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Over the past few years, the debate on GVCs and their role in economic growth has gained significant traction with the emergence of more nuanced views. Traditionally, GVCs have been regarded as a driver of economic growth, providing countries with access to larger markets, enhancing the international division of labour and efficiency gains, as well as providing countries with access to frontier technology (Baldwin, 2013; Taglioni and Winkler, 2016). However, it has also become clear that such benefits are far from automatic, as they depend on the position countries occupy within GVCs (Simonazzi et al., 2013; Altzinger and Landesmann, 2008), and on the fact that productivity gains do not always translate into employment and economic upgrading (Pahl and Timmer 2019; Bramucci et al. 2021; Bontadini et al., 2021).

This more nuanced view of GVCs and their economic implications has emerged at the same time that economic integration and globalisation has slowed down, losing steam since the great trade collapse during the financial crisis, bringing the future of GVCs into question. More recently, the COVID-19 pandemic and the war in Ukraine have laid bare key dependences of production systems vis-à-vis foreign suppliers and raised questions concerning international fragmentation, its structure, and the propagation of shocks.

A trade-off has taken place, in the policy debate, between economic efficiency and economic security (Baldwin and Evenett 2020). This is reflected in the Inflation Reduction Act in the US, the emerging idea of "open strategic autonomy" in Europe and the growing tensions around the supply of key materials for the green and digital transitions.

As a result, GVCs' role within the global economy has come into question on two accounts. First, the intensity, i.e. whether the degree of participation in GVCs is linked to higher exposure to shocks. When considering GVC integration, policy makers are faced with a choice between exposure to global shocks and exposure to local shocks (Borin et al. 2021). For example, on the one hand, the implementation of very strict measures to contain the spread of the pandemic across the world has brought production processes that heavily relied on foreign inputs to a halt. On the other hand, GVC participation allows firms to access a broader supplier base, making relationship-specific investments that improve resilience to local shocks (Miroudot 2020).

Second, the debate on GVCs has also focused on changes in the *structure*, rather than the *intensity,* of GVC participation. The recent disruption of international trade flows has drawn attention to the need to diversify and shorten production chains (Javorcik 2020, Bontadini et al. 2022). In the current, more turbulent, economic context it has become relevant to consider what changes GVCs should undergo in order to ensure economic production. Specifically, the notion of nearshoring has drawn significant attention in the policy debate to the future of GVCs.

It remains, however, unclear what structural features of GVCs are important in this debate as nearshoring, shortening, and concentration are hard to distinguish from one another. The most intuitive interpretation of nearshoring would be to bring production stages closer to final demand (Bontadini et al. 2022). Shortening of GVCs implies a reduction of the degree of fragmentation and a reduction of the number of intermediate stages. The idea of diversification focuses on reducing the concentration of suppliers.

Literature on international business has devoted significant attention to the issues of reshoring, backshoring and nearshoring, providing qualitative evidence and a discussion of the firm level drivers (Piantanesi and Arauzo-Carod, 2019, Barbieri et al., 2020, Pietrobelli and Seri 2023). However, there is currently no systematic quantitative evidence exploring how different GVC structural features and production are related to each other. We set out to remedy this not only by studying the association between GVC final output growth and their structure, but also by focusing on the propagation of supply shocks. We ask, specifically, two interrelated key questions. First, we assess whether GVC participation increases exposure to shocks, hampering GVC output. Second, we study whether GVC structural features, such as nearshoring, length and concentration, mediate supply shocks and their relationship with GVC output growth.

To achieve this, we use the latest inter-country input-output (ICIO) tables, compiled in 2021 by the OECD. Our unit of analysis are GVCs across countries, i.e. a vertically integrated sub-system (Pasinetti 1973), and we identify GVCs by their country of completion, in line with the methodology developed by Los et al. (2015). For illustrative purposes, we consider as German automotive GVC the production of cars reaching completion in Germany and all the intermediate inputs that contribute to it, regardless of the industry and country of origin.

We then compute real output growth for each GVC in each country of completion and calculate measures of GVC integration and its structure. Concerning the latter, we focus in particular on measures of (i) farshoring, following Los et al. (2015), (ii) GVC length as in Antràs et al. (2018) and (iii) GVC concentration (Jimenez et al. 2022). We combine ICIO data with the World Bank global database on inflation (Ha et al. 2023) to compute price volatility for each GVC, which we use to study the interaction of supply side price shocks with GVC participation and its structure.

Our results suggest that GVCs that are more domestic, i.e. production processes sourcing little value added from abroad, see slower real output growth and have a stronger negative association with supply shocks. Among the structural features of GVCs we find more heterogenous results. The length, i.e. the degree of fragmentation of production, is associated with slower growth in GVC's real output but at the same time seems to attenuate the negative relationship between supply shocks and real GVC output growth. These results offer novel evidence and contribute to a nuanced understanding of how GVC integration and its structure relates to output growth and the propagation of shocks. We discuss these results in the context of the revived interest in industrial policy and strategic autonomy in Europe.

The remainder of the paper is organised as follows. The next section selectively reviews the relevant streams of literature and frames our contribution accordingly. Section 2 discusses in detail the data, our measurement approach and the econometric setup. Section 3 presents the results and the last section concludes the paper.

1. Relevant literature and contribution

Literature has highlighted how shocks can propagate through production networks, leading to significant changes in output at the aggregate level. Intuition suggests that small shocks at the industry level would even out and dissipate at the aggregate level. However, Gabaix (2011) has shown that the asymmetric distribution of inter-sectoral linkages (few large firms dominate key sectors) can propagate shocks across the economy, leading to macroeconomic volatility. In line with this, there is now a growing body of literature that has bridged general equilibrium models and the insights from network theory, highlighting how network effects emanating from inter-sectoral and inter-firm linkages can help explain how fluctuation shocks lead to aggregate volatility (Carvalho 2008, Acemoglu et al, 2016, Carvalho and Tahbaz-Salehi, 2019, Baqaee and Farhi, 2019, 2020).

The key takeaway from this literature is that when input-output production networks exhibit high disparity in the centrality of suppliers, i.e. when there are key suppliers on which many industries depend, shocks can propagate far and wide along the network, leading to significant aggregate fluctuations.

This has provided theoretical understanding of the role of production networks in explaining aggregate changes in production. Broad literature is currently studying how natural disasters propagate through firm level input-output networks (Carvalho et al., 2021, Boehm et al., 2019). At the macro level, Acemoglu et al. (2016) were the first to put forward a model explaining the mechanisms behind upstream and downstream shocks, coupled with empirical evidence for the US economy. In this framework, shocks propagate through the production network, captured with the Leontieff inverse in line with standard input-output analysis.

They show that in an input-output framework, supply-side shocks propagate downstream, while demand-side shocks do so upstream.

The literature has not only established the importance of input-output linkages in acting as channels for the propagation of shocks, both in terms of output (Carvalho and Tahbaz-Salehi, 2019, Baqaee and Farhi, 2019, 2020) and price fluctuations (Auer et al. 2019). More recently, Joya and Rougier (2019) showed that specific features of the production network mediate the propagation of the shock. They found that country-industries located in very dense parts of their network tend to diffuse the shocks by fading it out across multiple paths, while very influential nodes trigger a stronger contagion effect, increasing aggregate volatility.

These studies focus on output fluctuations at the country level that are driven by industry-level shocks. However, there is scarce empirical evidence on how shocks in a given country-industry propagate through vertically integrated sectors leading to fluctuations in the production of final goods – i.e. through GVCs.

The literature looking specifically at GVCs has developed significantly in the past few years, putting forward a range of measures of GVC participation of countries and industries. Baldwin et al. 2022 systematise the wide array of measures that have been put forward in the literature since the seminal contributions of Koopman et al (2014) and Johnson and Noguera (2012). The well-established measures of backward and forward GVC participation look at how deeply inserted a country-industry is within GVCs and the most recent literature on GVCs has used them as proxies of dependence vis-à-vis foreign partners (Johnson and Noguera 2017, Baldwin and Freeman 2021, Schwellnuss et al. 2022).

This strand of work has so far focused especially on measures capturing the intensity of GVC participation at the country-industry level, framing these around the trade-off between exposure to foreign shocks and access to a diversified pool of suppliers (Borin et al. 2021, Di Giovanni and Levchenko, 2009). There are, however, also measures that look at the structure of GVCs, taking the vertically integrated subsystem as unit of analysis. Los et al. (2015) study the geographical distribution of value added sourcing along GVCs, while measures of upstreamness and downstreamness have also been developed (Antràs et al. 2012, 2018). The latter is particularly relevant as it has been used in the literature as a measure of the length of GVCs (Johnson, 2018).

Despite this wide array of measures, there is a dearth of empirical evidence on how shocks propagate along GVCs and, more importantly, how they interact with the structure of GVCs. We aim here to bring together the theoretical insights from the literature, merging network analysis with the general equilibrium and the measurement literature studying the structure of GVCs as vertically integrated systems, in order to study how the intensity and the structure of GVC integration mediate the propagation of supply-side shocks. We set out our framework and methodological approach in the following section.

2. Framework and methodological approach

The literature on how inter-sectoral linkages affect production growth has identified two contrasting channels. On the one hand, diversification of suppliers offers the possibility of *substitution*, i.e. if for whatever reason a supplier fails, another one can take its place (Borin et al. 2021, Di Giovanni and Levchenko, 2009). Therefore, diversification allows to “average out” shocks to individual suppliers that do not result in higher volatility of aggregate production. On the other hand, however, if the production networks are highly asymmetrical, idiosyncratic shocks to a single supplier can propagate to the aggregate level (Gabaix, 2011 and Acemoglu et al. 2012). This is what Joya and Rougier (2019) refer to as the *contagion* effect, i.e. the existence of highly influential suppliers that can spread shocks across the whole network.

Acemoglu et al (2016) discuss the importance of input-output networks in propagating production shocks, similarly to what Auer et al. (2019) argue concerning price comovements. The core intuition of these models is that the impact of a shock in industry j on industry i is mediated by the importance of industry j in the output of industry *i*. In the case of supply shocks, Acemoglu et al. (2016) show that propagation takes place downstream. This means that when an industry experiences a negative shock, this will be passed on to its customers, who will in turn pass it down to their customers and so forth. The extent to which the shock propagates depends on how reliant the customers are on the industry that has experienced the shock.

