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Shocks in a Highly Interlinked Global Economy

Christine Arriola, Przemyslaw Kowalski, and Frank van Tongeren

This report analyses the broad risks associated with sectoral output disruptions both domestically and abroad, examining several exposure metrics. The results indicate that domestic shocks generally have larger sectoral impacts than foreign shocks. In most cases, foreign production disruptions cause minimal domestic output responses, suggesting that domestic and international linkages, along with economic adjustment mechanisms, tend to dampen rather than amplify foreign shocks. However, a cumulation of adverse shocks can significantly affect specific sectors, with manufacturing sectors are on average much more exposed to foreign output shocks than services and agrifood given their greater internationalisation of output and inputs. Economies with strong backward and forward global value chain links to major foreign economies also tend to be more exposed to foreign shocks.

Key words: Supply Chains; Global Value Chains; GVC; CGE; METRO model; Exposure risk; Shock transmission

JEL codes: C68, F14

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Key messages

Exposure of national economies and economic sectors to potential shocks depends on the nature of their specialisation and integration in global value chains (GVCs). This report uses the OECD global trade model METRO to unpack some of the broad risks associated with output disruptions which can occur in domestic and foreign sectors. Main findings include:

- **The impacts of shocks occurring domestically tend to be larger than impacts of shocks occurring in foreign sectors**, due to the adjustment and diversification role of international markets and the greater reliance on domestic inputs from product and factor markets in most sectors.
- In most cases, **production disruptions elsewhere in the global economy cause small output responses domestically**, suggesting that **global supply chains and trade networks tend to dampen the domestic impacts of foreign production shocks rather than amplify them**. That said, in small portion of cases, responses can be more than two to three times larger than the original shock. A cumulation of multiple adverse shocks can also have significant effects on a given sector, and some sectors and countries may be exposed more than others.
- **Manufacturing sectors are on average much more exposed to foreign output shocks than services and agrifood** given their greater internationalisation of output and inputs. Electronics, metals, iron and steel, machinery and equipment, and chemicals are the most exposed. Extractive industries, and some of the manufacturing sectors linked to them (metals, iron and steel and chemicals) are most exposed in the short term when factor markets have not had time to adjust.
- **Economies with strong backward and forward GVC links to major foreign economies tend to be more exposed to foreign shocks**, with Canada, France, Germany and the United Kingdom leading the rankings, and the United States, Brazil and the People's Republic of China (hereafter 'China') appearing relatively less exposed.
- **A wide variety of economic adjustment mechanisms is at play**, notably price signals leading to substitution of suppliers or markets and responses of labour and capital markets. Impacts of shocks across national economies tend to be smaller when factors of production cannot move across sectors (short term) then when they can move freely (medium to long term). That said, there are differences between sectors, including depending on their weight in domestic labour and capital markets.
- **Services can be sources of shocks with relatively big impacts across the global economy**. However, such shocks are not transmitted through traditional GVC channels but instead through general equilibrium impacts on factor markets. The exception are shocks to business services, due to their strong backward and forward linkages to manufacturing sectors.
- There is more variation in the measures of exposure across sectors than there is across countries, suggesting potential for sectoral initiatives to address exposure to shocks.

Executive summary

The transmission of shocks through the global economy has recently come to the fore in policy and business discussions in the context of some recent instances of supply disruptions and increasingly uncertain global economic and geopolitical environments. Exposure of national economies to potential shocks depends on the nature of their specialisation and integration in global value chains (GVCs) and is not always easy to gauge. This report uses the OECD global trade model METRO to unpack some of the broad relationships with a view to informing government and business efforts to enhance resilience. It does so by studying simulated responses of output of national economic sectors to production shocks occurring in other domestic and foreign sectors connected vertically through value chains and horizontally through competition in product markets. In addition to assessing the overall magnitude and nature of shock transmission, the analysis identifies countries and broad sectors which may be particularly vulnerable to shocks or could be a more significant source of risk for others. The modelling relies on several assumptions which necessitate a careful approach to policy implications, but a few broad findings and policy consequences are of interest:

- In most cases, production disruptions somewhere in the global economy cause relatively small output responses elsewhere, suggesting that the current structure of domestic and international linkages and economic adjustment mechanisms that operate through them tend to dampen the impacts of shocks rather than amplify them. That said, there are also some large outliers indicating that shocks in some segments of the global economy may have more consequential effects than others.
- The impacts of shocks occurring in other domestic sectors tend to be larger than impacts of shocks occurring in foreign sectors. This is because in most sectors the reliance on foreign inputs and foreign markets for final products is still smaller than reliance on domestic inputs and product and factor markets. In addition, international markets offer broader adjustment and diversification options than domestic ones.
- Production disruptions originating in foreign vertically-linked sectors — the kind of shocks that are at the centre of the debate on propagation of shocks in GVCs (‘GVC shocks’ hereafter) — do not appear to be the main source of disruptions. While the results confirm that disruptions in upstream sectors in the value chain can constrain access to intermediate inputs, and output declines downstream can lower demand for inputs, most impacts are two orders of magnitude smaller than the original shocks. The dispersion of impacts is also smaller than for domestic shocks. Again, this reflects the current levels of diversification and greater possibilities for adjustment in GVCs.
- The transmission of GVC shocks is also less pronounced than the transmission of horizontal shocks, that is, shocks which originate in the same sector but in a foreign country. In addition, impacts of such shocks have a tendency to be positive because a decline in output of a foreign competitor tends to create new production opportunities elsewhere.
- More broadly, the results suggest that a wide variety of domestic and international economic adjustment mechanisms is at play. Price signals leading to substitution towards other suppliers or other market outlets, and responses of labour and capital markets play an important role in shaping responses to shocks. They should therefore be part of assessments of resilience to shocks. In this context, the analysis presented here considers sensitivity checks with respect to the extent of possible substitution in international markets and adjustments in domestic factor markets.
- The results show that the degree of factor market adjustment can affect the transmission of shocks. Impacts of shocks across national economies tend to be smaller when factors of production cannot move across sectors (short term) then when they can move freely (medium to long term). Among others, this underscores that short-lived disruptions may matter less than disruptions which last longer and allow more time for factor markets to react and pass on the impacts to other sectors. It also suggests that policies protecting employment or restricting capital movements may play an attenuating role in the face of temporary shocks. That said, the differences in impacts under different factor mobility assumptions vary across sectors and depend also on whether the impacted sector has a significant weight in domestic labour and capital markets.

