United States and European Union aid cuts risk exacerbating links between aid, trade, and human and environmental crises

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Abstract

Both the United States and European Union have been considerable providers of official development aid, but political pressure is mounting to reduce future disbursements. Here, we conduct a system-wide association study linking detailed trade flows with various aid purposes—including untied, humanitarian, and typically non-trade-related aid—to explore how aid and trade may interact in indirect or unintended ways. Using OECD aid data and global trade statistics, we find strong and persistent correlations between specific imported goods and aid purposes. These links reflect trade-offs among the UN's Sustainable Development Goals and suggest that a major reduction in U.S. aid could disrupt efforts to mitigate the impacts of its food and precious metal imports. The findings also highlight the fragile relationship between aid, minerals, and conflict. This shift may offer a strategic opportunity to nations to reduce their supply chain vulnerabilities and rethink the broader relationship between aid, trade, and human and environmental crises.

Keywords: Trade, development aid, biodiversity, mining, minerals, sustainability

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1 Introduction

Official Development Assistance (ODA) is a subset of government foreign aid measured by the Development Assistance Committee (DAC) of the OECD and targeted towards the development and welfare of recipient countries, as well as shaping relations between donor and recipient nations [1], [2]. ODA allows for cooperation between global economies [3], [4], particularly in sectors such as critical raw materials [5] that are also linked to biodiversity conservation [6]. Therefore, by directing ODA towards trade-related environmental and sustainability initiatives, donor countries can shape policies that aim to reduce biodiversity loss [6], alleviate water crises [7], or contribute to climate mitigation and adaptation [8]. At the same time, ODA investments in infrastructure, regulatory frameworks, and technical expertise are intended to help secure stable and sustainable access to critical minerals necessary for advanced technologies, including clean energy, microelectronics and defence applications [9]–[11].

The relationship between international aid and trade is widely recognized within the framework of Aid-for-Trade literature, where integration of nations into global value chains (GVCs) is explored. Evidence suggests that targeted aid interventions can lead to considerable improvements in trade performance [12], improve production capacities [13], and support export resilience, while also enhancing the economic complexity of the recipient countries [14]. Nevertheless, it is important to stress that the focus in this literature is usually on official Aid-for-Trade flows, where data is often derived from the OECD's Creditor Reporting System in the category Trade Policies and Regulations, or in related areas such as building trade-related infrastructure. Aid-for-Trade flows are a fraction of total development aid, and although their role has been pivotal on developmental outcomes of targeted regions and sectors [7], the wider relationship between international aid and trade, especially untied or humanitarian aid, remains under-explored.

Even though some forms of aid such as health or humanitarian aid should not come with official ties to trade, this may not be the case in practice. For example, the issue of mineral supply chain security may heavily influence where aid, beyond Aid-for-Trade, is directed. For example, Arezki et. al. 2024 [15] found that a recipient country received 36% more aid following a mineral discovery. Given there are established links between minerals and conflict [16], applications of aid in this area can quickly become a politically sensitive topic. One study found that the connections between some forms of aid and natural resources correlates with political instability, although this correlation is weak for aid structured as grants or humanitarian aid [17].

Contracts for aid projects are often awarded to suppliers from donor nations; if this is a requirement of receiving aid, then the aid is known as tied. The action of tying aid can therefore connect it to a donor nation's exports even if the aid is for purposes unrelated to trade. The actions of major donor countries are coordinated by the OECD Development Assistance Committee (DAC). DAC is a consortium of 32 member countries that coordinates international aid policies among major donor countries, official institutions, and private foundations. A primary goal of DAC is to set the scope and standards for ODA. While the DAC has committed to untying their bilateral ODA, a difference between *de jure* and *de facto* untying of aid persists [18]. This is also reflected in academic research, which shows that even if aid projects are untied, contracts are likely to be awarded to suppliers from donor countries [19], [20].

Given that official development aid is seen as a vital component for achieving the UN's 2030 Sustainable Development Goals (SDGs) [1], alongside mineral security [21], there is a clear overlap between sustainable development and supply chain security (minerals being a critical component of the green transition), when it comes to the interests of both donor and recipient nations when deploying ODA. However, aid aligned with the SDGs may not always match recipient priorities and instead be primarily influenced by the geopolitical or commercial motivations of donor nations [22]. The influence of donor motivations

mean aid often viewed as an instrument of soft power [23], with some critics arguing foreign aid leads to dependence on donor nations [24][25]. Nevertheless, climate-relevant ODA has contributed to the achievement of multiple sustainability targets, and there is also evidence that ODA has become more responsive to recipient needs over time [22], with studies showing both donor and recipient interests play a role [26].

In light of this multifaceted relationship between aid and trade, the question arises as to how disruptions in aid policy affect bilateral trade flows. Public support in donor countries towards international aid has shifted over time, falling in France, Germany, and the United States since 2019 [27]. The urgency of this was underscored when the U.S. government initiated a 90-day suspension of foreign assistance programs in January 2025, including considerable funding cuts to the United States Agency for International Development (USAID). As of March 2025, about 5,200 or about 83% of USAID programs were confirmed terminated, purportedly saving taxpayers tens of billions of dollars [28]. The OECD further confirms that for the first time in nearly 30 years, three of the largest providers of ODA, France, Germany, the United Kingdom, have all announced cuts to ODA alongside the United States [29].

This abrupt funding freeze from the U.S. has severely disrupted global humanitarian efforts, with numerous organizations forced to downsize or cease operations. The 2026 fiscal year Department of State budget request includes a two-thirds reduction in bilateral global health programmes [29]. Therefore, these cuts are not only likely to undermine essential services, such as HIV assistance and food security programs, but also to block progress in areas such as the reduction of infant mortality, where USAID funding has had a measurable impact [30], [31]. Experts have warned about serious consequences arising from sudden reduction in aid, particularly for children [32], [33]. This not only has devastating humanitarian implications, but has the potential to diminish U.S. influence abroad, creating the opportunity for other nations to expand their geopolitical reach.

The research objective of this work is to identify signifiers of relationships between aid and trade, beyond the scope of officially designated aid-for-trade, including untied, humanitarian, and typically non-trade related aid, by performing a system-wide association study at a previously unseen level of granularity. While previous studies have examined particular relationships between aid and trade [10][8][7][13][19], or looked at whether aid [30][31] or specifically aid-for-trade [12][34][14] has succeeded in its goals, here we aim to build on this previous work and examine long-term trends in relationships between aid and trade. In particular, we seek to uncover relationships which may not be transparent, well known, or declared in the aid purposes by searching for strong signals against a background of noise. We do this at two hierarchical levels: first, between ODA disbursements of 32 distinct aid sectors and imports of 21 different traded products, and then between ODA disbursements of 275 distinct aid purposes and imports of 96 different traded products. To this end, we use a comprehensive and highly stratified dataset of aid flows with global coverage, the OECD's ODA database that covers the DAC. More specifically, we use the Creditor Reporting System (CRS) which provides the official, standardized and comparable project-level data on aid flows with detailed information on purpose, policy goals, and targeted sectors [35]. ODA flows include grants, loans (including loan repayments that appear as negative flows), export credits, and other flows which do not fall into any of the previous categories. The vast majority of these flows are structured as grants. For this analysis we focus on bilateral country-country flows, although multilateral flows and flows from international institutions are also available. We combine this with the CEPII BACI dataset, which comprises of annual bilateral trade flows for 200 countries at the product level [36][37]. Products in this dataset correspond to the World Customs Organization's (WCO) Harmonized System nomenclature (6 digit code).

We first look at the distribution of ODA and how it has changed over time in constant prices, investigating the share of disbursements from the U.S. and EU. We then perform a system-wide screening of how the

total bilateral ODA disbursements originating from the U.S. and E.U. 27 correlate with the distribution of imports of products from the recipient countries. Current prices are used in this screening to avoid distortions when deflating flows for very different products.

Using a multiplex network setup, where each layer is a directed network corresponding to a single category of aid or trade [38], and each node represents a country or region, we perform the calculation of 26,400 correlations a year at the finest level of granularity, with the aim of identifying strong signals in a vast sea of data. We uncover temporally robust edge-weight correlations between aid and trade flows for a variety of products and aid purposes, potentially indicating long-term strategic collaborations, or the mobilization of aid to address the impacts of trade. However, it is important to stress that causal inference is beyond the scope of this analysis.

A visualisation of two layers in the multiplex network can be seen in Figure 1.

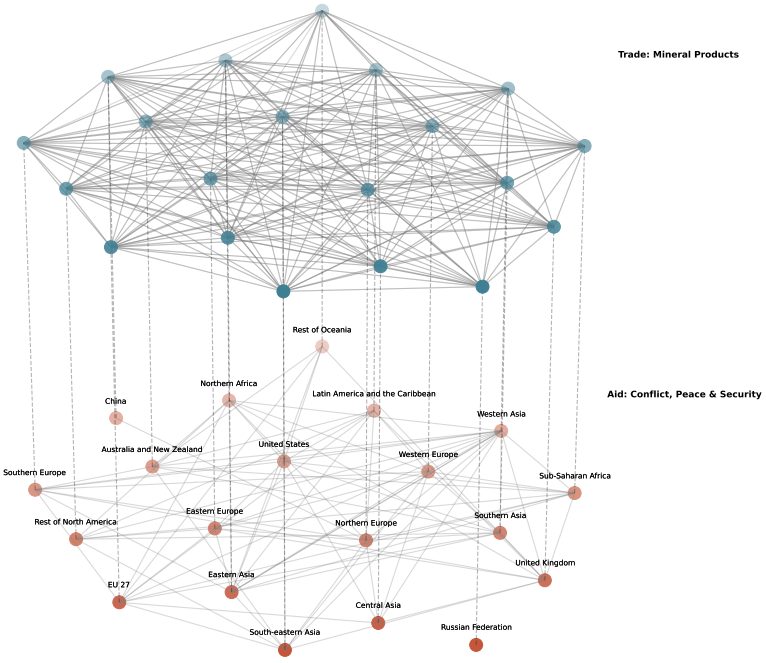


Figure 1: Visualization of two layers (one trade, one aid) in the multiplex network in 2022. Each layer represents a directed network. The top layer represents the HS category of Mineral Products, with edge weights corresponding to imports in current USD and nodes (blue) corresponding to world regions. The bottom layer represents the ODA sector Conflict, Peace, & Security, with edge weights corresponding to disbursements in current USD, and nodes (red) again representing world regions. Our analysis performs a pairwise comparison of the network neighborhoods of the U.S. and the E.U. for each pair of aid and trade layers. For both layers, flows can go in both directions, however bilateral flows typically only appear in the trade layer.

