade Risks. Italy (IT) was high on both measures, indicating significant direct exports to threat countries and significant exports to intermediaries with significant exports to threat countries.

In Figure 3, a third cluster of countries found to have elevated Proliferation Trade Risk includes Russia (RU), Belgium (BE), Switzerland (CH), Czech Republic (CZ), Austria (AT), Poland (PL), Hong Kong (HK), Spain (ES), Sweden

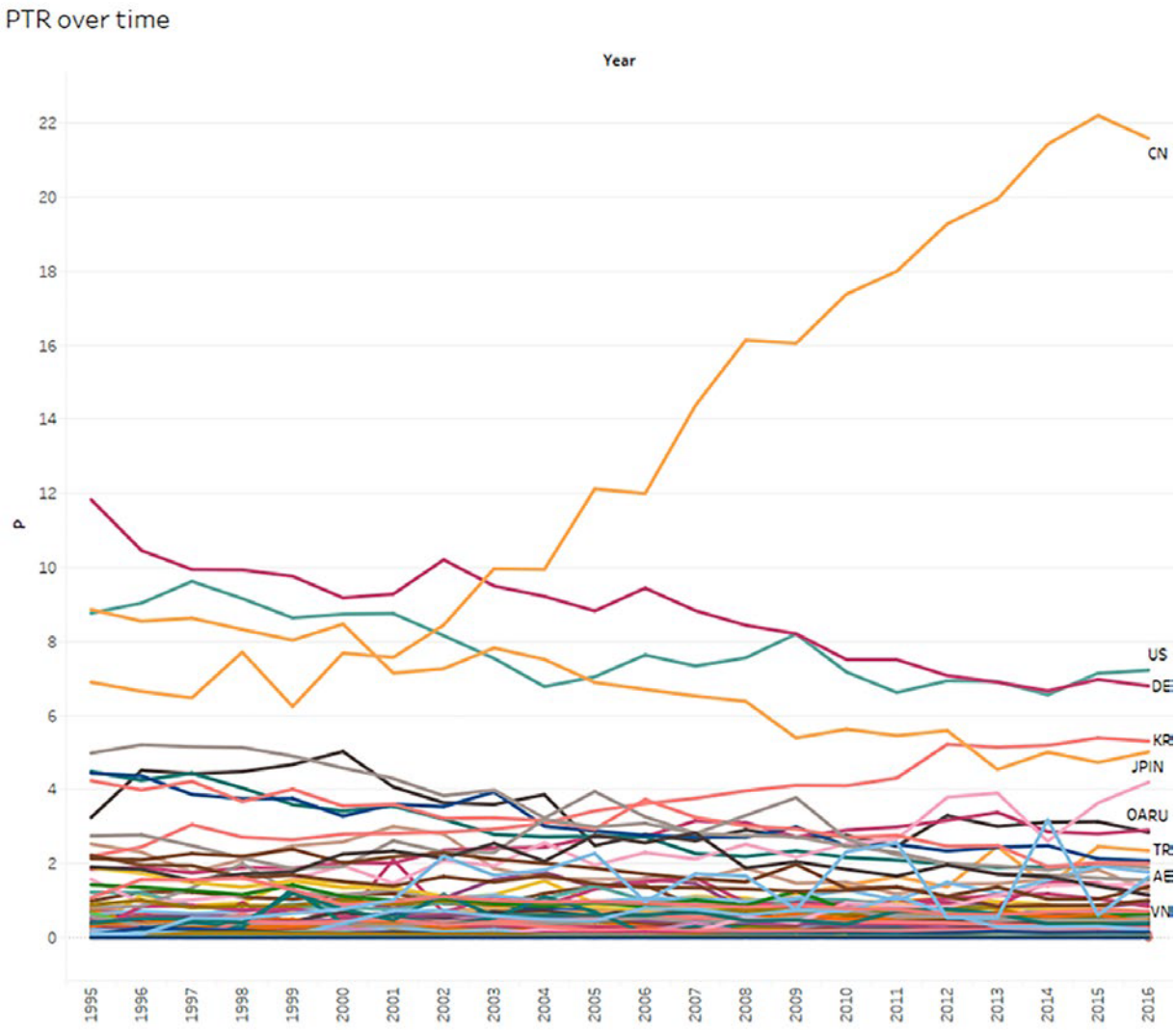

Figure 1: Proliferation Trade Risk over time.