- While most of the impacts of GVC shocks are much smaller than initial shocks, in a small portion of cases responses can be more than three times larger. In addition, a cumulation of multiple adverse shocks (as was for instance the case during the COVID-19 pandemic) can have more significant implications. Statistics summarising responses to such highly adverse constellations of shocks suggest that that some sectors and countries may be exposed more than others.
- Economies with strong vertical links to major foreign economies tend to be more exposed to GVC shocks, with Canada, France, Germany and the United Kingdom leading the rankings, and the United States, Brazil and the People's Republic of China (hereafter 'China') being relatively less exposed due to their greater reliance on domestic product- and factor markets in most sectors. The Russian Federation (hereafter 'Russia') and South Africa move to the top of the ranking of the most exposed countries under the assumption of immobile factors because sectors in which they tend to specialise, such as petroleum and coal, mining and chemicals sectors, are more exposed to external shocks and have more difficulty adjusting when labour and capital cannot migrate to other sectors.
- There is more variation in the measures of exposure across sectors than there is across countries, suggesting potential for sectoral initiatives to address exposure to shocks.
- Manufacturing sectors are on average much more exposed to foreign output shocks than services sectors and agriculture and food because they are more internationalised in terms of destination of output as well as sourcing of intermediate inputs. For this reason, manufacturing of electronics, metals, iron and steel, machinery and equipment, and chemicals appear as the most exposed. When production factors are immobile, extractive industries, as well as manufacturing sectors linked to them (metals, iron and steel, chemicals) move towards the top of shock exposure rankings.
- There are also important differences across countries and sectors in terms of which shocks contribute the most to exposure. For example, Germany's motor vehicles sector, while overall only moderately exposed to GVC shocks, tends to be relatively more exposed than that of the United States, and a bigger portion of this exposure can be attributed to shocks originating in China.
- Services sectors, which in some countries employ large shares of labour resources, (e.g. hospitality and recreation, retail trade, construction or warehousing and support activities), can be sources of shocks with relatively big impacts across the global economy, but these tend not to be transmitted through constrained access to, or demand for, intermediate inputs, but rather through domestic economy-wide impacts involving factor markets. In the medium to long-run, an output reduction in those sectors tends to be associated with a release of labour and capital that finds employment in other parts of the economy, which impacts other sectors. Shocks to business services, a sector which has strong upstream and downstream linkages to manufacturing sectors, are characterised by more classical transmission of vertical foreign shocks through GVCs.

1. Introduction

The economic shocks of the COVID-19 pandemic and Russia's war of aggression against Ukraine have reinvigorated the debate on whether the benefits of international trade outweigh the associated risks and what might be the best ways of managing these risks. Increasing policy uncertainty, geopolitical tensions, but also more extreme climatic conditions and competition for scarce natural resources, suggest a more uncertain economic environment. Calls for economic security and strategic autonomy, and the associated pleas to limit 'dependency' on foreign economies, are putting open markets and the rules-based trading system under pressure. Most recently, concerns about trade dependencies and exposure to shocks have resulted in a new wave of calls for 'deglobalisation', 'friendshoring', 'nearshoring', creation of 'trading blocks' or 'relocalisation' (e.g. (Arriola et al., 2020[1]), (Crowe and Rawdanowicz, 2023[2])). At the same time, there are concerns that some of the policy responses which aim to minimise trade risks and improve supply chain resilience may not be well designed and may in fact unnecessarily undermine the benefits of international trade.

Production in global value chains (GVCs) has attracted particular attention in this context. The emergence of GVCs in the early 1990s reflected the seizing of new opportunities associated with finer levels of specialization (Baldwin, 2011[3]). In contrast to previous stages of globalisation, when specialisation and international commerce centered around final products, specialisation in GVCs has increasingly been determined at a finer level of capabilities, tasks and intermediate inputs. Linking actors mastering specialised smaller products and tasks, GVCs enabled the pooling of larger sets of capabilities. This supported technology transfer and innovation and production of more sophisticated and diversified products (Hausmann, 2013[4]) and it enabled greater participation in the global economy of smaller actors, most notably smaller firms and participants from emerging and developing economies (Baldwin, 2011[3]).

However, the emergence of GVCs has also changed the nature of linkages in the global economy and, at the same time, the exposure to—and ability to cushion—various economic shocks. In the GVC era, in addition to connecting domestic producers to distant consumers through trade of final products, international trade connects distant producers in complex international supply chains. In the pre-GVC era, location-specific shocks impacted either production or consumption of specific final products. The emergence of 'vertical' GVC links between geographically remote sequential production stages meant that the different production locations have become more interdependent. In GVCs, shocks occurring in specific locations can be transmitted vertically, either downstream in the case of disruptions in provision of inputs, or upstream through fluctuations in demand for inputs.

At the same time, fragmentation of production in GVCs can also offer a wider range of alternatives in terms of input sourcing or participating in specific chains, and these alternatives make it easier to adjust to shocks. When a shock hits, it may be easier to reconfigure or relocate a segment of a supply chain or switch to another supplier of a component than to overhaul a whole production system. In this sense, GVCs have also opened new possibilities for diversification and improved resilience (e.g. (Lafrogne-Joussier, 2021[5]), (Arriola et al., 2020[1])).

The recent shocks experienced during the COVID-19 pandemic, as well as Russia's invasion of Ukraine, illustrated indeed both the extent to which GVCs matter for transmission of shocks and the extent to which they can facilitate adjustment. Problems with supply were observed on several occasions in these contexts but it is far from obvious whether the geographical fragmentation of production in GVCs was more of a contributing or an attenuating factor. During the pandemic, some supply chains experiencing unprecedented pressures reconfigured swiftly to address the new realities, for example, when it came to delivering masks, tests and vaccines (OECD, 2022[6]) and home-nesting and electronic products (Arriola, Kowalski and van Tongeren, 2021[7]). Russia's aggression against Ukraine and the sanctions imposed by several countries on Russia initially resulted in disruptions of supplies of several agricultural and industrial commodities. But even the supply chains that were most exposed to sourcing from Russia, such as oil and oil products, natural gas or fertilisers, have adjusted to the new realities, and many of the products have begun to be sourced from alternative sources relatively quickly. These examples show that it is not clear if the experienced supply problems would not have been even more pronounced had the pandemic-related measures and the trade disruptions related to Russia's aggression occurred in a pre-GVC global economy or in an economy characterized by shallower GVC integration.

There are also questions about what actions should be taken, and by whom, to enhance resilience to future shocks. On the one hand, minimisation of supply chain risks is in the best interest of private profit-maximising firms.[1] An efficient and competent private sector is therefore a key element of resilience in GVCs. On the other hand, private firms concentrate on risks specific to their business and may not fully account for—or be able to see—systemic risks which matter from a public policy perspective. Such systemic risks are typically defined not at the level of specific firms but rather in terms of supply of specific essential products or viability of systemically important industries (e.g. OECD (2022[8])). Governments therefore are compelled to develop their view of systemic GVC risks and identify their potential sources, diagnose the possible wider economic and social impacts and devise the best policies that can minimise exposure to these risks as indicated in the OECD's Keys to Resilient Supply Chains (OECD, 2021[9]).

Supporting government efforts to enhance supply chain resilience in this context has been one of the key priorities of OECD in recent years. As a forum for discussion and co-ordination, the Organisation convened a number of exchanges between business and governments on supply chain resilience and interdependencies.[2] In addition, leveraging its analytical capacity, the OECD has helped frame resilience discussions, diagnose the possible wider economic and social impacts and identify the best policies that can minimise exposure to risks. Regarding the latter, a number of recent OECD studies used detailed trade and Trade in Value Added (TiVA) statistics and the OECD computable general equilibrium (CGE) trade model METRO to identify some of the potential supply chain bottlenecks. Amongst others, these studies found that vulnerabilities to shocks associated with high GVC dependence are amplified by high geographic concentration of suppliers or buyers, and that large manufacturers, China in particular, are some of the most critical potential choke points in GVCs across a broad range of industries, both as a dominant supplier and as a dominant buyer (Schwellnus, 2023[10]). Other studies emphasised the implications of possible policy responses, particularly the costs of policies that could be used to make value chains more localised (Arriola et al., 2020[1]). [3] A recent OECD report summarised the large and still emerging evidence within OECD and elsewhere on GVC risks and possible responses (Crowe and Rawdanowicz, 2023[2])

The current study continues this line of work. It adopts a modelling approach similar to (Arriola et al., 2020[1]) but it considers effects of a granular set of sector and country-specific production shocks. While production shocks may not be fully representative of some of the examples of shocks used to motivate this analysis above[4] and insights from studying other types of shocks may be different, they best mimic the kind of shocks referred to in the recent policy debate on supply chain disruptions whereby specific production nodes of the global economy are perturbed and have to downscale their supply due to natural or policy-induced causes. The production shocks considered in this analysis can occur in—and can in

[1] These firms invest in assessing risks in different segments of their business and manage their supply chains so as to, on the one hand, minimise the costly inventories of intermediate inputs and final products and, on the other hand, maximise continuity and reliability of supply of their products to clients in the face of shocks (e.g. (Lafrogne-Joussier, 2021[5]).