Clear patterns emerge, highlighting how certain imports likely have strong connections to aid for envi-

ronmental purposes, or to ongoing emergencies: a surprising result, as emergency aid should in theory have no links with trade. Specific aid–trade correlations stand out. These include food, precious metal, and mineral products displaying surprisingly strong correlations with forms of emergency aid, as well as persistently strong correlations between biodiversity aid and trade in products such as cocoa and coffee, among others. Interestingly, the correlations between aid and trade often parallel known tensions between different SDGs which are known to be difficult to resolve [1]. Our analysis, therefore, reveals specific areas of potential strategic interest in which the U.S. suspension of aid flows is likely to create a vacuum. It is argued that the E.U. may see this as an opportunity to fill this vacuum in alignment with its strategic interests, in particular in regard to improving the resilience and sustainability of its supply chains. Nevertheless, the persistent correlation between these imports and aid related to biodiversity, health, emergencies, and conflict over time raises concern, and highlights why it is crucial to ensure tensions between the SDGs are addressed and the human and environmental impacts of trade are taken into consideration.

2 Results and Discussion

2.1 Distribution of aid ODA disbursements

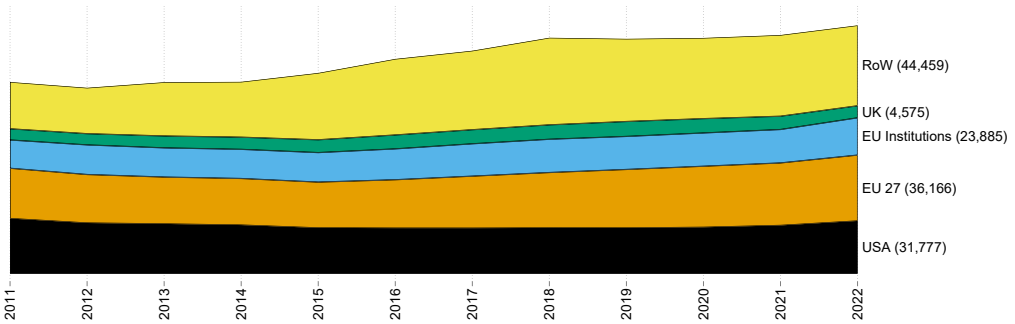
The combined global disbursement of official ODA between 2020 and 2022 amounted to USD 322 billion in constant prices, of which about USD 83 billion (25.8% of total) came from the U.S. while USD 101 billion (31.3%) came from E.U. 27 countries. Figure 2 a) shows how total development aid disbursement has evolved over time in constant millions of USD. Disbursements from E.U. institutions (agencies include the European Commission, the European Investment Bank, and the European Development Fund) make up a considerable share of total ODA from the European Union.

Figure 2 b) shows the distribution of 2020-2022 flows for the top 15 countries receiving majority of disbursements. The largest recipients include Syria, India, Egypt, Bangladesh, and Indonesia, who receive most of their aid flows from regions other than the U.S. and the EU. However, in conflict-affected countries such as Ukraine, Afghanistan, Ethiopia, Jordan, Nigeria, or Yemen, U.S. and E.U. flows dominate. Flows from E.U. institutions are particularly important for Ukraine, where they markedly outweigh bilateral flows from E.U. 27 member states.

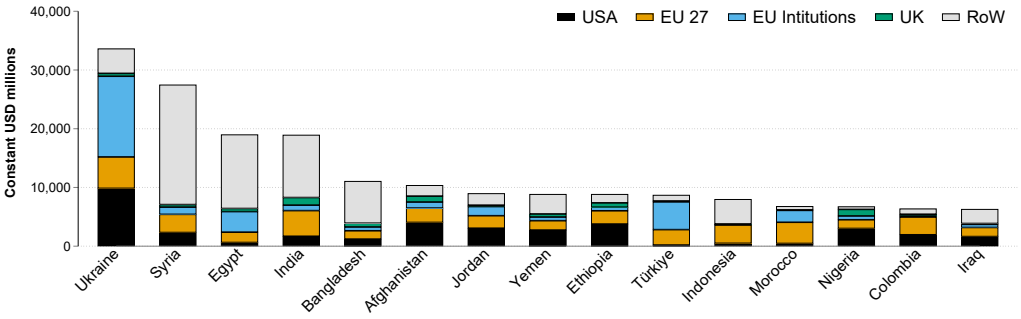
Note that not all aid may be captured by the data presented here, which only accounts for bilateral flows where the disbursement in United States Dollars (USD) is recorded and the flow can be identified as country-to-country pairs. The full database includes bilateral flows from individual countries to both countries and broader regions (both from OECD member states and states which are not members of DAC but choose to report their ODA), with some data missing or unreported. Additionally, the database also includes flows from multilateral donors and private donors.

Figure 3 compares the relative contributions of the U.S. and the E.U. 27 to each aid purpose category. The data shows that the U.S. and the E.U. follow different approaches with their aid programs: the U.S. shares dominate in fewer areas, most with a high volume of overall aid, such as emergency response; aid purposes dominated by the E.U. appear to be split between many different categories, with education standing out. Both contribute equally to health aid.

Figure 4 provides details on U.S. ODA disbursements between 2020 and 2022. The size of the markers is proportional to the size of total disbursements to a particular region (columns) and for a particular aid purpose (rows). The color indicates the share of U.S. giving for each purpose and country. Large markers with a saturated color therefore indicate a strong dependence on U.S. contributions. In other



(a)



(b)

Figure 2: Total ODA by donating region. Disbursements over time are shown for the U.S. (black), E.U. 27 (orange) and E.U. institutions (blue), UK (green), and the rest of the world (RoW) (yellow) in constant millions of USD. Panel a) shows the distribution of ODA from 2011-2022 by donating region. Region labels appear next to the corresponding flow. Panel b) shows the top 15 recipient countries by total disbursed ODA from 2020-2022.