The network of inter-sectoral linkages that propagates shocks has usually been depicted with input-output models, where production is given by:

$$X = (I - A)^{-1} * F = B * F \quad (1)$$

Where X is the total output column vector of each country-industry, i.e. including both production of intermediate and final goods; F is a vector of production of final goods (e.g. German cars or French bottles of wine, but not German wheels and French grapes). B is the Leontieff inverse that tells us for each dollar of final goods how much intermediate production is necessary.

Two remarks are in order here. First, while most of the literature has used the Leontief Inverse to study propagation of shocks across countries and industries, the coefficients of the B matrix connect the production of final products (F) with the sourcing of intermediate goods. When considering interactions among multiple countries and sectors, the Leontief Inverse matrix can be used to look at entire value chains, i.e. the vertically integrated network of inter-sectoral linkage that leads to the completion of a given final good in a given country.

Second, the Leontieff inverse presents some additional features that are useful for our purpose. It is in fact a square matrix that can be interpreted as an adjacency matrix depicting a directed and weighted production network, taking the example of three countries *a, b,* and *c:*

$$(I - A)^{-1} = B = \begin{pmatrix} b_{aa} & b_{ab} & b_{ac} \\ b_{ba} & b_{bb} & b_{bc} \\ b_{ca} & b_{cb} & b_{cc} \end{pmatrix} \quad (2)$$

Each *column* in this matrix represents a value chain and the distribution of the values of each b_{ij} can be used to capture the structure of the GVC. Note that equation 2 is populated by coefficients. To look at production values, we can pre-multiply the Leontieff inverse by a diagonalised vector of value added shares and post-multiply it by a diagonalised vector of production of final goods (F'), i.e. $V'BF'$:

$$\begin{pmatrix} v_a & 0 & 0 \\ 0 & v_b & 0 \\ 0 & 0 & v_c \end{pmatrix} * \begin{pmatrix} b_{aa} & b_{ab} & b_{ac} \\ b_{ba} & b_{bb} & b_{bc} \\ b_{ca} & b_{cb} & b_{cc} \end{pmatrix} * \begin{pmatrix} f_a & 0 & 0 \\ 0 & f_b & 0 \\ 0 & 0 & f_c \end{pmatrix} = \begin{pmatrix} v_a b_{aa} f_a & v_a b_{ab} f_b & v_a b_{ac} f_c \\ v_b b_{ba} f_a & v_b b_{bb} f_b & v_b b_{bc} f_c \\ v_c b_{ca} f_a & v_c b_{cb} f_b & v_c b_{cc} f_c \end{pmatrix} \quad (3)$$

The matrix in equation 3 is populated by the output contributions of each country-industry (in the rows) to each value chains (in the columns). The column sum of the matrix above provides us with the total output of each GVC identified by the country of completion, i.e. German cars and their components irrespective of the country of production. It follows that total output of a GVC can be broken down into a final product component (F) identifying the last round of production (e.g. the assembly of a car) and a structural component (B) that captures the distribution of intermediate contributions of all other country-industries engaged in the GVC.

This approach is in line with the most recent contributions on shock propagations along production networks (Acemoglu et al, 2016, Carvalho and Tahbaz-Salehi, 2019, Auer et al. 2019). We complement this approach, blending this with the insights from the measurement literature that uses the Leontieff inverse to capture GVCs' structural features (Los et al. 2015, Bontadini et al. 2022), as we discuss in the following subsection.

2.A Measuring GVC participation and nearshoring

Our interest in this study is twofold. On the one hand, we want to assess the relationship between GVC participation and GVC output growth; on the other hand, we want to explore how shocks propagate through the GVC structure.

To capture the former, we resort to a standard measure in the literature on GVC (Los et al. 2015), i.e. the domestic value added share. This means that for each GVC we compute the share of value added in total final production that is provided by the country of completion. As an illustration, in equation 3 the DVAS for country a is equal to:

$$DVAS_a = \frac{v_a b_{aa} f_a}{(v_a b_{aa} f_a + v_b b_{ba} f_a + v_c b_{ca} f_a)} \tag{4}$$

Concerning the structure of the inter-sectoral production network, the literature has highlighted that the Leontieff index captures how shocks propagate across the economy and that structural features of the network of inter-sectoral linkages can mediate the propagation of shocks.

Focusing on GVCs specifically, we build on this and link it with measures of GVC structure and length developed in the literature. We rely on three measures that are consistent with different definitions of nearshoring. Despite the growing interest in the idea of nearshoring, there is little clarity on what exactly this means. The most intuitive way of thinking about this concept is from a geographical point of view. Nearshoring implies bringing GVCs closer to their market. If, however, nearshoring is supposed to be an antidote to exposure to volatility from foreign suppliers, it is important to note that this may not necessarily come from the geographical location of production per se.

Rather, there may be other features of the structure of GVCs at play. First, production may in fact locate geographically closer to its final demand, but still be highly fragmented across countries and sectors retaining high levels of exposure to external shocks. Second, production in a GVC may still be highly concentrated in few key suppliers, regardless of their geographical location. Should these main suppliers suffer external shocks, production downstream might grind to a halt, leading to contagion effects (Joya and Rougier, 2019).

There are, therefore, different facets to the idea of nearshoring that cannot be easily captured with a single indicator. Consequently, we develop three separate indexes drawn from the literature on GVCs to capture these three key aspects of GVC structure:

1. *Farshoring (FARSH)*, as a measure of the geographical distance of production with respect to final demand. We compute this index building on the work of Los et al. (2015) and our own work on nearshoring (Bontadini et al. 2022). For each GVC we compute the share of foreign value added that is supplied from outside the region in which the GVC reaches final demand and the share that is supplied from within the region. We then take the ratio of the two, capturing how important extra regional foreign value added is, with respect to regional value added. In the example of equation 3, assuming that country a and b are in the same region, farshoring would amount to $\frac{v_c b_{ca} f_a}{v_v b_{ba} f_a}$.
2. *Downstreamness (DOWNSTR)*, as a measure of the length of a GVC. We compute this following Wang et al. (2017) as "the sum along the column of the Leontief inverse matrix, which equals the total value of inputs induced by a unit of final product produced in a particular sector" (p.12). In our

example above this is $b_{ba} + b_{ca}$. This measure is particularly relevant for the idea that longer GVCs require larger working capital and higher financial costs.

3. *Herfindahl-Hirschman index (HHI)*, as a measure of the concentration of value added supplied by foreign country-industries. This index is computed following Jimenez et al. (2022), and we normalise it to vary between 0 and 10,000, regardless of the length of each GVC. This is intuitively related to the idea of asymmetry of a network highlighted in the literature.

These structural features have been highlighted in the GVC literature as relevant to characterising the way in which production is fragmented across countries. It is difficult to have clear-cut ex ante expectations as to how they might be linked to GVC output growth and shock propagation. We attempt, nonetheless, to flesh out the main mechanisms that are likely to be at play here.

Farshoring is inherently linked to the choice firms make about the location of productive activity, which has drawn considerable attention from international business literature. Several factors affect firms' choice with respect to both original and offshore location features and, crucially, the distance between the two. This latter element is tightly related to the idea of farshoring. Substantial distance between production and the consumption market can affect production in several ways: (i) the cost of transportation and communication (Pietrobelli and Seri 2023) (ii) the challenges related to coordinating a complex production process (Fratocchi et al. 2014), (iii) hindering supplier-producer interaction, thus reducing innovation and productivity growth (Gray et al. 2017, Pietrobelli and Rabellotti, 2011). In light of this, nearshoring could be a strategy to maximise the benefits of locating production segments in countries with optimal characteristics and at the same time minimising the costs of offshoring production too far (Piantanesi and Arauzo-Carod, 2019).

Concerning the length of a GVC, i.e. its degree of fragmentation regardless of geographical location, we can hypothesise two contrasting channels. On the one hand, higher fragmentation is likely to lead to higher coordination costs in a fashion similar to what we discussed above. On the other hand, higher fragmentation can leverage the benefits of the division of labour and of having suppliers specialise in very specific segments of production where they are most productive, making the whole value chain more efficient. Long GVCs are also, on the one hand, exposed to more potential shocks; on the other hand, such shocks are more likely to dilute along the value chain itself and long GVCs may provide a higher level of diversification among suppliers making them more resilient to supply-side shocks.

Finally, concentration along the value chain can also have an ambiguous relationship with output growth. On the one hand, it would be intuitive to consider that concentration is indicative of a lack of competition among suppliers that lowers GVC efficiency and final output growth. On the other hand, concentration of value added sourcing is a feature of value chains that are intensive in geographically concentrated natural resources or of intermediate products in which economies of scale play a significant role and whose production becomes more efficient when concentrated. When thinking of the implications of concentration for shock propagation, it would also be intuitive to think that more concentrated value chains would suffer more from shocks. However, it is also possible that when a value chain is dominated by large suppliers, other actors will perform relationship specific investment prioritising these relationships and absorbing the shock. For example, Miroudot (2020) argues that, instead, concentration itself may not hamper GVC resilience. He puts forward that concentrated GVCs can in fact rely on large MNEs acting as "control towers" managing risks, and he concludes that "…single sourcing and a long-term relationship with a single supplier is a strategy often observed for improving supply-chain resilience" (Miroudot, 2020, p.124).