[2] For example, the 2022 OECD Global Forum on Trade addressed trade policy and responsible business conduct approaches for sustainable and resilient supply chains. In 2022 and 2023, the OECD organised two Chief Economists Conferences on Supply Chain Interdependencies which aimed at facilitating discussion among Member countries to better understand, analyse and monitor the nature and magnitude of international crises and supply chain disruptions and to better coordinate related policy responses. In 2023, the workstream on Macro-Economic and Structural Policy Analysis of the OECD Economic Policy Committee organised a workshop on "Globalisation in Retreat? Trends, challenges and policy implications" with resilience and risks and opportunities of reshaping GVCs as main theme.

[3] Arriola et al. (2020[1]) used the METRO model to compare economic efficiency and the extent of international transmission of country-specific trade cost shocks under different assumptions about countries' openness and integration into GVCs. Findings from that study included that policies that may result in more localised and less flexible value chains are likely to be costly in terms of efficiency and do not necessarily offer more stability in the face of shocks. This is because openness and geographical diversification of sources of inputs and destinations of output in flexible GVCs can offer better possibilities of adjustment to disruptions. Among others, this research suggested that transmission of trade shocks through value chains is highly context-specific, and that product- or supply chain-specific research can offer valuable insights.

[4] For example, the large output variations across countries and sectors seen during the COVID-19 pandemic were in large part due to demand and labour productivity fluctuations (Arriola, Kowalski and van Tongeren, 2022[35]).

principle be transmitted to—any sector and geographical location that can be reasonably accounted for in a detailed global trade model. The approach enables an assessment of knock-on effects of such country and sector-specific shocks and their different constellations on other parts of the global economy which is akin to stress-testing, an approach often mentioned in the debate on supply chain resilience. The approach also permits analysis of how shock propagation—or attenuation—may depend on the relative position in GVCs of the sources of shocks and locations where they are felt. This approach yields a large set of data on responses to output shocks which can be analysed in several ways and this paper offers some examples in this respect.

In the remainder of the report, Section 2 sets out additional motivation for considering the propagation of country and sector-specific production shocks and outlines the adopted methodological approach. In section 3.1, distributional and regression analyses of simulation results are performed to shed light on differences in average impacts across the different sources and destinations and transmission channels of shocks. The results show that average impacts tend to be low, but their dispersion is relatively high, suggesting that shocks that may occur in some segments of the global economy have bigger impacts and are therefore of greater concern than others. Consequently, Section 3.2 elaborates on three summary measures of exposure to shocks originating in foreign vertically-linked industries, focusing on possible deviations from average impacts and enabling the ranking of sectors and countries according to their shock exposure. Section 4 concludes and elaborates on main implications.

2. Modelling of global transmission of production shocks in the OECD global trade model METRO

2.1. Growing geopolitical, policy and economic uncertainty?

One of the factors that has contributed to an amplified focus on possible negative aspects of interconnectedness and propagation of shocks in GVCs is a posited increase in geopolitical, policy and economic uncertainty. A few recent studies and measurement initiatives have presented data showing signs of increased incidence of shocks and higher uncertainty although measurement of these phenomena is complex, and results are not always straightforward to interpret.

The economic policy uncertainty index, which draws on analysis of words used in major newspapers, official policy sources and surveys of professional forecasters (Baker, Bloom and Davis, 2016[11]), shows, for example, that global economic policy uncertainty has increased progressively during recent episodes of economic and geopolitical shocks. Global policy uncertainty increased markedly in the aftermath of the 9/11 terrorist attacks in 2001, during and in the aftermath of the 2008-09 Global Financial Crisis (GFC), during the COVID-19 pandemic and after Russia's large-scale invasion of Ukraine in 2022. As measured by this index, in the last three years, policy uncertainty was on average significantly higher than in any of the previous decades covered by this methodology (Figure 2.1, Panel A).

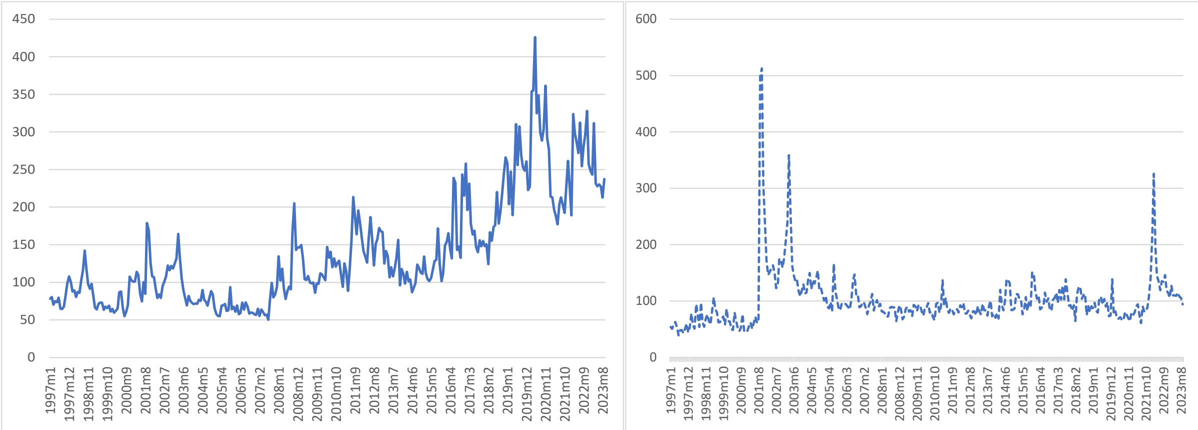
The newspaper-based index of geopolitical risk index constructed by (Caldara and Iacoviello, 2022[12]), which measures the perception of risk related to wars, terrorism and tensions among states and political actors, shows an increase in geopolitical risk following the 9/11 terrorist attacks in 2001 and another significant increase in the aftermath of Russia's invasion of Ukraine in February 2022 (Figure 2.1, Panel B). Considered from a longer historical perspective, however, the same index shows also that the levels of geopolitical risk attained in the early 2020s were higher than those seen in the late 1990s but they were still markedly lower than those seen during some previous episodes of geopolitical tensions, for example around the Gulf War, Korean War and, particularly, World War I and World War II (Caldara and Iacoviello, 2022[12]).

The OECD Business and Consumer Confidence Indices, which are based on surveys of attitudes towards future developments, show, for the OECD area, increases in both business and consumer uncertainty in the aftermath of 9/11, the GFC, at the beginning of the COVID-19 pandemic and, particularly for consumers, following Russia's invasion of Ukraine (Figure 2.2).