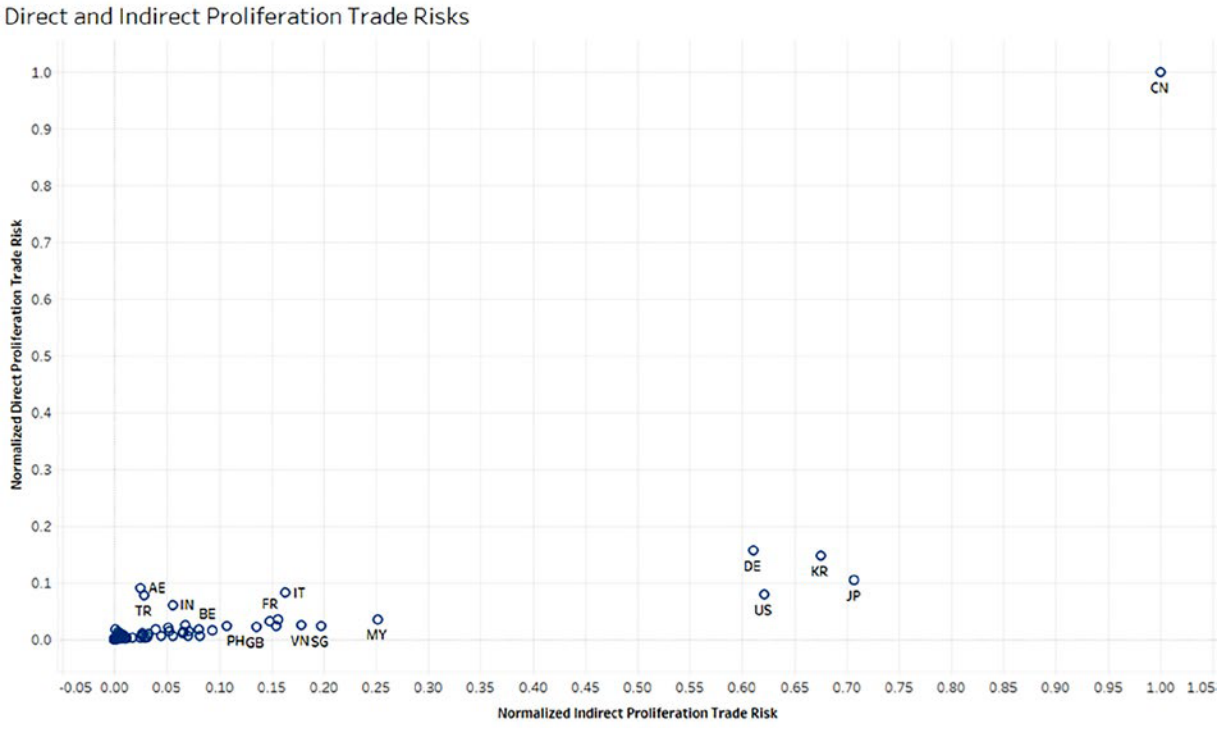

Figure 2: Normalized Direct and Indirect Proliferation Trade Risks for 2016.

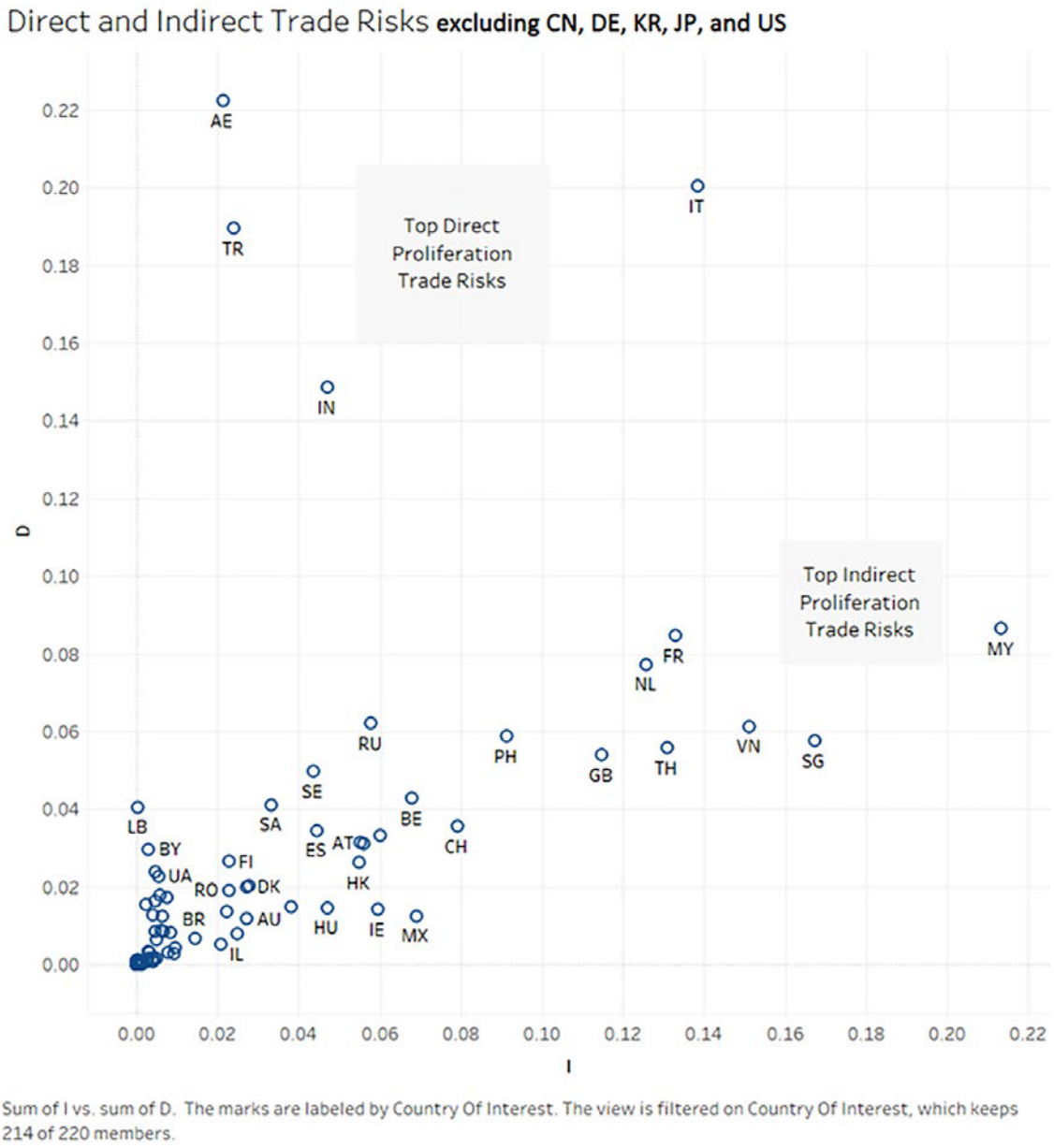

Figure 3: Direct and Indirect Proliferation Trade risks for 2016, excluding China, South Korea, Germany, Japan and the United States.