2.B Shocks along the value chain

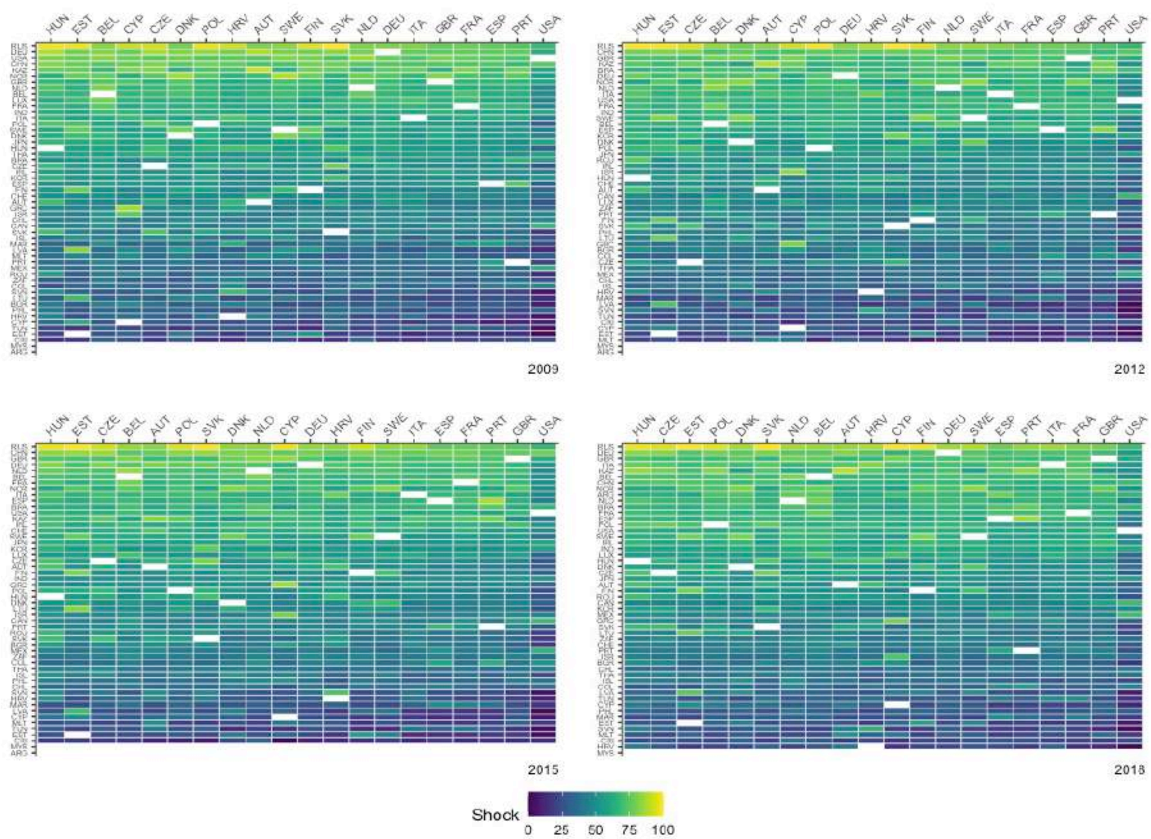
Our core contention is that the structure of GVCs is important for the growth of GVCs' output and for mediating the propagation of supply shocks. We first look at a measure of supply-side shocks. Acemoglu et al. (2016) focus on the US economy and study shocks deriving from import from China, government spending, TFP increases or patent production. We take a different approach here and look at volatility in suppliers' prices. Generally speaking, spikes in prices can be related to negative shocks in supply (Carvalho and Tahbaz-Salehi, 2019), and volatility of price of inputs has become particularly important in the last few years because of growing trade disruptions. Naturally, increases in producers' prices, to the extent that they capture reductions in provision of inputs to a GVC, may be connected to reduction in the GVC output almost mechanically. We therefore focus on the volatility of prices, using the World Bank global database on inflation (Ha et al. 2023). The database reports producer price indexes (PPIs) for a large sample of countries on a monthly basis. For each year and country, we therefore compute the standard deviation of the monthly PPIs in a given year, capturing supply shocks generated by price instability.

The next step is to compute an index that will capture how such volatility in PPIs propagates through GVC suppliers. To do this we use an approach similar to Joya and Rougier (2019) and consider that the shock a GVC experiences is a weighted average of the PPI volatility of each country participating in the GVC, which in more formal terms:

$$S_{j,t} = \sum_{i} w_{ij,t} * Sppi_{i,t} \tag{5}$$

Where $Sppi_{i,t}$ is the standard deviation of PPIs in country *i* at time *t* and the weight $w_{ij,t}$ is built using Leontief coefficients. Recall that each GVC is represented as a column of the Leontief inverse and is a vector of coefficients that tell us how much each country and industry contribute to it. We therefore aggregate the Leontieff inverse by country *i* across all its industries *k* that contribute to GVC *j*, obtaining $b_{ij,t} = \sum_k b_{ijk,t}$, which we then combine to compute country-level weight $w_{ij,t} = b_{ij,t} / \sum_j b_{ij,t}$. Note that the numerator here is the length of the GVC; however, this is not mechanically related to the weights.

To illustrate how our measure captures price instability along the supply chain, we report in Figure 1 the shocks along GVCs. Each matrix in the figure reports countries in which price instability occurs in the rows and GVCs in the columns. To improve readability, GVCs have been aggregated at the country level, using GVCs' final output as weights and we focus our analysis on a subset of 19 EU countries[1] and the US. The shock has also been bound between 0 and 100, so the lighter the colour in the cell, the stronger the price instability the country in the row has propagated to the GVCs on the column. We find Russia to be a major source of price instability, affecting mostly Eastern European countries that have closer and greater links with Russia. As expected, price instability propagates the most when originating in large economies such as China, Germany, the UK and the US. The figure also shows that the US economy, and to a lesser extent the UK, is more insulated from foreign price instability, which reflects the much larger reciprocal integration of EU economies (Bontadini et al. 2022).



Source: ICIO data and World Bank global database on inflation. Each matrix is populated with the log of the supply-side shock as computed in equation 5, bound between 0 and 100. Rows and columns are ordered using the average size of the shock they supply or receive, respectively. Tiles connecting a country with itself or for which no price data is available are left blank.

[1] We have excluded from our sample Bulgaria, Latvia and Romania because they present very large variations in both ICIO and World Bank global database data. We are left with Austria, Belgium, Cyprus, Czechia, Germany, Denmark, Spain, Estonia, Finland, France, UK, Croatia, Hungary, Italy, the Netherlands, Poland, Portugal, Slovakia, and Sweden.

2.C Empirical specification

For our econometric analysis we focus on the subset of 19 EU countries and industries in the market sector.[2] In order to maximise the number of countries covered in the World Bank data on producer price indexes we also focus on the period 2005-2018. We build on the empirical approaches in Joya and Rougier (2019) and Acemoglu et al. (2016) to obtain our two baseline specifications. First:

$$dln(FINO_{j,t}) = \alpha_{j,t} + \gamma dln(FINO_{j,t-1}) + \beta_1 S_{j,t} + \beta_2 DVAS_{j,t-1} + \beta_3 S_{j,t} * DVAS_{j,t-1} + \varphi_{ij} + \tau_t + \varepsilon_{j,t} \quad (6)$$

$FINO_{j,t}$ is the growth rate of each European GVC's final output, which we have deflated using gross output deflators from EUKLEMS-INTANProd data. We test this model in an autoregressive framework, following Acemoglu et al. (2016) and include as regressors our proxy for supply-side shock $S_{j,t}$, the share of domestic value added in each GVC j, $DVAS_{j,t-1}$, and the interaction of these two terms. This model allows us to explore our first research question concerning the relationship between GVC participation and shock propagations. If our interaction term β_3 has a negative sign, this would suggest that as GVCs increase the share of value added they source from abroad, they become - on average - more exposed to price volatility shocks.

The second key issue of interest to us is the role the structure of GVCs plays in propagating supply shocks. To explore this, we modify our specification above as follows:

$$dln(FINO_{j,t}) = \alpha_{j,t} + \gamma dln(FINO_{j,t-1}) + \beta_1 S_{j,t} + \beta_2 FARSH_{j,t-1} + \beta_3 S_{j,t} * FARSH_{j,t-1} + \beta_4 LENGTH_{j,t-1} + \beta_5 S_{j,t} * LENGTH_{j,t-1} + \beta_6 HHI_{j,t-1} + \beta_7 S_{j,t} * HHI_{j,t-1} + \beta_8 DVAS_{j,t} + \varphi_{ij} + \tau_t + \varepsilon_{j,t} \quad (7)$$

[2] As a result, we exclude from our analysis services such as public administration, defence, health, education and real estate,, as well as arts, recreation and other services. These industries have minimal international fragmentation and would risk biasing our results.

We augment equation (6) with our three variables capturing the GVCs' structure. We can test the association between GVC structural features, notably how global a GVC is ($FARSH$), its length ($LENGTH$) and concentration (HHI), and the growth of its final output. In this specification, the interaction terms inform us of how these GVC structural features mediate supply-side shocks. In both specifications we include both the lag of the outcome variable and country-industry fixed effects (φ_{ij}), which is likely to make our estimates biased, due to the Nickell bias (Nickell, 1981). To mitigate this we also test two additional specifications: (i) instead of controlling for country-industry fixed effects, we include country and industry dummies separately along with the pre-sample mean of the outcome variable (computed over the period 1995-2004) in line with Blundell et al. (1995; 2002); (ii) we also test our model with a system GMM that treats all regressors as endogenous, instrumenting with past lags. Results for these two approaches are available upon request. Finally, we cluster our standard errors at country level and include time dummies (τ_t) to account for year fixed effects.

3. Results

We now present empirical evidence providing answers to our two research questions. Table 1 presents OLS results for our first specification, exploring the role of GVCs' foreign share of value added and its interaction with supply-side shocks. The first four columns report our results looking at all industries, at manufacturing alone and at high- and low-tech manufacturing industries, respectively.[3] The second four columns include the interaction term between GVC participation and the shock itself.

As expected, supply-side shocks are negatively associated with GVC final output growth. We also find that, on average, value chains that are less internationalised, i.e. with larger shares of value added being sourced from within the country of completion (DVAS), grow slower. Furthermore, when shocks on the supply side hit these chains, their output grows even slower, as we can see from the negative coefficient for our interaction term. Overall, this seems to be consistent with the notion that integration with foreign suppliers has a positive relationship with output growth, which is in line with the broad literature on exports and economic growth. It has indeed been argued that GVCs offer countries the opportunity to link up with higher quality inputs, to have access to foreign technology and to focus on segments of production in which they have a clear comparative advantage. The fact that GVCs with a higher foreign share of value added appear to be resilient to supply-side shocks also suggests that engaging with the global economy gives

[3] We allocate manufacturing industries to either the high- or low-tech category following Eurostat's classification: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:High-tech_classification_of_manufacturing_industries

producers the possibility to diversify across suppliers and to minimise the shocks' repercussions (Borin et al. 2022).