Figure 2.1. Indices of policy uncertainty and geopolitical risk

Panel A. Global Economic Policy Uncertainty Index

Panel B. Geopolitical risk index



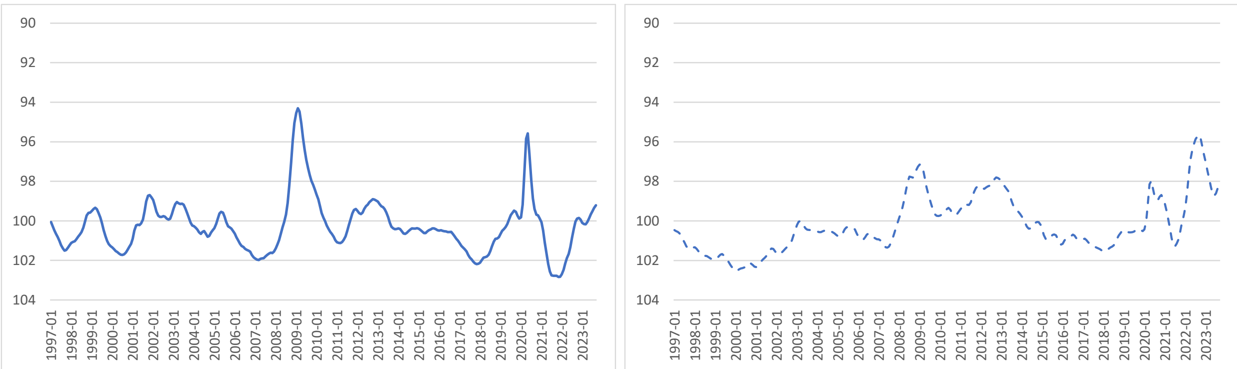
Note: scales in the two panels are based on two different methodologies and are not comparable.
Source: For Panel A, https://www.policyuncertainty.com/ and (Baker, Bloom and Davis, 2016[11]). For Panel B, https://www.matteoiacoviello.com/gpr.htm and (Caldara and Iacoviello, 2022[12]).

Figure 2.2. Uncertainty as perceived by businesses and consumers

Values of OECD Business and Consumers Confidence indices* for the OECD area (in reversed orders)

Panel A. Uncertainty perceived by business

Panel B. Uncertainty perceived by consumers

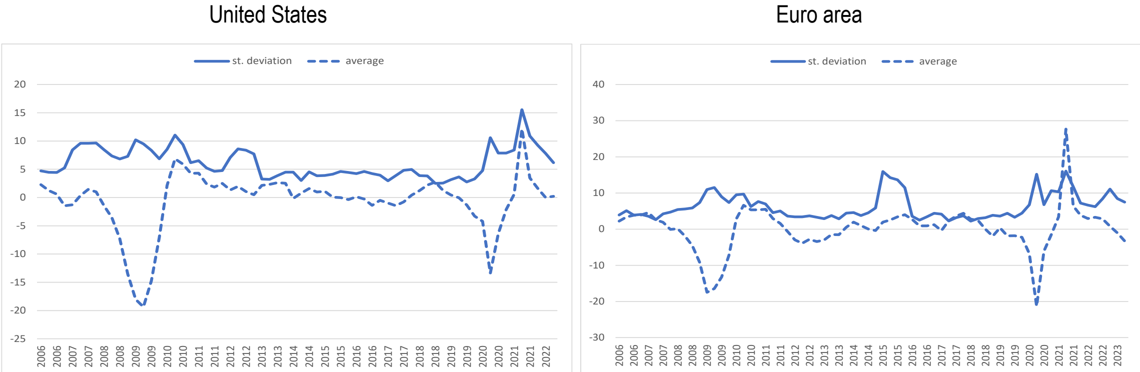


Note: These confidence indicators provide information on future developments. For business confidence, they are based upon opinion surveys on developments in production, orders and stocks of finished goods in the industry sector. Numbers above 100 suggest an increased confidence in near future business performance, and numbers below 100 indicate pessimism towards future performance. For consumer confidence, they provide an indication of future developments of households' consumption and saving, based upon answers regarding their expected financial situation, their sentiment about the general economic situation, unemployment, and capability of savings. Numbers above 100 suggest an increased confidence in near future business performance or consumer confidence, and numbers below 100 indicate pessimism towards future performance.
Source: OECD Business and Consumer Confidence Indices data.

The recent periods of uncertainty were also characterised by a significant increase in fluctuations of industrial output. Industrial production data shows that the GFC and the COVID-19 pandemic were characterised not only by marked decreases in aggregate output but also by equally noticeable increases in dispersion of sectoral output growth rates across different economic activities, as shown in Figure 2.3 on the example of the United States' and the Euro area's manufacturing. Even if this does not imply that sector-specific idiosyncratic perturbations where the main source of economic shocks during these crises periods[5], it indicates that increased cross-sectoral output volatility was an important reality during these crises and provides additional motivation for studying exposure to location and sector-specific production shocks.

Figure 2.3. Variation of quarterly output growth rates across manufacturing sectors

Average and standard deviation of quarterly (y-o-y) growth rates across different manufacturing sectors



Note: For the United States the indicators are calculated across all 19 durable and non-durable manufacturing industries based on the NICS classification while for the Euro area they are calculated across 23 manufacturing industries based on the NACE rev. 2 classification.
Source: authors' calculations based on, for the United States Bureau of Economic Analysis data, and, for the Euro area, based on Eurostat data.

2.2. Transmission of production shocks in the OECD global trade model METRO

The current analysis focuses on country and sector-specific production shocks which can occur in any economy and economic sector. As already foreshadowed in the introduction, the idea is to mimic the kind of shocks referred to in the debate on supply chain disruptions whereby specific production nodes of the global economy (i.e. specific national sectors) are perturbed and have to downscale their supply due to natural or policy-induced causes. Technically, these shocks are implemented as sector and country-specific production tax increase (or decrease for positive production shocks) in order to elicit a sectoral production decline (increase).[6] Since products are either consumed domestically or abroad, or used as inputs into production in other domestic or foreign sectors, location-specific production shocks can

[5] There is evidence that sector-specific perturbations were relatively more prominent during the COVID-19 pandemic than during the GFC. Arriola, Kowalski and van Tongeren, 2021[7]), for example, showed that the COVID-19 pandemic was associated with higher dispersion of trade growth rates across the main traded merchandise products. (Arriola, Kowalski and van Tongeren, 2022[35]) showed further that the disruptions in supply of some products which were in the spotlight during the COVID-19 pandemic were a result of combination of several factors. Social distancing measures and lockdowns, implemented in different periods in different countries, had uneven impact on supply capabilities of different economic sectors. Temporary border closures and movement of workers restrictions also had heterogenous impacts on different modes of transport and trade routes. There were also product specific consumer demand shifts as well as aggregate demand shifts related to fiscal and monetary policy responses, and these also had unequal impacts across product and factor markets.

[6] In principle, equivalent declines (or increases) could have been obtained with appropriately scaled quantitative restrictions (quotas) but this latter approach is technically more difficult to implement in the model and does not offer any advantages. The main difference between the tax and quota approach is that in the case of a quota the decline in consumer surplus (higher consumer price) is to a large extent accounted for by an increase in producer surplus, while in the case of the case of a tax it is accounted for by the increase in government tax revenue. Related to the latter, an assumption of unchanged government spending is used in the model so that the changes in government revenue do not translate to government spending minimising any effects on demand. The extra (reduced) tax revenue from the production shock ends up in (is deducted from) government savings. Note also that sectoral output declines result in a reduced demand for factors of production which are released from the declining sectors into the economy-wide factor markets.

propagate domestically and across national borders through knock-on effects in final and intermediate product markets.