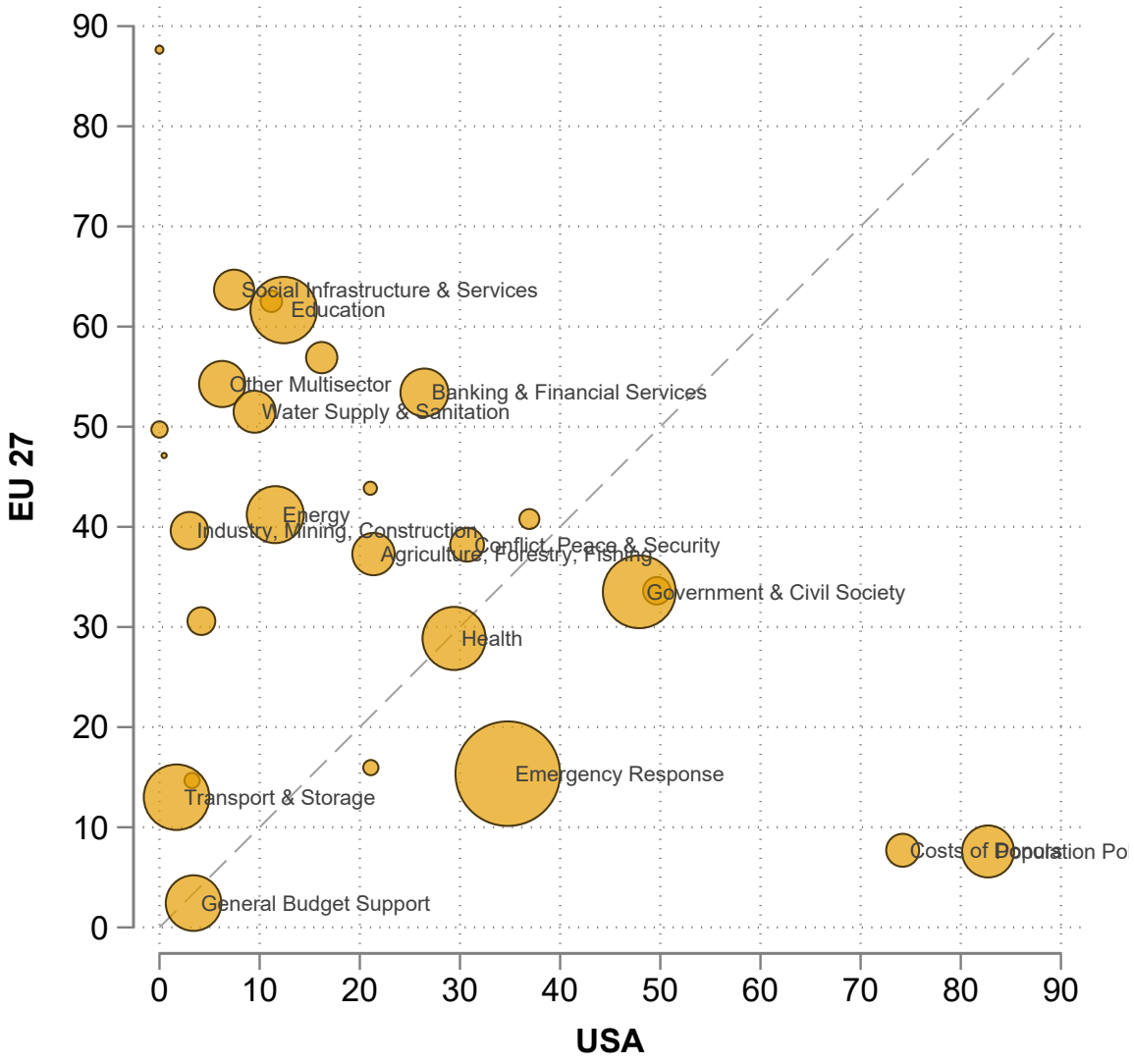


Figure 3: Comparison of U.S. and E.U. aid disbursements by share of total disbursed aid. For each category, we show the share of U.S. (x-axis) and E.U. (y-axis) aid flows in total aid disbursement. The size of the orange markers indicates the volume of aid allocated to that category. The median (dashed line) indicates equal contributions from the E.U. and the U.S., while a value close to the x(y) axis indicates that most contributions come from the U.S.(E.U.). Captions are shortened for readability.

words, a cessation of the corresponding U.S. aid disbursements would likely have a considerable impact.

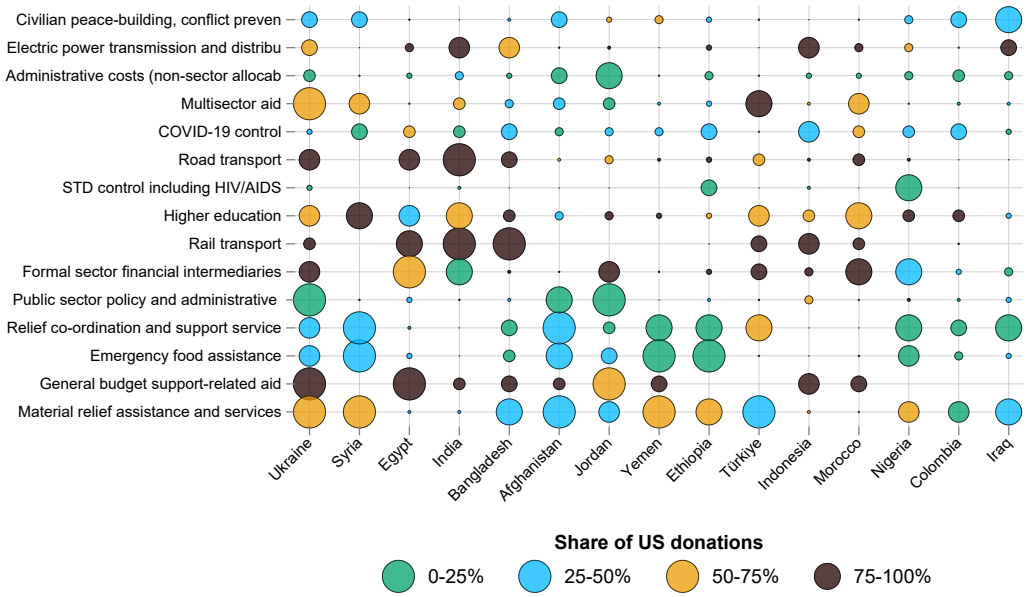


Figure 4: Aid flows by purpose for the top 15 ODA recipients (2020-2022). For each recipient country and category of aid flow, we show the size of the corresponding aid flows (marker size) and the share of U.S. donations (green: 0-25%, blue: 25-50%, orange: 50-75%, brown: 75-100%). Large markers with orange or brown shading indicate policy purposes and regions that are heavily dependent on U.S. donations.

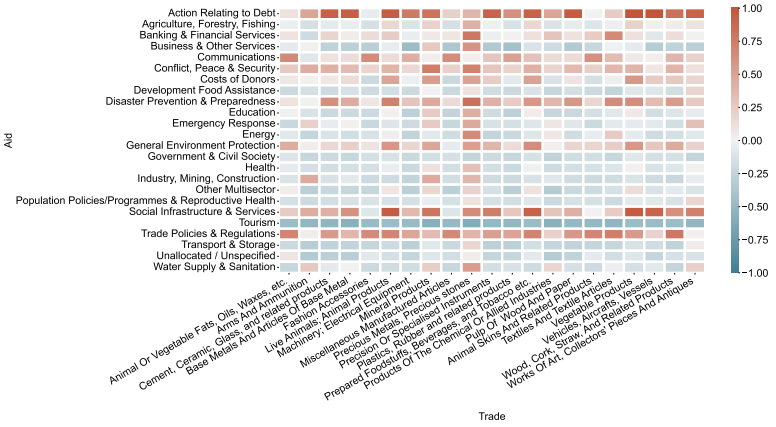
These strong dependencies on large U.S. contributions are spread across many countries and purposes. This includes road and rail transport in India, Egypt and Bangladesh; higher education in Syria, Bangladesh, Morocco and China; or budget-support related aid for Ukraine, Egypt, Bangladesh, Indonesia, Jordan, Philippines, Sudan, and Myanmar, next to several other important contributions.

2.2 Correlating aid and trade: the big picture

We evaluate pairwise edge-weight Pearson correlations between aid and trade layers in a hierarchical multiplex, network which evolves over time, taking aid disbursements and imports in current prices [38]. Each level in the network hierarchy corresponds to a finer resolution of aid or trade flows. Nodes are world regions, with certain large economies separated out. Results are first presented for the broadest level using 21 Harmonized System (HS) trading product sections (as defined by the World Customs Organisation) and 32 aid sectors (as defined by the Development Assistance Committee). These include all bilateral disbursements in current prices, beyond those officially documented as related to trade or Aid-for-Trade. We find correlations between imported products and aid disbursements ranging from strongly positive to negative, suggesting there is no broad, positive correlation between aid flows and import flows and rather particular relationships.

The results for the U.S. for 2022 can be seen in Figure 5(a). Strong correlations across most types of imports can be seen for a few aid sectors: Action Relating to Debt, Social Infrastructure & Services, and Trade Policies & Regulations. Interestingly, Tourism aid stands out as negatively correlated with trade. Looking at the trade axis, we instead see strong correlations across a wide range of aid sectors for trade in Precious Stones and Metals, and Mineral Products. These correlations point to countries which trade

in these products receiving a wide range of aid.



(a) USA

(b) EU 27

(c) EU Institutions

Figure 5: Aid-Trade correlations in 2022 at the broadest hierarchical level. Correlations between imports by product category (columns) and aid by sector (row) are displayed as a heat map for (a) the U.S., (b) the E.U. 27, and (c) E.U. institutions. Red (blue) colors indicate a positive (negative) correlation, with the strength of the correlation corresponding to the color saturation. Captions are shortened for readability.

The 2022 results for the bilateral E.U. 27 country flows can be seen in Figure 5(b). On the trade axis, Precious Stones and Metals and Mineral Products also stand out, although correlations in aid sectors such as Social Infrastructure & Services and Trade Policies & Regulations are weaker than in the U.S., with seemingly fewer trends visible on the aid axis.

This can be contrasted with the results for E.U. institutions in 2022, seen in Figure 5(c). The trade axis shows similar patterns, however the aid axis shows trends not seen for flows from individual E.U. 27 members: Population Policies, Reproductive Health and Reconstruction Relief and Rehabilitation stand out.

When analyzing changes over time, we focus on comparing bilateral flows from the U.S. and current E.U. 27 member countries only to allow details to be explored and to avoid introducing complications due to Brexit. At a greater level of detail, using 275 aid purposes and 96 HS level 2 codes from the 2002 (HS02) classification, we can observe additional patterns. Figure 6 compares the distributions of correlation coefficients for the U.S. for the top 15 HS02 traded products over all aid purposes from 2020–2022 with 2011–2013. While most product categories show similar correlations, there is a notable increase in aid-trade correlations for cocoa and nickel, as well as, to a lesser extent, ores, slag, and precious metals.