(SE), Saudi Arabia (SA), Canada (CA), Finland (FI), Indonesia (ID), Denmark (DK), Belarus (BY), and Lebanon (LB).

4. Decomposition of Proliferation Trade Risk for individual countries

In addition to providing an overall scoring mechanism for ranking and comparing countries, these computations also provide a means for better understanding the specific proliferation risks faced by individual supplier or intermediary countries. For example, the Proliferation Trade Risk for Jordan (JO) can be broken down as shown in **Figure 4**, which shows the contributions of each export destination to Jordan's Proliferation Trade Risk score. It shows that Jordan's Proliferation Trade Risk derives primarily from direct exports of proliferation-relevant goods to Syria (SY) and Pakistan (PK), followed by indirect trade risk from proliferation-relevant exports to India. Syrian imports from Jordan make a large contribution to Jordan's Proliferation Trade Risk score not because they represent a large share of Jordan's exports, but because they represent an important share of Syria's proliferation-relevant imports (see Figure 10). Such decompositions of Proliferation Trade Risk can be generated for any country of interest.

In addition, the data supports further decomposition of these proliferation trade risks by commodity type. The breakdown of Jordan's proliferation trade risk by industrial sector, depicted in **Figure 5**, shows that the risk comes predominantly from metals exports (to Syria and Pakistan), accounting for approximately 70% of Jordan's proliferation trade risk. Chemicals represent approximately 25% of proliferation trade risk from exports to China, India, Syria, and Iran. Equipment exports account for a minor share of proliferation trade risk, primarily from equipment exports to Syria.

Figure 4: Tree-map representing Jordan's proliferation trade risk by trading partner.

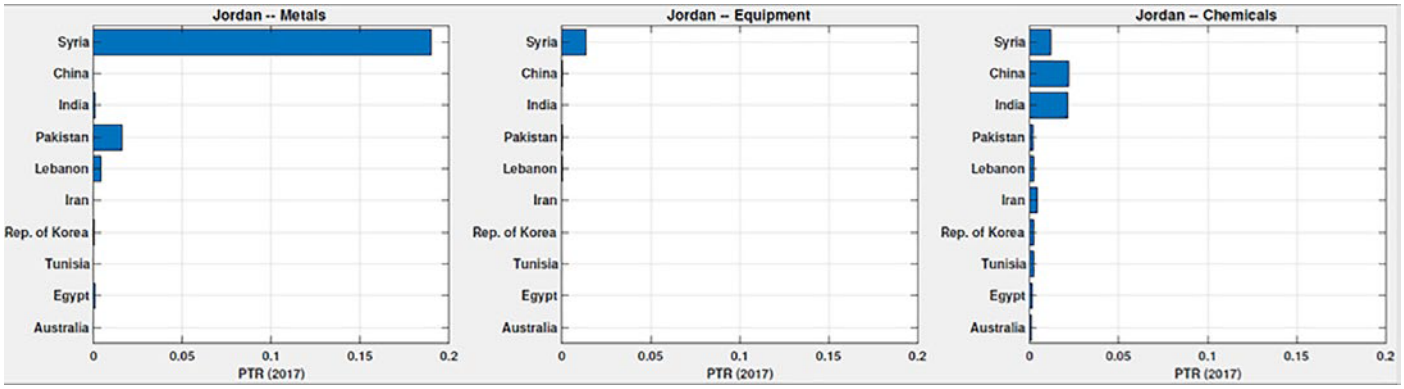

Figure 5: Jordan's Proliferation Trade Risk profile by industrial sector.

Figure 6 digs deeper into Jordan's metal trade to Syria. The top portion shows that Jordan's major metal export is aluminum (HS Chapter 76). Of this, less than 2% is exported to threat countries (shown in red). However, looking at the bottom portion of Figure 6, Jordan's exports represents a significant fraction of Syria's imports; Jordan is Syria's fourth largest supplier of Aluminum (shown in blue). This is a small trade flow for Jordan, but an important one for Syria, which is what the Proliferation Trade Risk metric measures.

It is also possible to use this methodology to rank the proliferation trade risk of imports to an intermediary country, and to decompose that trade risk by supplier and commodity type. Figure 7 shows the highest Proliferation Trade Risk scores arising from exports to Jordan based on their potential for re-export to threat countries. This suggests, for example, focusing transshipment control efforts on shipments of metals from United Arab Emirates, China, Saudi Arabia, Bahrain, South Korea, and Qatar; shipments of chemicals and equipment from China and chemicals from Saudi Arabia.