Table 1 – GVC participation and supply-side shocks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Supply shock	-0.0259**	-0.0270**	-0.0269*	-0.0283**	-0.0537***	-0.0789***	-0.0972***	-0.0673***
	(0.0120)	(0.0122)	(0.0148)	(0.0128)	(0.0109)	(0.0222)	(0.0291)	(0.0229)
Domestic value added share (log)	-0.211**	-0.0578*	0.0333	-0.107***	-0.181*	-0.0225	0.0542	-0.0705
	(0.0909)	(0.0323)	(0.0677)	(0.0365)	(0.0884)	(0.0386)	(0.0669)	(0.0413)
GVC final output growth (t-1)	-0.263***	-0.181***	-0.181***	-0.178***	-0.263***	-0.181***	-0.182***	-0.177***
	(0.0728)	(0.0350)	(0.0372)	(0.0370)	(0.0732)	(0.0360)	(0.0375)	(0.0378)
Supply shock * DVAS (log)					-0.0957***	-0.123**	-0.163**	-0.0944**
					(0.0310)	(0.0454)	(0.0698)	(0.0401)
Constant	-0.0527	-0.00887	0.0460	-0.0387**	-0.0448	0.00371	0.0545	-0.0266
	(0.0309)	(0.0152)	(0.0320)	(0.0169)	(0.0300)	(0.0175)	(0.0318)	(0.0187)
Observations	9,264	4,173	1,703	2,470	9,264	4,173	1,703	2,470
R-squared	0.245	0.324	0.311	0.341	0.246	0.328	0.314	0.343
Country-industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry	All	Manuf.	HTM	LTM	All	Manuf.	HTM	LTM
S.E. clustered	Country	Country	Country	Country	Country	Country	Country	Country

Source: authors own elaboration using ICIO data and World Bank global database on inflation and EUKLEMS-INTANProd data. HTM and LTM stand for high-tech and low-tech manufacturing, respectively. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

The results above provide an answer to our first research question concerning GVC participation and shock propagation. GVCs are, however, not all the same: there are specific structural features that are likely to mediate how shocks propagate along GVCs. In Table 2, where we focus on this aspect in particular, as in the previous table, the supply-side shock consistently shows a negative association with GVC output growth and so does the domestic value added share. As in Table 1, we first look at the relationship between GVC structure and final output growth across all industries, manufacturing and high- and low-tech manufacturing. We then look at how each of these three structural features interact with supply shocks. Out of the three structural features we explore, we find length and farshoring to have a negative and statistically significant association with GVC final output growth.

Controlling for a GVC's integration in the global economy, longer GVCs and those that source a larger share of value added from outside their region of completion tend to grow at a slower pace. There appears to be some tension between integration within the global economy, with Table 1 reporting a positive association between GVC final output growth and the share of foreign value added, and the structural features of GVCs themselves. This can be related to the coordination costs of production processes, which are highly fragmented (large length) over very distant geographical areas (farshoring). It would seem that GVCs that do not stretch too thin by fragmenting production across a vast number of stages dispersed across the world are best positioned to grow the fastest.

When we turn to the interaction terms, we find an interesting positive and statistical coefficient for the interaction between the supply shock and the length of the GVC. It appears that longer GVCs are better equipped to withstand supply-side shocks. This is likely due to the diversification effect: longer GVCs may rely less on key suppliers and can therefore smooth out supply shocks by diverting their intermediate demand towards alternative suppliers. As a speculation, it is also worth mentioning that such GVCs are also likely to be dominated by large multinational firms that can shift resources within their internal network to better endure localised shocks.

This presents further tension concerning the relationship between the length of a GVC and its final output growth. GVC length per se is associated with slower growth, but at the same time it seems to attenuate the propagation of shocks. These results seem to apply to the manufacturing industry and to the low-tech sectors in particular. This makes sense, intuitively, as trade relationships in these industries are often more at arm's length or dominated by powerful suppliers that can interrupt them easily and are unlikely to have performed a large amount of relationship investment (Gereffi et al, 2005). Furthermore, low-tech products often compete on price and large scales rather than on quality and technology. Such GVCs are therefore more likely to be exposed to price instability.

The results are overall robust also when testing our two alternative specifications, which are available upon request. When using the PSM to control for GVC time-invariant features, we find results for the structure of GVCs to be very similar to our OLS results. Concerning the relationship between the foreign value added share of a GVC and the propagation of shocks, we also find consistent results. While our estimates remain stable for the manufacturing industry as a whole, they do lose precision as we break down the manufacturing industry.

Finally, our GMM results show that the share of domestic value added by itself loses significance, but its interaction with the price instability shock remains negative and significant. This confirms that while GVCs with a larger foreign value added share may not grow slower, they are more exposed to foreign price instability shocks. When turning to the role of the GVC structure we find less stable results, although the main effects for manufacturing and high-tech manufacturing GVCs are confirmed.

Table 2 – GVC structure and supply-side shocks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Farshoring, (log t-1)	-0.0542**	-0.0609**	-0.120**	-0.0192	-0.0500**	-0.0623***	-0.128***	-0.0178
	(0.0203)	(0.0226)	(0.0427)	(0.0163)	(0.0190)	(0.0215)	(0.0430)	(0.0184)
Length (log t-1)	**-0.381****	**-0.295*****	**-0.284**	**-0.283****	**-0.382****	**-0.351*****	**-0.289**	**-0.384****
	(0.170)	**(0.0957)**	**(0.171)**	**(0.123)**	**(0.169)**	**(0.0994)**	**(0.168)**	**(0.146)**
HHIB (log t-1)	-0.0154	0.0272	0.0503	0.00297	-0.0196	0.0275	0.0470	0.00176
	(0.0139)	(0.0292)	(0.0558)	(0.0186)	(0.0140)	(0.0277)	(0.0522)	(0.0170)
Supply shock	**-0.0273****	**-0.0295****	**-0.0296****	**-0.0306****	**-0.0959**	**-0.243****	**-0.329*****	**-0.346****
	(0.0113)	**(0.0121)**	**(0.0140)**	**(0.0133)**	**(0.0616)**	**(0.0859)**	**(0.103)**	**(0.129)**
Supply shock * Farsh. (log t-1)					-0.0190	0.00380	0.0516	-0.00310
					(0.0132)	(0.0143)	(0.0326)	(0.0185)
Supply shock * Len. (log t-1)					**0.00402**	**0.219*****	**0.0686**	**0.343*****
					(0.0660)	**(0.0753)**	**(0.0775)**	**(0.104)**
Supply shock * HHIB (log t-1)					0.0147*	0.00459	0.0604*	0.00178
					(0.00736)	(0.00957)	(0.0298)	(0.0112)
Domestic value added share (log) (DVAS)	-0.346**	-0.107**	-0.0488	-0.133**	-0.346**	-0.107**	-0.0589	-0.125**
	(0.132)	(0.0470)	(0.120)	(0.0475)	(0.132)	(0.0488)	(0.115)	(0.0472)
GVC final output growth (t-1)	-0.261***	-0.182***	-0.187***	-0.176***	-0.261***	-0.183***	-0.191***	-0.176***
	(0.0719)	(0.0363)	(0.0369)	(0.0366)	(0.0720)	(0.0370)	(0.0370)	(0.0383)
Constant	0.266*	0.103	0.00850	0.190*	0.285*	0.151	0.0205	0.290**
	(0.153)	(0.160)	(0.320)	(0.109)	(0.153)	(0.144)	(0.309)	(0.116)
Observations	9,264	4,173	1,703	2,470	9,264	4,173	1,703	2,470
R-squared	0.252	0.328	0.318	0.342	0.252	0.331	0.323	0.347
Country-industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry	All	Manuf.	HTM	LTM	All	Manuf.	HTM	LTM
S.E. clustered	Country	Country	Country	Country	Country	Country	Country	Country

Source: authors own elaboration using ICIO data and World Bank global database on inflation and EUKLEMS-INTANProd data. HTM and LTM stand for high-tech and low-tech manufacturing, respectively. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

4. Conclusions

This paper has delved into two key issues that in the past few years have come to the forefront of the policy debate on globalisation. In fact, new questions have emerged on the future and the nature of GVCs as we enter a more turbulent geopolitical era in which the international fragmentation of production can become a channel for economic instability.

In this paper we have looked at European GVCs over the period 2005-18 and studied the relationship between final output growth and not only the GVCs' degree of foreign integration, but also their structural features. We have further advanced our analysis by looking specifically at how shock propagates through these two aspects. Overall we have found rather nuanced results, fraught with trade-offs.

On the one hand, GVC integration with foreign suppliers is associated with faster output growth and also seems to attenuate the propagation of shocks. On the other hand, we identify salient structural features – notably the length, i.e. the degree of fragmentation – of GVCs that have ambivalent results themselves. Longer GVCs tend to grow slower, but at the same time they appear to be less associated with price instability shocks.

It appears, therefore, that there is no clear-cut answer as to whether GVC participation is a conduit for shock propagation. Participation in GVCs is associated overall with faster output growth and less shock propagation. However, GVCs vary widely across industries and countries in their structural features, in terms of where they source their value added, through how many steps they do so and how concentrated their suppliers are.

As the EU, along with many other major economies, embarks in a new debate on globalisation and the location of production stages, it appears paramount to be nimble and flexible in the policy approach, taking into account the structural features of GVCs, rather than simply the measures of intensity of GVC participation.

The evidence put forward in this paper clearly makes this contribution and paves the way for further research on several fronts. On the one hand, macro-level evidence on GVCs should be complemented with product- and firm- level analysis in order to fully assess the specific structures of GVCs, which will likely require both quantitative and qualitative analysis. On the other hand, it is important to bear in mind that our analysis relies on data from a relatively calm period where price instability was relatively modest and largely driven by natural resource cycles. As more data becomes available for more recent years, new research should focus on the most recent and most turbulent period to further investigate the issues we have tackled in this contribution.