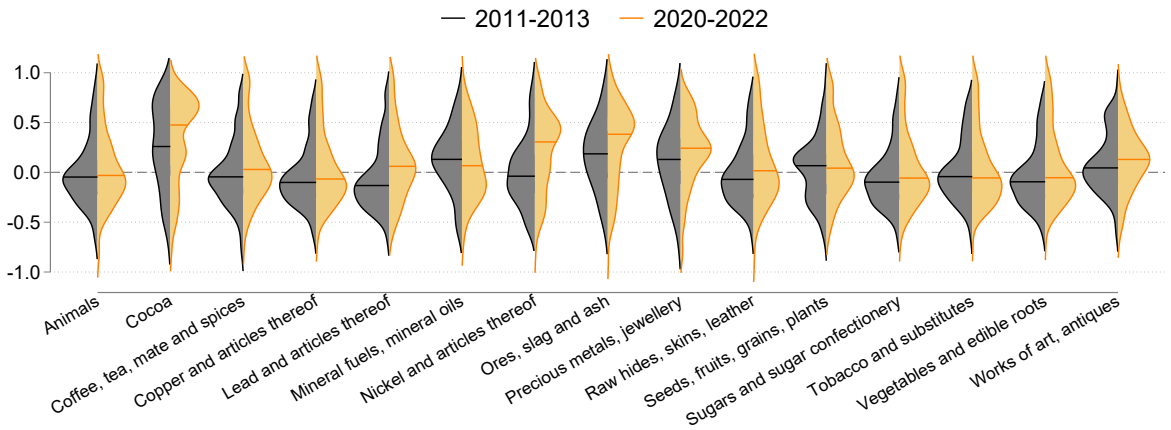
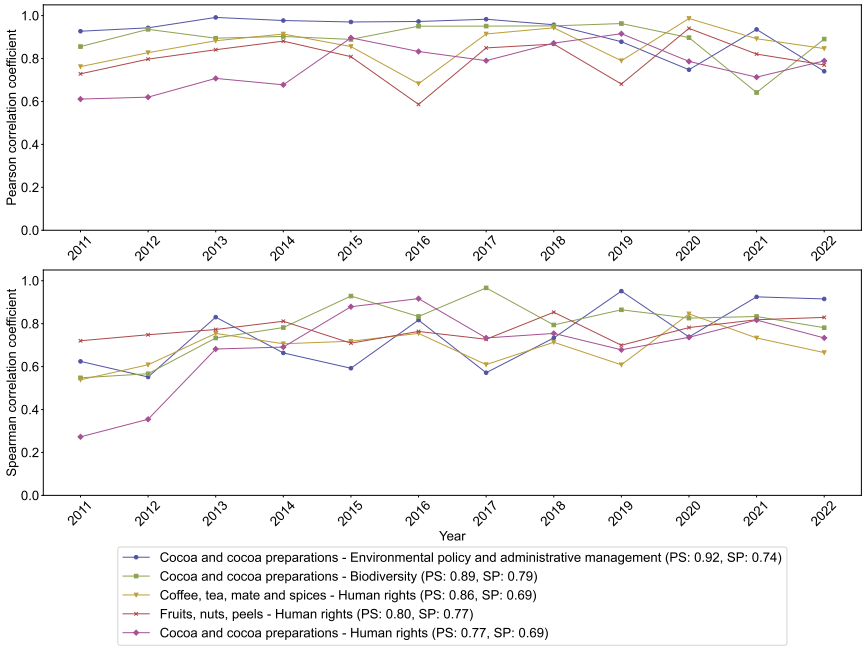


Figure 6: Change in correlations for the top 15 imported products. The distribution of correlation coefficients between traded product categories and all aid purposes are shown for 2020–2022 (orange, right hand side) in comparison with the same distribution per product category in 2011–2013 (grey, left hand side). Captions are shortened for readability.

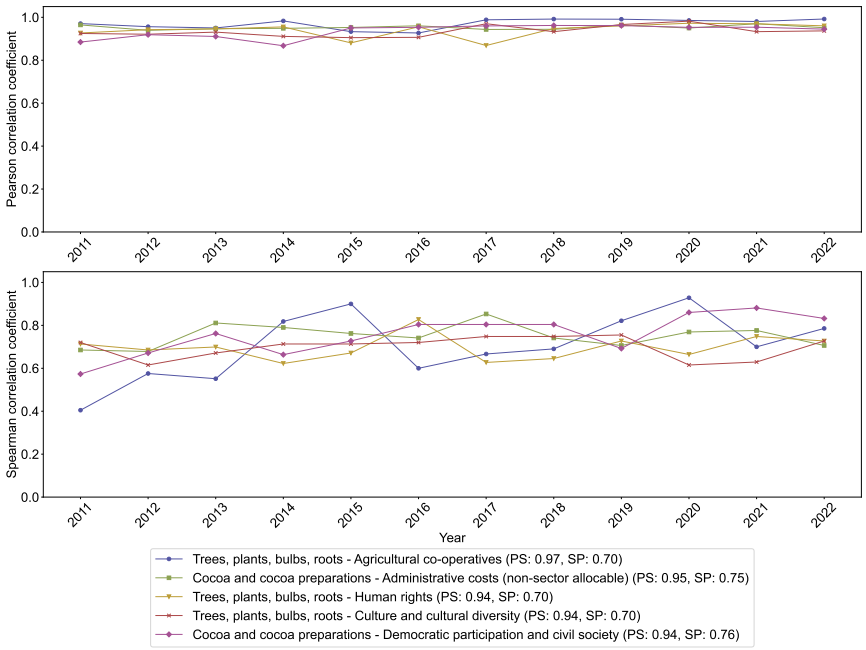
Changes over time for a selection of product-aid purpose pairs with the strongest average correlations, no missing values, and an average Spearman correlation of above 0.65 can be seen for the U.S. in Figure 7 a) and for the E.U. 27 in b). For both regions, the top five trade categories correspond to agricultural or forestry products. In every case, the Pearson correlations are higher than the Spearman, suggesting the presence of individual outlying observations or a large amount of zero or near-zero values due to some regions receiving no aid at all.

In the following subsections, we look at products and aid purposes that stand out due to their strong and persistent correlations in depth, see also the detailed results seen in Supplementary Note 1.

Excluding cases with missing data for more than 50% of the years included in this analysis, biodiversity (a subset of general environmental protection aid) appears for both the U.S. and the E.U. 27 as an aid purpose with strong correlations across several specific products, including cocoa, which stands out in Figure 6 and Figure 7. These correlations do not persist across all traded products, indicating that



(a) USA



(b) EU 27

Figure 7: Correlations over time for imported product-aid purpose pairings. The top five pairings with the strongest average Pearson correlation across 2011-2022 are displayed for each region. From strongest Pearson correlation to weakest, the series are identified by black circles, orange squares, blue triangles, green crosses, and yellow diamonds. Results for the U.S. can be seen in panel (a) and for the E.U. 27 (b). Series with missing values, or with an average Spearman correlation of below 0.65, are excluded.

biodiversity aid is not correlated with trade across the board. Furthermore, under the same conditions, strong correlations persist over time for trade in precious stones and precious metals for both the U.S. and the E.U. 27, with certain unique aid purposes again standing out for each region. We discuss these results and compare the correlations and project descriptions with related literature.

We then look into the broader category of mineral products due to their prominence in Figure 5, which are of vital importance to supply chain security and highly relevant to the discussion of the withdrawal of USAID, and discuss correlations with aid for products in this HS section, as well as related products such as copper, nickel, and ores.

2.3 Biodiversity

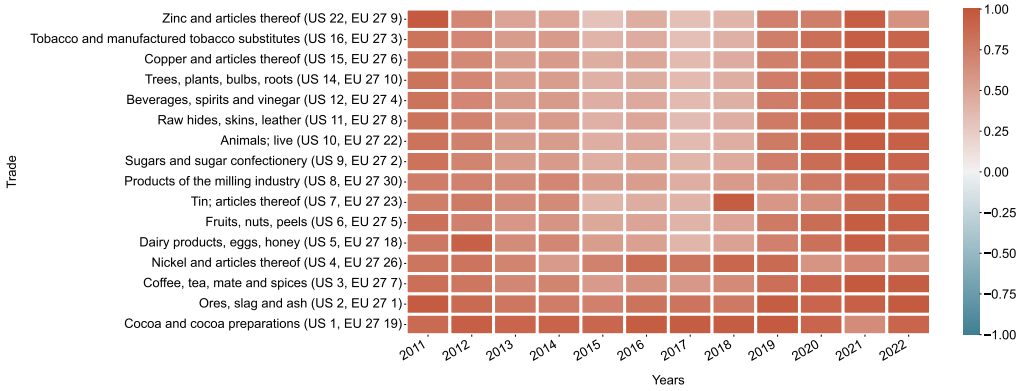
The correlations over time between biodiversity aid flows and the top ten imported products for the U.S. and the E.U. 27 combined can be seen in Figure 8. For trade in certain products, correlations are not only strong, but extremely persistent over time. Cocoa and cocoa products show the strongest average correlations over time for the U.S. in panel a) (0.89), and ores, slag and ash show the strongest average correlations over time for the E.U. 27 in panel b)(0.86), ranking second in strongest average correlations for the U.S., also. Coffee ranks third for the U.S., and sugar and tobacco products rank second and third for the E.U. 27, indicating potentially strong relationships between agricultural imports and biodiversity aid disbursements. For the E.U. 27, most categories also show strong Spearman correlations, however the Spearman correlation for ores, slag and ash is only 45%. Examining a scatter plot reveals a cluster around zero for some data points, and a positive relationship for a few others. While these points may be outliers, it does appear that the data can be split into two classes: one with no relationship and one with a relationship, which would explain the lower Spearman correlation result. There are no results with concerning Spearman correlations in the U.S. top five.

Exploring aid for biodiversity purposes reveals that these are not trade-related flows, meaning there are no trade markers in the CRS database, despite strong correlations with certain traded products. Nevertheless, in some years a considerable proportion (over 25%) of aid project long descriptions mention agriculture or deforestation, with certain projects explicitly mentioning products like coffee and cocoa, or the mining industry.