5. The big picture

Figure 8 brings together the overall ranking and comparison among countries with the breakdown of each country's risky trade relationships all on the same scale. The first block at the top left represents China's Proliferation Trade Risk and is subdivided to show the relative contributions arising from China's export destinations. The block at the lower left similarly represents South Korea's Proliferation Trade Risks, and so on. The colour scale indicates the relative magnitude of Direct Proliferation Trade Risk while the size of each area represents the total Proliferation Trade Risk (Direct plus Indirect).

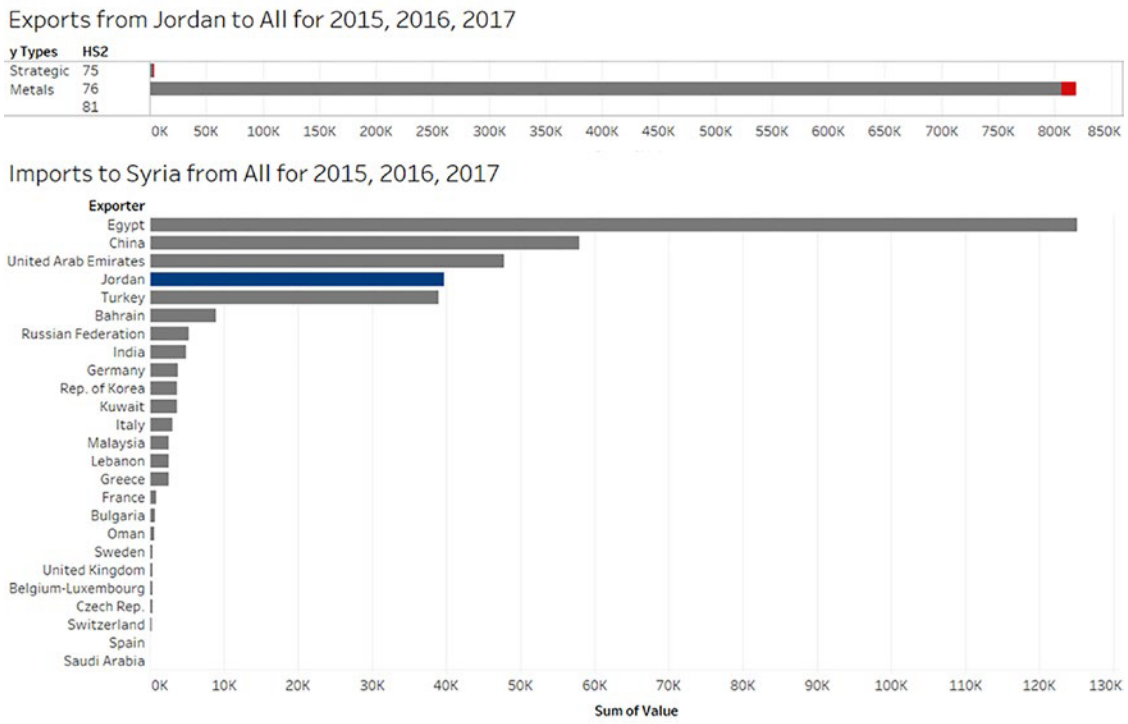

Figure 6: Jordan's exports of metals to Syria and Syria's imports of metals from all suppliers.

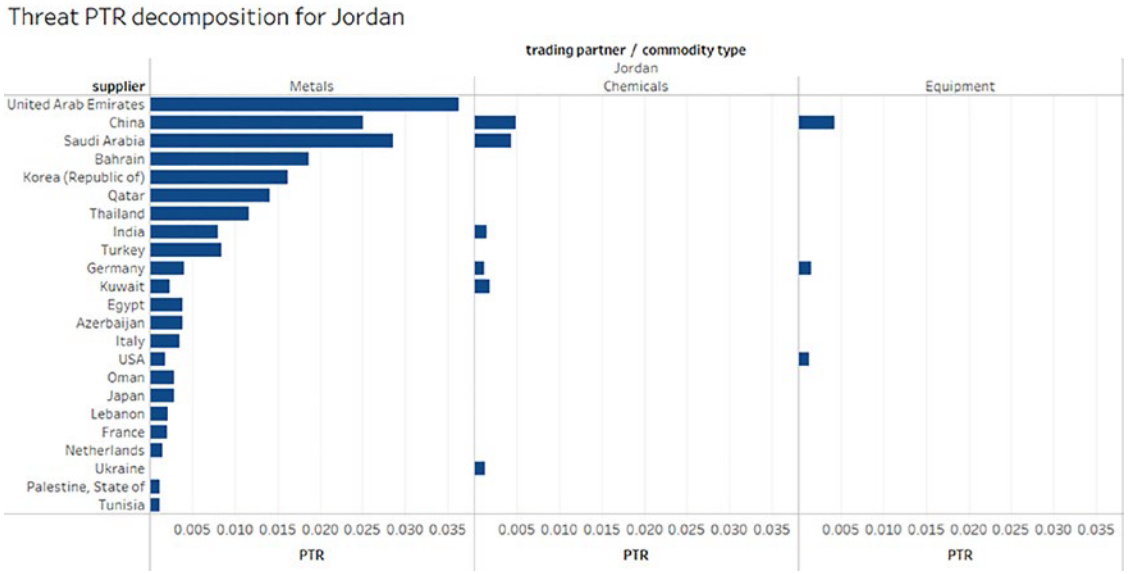

Figure 7: Import risk profile for Jordan.