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European and Italian strategic dependencies for the twin transition: strengthening trade relationships with Africa

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European and Italian strategic dependencies for the twin transition: strengthening trade relationships with Africa

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Abstract

This policy brief shows Europe and Italy's position in the green and digital value chains and identifies in which areas strengthening trade relationships with Africa would help Europe to increase its open strategic autonomy. We also suggest that Italy and Europe should rely on a comprehensive strategy, concentrating resources to increase the manufacture of selected intermediate and final products and, at the same time, diversifying imports of raw materials and building stronger relationships with African countries. In so doing, Europe should implement inclusive policies that not only support its open strategic autonomy but also broadly facilitate technology transfer and favour the upgrading of economic activities in African countries.

The European concept of open strategic autonomy and the EU raw materials initiative

First the pandemic and then Russia's invasion of Ukraine have triggered a debate on the vulnerability of global value chains and the importance of ensuring European strategic autonomy. Indeed, the concept of strategic autonomy emerged in the context of common European foreign and security policies (European Council, 2013; European Union Global Strategy, 2016[1]) in a period of political tensions with Russia's annexation of Crimea in 2014 and the protectionist policies of the Trump Administration (European Central Bank, 2023).

The current debate on the vulnerability of global value chains fuelled by the bottlenecks emerging during the pandemic and Russia's invasion of Ukraine has its roots in the shifting of technological power towards Asia,

[1] The Global strategy for the foreign and security policy of the European Union adopted on 28 June 2016.

resulting from China's (and a few other East Asian countries') catching up in the high value added stages of the (manufacturing) value chains. It can be argued that the China-US trade war is one of the main underlying causes of the deceleration in globalization that has taken place since the beginning of the 21st century.

The European, and particularly the German, market-based export-oriented model began to be questioned in a world where China and the United States are increasingly using trade and industrial policy measures to ensure technological leadership in critical value chains. In this context, the European Commission revised its trade policy in 2021, including the concept of strategic autonomy within economic policies, but added the term "open" in order to imply its willingness to maintain a pro-trade approach. Referring to the new strategy, Executive Vice-President and Commissioner for Trade Valdis Dombrovskis said: ***"The challenges we face require a new strategy for EU trade policy. We need open, rules-based trade to help restore growth and job creation post-COVID-19. Equally, trade policy must fully support the green and digital transformations of our economy and lead global efforts to reform the WTO. It should also give us the tools to defend ourselves when we face unfair trade practices. We are pursuing a course that is open, strategic and assertive, emphasising the EU's ability to make its own choices and shape the world around it through leadership and engagement, reflecting our strategic interests and values"*** (European Commission Press Release, February 2021). The attempt to reconcile an open and multilateral approach with the priorities of reaching the goals of the green transition through stringent rules on European firms and at the same time defending them from unfair competition is the strategy's most ambitious and challenging goal. There are clear tensions between this model and the aggressive trade and industrial policies of the other two main economic areas, the US and China.

Besides trade policy, the EU is also rethinking its traditional approach to industrial policies, which for a long time were only based on market-oriented competition policies and the need to protect the single market by constraining state aid. The "new industrial strategy" for Europe explicitly refers to the need to ensure strategic autonomy in the context of the green and digital transitions, a strategy "that will support the twin transitions, make EU industry more competitive and enhance Europe's strategic autonomy" (Commission Communication, March 2020).[2]

But is this approach consistent with the challenges of the green and digital transition and Europe's position within these strategic value chains?

There is no doubt that the recent geopolitical developments, the pandemic and the war, have led to a more active role of the European Commission and the European Union in looking for new strategies and policies also as a response to those implemented by China and the US. The idea that some materials, products and technologies are more "strategic" than others means departing from a horizontal untargeted approach to more selective and mission-oriented industrial policies. The EU raw materials initiative (2008), which produces a periodic list of critical materials based on their economic importance and supply risks, goes in this direction by

[2] Indeed the attention to critical raw materials dates back to 2008 with the purpose of identifying a list of critical materials every three years (the assessments of 2010, 2014, 2017, 2020 and 2023 have produced lists based on economic importance and supply risks).

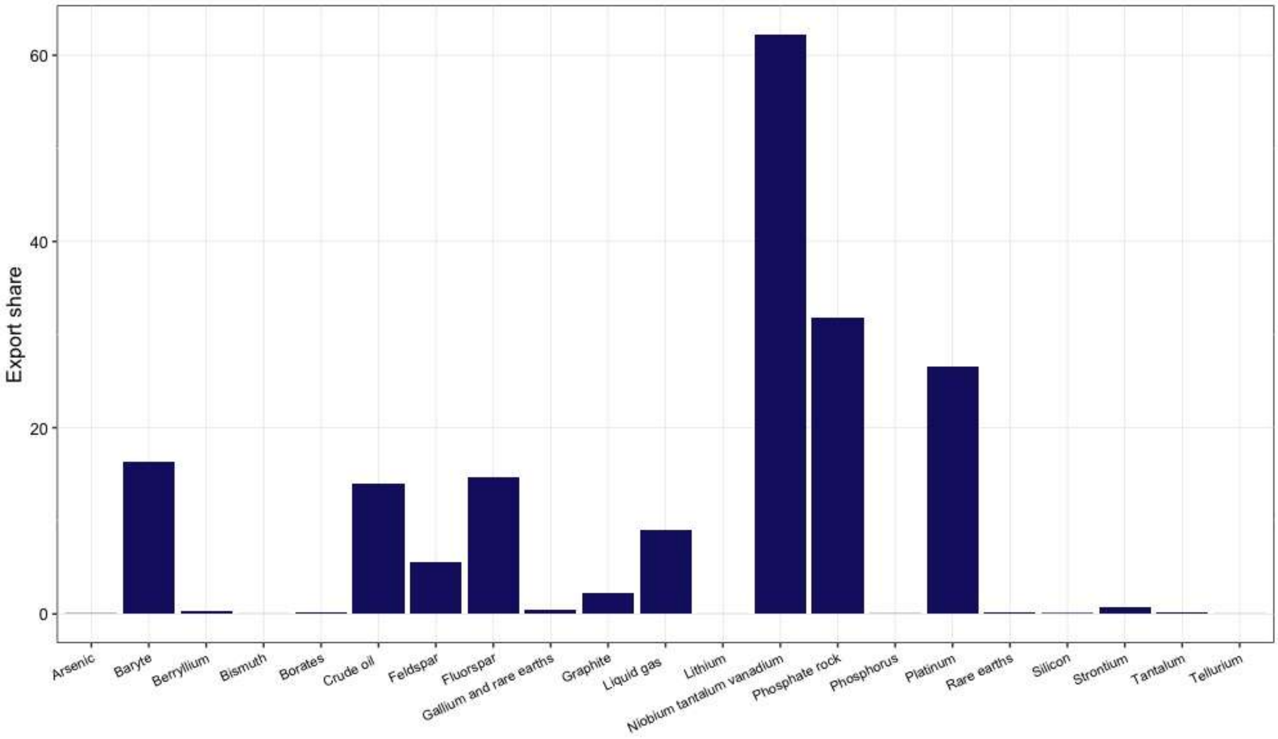
monitoring the possible European bottlenecks in the face of the double transition. In 2023, the European Raw Materials Act has identified European targets for strengthening Europe's position along the strategic raw materials value chain. In particular, these include: i) at least 10% of the EU's annual consumption for extraction; ii) at least 40% of the EU's annual consumption for processing; iii) at least 15% of the EU's annual consumption for recycling; iv) no more than 65% of the EU's annual consumption from a single third country. At the same time, the European Commission has published the fifth list of strategic materials following those of 2011, 2014, 2017 and 2020. Materials included in the list are selected on the basis of two criteria: economic importance and supply risk. The 2023 list includes 34 Critical Raw Materials (CRMs, hereinafter) compared to the list of 30 CRMs in 2020, with six new CRMs (Arsenic, Feldspar, Helium and Manganese) and two which have been excluded (Indium and Natural rubber). Moreover, Copper and Nickel, although not meeting the criteria to be included among CRMs, have been identified as strategic materials with important applications respectively for electrification and for batteries.

A large number of these materials enter the strategic value chains of several green and digital products. In this policy brief, we first look at the position of African countries in the supply of CRMs and then focus on selected CRMs which enter the value chain of important products for the green transition (electric vehicles, photovoltaic cells and hydro-turbines) and for the digital transition (computers, communication equipment, microchips). We show the position of Africa, China, the US, Europe and Italy in the different stages of these value chains and identify in which areas strengthening trade relationships with African countries would help Europe to increase its open strategic autonomy. We also suggest that Italy and Europe should rely on a comprehensive strategy, concentrating resources to increase the manufacture of selected intermediate and final products and, at the same time, diversifying imports of raw materials and building stronger relationships with African countries. In so doing, Europe should implement inclusive policies favouring the upgrading of economic activities in African countries.