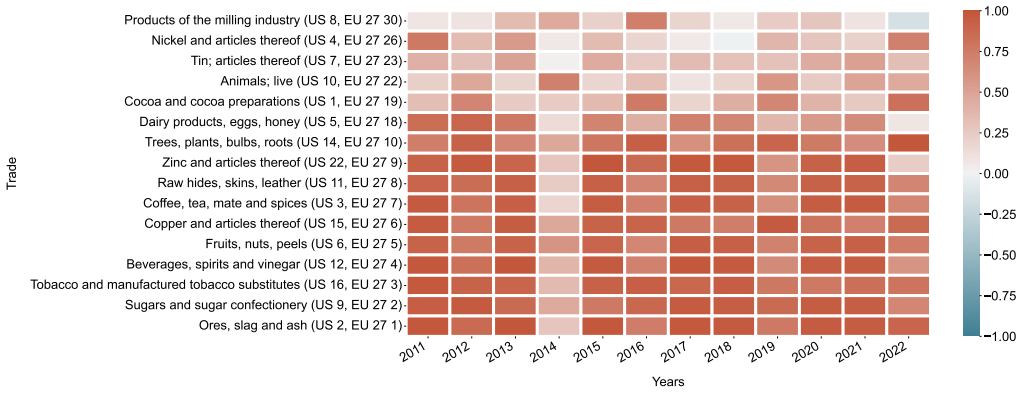
The correlation between the need for biodiversity aid and international trade is supported by various examples in the literature, with exports in general linked with decreasing (animal and plant) species diversity [39]. Strong correlations with cocoa and coffee imports and biodiversity aid are also reflected in literature, with the cocoa trade linked to deforestation in Côte d'Ivoire and Ghana [40], and evidence of plant biodiversity declining with increasing coffee yield in Ethiopia [41]. Products such as cocoa and coffee are also at risk of extreme price volatility with an increasingly changing climate [42], [43].

Biodiversity is also threatened by global mining waste [44], which shows further alignment with the observed correlations. Although aid may be mobilized to address the environmental impact of trade, its impact is not always positive: for example, formalizing artisanal gold mining may accelerate ecological destruction [24]. Precious metals, and mining in particular, correlate strongly with many types of aid, which we discuss in the next two sections.

These correlations, alongside the strong link between agricultural imports and human rights aid seen in Figure 7 reflect known trade-offs between the UN's Sustainable Development Goals (SDGs). For example, there may be tension between goals such as ending hunger (SDG 2) and economic growth (SDG 8), and biodiversity (SDG 15) and human health (SDG 3). Taken together, these findings suggest that both the E.U. 27 and U.S. may attempt to offset environmental impacts of their imported mining and food



(a) USA



(b) EU 27

Figure 8: Correlations over time between biodiversity aid and selected traded products. Panel (a) displays results for the U.S. and (b) the E.U. 27. Traded product categories (y-axis) are the union of top 10 of U.S. and E.U. 27 correlation values. The graphs are sorted by the average correlation over time of top 10 aid sectors for each region. Red (blue) colors indicate a positive (negative) correlation, with the strength of the correlation corresponding to the color saturation. Captions are shortened for readability.

products using ODA, particularly in regard to biodiversity preservation and deforestation, which would be in line with their commitment to the SDGs, as well as in the interest of their own supply chain security.

Although these correlations do not provide causal links, the literature clearly demonstrates why removal of biodiversity aid creates a risk of the environmental consequences of trade going unchecked. Therefore, these signals could provide indicators of potential conflicts between SDGs as well as of products which are at high risk in the case of aid removal.

2.4 Precious metals and precious stones

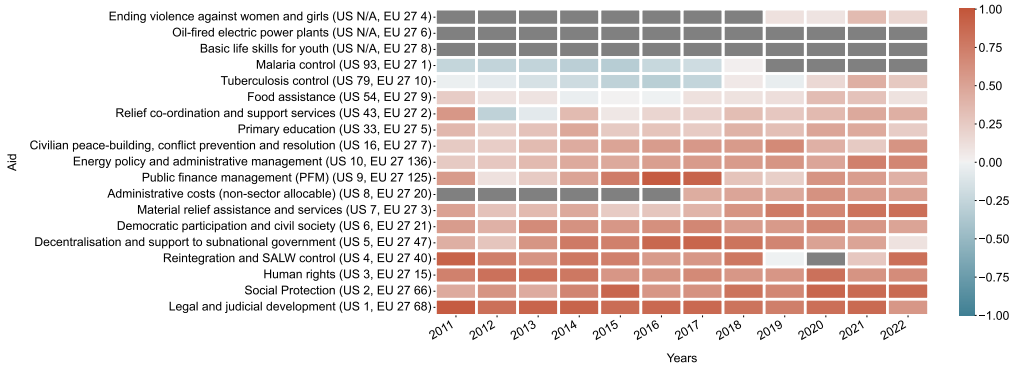
Also of note in this analysis is the strong correlation between trade in precious metals and stones, such as gold and diamonds, and related products such as pearls, and aid, see Figure 9. This category can include unwrought gold and silver (dust or nuggets), but precious metal ores are included in the HS broad category of Mineral Products, which we will discuss in the next section. For the U.S. in panel a), the aid purpose with the strongest average correlation (controlling for less than 50% of values missing) is legal and judicial development with a Pearson correlation of 0.83, with social protection and human rights ranking second and third.

For the E.U. 27 in panel b), top correlations over time correspond to aid for malaria control (with an average Pearson correlation of 0.84), followed by relief coordination and support services, and material relief assistance and services (both the two latter categories are types of emergency response aid). Links between this industry and the need for aid related to malaria and tuberculosis (E.U. 27 rank 8 in Figure 9 b)) can be found in the literature: malaria has been associated with gold mining areas [45], and negative health outcomes can include lung disease due to inhalation of silica dust when cutting gem stones or mining, with a recent study calling for urgent policy changes in this area [46]. Environmental aid categories do not strongly feature, but they are more prominent when examining mineral products, which include precious metal ores.

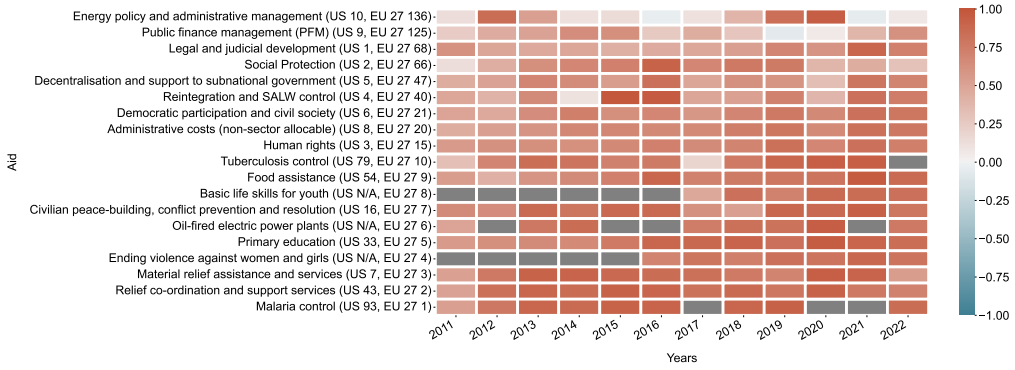
At the broader level, the U.S. shows the strongest average correlations over time for Government & Civil Society, and Social Infrastructure & Services. The E.U. 27 for Emergency Response and Conflict, Peace, & Security.

Precious stones and metals are well known to be linked to conflict, poor labor conditions, and damaging environmental impacts, and both the European Union and the United States have been open about their aid approaches in this industry: USAID published an article in 2020 on how they are 'breaking the links between artisanal mining and harmful impacts on people and the environment' [47], and the E.U. Aid-for-Trade 2021 progress report explicitly mentions how Aid-for-Trade is used to ensure diamonds entering the E.U. are conflict-free via the Kimberley Process [48], the success of which is controversial: Global Witness, an NGO involved in the establishment of the process, exited the scheme in 2011 [49]. These approaches point to increased regulation of the industry, and not only a humanitarian response, although correlations point to a more heath and emergency-focused strategy for the individual E.U. 27 nations, compared to the approach of strengthening institutions, implied by the descriptions of legal and judicial development and human rights aid by the DAC, for the U.S.. It could be argued that both approaches are humanitarian, although emergency aid more so.

Humanitarian aid generally includes the stipulation that it should not be tied, meaning there is no requirement that it must be used to procure goods and services from the donor country. The DAC has committed to untie all ODA [18], however, as noted by the DAC many contracts are awarded to suppliers from donor countries [19], [20]. It further should adhere to the fundamental humanitarian principals of



(a) USA



(b) EU 27

Figure 9: Correlations between trade in precious metals and stones and development aid over time. Panel (a) displays results for the U.S. and (b) for the E.U. 27. Aid sectors (y-axis) are the union of top 10 of U.S. and E.U. 27 correlation values. The graphs are sorted by the average correlation over time of top 10 aid sectors for each region. Red (blue) colors indicate a positive (negative) correlation, with the strength of the correlation corresponding to the color saturation. Captions are shortened for readability.

neutrality, humanity, independence, and impartiality.

It is therefore pertinent to ask why strong correlations between aid for health, justice, conflict, and human rights persist. The mining of gold and diamonds may be seen as an important route to economic development, and therefore these correlations reflect a known tension between the SDG of economic growth, and other goals such as 3 Good Health and Wellbeing and 16 Peace, Justice, and Strong Institutions [1]. While the deployment of humanitarian aid may be seen as a way to address these tensions, it has been noted 0.7% of Gross National Income is insufficient to reach all SDG targets [50]. Moves towards a global reduction in aid therefore pose a risk of amplifying these existing patterns.