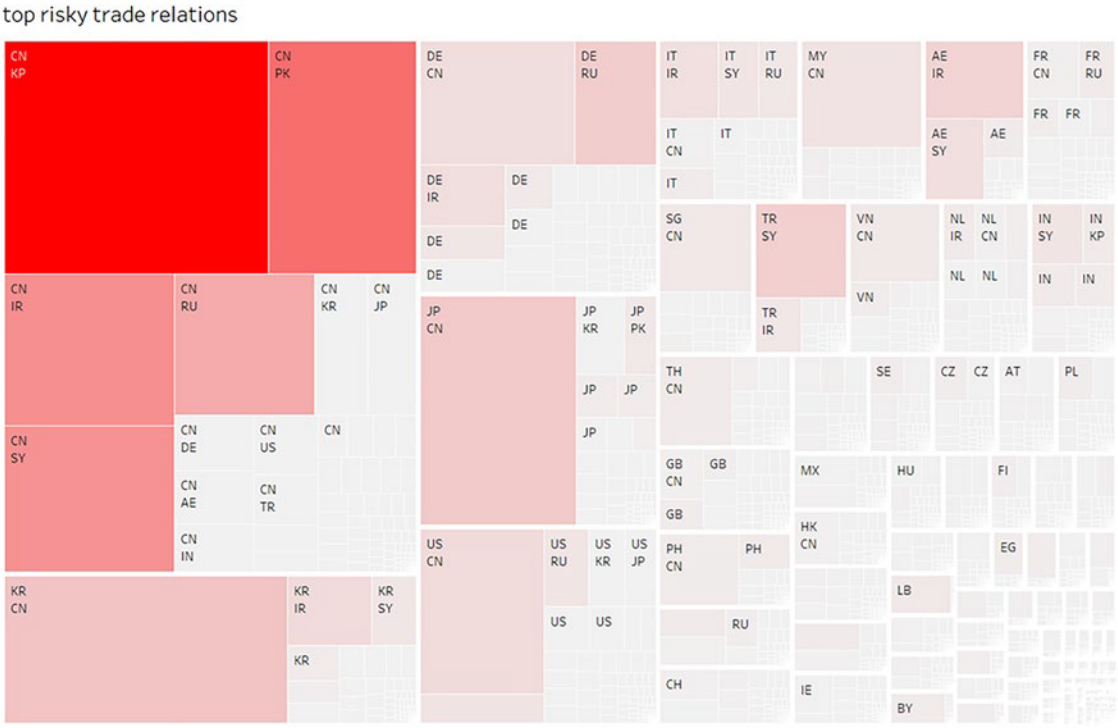

Figure 8: Global Proliferation Trade Risks.

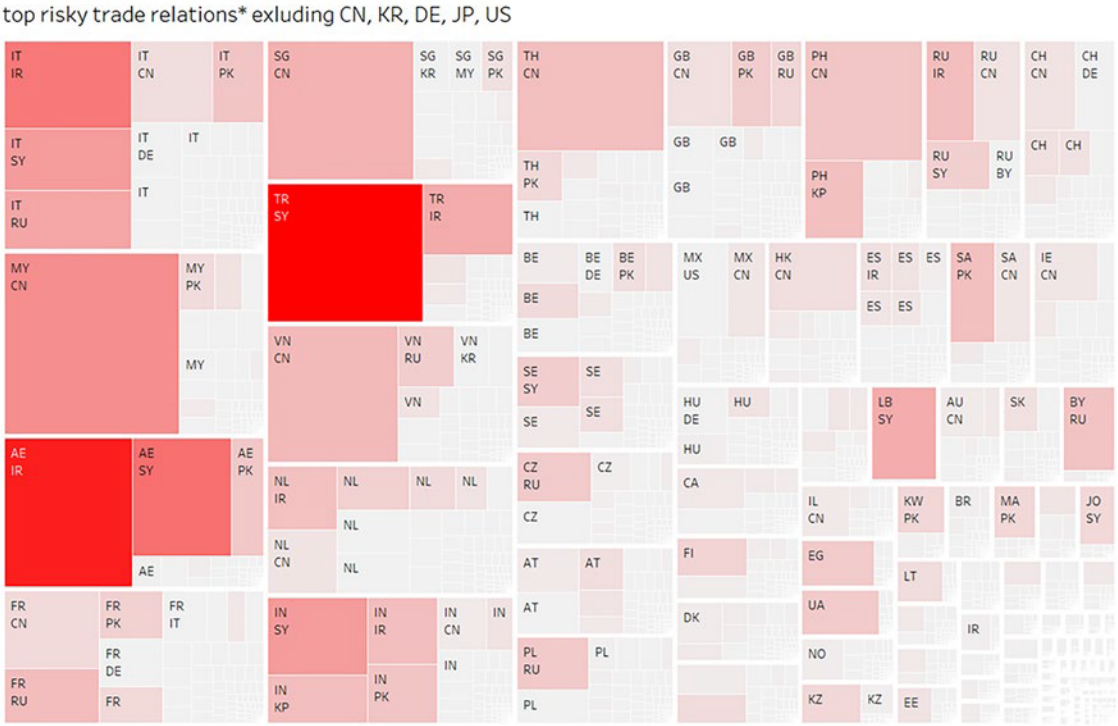

Figure 9: Global Proliferation Trade Risks excluding China (CN), South Korea (KR), Germany (DE), Japan (JP) and the United States (US).