The European and Italian position in the digital and green value chains and the role of Africa

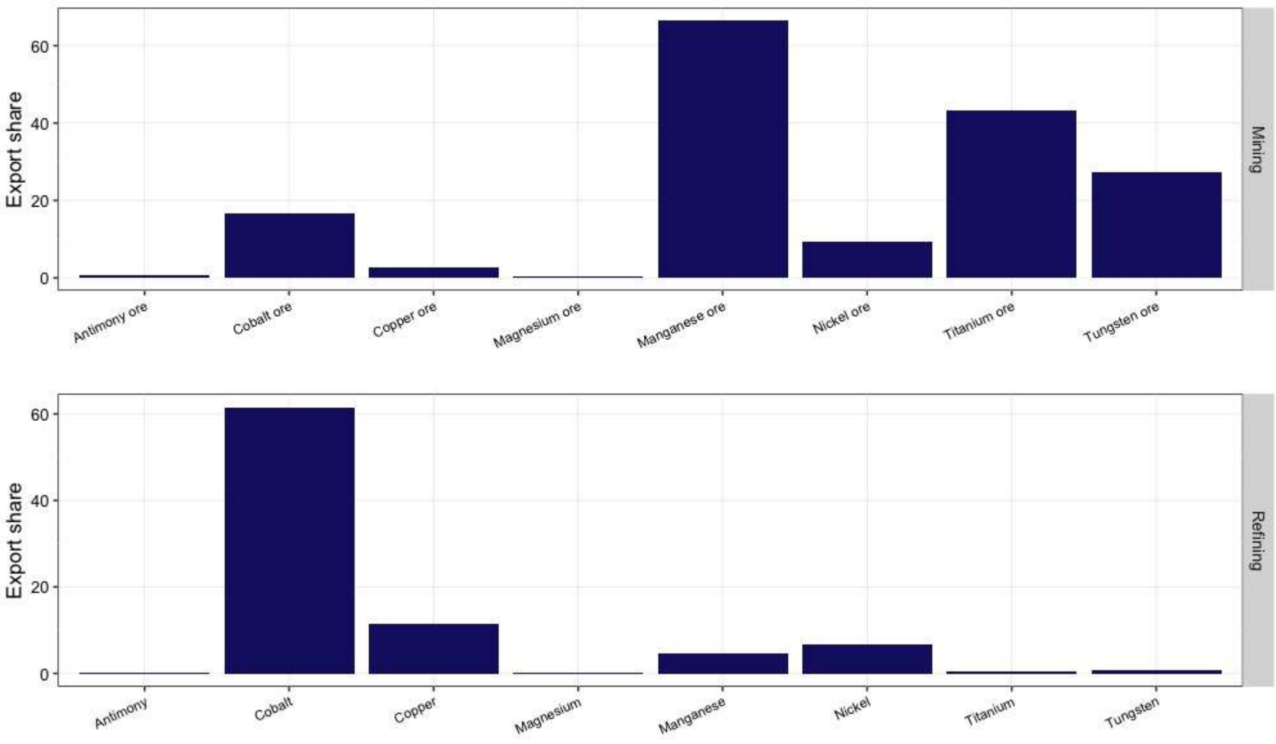
Figures 1 and 2 show the African share of exports of CRMs. For comparison we also include data for oil and liquid gas. In figure 2 we provide different figures for mining and refining for a subsample of CRMs for which data are available. The source of the data is the BACI-CEPII database, which uses trade data from UNCOMTRADE. Not all CRMs are reported.

Figure 1: Africa's export shares in CRMs in 2021



Source: own elaborations on BACI-CEPII database

Figure 2: Africa's export shares in CRMs in mining and refining in 2021



Source: own elaborations on BACI-CEPII database

The figures show the important role played by Africa in some materials such as Cobalt ore, Niobium, Tantalum and Vanadium, Manganese ore, Titanium. In particular, Cobalt, which is strategic for batteries, is concentrated in the Democratic Republic of Congo, a country that is also the main producer of Tantalum contained in capacitors for electronic devices. Also Rwanda and Nigeria have considerable export shares in this material. South Africa is the main producer of Manganese used in steel making and batteries and of the Platinum group of metals used in chemical and automotive catalysts, fuel cells and electronic applications.

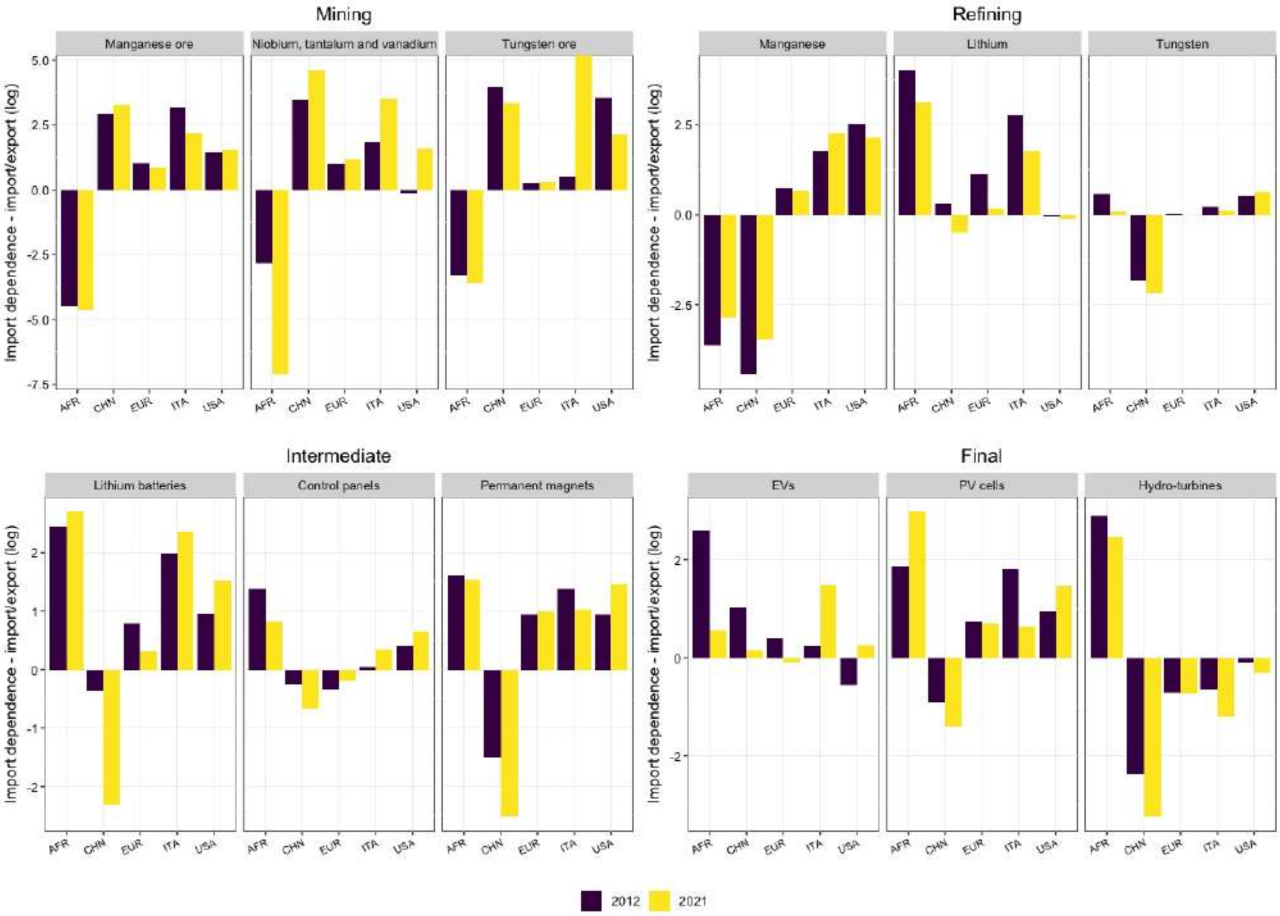
But what is the role of these CRMs in the value chain that leads to the production of green and digital goods?

In order to grasp the challenges that Europe and Italy face in managing the green and digital transition and the potential role of intensifying trade relationship with African countries, we look at the evolution of European and Italian import dependencies at the various stages of the value chain leading to selected green and digital products and the African strengths and weaknesses in the same value chains. The selected products are based on a recent study performed by the European Parliament's Committee on Industry, Research and Energy (ITRE, 2022).

The focus is on products of the green and digital transition, since these are the areas that will absorb a large amount of investments, given the necessity to move towards decarbonization.

Figure 3 shows the position of Europe, Italy, China, the US, and Africa in the supply chain of selected green products (electric vehicles, photovoltaic cells and hydro-turbines).

Figure 3: Import dependencies in the value chain for selected products of the green value chain in 2012 and 2021