The OECD CGE model METRO model and database, which are used in this analysis to shed more empirical light on the nature of such shock propagation, take into account the main characteristics of GVC integration identified in the literature and reflected in the OECD's Inter-Country Input-Output (ICIO) Tables and Trade in Value Added (TiVA) methodologies.[7] There are several channels through which country and sector-specific production shocks propagate throughout the global economy in this model, and only some of them are related directly to GVC integration.

First, to the extent producers compete in domestic and foreign markets for intermediate and final products, disruptions of supply of products have 'horizontal' impacts on foreign competitors producing substitutes. In a simplified two-country three-industry example depicted in Figure 2.4, a hypothetical negative production shock to China's metals industry will, absent any other effects, lower the supply of Chinese metal products and increase their prices. It will also drive up the demand for—and thus the prices of—German metal products which can be used by intermediate and final consumers instead of Chinese products. In the model, the magnitude of such *horizontal* effects (depicted as green arrows in Figure 2.4) will depend directly on the elasticities of substitution between the two different varieties of metal products (used for both final consumption and as inputs into production) and on the initial shares of Chinese metal products in the final and intermediate metal products markets. The higher the share of China in these product markets, the larger will be the impacts of shocks on other producers. At the same time, proportional impacts of shocks can be expected to be larger for producers with small market shares.[8]

Second, to the extent products are used as intermediate inputs for production in other sectors, production shocks will also propagate to downstream and upstream industries. Continuing with the simplified two-country three-industry example, this channel of shock propagation is depicted in Figure 2.4 as 'vertical' while distinguishing between impacts on domestic (yellow arrows) and foreign (blue arrows) *vertically-linked* industries. To the extent metal products are used as inputs in production of electronics (lower four boxes in Figure 2.4) and mining products are used as inputs in production of metal products (upper four boxes in Figure 2.4), a negative production shock in China's metals industry will be transmitted *vertically* to German and Chinese electronics and mining industries which will be both affected negatively because the negative supply shock to China's metals industry will diminish the availability of intermediate metal inputs into electronics production and increase their prices. In a similar fashion, mining, which is depicted as being located upstream of metals production, will also be affected negatively because mining products are used as intermediate inputs in the disrupted Chinese metals production.

Note that the production shocks will be transmitted vertically either to other 'domestic' sectors (i.e. from the Chinese metals industry to the country's own electronics and mining industries—yellow arrows in Figure 2.4) or 'foreign' sectors (i.e. from the Chinese metals industry to foreign electronics and mining sectors which use Chinese metal inputs—blue arrows in Figure 2.4). These vertically transmitted shocks originating in foreign sectors are referred to in the remainder of this paper as 'GVC shocks'.

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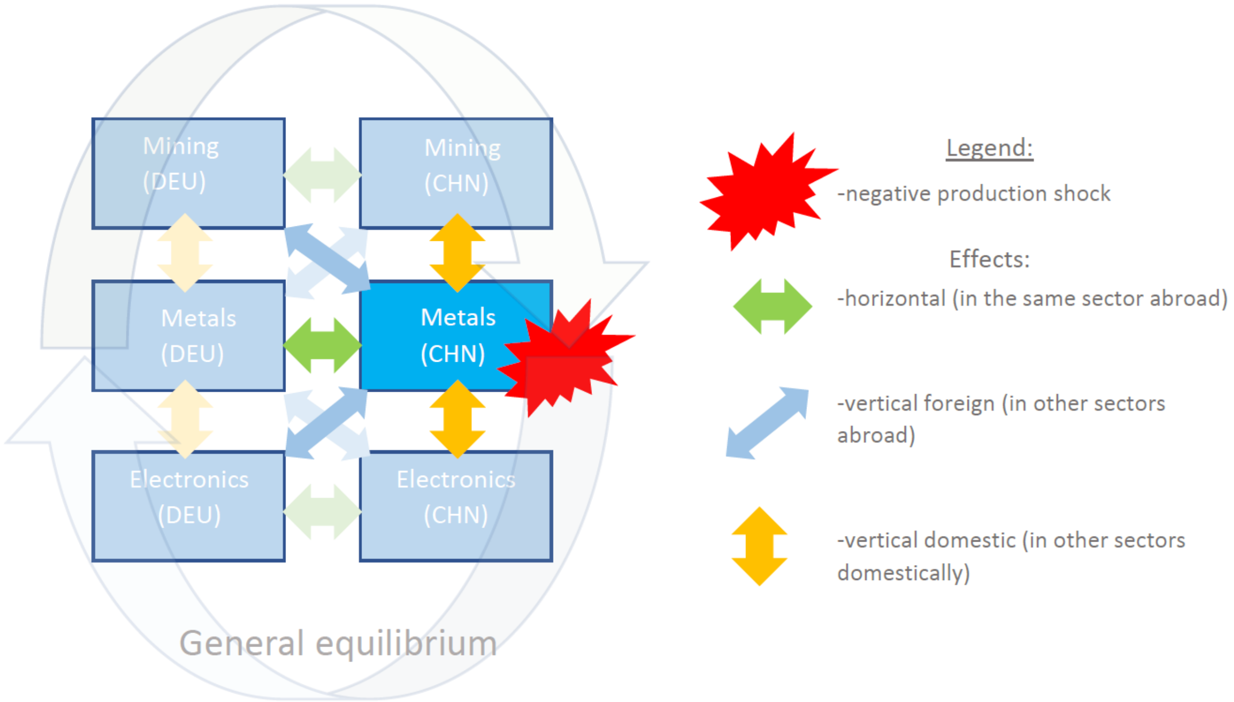
[7] For example, the model can be used to calculate the foreign content of gross exports (i.e. a measure of 'backward' GVC participation) or domestic value added content in other countries gross exports ('forward" GVC participation) in the baseline and in analytical scenarios. The OECD METRO's 'ICIO-TiVA module' produces GVC indicators using a similar approach as the one used to produce the OECD TiVA database (OECD, 2018[33]). The METRO model database is based on the Global Trade Analysis Project (GTAP) database and values of GVC indicators may differ from those based on the OECD ICIOs. For more information on the model used see Annex A.1.

[8] Note that to the extent that these horizontal impacts concern also intermediate products, they similarly capture the GVC diversification effects discussed in the introduction as producers can switch between different sources of these products. However, for industries which source an important share of inputs from within the industry (e.g. the bulk of intermediate inputs in the electronics sector comes from within the sector) these 'horizontal effects' will capture also own-industry vertical effects (i.e. a decline in supply of intermediate inputs from the foreign locations of the electronics industry itself).

Figure 2.4. Main channels of propagation of production shocks in GVCs



Source: Authors' own elaboration.