As was done in Figure 3, Figure 9 repeats the previous figure but excludes the top 5 Proliferation Trade Risks to show the remaining countries more clearly.

6. Threat perspective

The calculations can also be used to view proliferation-relevant trade from the perspective of the designated threat countries. Based on the original PNNL study, the figures that follow show the top suppliers of proliferation-relevant trade to each of the designated proliferation threat countries [1].

Syria's (SY) most important suppliers based on Proliferation Trade Risk were China (CN), Turkey (TR), United Arab Emirates (AE), India (IN), Italy (IT), South Korea (KR), Lebanon (LB), and Germany (DE).

Iran's (IR) most important suppliers based on Proliferation Trade Risk were China (CN), United Arab Emirates (AE), South Korea (KR), Germany (DE), Italy (IT), Turkey (TR), Russia (RU), and India (IN).

Pakistan's (PK) most important suppliers based on Proliferation Trade Risk were China (CN), the United States (US), Germany (DE), Japan (JP), Saudi Arabia (SA), Italy (IT), India (IN), United Arab Emirates (AE), and the United Kingdom (GB).

DPRK's most important suppliers based on Proliferation Trade Risk were China (CN), India (IN), and the Philippines (PH).

China's (CN) most important suppliers based on Proliferation Trade Risk were South Korea (KR), Japan (JP), the United States (US), Germany (DE), Malaysia (MY), Singapore (SG), Vietnam (VN), and Thailand (TH).

Russia's most important suppliers based on Proliferation Trade Risk were China (CN), Germany (DE), the United States (US), Italy (IT), France (FR), South Korea (KR), Belarus (BY), Japan (JP), Poland (PL), Czech Republic (CZ), and Ukraine (UA).

7. Conclusion

The Proliferation Trade Risk metric was developed to help prioritize non-proliferation export control capacity building engagement and to tailor that engagement to maximize risk reduction. Beyond this purpose, the metric can help inform any country's export control efforts. The decomposition of the proliferation trade risk metric can identify specific industrial sectors and trade relationships of greatest importance for outreach and enforcement measures. These supply-side perspectives can also be complemented by threat-based profiles identifying the most important suppliers to each threat country.