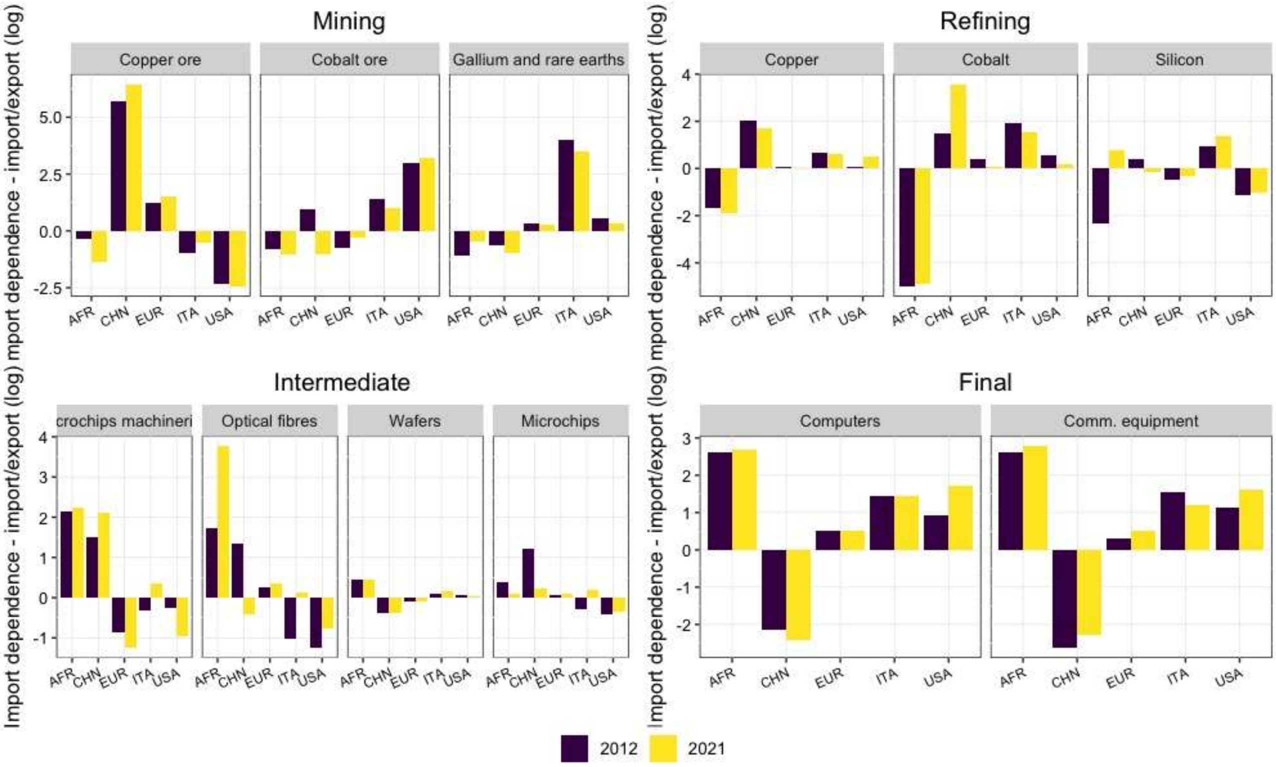


Source: own elaborations on BACI-CEPII database

At the final stage of the value chain, Europe is a net exporter (although marginally but improving its position since 2012) of electric vehicles (EVs) and hydro-turbines, but a net importer of photovoltaic cells, while Italy is a net exporter only of hydro-turbines. The dependencies are stronger at the intermediate stages of the value chains. Although Europe's dependence on lithium batteries decreased between 2012 and 2021, the area continues to have a trade deficit. In the case of Italy the deficit is larger and it has been increasing in the last ten years. Also for permanent magnets Europe and Italy strongly depend on imports. It is worth observing that China has an increasing trade surplus at all these intermediate stages, and also at the final stages with the exception of electric vehicles, an area in which it is decreasing its import dependency. Not surprisingly Africa as a continent has important import dependencies at all intermediate and final stages of the green value chain. At the same time, in terms of mining it is a net exporter of manganese, of niobium, tantalum and vanadium (with increasing surpluses over time) and of tungsten. China, Europe and the US are net importers of all these materials in 2021. In terms of refined materials, Africa has a trade advantage only in manganese, an area in which also China has a trade surplus, in addition to other refined materials such as lithium and tungsten in 2021 (with all other areas being net importers). Overall, China undoubtedly shows the strongest position in the green value chain and the more pronounced positive dynamics.

Figure 4 focuses on the value chain for digital products (computers and communication equipment).[3]

Figure 4: Import dependencies in the value chain for selected products of the digital value chain in 2012 and 2021



Source: own elaborations on BACI-CEPII database

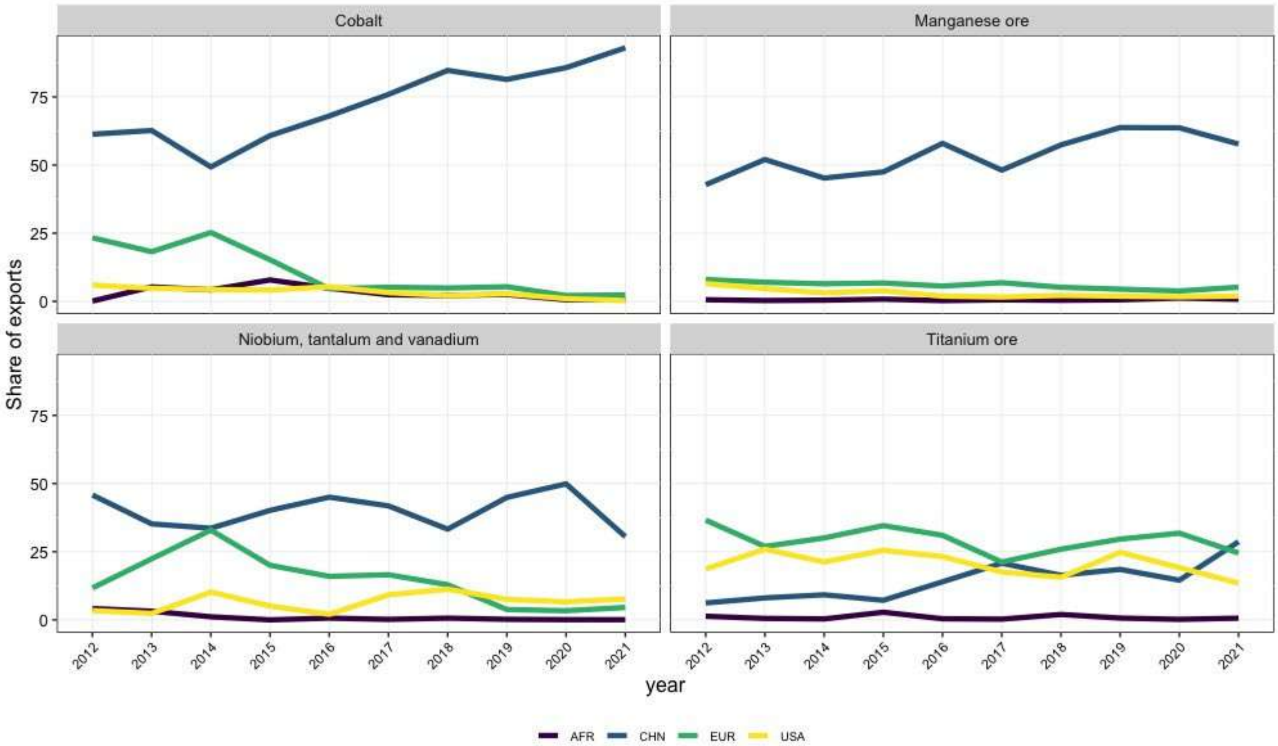
Europe, and Italy even more so, has a trade deficit in both communication equipment and computers. Europe as a whole is also a net importer of some key components entering the production of these goods, namely microchips and optical fibres, while it is a net exporter of machinery for microchips. Between 2012 and 2021, Europe increased both its disadvantages in microchips and optical fibres and its advantages in machinery for microchips. Italy has similar dependencies but has lost its trade surplus in the machineries for microchips and in optical fibres between 2012 and 2021. China has a trade advantage in the final stages of the chain (computers and communication equipment) but a trade disadvantage in microchips and microchip machineries. The US has a trade disadvantage in computers and communication equipment but is a net exporter of microchips, microchips machineries and optical fibres. Finally, as expected, Africa is import dependent in all final and intermediate stages of the digital value chain. However, it has a trade advantage in exporting copper, cobalt and gallium (ores) and refined copper, cobalt and silicon (this last material only in 2021). Among the other areas, China is strongly dependent on copper, the US on cobalt, Europe on copper and Italy on gallium and rare earths.

[3] Machineries for microchips are represented at the intermediate stage of the chain since they are used to produce microchips. However, in an input output perspective they are a final capital good.

Overall, the data show strong interdependencies between Europe, China and the US in the digital value chain, with the three economic areas specialising in different stages and products and the role played by Africa mainly at the stage of mining and in some cases at the stage of the refining of the CRMs.[4]

But what are the trade relationships between Africa and the other areas (Europe, China and the US) in CRMs? Figure 5 focuses on four CRMs that are strategic for either the green or the digital value chain and for which Africa has a trade advantage. It also shows the dynamics of exports to the different geographic areas.

Figure 5: African exports of CRMs by destination (2012-2021)



Source: own elaborations on BACI-CEPII database

The predominant role of China in the trade relationship with Africa is apparent. In the case of cobalt, the share of African exports going to China has been constantly increasing and has reached 93% in 2021. Europe, which had a share of about 25% in 2014, sees a sharp decrease in the following years, approaching zero at the end of the period. In the case of manganese, the dynamic is less pronounced but the dominance of China is clear with a share of 80% in 2021. When looking at niobium, tantalum and vanadium, we also observe the dominant position of China and the decreasing importance of Europe. Titanium is the only material for which the market is more spread across the different areas (in 2021, China has a share of 29%, followed by Europe with a share of 24% and by the US with a share of 13%). But also in this case, while China shows an increasing trend, Europe and the US decrease their imports from Africa. These data reflect China's growing interest in Africa, which has

[4] These data do not take into account the advantages and disadvantages at the level of the technologies (for some evidence on this point, see Guarascio et al. 2023). Yunxiong Li et al. (2022) show that African countries do not have technological capabilities in these areas as proxied by patent data.

become China's largest trading partner since 2009. At the same time, concern has been expressed by unions and civil society about the poor working conditions in Africa and the lack of willingness on the part of the Chinese enterprises investing in the continent to preserve the environment.

The position of the various areas in trading CRMs can be better assessed with the use of Social Network Analysis (SNA). By harnessing the power of SNA, we can uncover the intricate dynamics of CRM trade networks, shedding light on the global implications of these strategies for different regions and economies.

In the network, a node's centrality signifies its level of involvement in trade with other nations, identifying significant players in the trade network. The nodes in the network represent countries, and the links denote trade flows between them. Node size corresponds to the number of connections, while link size reflects the exported goods' value.