The magnitudes of impacts of GVC shocks are determined by an interplay of economic theory assumptions concerning how choices between the different inputs into production and consumption are made, the empirical estimates of elasticities[9] and trade-and production shares[10] as well as on the overall input-output structure underlying inter-industry linkages represented in the model. The impacts of foreign production shocks on domestic production depend on the elasticities of substitution of different inputs used in production. They will be larger the higher the intensity of the use of the particular imported intermediate in generating output in the given industry as determined by the Leontief inverse[11] of the underlying inter-country input-output matrix (Acemoglu, Akcigit and Kerr, 2015[13]) This means that supply shocks in upstream sectors, products of which are used intensely in the production of a given affected industry, are

[9] To assess the sensitivity of the results to the elasticities used in the model, the full set of simulations were performed with trade and substitution elasticities reduced by ten percent (see Annex A.2). Lower elasticities make switching from domestic to foreign inputs, and from different foreign sources, more difficult in the face of a production shock. On the supply side, it also makes changing the destination of output between domestic and foreign markets as well as between different foreign markets more difficult and expensive. Overall, the sensitivity analyses found that the results under the two sets of elasticities are largely the same with marginal output changes slightly less pronounced with lower trade elasticities. The transmission of the shocks to foreign vertical sectors is found to be slightly less under lower trade elasticities, as the effect of the production shock is felt more domestically, since domestic producers find it harder to switch between domestic and foreign sources and between different foreign markets. Nevertheless, the rankings of the most exposed sectors and regions to GVC shocks presented and discussed in Section 3.2 do not change with lower trade elasticities. Note that the results of this sensitivity analysis, presented in Annex A.2, were obtained under the assumption of factor mobility (See Annex A.2 for more detail).

[10] A more detailed discussion of factors affecting the magnitude of transmission of vertical shocks is provided in Annex A.2.

[11] The elements of the Leontief inverse matrix can be interpreted in the context of this study as coefficients measuring the extent of dependence of sector *k* in country *i* on inputs of industry *m* in country *j* using the notation introduced in Section 2.3 below.

expected to be transmitted more than shocks in sectors whose products are not used intensely in production.

Note that the horizontal and vertical transmission channels depicted in Figure 2.4 work in parallel across all sectors and countries represented in the model and it is not straightforward to determine which of them will dominate the outcome in a given affected industry.[12] Moreover, and in addition to these more direct effects, production levels in affected industries will also be shaped by less direct—but not necessarily less significant—general equilibrium effects such as, for example, those related to reallocation of production factors across sectors (e.g. labour freed from one sector is employed in others), heterogenous impacts of falling or increasing incomes, as well as different relative price and consumption changes. The co-existence of the multiple different effects, which are hard to disentangle and multiply with the number of considered sectors and countries, is one motivation for using a CGE model: the modelling can reveal effects which are difficult to foresee otherwise.

To better disentangle the impact of adjustments through factor markets, and to reflect the reality that adjustments in these markets may take time, the model simulations were run under two alternative sets of assumptions regarding factor markets: (i) that factors are fully employed and mobile across sectors so that their sectoral use adjusts following a shock (factor mobility assumption thereafter) [13]; and (ii) that factors are fully employed but fixed in sectors where they are initially used (factor immobility assumption).

2.3. The model set-up and design of simulations

The analysis uses the OECD CGE METRO model's most recent database and a bespoke model database aggregation.[14] Regarding the aggregation, the objective is to keep separate as large a number of major OECD and non-OECD economies, and as large a number of distinct economic sectors, as possible, while minimising the computational costs in the context of the large number of model simulations that have to be performed for each sector-county pair. The resulting analytical database consists of 22 countries or regions, including: ten individual OECD countries; two aggregate regions composed mostly of OECD countries; Argentina, Brazil; China; Indonesia; India; Russia; South Africa as well as three other aggregated regions.[15]

The aggregation also distinguishes between 23 sectors (including 15 manufacturing and 8 services sectors, Annex Table A B.1). While this is a relatively high degree of sector detail for this class of models, the approach may still overlook impacts on some more specific categories of products which are at the centre of debates on the propagation of shocks and supply chain resilience (e.g. semiconductors, minerals used in green technologies or specific food and medical product categories). This may be particularly problematic if, in reality, there is a lot of heterogeneity within the broader sectors. For example, different

[12] For example, a negative production shock in the Chinese metals industry may end up having a positive impact on the output of the German electronics sector. This may be the case if the direct negative vertical effect, associated with more expensive intermediate inputs into Germany's electronics production, is outweighed by the positive competitive effect from China's electronics industry whose production will be negatively impacted by the same shock. Whether this is the case will again depend on a range of market shares and elasticities and it is difficult to predict *a priori*.

[13]A conventional set of production function elasticities, which determine the degree of substitutability of factors within ad across sectors, is used in this type of modelling. The core production function elasticities used in the OECD METRO model are sourced from the Global Tarde Analysis Project (GTAP) database. Some are adjusted to fit the specificity of the METRO model. For more see Annex A).

[14] The analysis is performed using a set of conventional 'medium-term' closures rules: labour and capital are mobile across the domestic sectors; government's expenditures are fixed while government's balance is flexible; investment is fixed as a share of domestic absorption and the household savings rates are flexible; and trade balance is flexible while the exchange rate is fixed. In general, the medium-term represented in a CGE model is thought to be about 5 years – long enough for factors to adjust and move across sectors but not long enough for factor endowments to change. See Annex A.1 for more information about the METRO model.

[15] Note that France, Germany and Italy are considered individually while some smaller EU countries are aggregated into the multi-country EU24 region (see Annex Table A B.1). This implies that some shocks and effects that are internal to the EU are considered as foreign from the perspective of the individual EU member. A discussion of EU-specific implications of these choices is provided in the results of Section 3.2.4.

raw materials which may be critical inputs into production in different industrial sectors are aggregated together, which may result in a too optimistic assessment of substitution possibilities for alternatives. However, if signs of exposure to shocks are detected in the analysis conducted at the broad sector level, this suggest that at least some of the more specific activities or products that are covered by this broad category are also likely to be exposed. The analysis and its implications should therefore not be seen as exhaustive but as a first filter for identifying those broad economic sectors which can be studied further in detail using methodologies allowing for more product detail.

With the model database aggregated to 22 countries/regions and 23 sectors, the global economy in the model is composed of 506 country-sector pairs. Production shocks can occur in each of these country-sectors ('shock country-sectors' thereafter) and their effects are felt in all the other country-sectors ('affected country-sectors'). Overall, there are total 1 012 production shocks to consider because there is interest in considering separately positive and negative shocks occurring in the same location (i.e. country-sector). The approximate linearity of the model means that the impacts of positive production shocks are of the same size as the impacts of the corresponding negative shocks, but they have opposite signs. Nevertheless, the direction of output responses in affected country-sectors is not only determined by the direction of the shocks but also by how these affected country-sectors are linked to the shock country-sectors in GVCs. Declines in output in some upstream sectors will have negative effects on output in some downstream sectors but others may have positive effects.[16]

To be able to compare impacts across shocks originating in different shock country-sectors, all shocks are designed to be of the same magnitude (i.e. 1% increase/decrease in the shock country-sector's output).[17] The effects of each the 1 012 country-sector and direction-specific shocks are felt in the remaining 505 affected country-sectors, giving 511 060 data points for analysis if we look at just one outcome variable: sectoral output.[18] These data points can be denoted as ΔQ_{ijkm} i.e. as a percentage change in output in an affected country *i's* sector *k* due to a 1% decline (increase) in output in country *j*'s sector *m.*[19]

In reality, any of such shocks could occur either in isolation or in parallel with others. The number of all possible constellations of the 1 012 shocks is prohibitively high to be considered explicitly in different model simulations. However, the approximate linearity of the model means that it is possible to run each of the 1 012 simulations separately and, for analysis of any specific combination of possible shocks, the corresponding individual results can be added together without the risk of overlooking important interactions.