2.5 Mineral products and metals

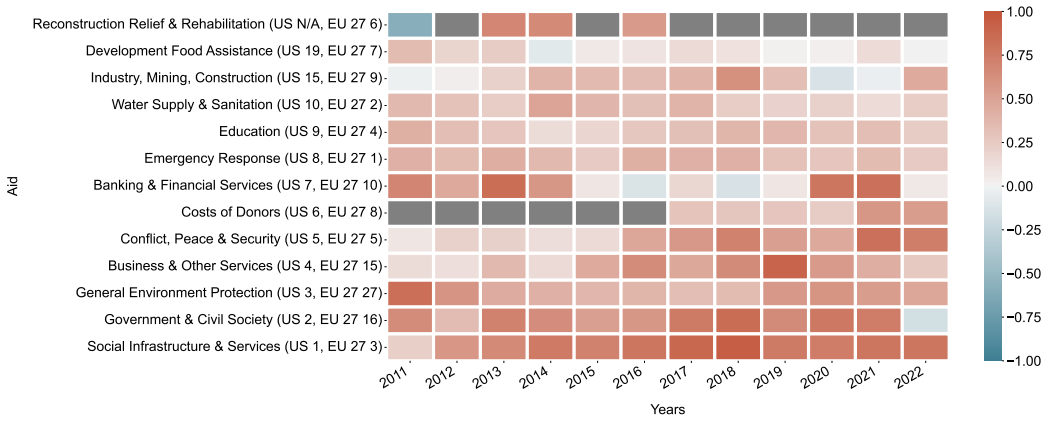
Strong correlations exist for both the U.S. and the E.U. 27, suggesting regions which trade the most in building materials, ores, and mineral fuels and oils are also notable recipients of aid. The top three results for both regions all also have Spearman correlations above 50%.

For the U.S., the top two aid sectors whose projects mention the key word 'mineral' include Government & Civil Society, and Conflict, Peace & Security. Including the key word 'mining' results in General Environmental Protection taking first place. These results are broadly consistent with Figure 10 a), with the U.S.'s top sector again being Social Infrastructure & Services with an average Pearson correlation of 0.72. This sector is third for the E.U. 27 in Figure 10 b), with Water Supply & Sanitation ranking second, and Emergency Response ranking first with an average Pearson correlation of 0.73. Note that aid for Trade Policies & Regulations, which can be counted as Aid-for-Trade, does not show strong correlations across time for the U.S. or the E.U. 27 when it comes to mineral products.

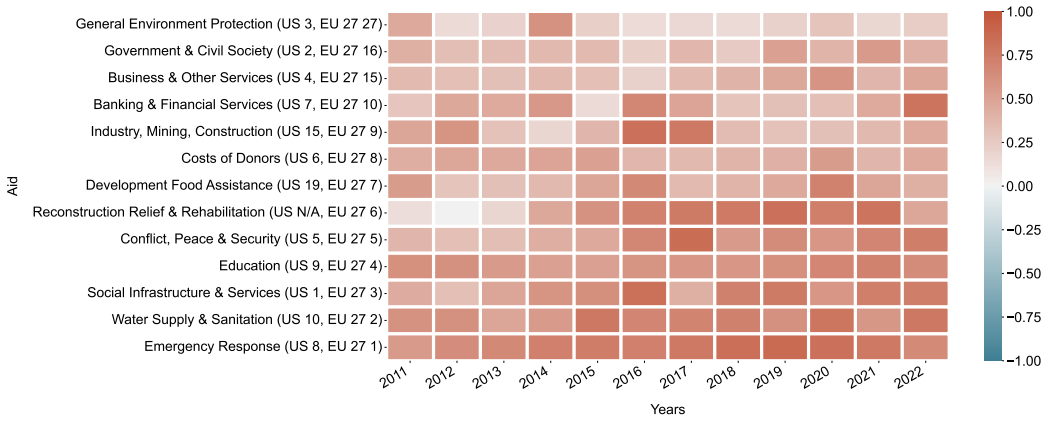
Up to 2022, where the correlation data ends, strong correlations between rare earth mineral imports and ODA flows do not exist, with strong signals instead for copper, nickel, and ores (which includes copper and nickel ores, see Supplementary Figures 1, 2, and 3 in Supplementary Note 1, where the signals can be seen in more detailed data). This may in part be due to current global rare earth mining and refining being dominated by China, which ranks 27th as a recipient of ODA (2020-2022), and is not a major recipient of aid from the U.S.. Note that if exports (to the U.S. or E.U. 27) are dominated largely by a single region, results will not appear in the correlation analysis due to a lack of data points, or a lack of a pattern across regions.

Many minerals are typically produced as by-products of major metals such as iron, nickel and copper. For example, cobalt is heavily dependent on by-product production from copper and nickel, as are platinum group metals, selenium and tellurium, while vanadium is strongly linked to specific types of iron ore. Overall, more than 60% of critical minerals are produced as by-products [51]. Therefore, access to a supply of base metals such as iron, copper and nickel goes hand in hand with access to many strategic minerals that are traded in much smaller volumes but play a critical role in many future technologies.

The persistence of correlations between ODA and mineral products over time for many types of aid outside the Aid-for-Trade umbrella, and strong correlations between ODA and metals such as copper and nickel, are perhaps unsurprising given both mineral security and ODA are considered essential for achieving the SDGs, and their interaction, alongside donor interests in supply chain security[9]–[11], may influence these correlations, with one working paper finding a recipient country receives 36% more aid following a mineral discovery [15]. While there are known links between aid and conflict [16], persistently strong correlations over time between aid for conflict and emergencies and trade in minerals is concerning given known warnings about how increased demand for minerals and metals essential to the green transition could impact states experiencing or at risk of conflicts [52]. The use of ODA to



(a) USA



(b) EU 27

Figure 10: Mineral product aid-trade correlations over time. Panel (a) displays results for the U.S. and (b) for the E.U. 27. Aid sectors (y-axis) are the union of top 10 of U.S. and E.U. 27 correlation values. The graphs are sorted by the average correlation over time of top 10 aid sectors for each region. Red (blue) colors indicate a positive (negative) correlation, with the strength of the correlation corresponding to the color saturation. Captions are shortened for readability.

reduce these conflict risks would be in line with SDG 16, Peace, Justice and Strong Institutions, and with removing tensions between the goals, however the interaction between some forms of aid and natural resources have been found to correlate with political instability, although the authors indicate that this is not true for aid structured as grants or humanitarian aid [17].

Mineral product imports and their relationship with ODA are of central importance in the discussion of the cancellation of USAID. The pause is reported to have hit humanitarian work in the Democratic Republic of the Congo [53], with a Congolese senator said to have contacted U.S. officials 'to pitch a minerals-for-security deal' [54]. 17 countries are reported by NGO Global Witness to have signed lobbying contracts with U.S. firms since the 2024 election, nine of which are reported to be resource rich nations experiencing conflicts, including the Democratic Republic of the Congo [55].

A mineral deal has now also been reported as signed between the U.S. and Ukraine following the temporary withdrawal of U.S. military and financial support [56].

Such deals signify a move away from traditional forms of development aid, which is required to be concessionary in nature by the OECD, towards an openly transactional relationship. While direct aid-for-minerals agreements may be more transparent and could still appeal to some SDGs such as 16 Partnerships for the Goals and 7 Affordable and Clean Energy, similarly to development aid, this will not guarantee a match with aid-recipient priorities [22], and marks a clear departure from a no-strings-attached humanitarian approach. Our results only indicate possible relationships and provide no causal inference, and therefore cannot provide insight into comparisons between ODA and resource deals. Nevertheless, they do indicate areas where SDGs concerning the green transition, the environment, and human rights continue to conflict, with correlations not weakening over time, re-enforcing that any new paradigms of aid must be prepared to address these issues.

3 Conclusions

The cessation of U.S. foreign aid, particularly through USAID, has the potential to reshape global geopolitical dynamics and influence. The humanitarian impact is already visible, with experts warning that lives are at serious risk [32], [33]. Our work examines the broader relationship between aid and trade beyond Aid-for-Trade, including untied, humanitarian, and typically non-trade related aid, at a high level of granularity. It identifies 26,400 correlations a year across an eleven-year time span, for up to 96 categories of traded products with up to 275 distinct aid purposes, and highlights how certain imported products are strongly correlated with certain types of development aid, at a much larger scope compared to aid declared as Aid-for-Trade, with correlations persisting over time. The strong correlations seen between agricultural products such as coffee and cocoa and mined products such as precious metals or critical minerals, and aid designed to address health, emergencies, or conflict, underscore the human and environmental impacts of trade reflected in the academic literature, motivating evidence of potential relationships between trade, donor interests, and aid deployment beyond Aid-for-Trade.

These results reflect how programs and policies under the UN's 2030 Sustainable Development Goals (SDGs) can conflict with each other [1][57]. For example, agricultural policies aimed at SDG 8, Decent Work and Economic Growth or SDG 2, Ending Hunger, can conflict with SDG 15, Life on Land, when it comes to protecting biodiversity, or SDG 3, Good Health and Wellbeing, when it comes to labor practices which have negative health and well-being impacts. The promotion of clean energy (SDG 7) has various tensions with responsible consumption and production (SDG 12), particularly when it comes to the mineral extraction needed for the green transition [1]. This can lead to further tensions with SDG 3 and SDG 15 due to the associated human and environmental consequences [21][52]. These trade-offs and

tensions are already known to pose a significant challenge to policy makers, and are inherently political, with different interest groups prioritizing some goals over others [1]. This is particularly relevant in the case of Official Development Aid allocations from OECD member states, where the interests of donor countries are widely known to have an influence [58][22].

The situation has recently been further aggravated by the UK, France, and Germany announcing a substantial reduction of their aid budgets who are other major providers of ODA [29]. The OECD projected a 9-17% decline in ODA in 2025, with eleven OECD DAC members having publicly announced aid cutes for the period 2025-2027. These countries collectively contributed three-quarters of total ODA in 2024, so while some nations have planned increases in or maintained high levels of ODA – such as Ireland, Korea, Spain, Denmark, Norway, and Luxembourg – aid reductions are still a major shock to international development cooperation [29].