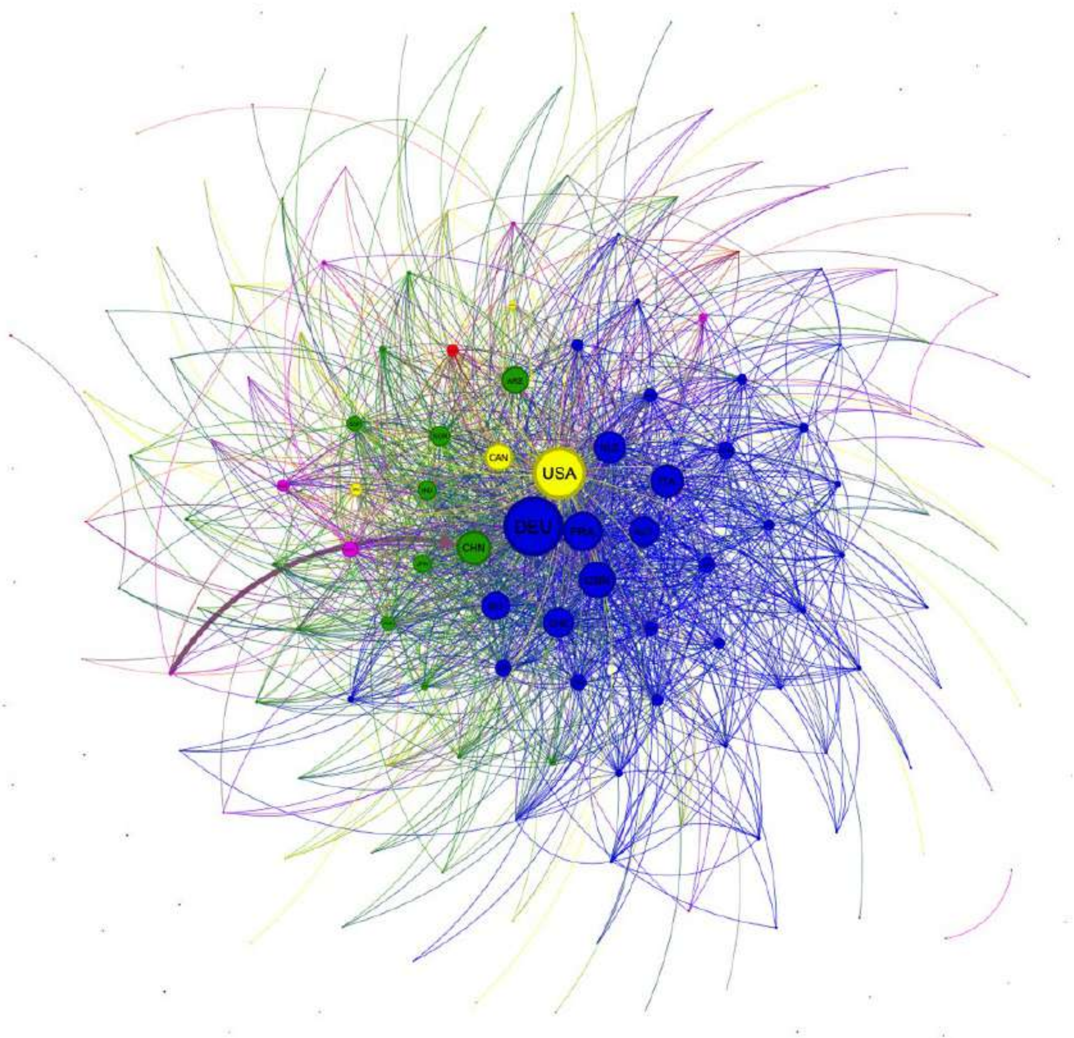
Figures 6 and 7, depicting world trade exports of CRMs like Cobalt and Niobium, highlight the substantial role played by African countries, particularly in these materials.

Notably, in the Cobalt network (figure 6) there is a pronounced flow of CRMs from semi-peripheral nations like the Democratic Republic of Congo to China, which acts as a core player in the network. European countries, in particular Germany, and the US are central in the network since they trade with a large number of countries but are peripheral to African countries.

For Niobium (figure 7), the US's dominance arises from its role as a bridge between all nations in trade. However, China's position as the world leader in Niobium trade is evident through its extensive trade relationships with African exporting countries in terms of quantity and trade value.

This SNA-based analysis underscores China's pivotal role in controlling the flow of CRMs from Africa and its broader influence on global trade. This central role can have significant economic and geopolitical implications. Europe's relative disadvantage in this context becomes evident, particularly concerning its direct access to resources that are critical to the green and digital transition.

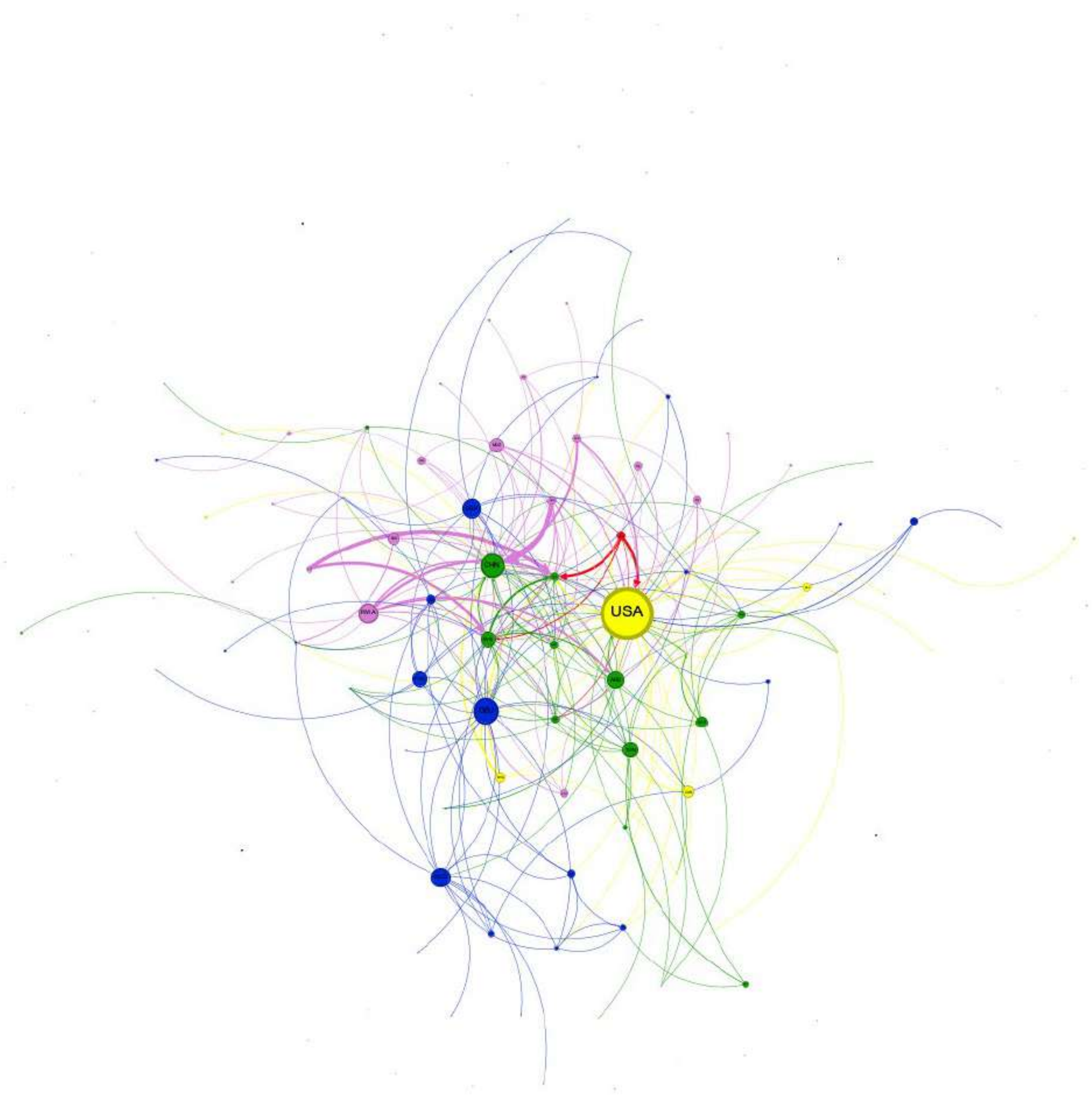
Figure 6: Cobalt network created with outdegree centrality measure.[5]



Source: own elaborations on BACI-CEPII database and Gephi network visualization software

[5] Colours of the continents: a) Africa purple; b) Europe blue; c) Asia green; d) America yellow; e) Oceania red.

Figure 7: Niobium network created with outdegree centrality measure



Source: own elaborations on BACI-CEPII database and Gephi network visualization software

Conclusions

In recent years, the EU has increased its attention to industrial policy as a strategy to cope with the green and digital transition. New tools have been conceived and new terms such as strategic autonomy have become popular and have been borrowed from the language of common foreign and security policies to be included within the EU industrial strategy. In her recent State of the European Union Address (September 2023), Ursula von der Leyen emphasized the role of Europe in the green transition but also recognised Europe's weaknesses: "***We have seen real bottlenecks along global supply chains, including because of the deliberate policies of other countries. Just think about China's export restrictions on gallium and germanium– which are essential for goods like semiconductors and solar panels. This shows why it is so important for Europe to step up on economic security. By de-risking and not decoupling***".

The data analysed in this policy brief show that much still has to be done for Europe to be competitive in the green and digital value chains, also considering the aggressive policies undertaken by China and US. The geopolitical tensions between the US and China and the discriminatory trade policies implemented by these countries require a centralized European response also in order to defend a rules-based international trade system and make it more inclusive.

As Soete and Van Kerckhoven argue, the "new" purposes of strategic autonomy in the European Industrial Strategy imply a focus on "de-risking" rather than increasing technological and industrial capabilities in digital and green value chains. This emphasis on reducing dependency might not only represent a trade-off in terms of public investment choices, but also have backlash effects on EU internal competition and, arguably, in terms of geopolitical tensions and inclusion. First, national policies and national funds risk being ineffective and putting countries with different fiscal capacities in an asymmetric position, as well as counteracting the effects of the EU Cohesion Policy. Second, missing the opportunity to strengthen trade relationships with Africa means not being able to contribute to raising environmental and work standards in crucial value chains in African countries (which China clearly shows less interest in) and to provide the opportunity of technology transfer that might support industrial upgrading in Africa.

Europe therefore requires bold political will to design an effective multi-fold strategy. On the one hand, it is essential to identify areas of potential advantage where European resources can be concentrated. These should involve mostly the final and intermediate stages of the value chains (such as electric vehicles, batteries, machineries for chips). Several instruments such as the Strategic Technologies for Europe Platform (STEP) or the Important Projects of Common European Interest (IPCEI) can be used to target technologies and manufacturing activities provided that they are funded and coordinated at the European level. At the same time, the reduction of risks associated with the concentration of certain materials, not only at the extraction level but also at the refining level, can be achieved by facilitating investments along commodity value chains in those emerging countries that can benefit from transfers of technological know-how to reduce the environmental impact of existing extractive activities, diversify production, and create local added value. In this policy brief we have shown the opportunities for increasing trade partnerships with African countries. While Europe has adopted an Africa-Europe investment package within the Global Gateway (the EU's investment strategy targeting partner countries), the increasingly dominant position of China in Africa requires a step forward in identifying effective strategies, also involving local actors, to invert this trend.

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