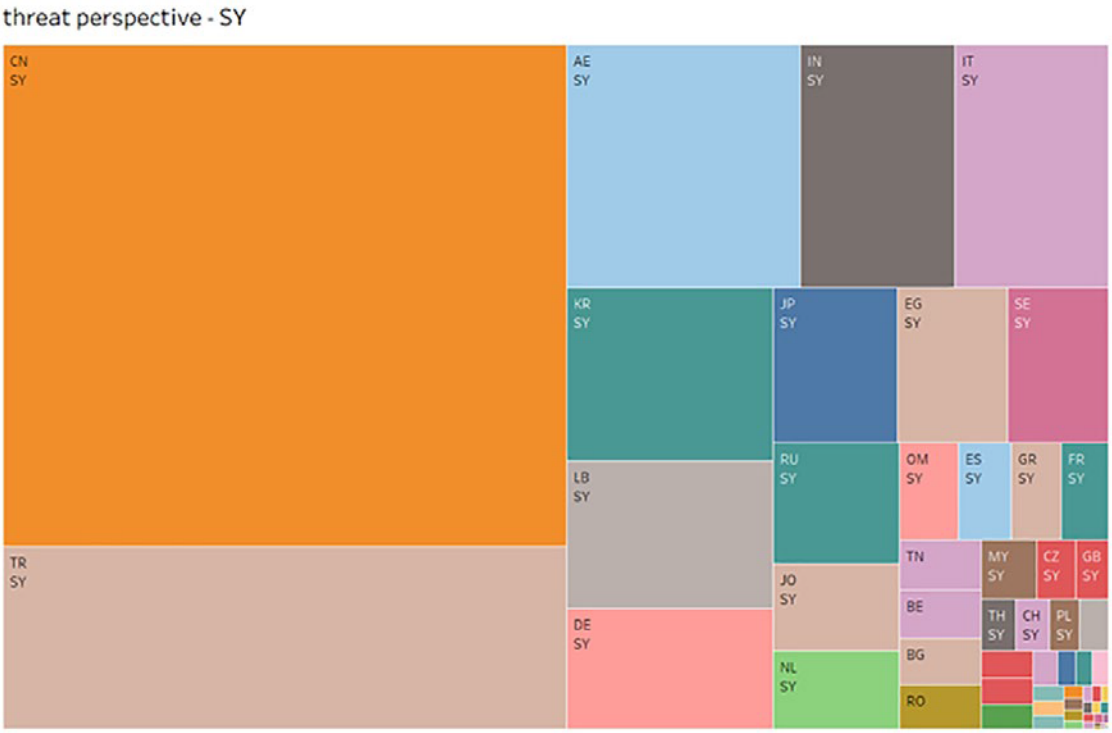

Figure 10: Top suppliers of proliferation-relevant exports to Syria (SY) in 2016

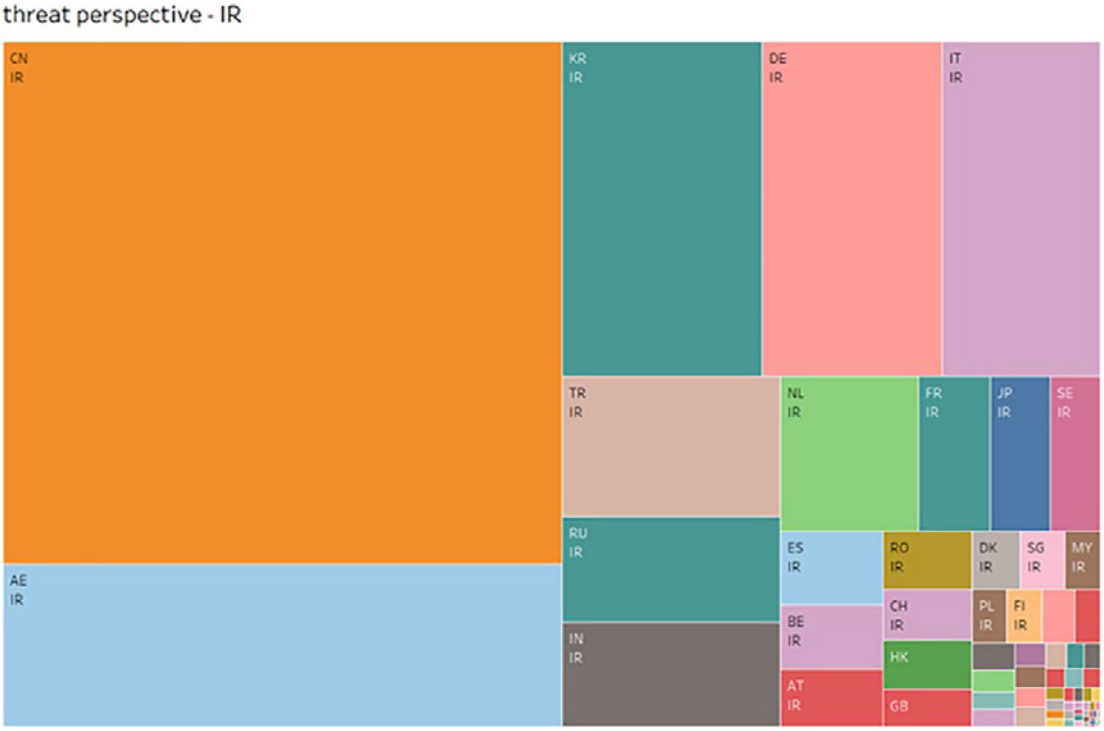

Figure 11: Top suppliers of proliferation-relevant exports to Iran (IR) in 2016

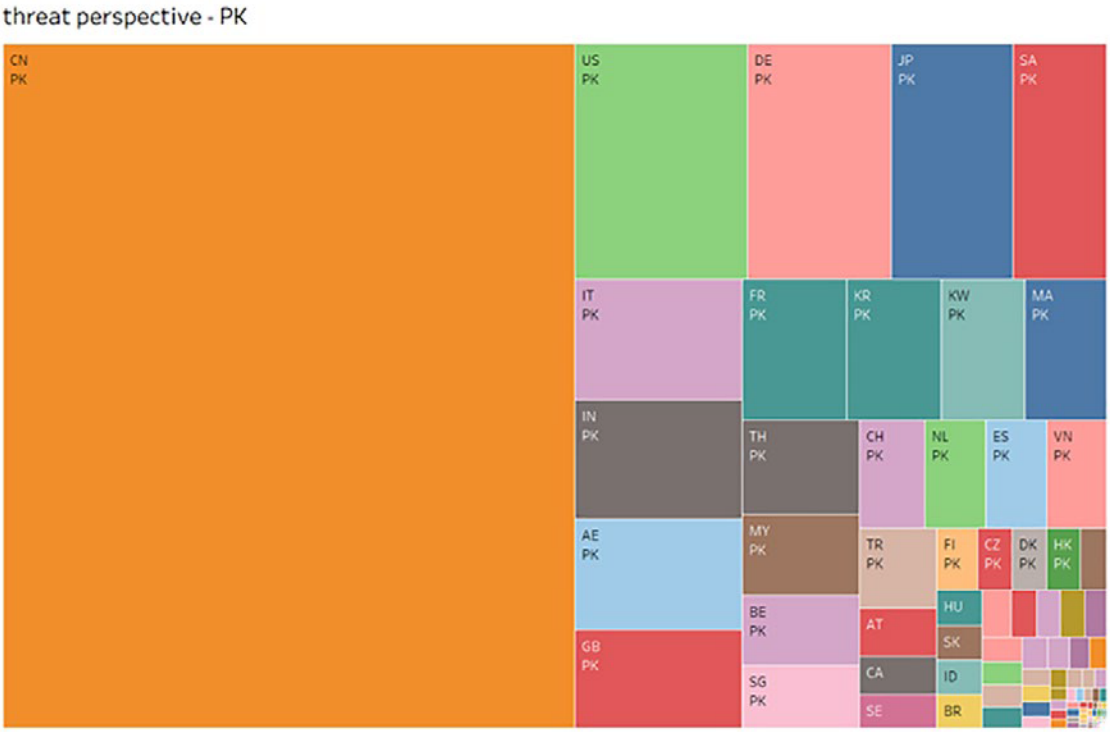

Figure 12: Top suppliers of proliferation-relevant exports to Pakistan (PK) in 2016