[16] This also means that the expected impact of equally probable negative and positive shocks is null. However, this would not be the case if shocks occur with different probabilities and in different constellations.

[17] As already foreshadowed, technically, these simulations are implemented as sector and country-specific production tax reductions or increases in order to elicit a sectoral production change. The size of these production changes varies by country-sector. Therefore, the results are scaled by the size of the output change in the country-sector that experiences the tax change in a given simulation so that the shocks can all be interpreted as 'marginal' output shocks of 1%.

[18] This number is obtained as follows: 1 012 shocks times 506 affected sectors less 1 012 shocks in 'own' sectors (i.e. where the affected sector is also the shock sector).

[19] The conclusions drawn in this paper would hold for reasonably larger shocks. Since the model is approximately linear, changing the size of the shock would increase the impact by approximately the same magnitude- i.e., the impact of a 10% shock would be about 10 times larger than the impact of a 1% shock. The analysis relies on average values and standard deviations of the marginal impacts which would not change with the size of the shock because the numerator and dominator would change by about the same magnitude. However, because the model is only approximately linear, there are limits to the size of the shocks where the conclusion would still apply. Results would not necessarily apply to extreme shocks where the global economy would remain in disequilibrium over an extended period of time.

3. Results: The effects of global production shocks

The simulations yield a large set of observations on output responses in all affected country-sectors to marginal shocks occurring in each shock country-sector, including shocks originating domestically. This model-generated set of results is analysed in this chapter to uncover some systematic differences in impacts across the different sources (foreign versus domestic) and how shocks propagate depending on the relative position of sectors in the global economy (i.e. horizontal versus vertical (upstream and downstream). To provide an overview of broad characteristics of shock propagation, Section 3.1 first considers global distributions of impacts and then reports on results of regression analysis of systemic importance of different sector and countries as sources and recipients of GVC shocks. Section 3.2 builds on key distributional properties of shock responses and discusses three summary statistics which can be used to rank countries and sectors by their overall vulnerability to GVC shocks. The section discusses also how the output responses dataset can also use to examine the exposure to different shocks or constellations of shocks of specific country-sectors using the examples of electronics, iron and steel and motor vehicles.

3.1. The global picture

3.1.1. How do the responses to shocks depend on the relative position of sectors?

The analysis of the distribution of responses to negative[20] output shocks presented in this section distinguishes between the different broad types of shock transmission channels described in Section 2.2: *horizontal*; *vertical domestic*; and *GVC* shocks. This distinction reveals some noteworthy distributional properties the main features of which are graphically summarised in Figure 3.1 while Annex Figures A B.1 and A B.2 depict full distributions.

Overall, when all transmission channels are considered together (*all shocks* in Figure 3.1), the responses are centered around zero and are characterized by high kurtosis. This means that there are many small output responses relative to the magnitude of original shocks, suggesting a generally small extent of transmission of shocks. However, the distributions are also ‘fat-tailed’, as illustrated by the relatively large values in output responses in a number of cases. This implies that some shocks have much more consequential effects than ‘average’ shocks.

Output responses to shocks that originate in the same industry but in a foreign country (dubbed *horizontal shocks* in Section 2.1) are positively skewed (Figure 3.1 and Panels B of Annex Figures A B.1 and A B.2 and). This is predictable because declines in output of competitors would be expected to create new production opportunities. The magnitude of some of these effects of *horizontal shocks* is larger than the magnitude of the initial shocks (which are all calibrated to 1%). This can be explained by the fact that even small changes in output of large market players can translate into relatively large consequences for smaller players. The dominance of positive output responses means that these competition effects dominate negative effects associated with constrained supply of foreign intermediates within the same industries (e.g. Chinese electronics used as intermediate goods for the German electronics industry) which are also inevitably captured in the category of horizontal shocks in this approach. The fact that competition effects dominate is revealing because, in most of the sectors considered in this analysis, intermediate inputs from within the sector typically account for at least 20% of all intermediate inputs.

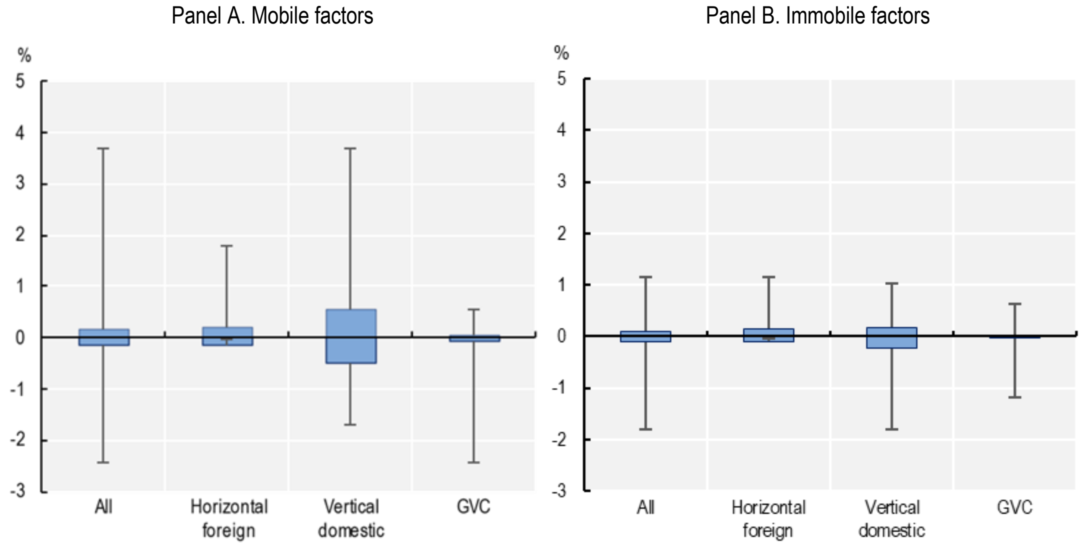
Responses to vertical shocks originating in domestic sectors (*vertical domestic* shocks) can be both negative and positive (and Panels C of Annex Figures A B.1 and A B.2). The effects of *vertical domestic* shocks also have higher dispersion than shocks transmitted via other transmission channels. Under the assumption of mobile factors some of the largest declines reach 2% and some of the largest increases

[20] This part of analysis focuses only on the negative shocks while bearing in mind that the effects of positive shocks are a mirror image of the latter. If positive shocks were considered instead, the distributions would remain the same, but the direction of shocks and output changes would be reversed. The idea of focusing on one direction of shocks is to be able to look at the different statistical properties, including average impacts, across the different transmission channels.

approach 4%. That is, in the most extreme cases the magnitude of output responses to a negative domestic sector shock can be from two to four times larger in absolute terms than that of the original shocks.

Figure 3.1. Comparison of sizes of shocks across the transmission channels

% impacts of global 1% output shocks, by transmission channel



Note: For each type of shock, the boxplot shows: the mean, the mean +/- two standard deviation values (the edges of the boxes) as well as the maximum and minimum values (the whiskers).
Source: OECD METRO model simulations.