In the absence of assistance from other regions, emerging global actors such as China and other regional powers may seize the opportunity to expand their influence through alternative aid programs and infrastructure investments, thereby shifting trade dependencies and geopolitical alignments. China positions its aid as a form of South-South cooperation and states that it adheres to the principals of not imposing political conditions on aid, and has increased global financial flows significantly through two channels: aid and international development. According to OECD estimates, in 2022 China disbursed bilateral development aid in the range of USD 3.1 billion comparable to the figure from the year before [59]. This went hand-in-hand with investments for international development through non-concessional loans under the umbrella of the Belt & Road Initiative that focuses on large and visible infrastructure projects aimed to improve transcontinental trade and transportation. It has been estimated that the Belt & Road Initiative will reduce global trade costs by 2.2% until 2040, thereby increasing world GDP by USD 7.1 trillions or 4.2% [60]. For China, the Belt & Road Initiative is also a central foreign policy tool to assume greater leadership in global affairs and signal its rising status and power. Indeed, China has already announced plans to replace USAID funding in the context of a landmine clearing project in Cambodia [61]. Such projects would fall under the Conflict, Peace & Security purpose, which shows strong and consistent correlations across multiple product categories in both the U.S. and E.U. 27, compare Figure 5. These approximate numbers come from various official and unofficial documents since China is not part of the ODA club (similar to India, South Africa and Argentina) but is a significant player in the global arena. Furthermore, there has been an increasing global role of emerging economies in development cooperation in general, which has disrupted established formats of cooperation [50]; this will likely become more visible as U.S. influence declines.

The E.U. has also long seen development assistance as a key tool to advance its strategic interests, including sustainability, geopolitical stability, supply chain resilience and economic growth, in line with the SDGs. Indeed, our analysis shows that both E.U. and U.S. biodiversity aid projects very often include keywords related to mining and agriculture, as well as deforestation, reflecting the known tensions between SDGs. Furthermore, the COVID-19 pandemic and geopolitical tensions, including disruptions caused by the war in Ukraine, have exposed vulnerabilities in global supply chains, prompting the E.U. to re-evaluate its dependencies, particularly in critical sectors such as pharmaceuticals, semiconductors, and raw materials. In this context, the E.U. recently announced plans for creating a E.U. Critical Raw Material Centre to jointly purchase raw materials, next to launching the Clean Trade and Investment Partnerships to diversify supply chains in mutually beneficial strategic partnerships. The E.U. and its member states together are the current largest contributor to ODA, see Figure 2 a), and consequently may see the U.S. cuts as providing an opportunity to strengthen its environmental and social commitments and lead in resolving tensions between SDGs, thereby reducing the risk of climate or conflict-induced instability that could lead to increased migration pressures and economic disruption.

We do not assume that these persistent correlations imply that aid is ineffective; given the literature on the human and environmental impacts of certain products [39][40][41][44][45], the knowledge that mineral security essential to achieving the SDGs could also lead to increased conflict risks for producing states [21][52], and that ODA is seen as a vital component required to achieve the UN's 2030 SDGs, the results are unsurprising. At an individual project level, aid can vary markedly in its outcomes: PEPFAR, U.S. President's Emergency Plan for AIDS Relief, is credited with saving about 26 million lives [62], whereas the effectiveness of international aid in the case of Lebanon is seriously questioned [63]. Why certain projects succeed or fail is therefore an important consideration, with Nobel Prize-winning economists Esther Duflo and Abhijit Banerjee making the argument that projects should be assessed case by case [63], [64]. Our research highlights relationships between aid and trade which should be part of the discussion when moving forward.

While a potential cessation of U.S. aid can therefore help the E.U. to improve its geopolitical position in strategic regions such as Africa or the Indo-Pacific, careful consideration should be given to the trade-offs between different SDGs, as well as the interests of donor and recipient nations. Although these shocks to international aid are worrying, it has been argued that they also pose an opportunity to 'reframe aid' and ensure public understanding of how aid is beneficial to donor countries, as well as ensuring recipient nations benefit long term by building self-sufficient systems [65]. Shifts towards aid-for-security deals, particularly when it comes to minerals, pose the same risks as traditional donor-recipient relationships when it comes to correlations with political instability, biodiversity loss or deforestation, and human rights violations, problems known to be exacerbated by extractivist operations [66][1]. An important step in addressing the correlations between crisis-related aid and trade is addressing trade-offs between the SDGS. Kroll et. al. 2019 demonstrate that in certain cases it is possible to turn SDG trade-offs into synergies, for example climate action (SDG 13) and sustainable cities and communities (SDG 11) [57]. More broadly, a movement towards a fairer, rules-based trade system is argued to be an important part of the international cooperation needed to address the SDGs while minimizing trade-offs, as well as ensuring transformations are not designed and imposed from the 'top down' [67].

It is not clear how the E.U. can balance its own policy goals and address the potential geopolitical, economic, and environmental implications of a shifting global approach to international aid. Strong and persistent correlations in the global aid-trade network as presented in this article can provide insight into areas at risk of SDG trade-offs and crises. More transparency about the risks and benefits of aid and trade relationships [65], and an international, collaborative [68][50], and mutually beneficial approach to addressing global challenges are a key first step [67], as is knowledge sharing when it comes to transformative technologies [57], knowledge co-creation [1], and encouraging inter-regional and south-south collaboration [69][1]. The opportunity to rethink aid, how it can be used to enhance sustainability goals and address shared concerns about climate change, and to improve security for everyone, should not be missed.

The analysis in the paper is limited by the availability of data, as well as its transparency. We focus on imported products, however, the same methodology can be applied to exports to yield differing patterns. Robustness checks are performed by examining Spearman as well as Pearson correlations between network layers, to ensure outliers were not responsible for strongly positive results. Nevertheless, our results do not imply causal inference. Based on our approach we could investigate the correlation of trade with humanitarian aid, tied or conditional aid, and aid directly connected to SDGs in more depth. Aid would need to be classified based on the information available in the Creditor Reporting System (CRS) database, and the resultant change in correlations could then be investigated. Future work can explore the addition of aid flows beyond the CRS database, expanding the global picture, with the potential to add financial flows, foreign direct investment, and remittances as additional network layers, as well as

exploring a far wider variety of network measures.

4 Methods

Bilateral, official development aid flows are taken from the OECD's Creditor Reporting System (CRS) database. All flows are identified using donor and recipient International Organization for Standardization 3 letter (ISO-3) codes, and total disbursement in current millions of U.S. dollars is aggregated by aid sectors and aid purposes. Note that disbursements can be negative, as they may include loan repayments.

The BACI dataset provides yearly bilateral trade flows at the product level. We identify exporters and importers also using their ISO-3 codes. Here, flows are also in current prices (thousands of U.S. dollars), and are aggregated either to HS sections or level 2 HS codes.

The two datasets are aligned, with missing data excluded from the analysis. Regions rather than individual nations are used for this analysis, with certain large economies separated. This is because aid typically flows between world regions, whereas trade flows both within and between. This means, at an individual country level, aid-trade correlations are difficult to see due to within-region trade biasing the results.

The network is built by creating an individual, directed network for each aid sector/purpose or trade sector/product, for each year ranging from 2011 to 2022. A multiplex network is then constructed, with each layer representing distinct aid or trade flows. Edge weights are the size of flows in U.S. dollars. For aid layers, either the U.S. or the E.U. 27 are isolated as the source, with recipient regions as the targets. For trade layers, the importing region is used as the source instead, with the exporting region as the target. This allows correlations between imports and aid out-flows to be easily assessed.

By constructing an edge by layer matrix for each year in the analysis, the Pearson correlation between layers can be calculated using the edge weights. Spearman correlations were also calculated to assess the influence of outliers on the results. For each year, comparing every layer in the dataset at the finest level of granularity amounts to 26400 correlations; this amounts to 290400 comparisons across eleven years. As we wished to assess such a large network and consider only if network layers may show similar patterns in their edge weights, rather than identify causal relationships, we decided to use the Pearson correlation as a simple and effective measure. Furthermore, given minimal parameters were required to calculate the Pearson correlation, it allowed us to assess whether potential relationships between layers of the network may exist, while introducing minimal bias.

Correlation results are only returned if there are at least 4 data points in the edge weight vectors. As we are looking at correlations, the normalization of the data by product or aid purpose has no effect on the results.

When assessing the strongest average correlations over time, series with more than six missing values were excluded, i.e. with more than half the values missing.

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6 Competing interests

The authors declare no competing interests.

7 Author contributions

R.H. co-designed the research, co-prepared data for analysis, designed multiplex network methodology and performed network correlation analysis, produced aid-trade correlation results, contributed to interpretation of results and co-wrote the paper.

A.N. co-designed the research, co-prepared data for analysis, produced aid disbursement results, contributed to interpretation of results and co-wrote the paper.

P.K. co-designed the research, contributed to interpretation of results and co-wrote the paper.