Figure 13: Top suppliers of proliferation-relevant exports to DPRK (KP) in 2016

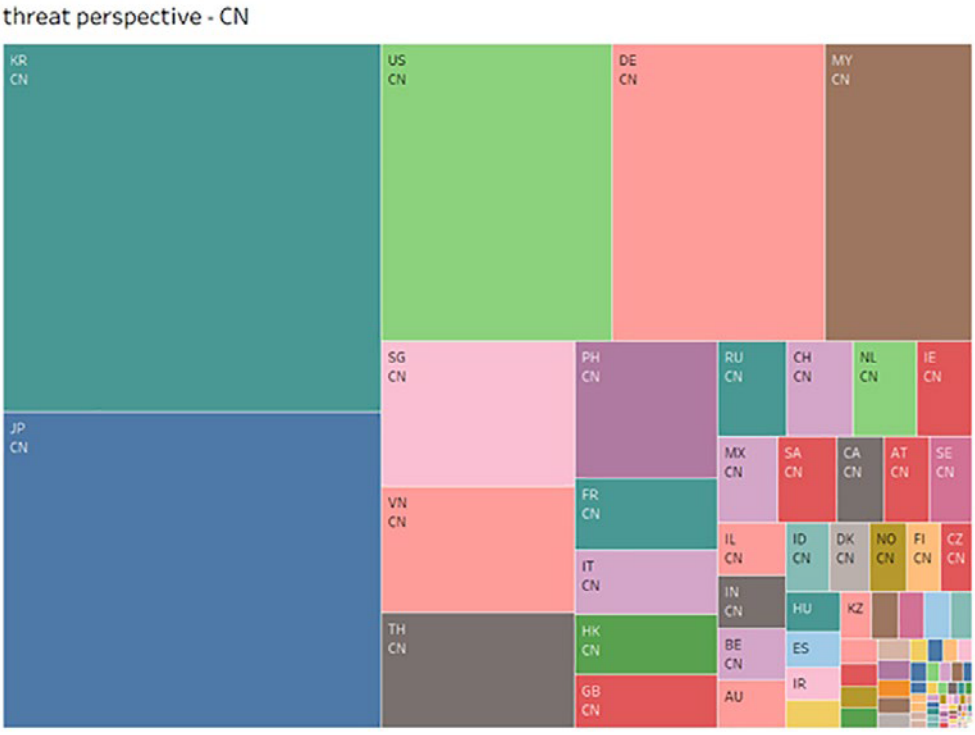

Figure 14: Top suppliers of proliferation-relevant exports to China (CN) in 2016

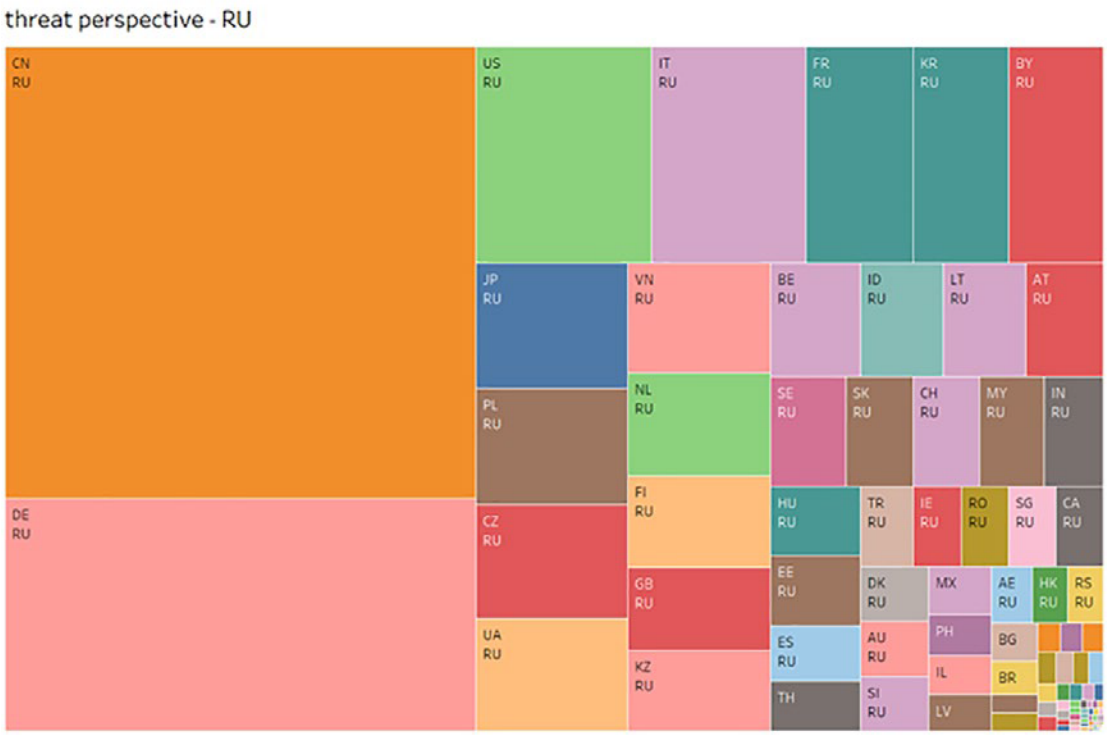

Figure 15: Top suppliers of proliferation-relevant exports to Russia (RU) in 2016

8. References

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