8 Data availability

The full multiplex network discussed in this study as well as additional data required to fully reproduce all results can be accessed at: Hayward, R., Naqvi, A., & Klimek, P. (2025). Multiplex network of development aid and trade [Data set]. Zenodo. https://doi.org/10.5281/zenodo.17533314

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Supplementary information

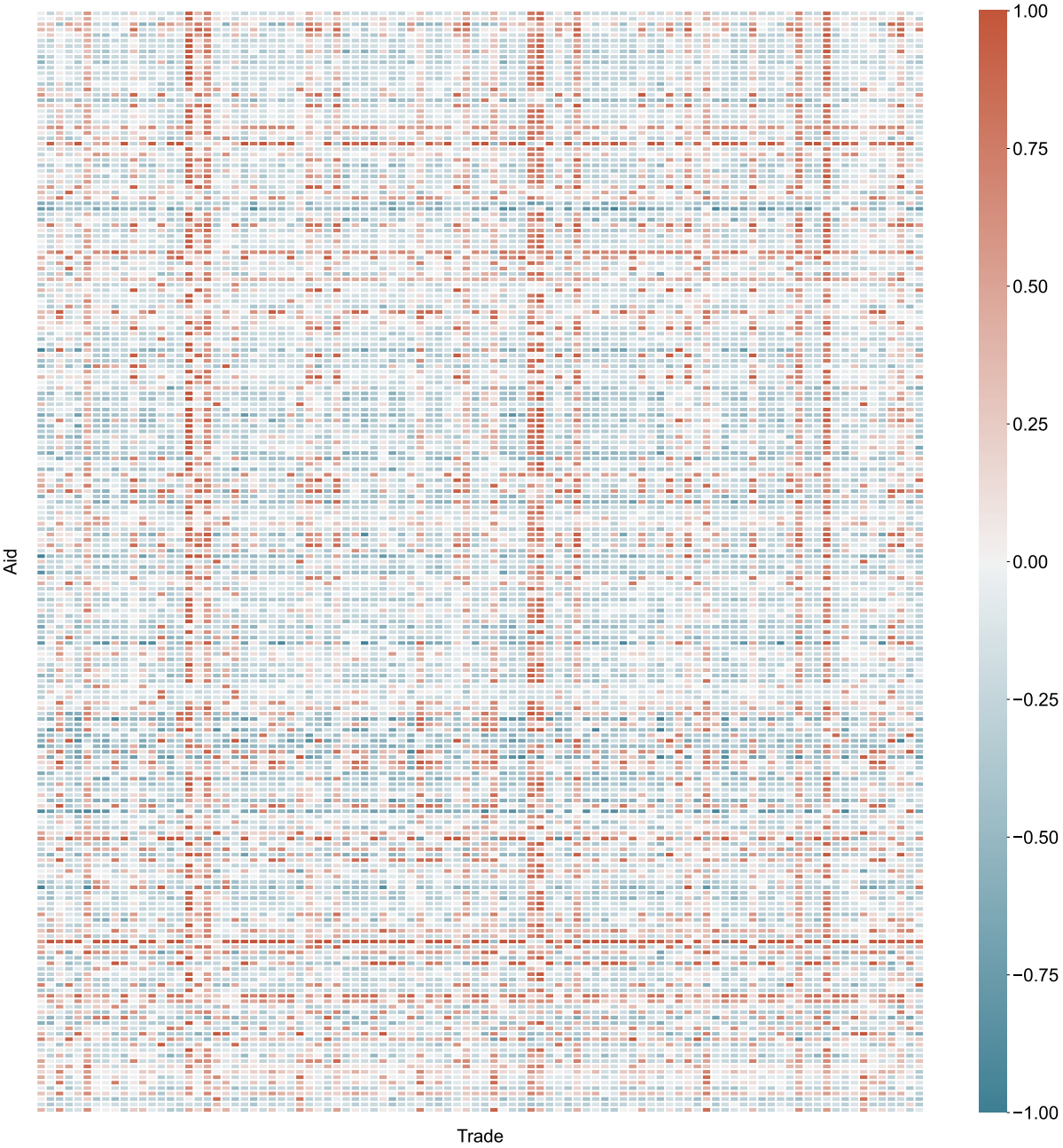
Supplementary Note 1

Here, we present the 2022 correlation results for the full multiplex network using 275 aid purposes and 96 level 2 codes at the HS 2002 (HS02) classification. The strong correlations which appear over either a broad range of traded products or a broad range of aid purposes, as well as which categories stood out across time, informed the aid and trade categories explored in this work: biodiversity aid, and trade in precious metals and mineral products.

Supplementary Figure 1: Heat map of all aid-trade correlations for the U.S. in 2022.

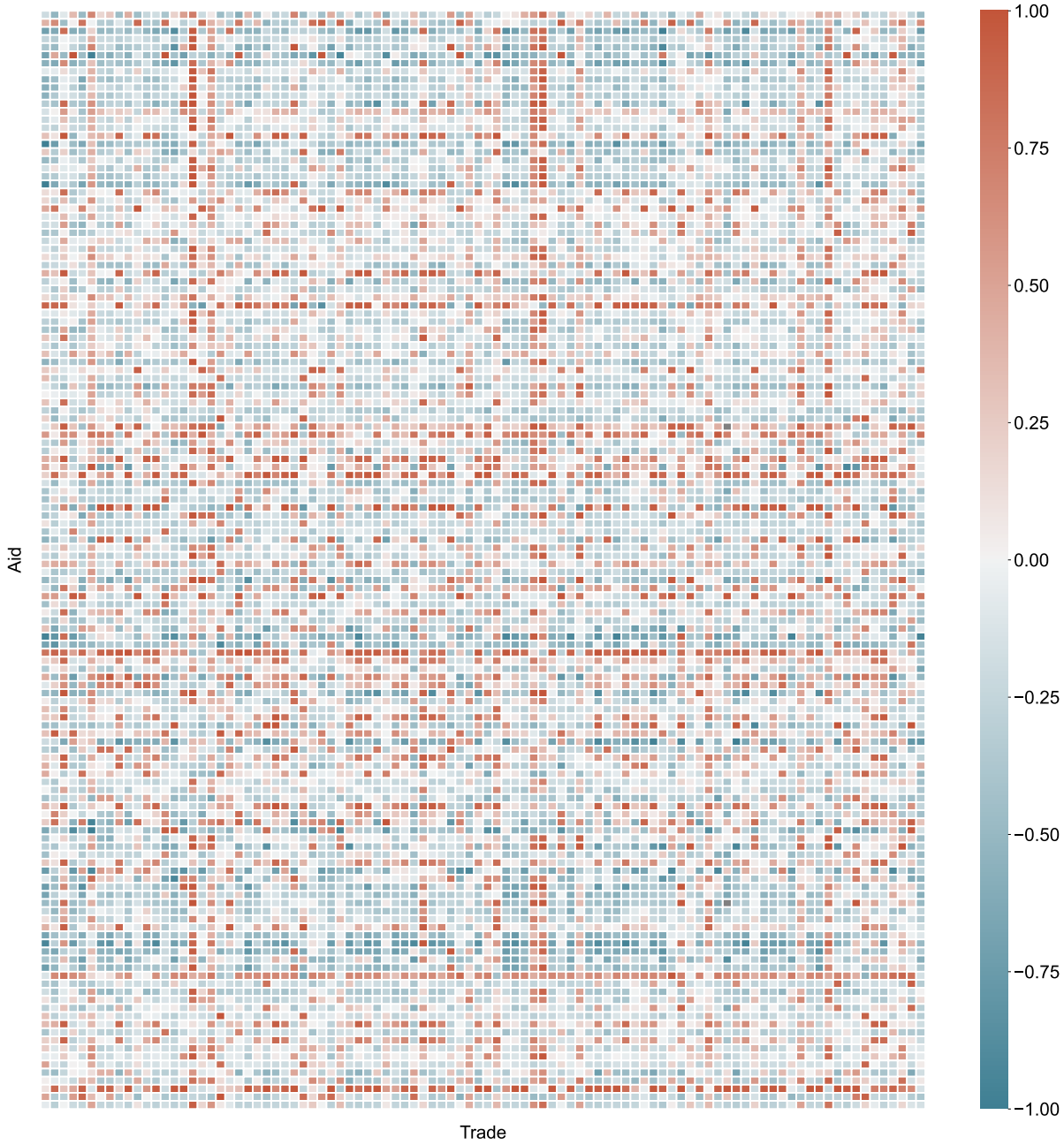
Supplementary Figure 1 shows the 2022 heat map of correlations for all traded products and all aid purposes for the U.S. The five trade categories with the highest average across all aid purposes are:

environmental research, labour rights, narcotics control, trade facilitation, and reintegration and SALW (small arms and light weapons) control. These categories appear as bright, horizontal lines. The five trade categories with the strongest correlations across all aid categories are: cocoa, precious stones and metals, nickel, oil seeds and oleaginous fruit, and ores, slag, and ash. These categories appear as bright, vertical lines. Although biodiversity does not appear in the top five for 2022, it is a stand out category across time, with strong correlations every year.



Supplementary Figure 2: Heat map of all aid-trade correlations for the E.U. 27 in 2022.

The same results for the E.U. 27 are displayed in Supplementary Figure 2. Vertical lines appear particularly bright in this figure, compared to the horizontal lines seen for the U.S. The two brightest horizontal lines correspond to aid for basic metal industries and social infrastructure and services. The top five trade categories which correspond to the brightest vertical lines are: cocoa, copper, precious stones and metals, nickel, and trees and other plants.



Supplementary Figure 3: Heat map of all aid-trade correlations for E.U. institutions in 2022.

The results for E.U. institutions are less stark, and can be seen in Supplementary Figure 3. Here, on the trade axis, macroeconomic policy and water transport stand out. The top five trade categories are interestingly exactly the same as those for the E.U. 27. This suggests that where individual E.U. nations differ from their institutions is where certain aid categories are correlated with trade across the board.

Cocoa, precious stones and metals, and nickel appear in all three cases above, and also appear in the discussions in sections 2.3, 2.4, and 2.5 respectively.