Under the assumption of mobile factors, the distribution of responses to *vertical domestic* shocks is skewed towards positive values. This may seem counterintuitive as the direct effect of weakening a link in the vertical chain is to reduce upstream demand and reduce downstream supply. The positive output responses, which in fact dominate the distribution for this transmission channel under the mobile factors assumption (on average responses are marginally positive – Panel C of Annex Figure A B.1), indicate that in several cases the adjustment effects related to domestic resource allocation are relatively strong. This is because prices of capital and different kinds of labour, which are freed from the sectors reducing production, decline, and these relatively attractively priced factors are absorbed by other sectors resulting in positive output responses. Factors released from declining sectors can cause particularly large parallel output changes in sectors which use these factors intensely for production. This underscores the importance of assumptions regarding factor markets and is illustrated additionally by the fact that, under the immobile factors assumption, the incidence of positive impacts of *vertical domestic* shocks is less prominent (Panel C of Annex Figure A B.2).

Effects of vertical shocks originating in foreign sectors—the *GVC* shocks—are skewed negatively and are on average marginally negative (*GVC* shocks, Figure 3.1 and Panels D in Annex Figures A B.1 and A B.2). The dominance of negative effects confirms the intuition developed in Section 2.2: negative output shocks upstream in the value chain constrain access to intermediate inputs and negative shocks downstream lower the demand for output. However, the majority of the negative impacts is of one to two magnitudes smaller than the magnitude of original shocks, and this is particularly visible under the assumption of immobile factors (Panel B of Figure 3.1 and Panel D of Annex Figure A B.2). Some negative output responses approach 3% but only when factors are mobile. This suggests that, in some cases, the responses to *GVC* shocks can be up to three times larger than the original shocks, but also that these largest responses are mainly due to factor markets adjustments, i.e. more likely in medium to long term. When factors are immobile the size of negative impacts of *GVC* shocks is much smaller.

Some of the positive output responses to *GVC* shocks, which cannot result from vertical transmission, as explained above, suggest that some competing sectors in other regions may be affected even more negatively by the same shocks. It is for either this reason, that the overall impacts on sector-countries turn positive, or, again, because domestic general equilibrium effects dominate and reverse the direction of the more direct impacts. The latter hypothesis is supported by the fact that with immobile factors assumption the incidence of positive responses to *GVC* shocks is more limited (Panel D of Annex Figure A B.2).

Overall, these results indicate that GVCs are not the main channel of international shock transmission. This is consistent with several stylised facts found in the GVC literature. First, in most national sectors, reliance on foreign inputs and foreign markets for final products is still smaller than reliance on domestic inputs and markets. In addition, in the face of shocks, GVCs offer opportunities for substitution towards suppliers and markets which are unaffected.

Assumptions about factor mobility are consequential. Perhaps in contrast to what is sometimes assumed, short-term effects of GVC shocks, when factors are fixed in sectors where they were initially employed[21], are smaller than medium-to-long term affects when factor markets are allowed to adjust. This is particularly the case when the sectors affected directly by the shocks account for large shares of domestic factors markets as this enables a wider transmission of shocks through the domestic economy in the medium term.

More broadly, the results also underscore an important reality: in complex economic systems, shocks trigger several parallel adjustments. Observers do not directly witness distinct shocks and their direct effects, but rather, as is often the case, rely on observations of what are likely to be direct and induced effects of multiple shocks and adjustments in complex economic structures, and thus may find it difficult to clearly separate causes and effects of different shocks. They may therefore not be able to reliably assess whether in these specific cases supply chains impede or facilitate adjustment to shocks. The kind of counterfactual general equilibrium modelling used here can help disentangle the complex transmission channels and adjustment mechanisms.

3.1.2. What determines the transmission of shocks through GVCs?

How can one identify countries or sectors that could potentially be sources of volatility should they experience production declines, or identify countries or sectors that are particularly sensitive to these declines? To this end, a fixed effects regression model is useful to decompose the values of the simulated output responses. Adding typical measures of GVC integration—the so called ‘backward’ and ‘forward’ GVC indicators—from the input-output methodology permits isolation of the effects of upstream and downstream transmission.[22] Separate estimation of the fixed-effects model for the two sets of results reflecting different assumptions about factor market adjustments further allows assessing the importance of these alternative assumptions.[23]

Overall, these regression analyses explain approximately 30% of the variability in responses to shocks. This means that close to one third of the variation in impacts can be explained by binary information on country and sector origins and destinations of shocks and with simple measures of input-output linkages. Consequently, the remaining part of the variation is thus due to factors which were not included in the regression, that is other structural parameters, elasticities and economic adjustment mechanisms characterising the model.

The coefficients on input-output network measures of downstream and upstream propagation of shocks are found to be statistically significant in both sets of regressions and have expected signs. They indicate that, in the METRO model, negative production shocks are transmitted both downstream and upstream the value chain. Downstream transmission of shocks is found to be much stronger[24] than transmission

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[21] The assumption that factors remain fixed in a sector and fully employed is not entirely unrealistic. In the short-run, firms may be reluctant to adjust factor demand in response to a shock due to difficulties in changing production technologies, contractual obligations preventing employee layoffs, or the perception that shocks are temporary, for example. Some of the furlough schemes introduced during the COVID-19 pandemic had maintain employment in specific activities intact as their main objective.

[22] The measures used are the corresponding elements of the Leontief index. For more see footnote 9 and Annex A.3.

[23] A more detailed description of this regression analysis is provided in Annex A.3.

[24] In the case of mobile (immobile) factors, the coefficient on downstream channel is more than ten (twenty-four) times larger than the coefficient on upstream channel.

upstream, particularly when factors were assumed to be immobile.[25] This is in line with the intuition developed by (Acemoglu, Akcigit and Kerr, 2015[13]) as discussed in Section 2.2.

The quantitative significance of the estimated vertical transmission effects can be illustrated in the following way. The values of the indicator used for measuring the downstream channel of propagation of production shocks—which are the corresponding elements of the so called Leontief inverse matrix—suggest that a one dollar increase in the final demand for *motor vehicles* in foreign countries results in between zero and eight cents increase in the output of *electronic equipment* products, depending on the country in which the vehicles are produced and the country from which the electronic products are sourced. The United Kingdom's motor vehicles sector's dependency on the Argentinian electronics industry is for example virtually non-existent, while India's motor vehicles sector's dependence on China's electronics is relatively strong and corresponds to the eight cents per one dollar spillover effect mentioned above. The interpretation of the corresponding regression coefficients is that a hypothetical increase in dependence of a *motor vehicle* industry on foreign *electronic equipment,* which would be equivalent in size to the difference between the level of dependence of the United Kingdom on Argentina to level of dependence of India on China, would result in an increase in average expected marginal decline in output (in response to idiosyncratically-occurring 1% declines in foreign production) from nil to -0.07% (with the assumption of immobile factors) and from nil to -0.04% (with the assumption of mobile factors).

As far as the estimation results regarding the fixed effects are concerned, only up to 38% are statistically significant at the 5% or higher level of statistical significance.[26] They indicate some interesting features of shock transmission but must be interpreted carefully.[27] To give a broad sense of their importance, the largest statistically significant coefficients are plotted in Panel A of Annex Figure A B.3. Results differ between the two alternative factor mobility assumptions confirming again their importance. Under the assumption of immobile factors, a smaller number of fixed effects are statistically significant. This suggests that, having accounted for the size of the vertical transmission effects, fixed effects are relatively less important in explaining the transmission of foreign vertical shocks when the general equilibrium effects are attenuated.[28] Also, the estimated coefficients tend to be generally smaller under the immobile factor assumption and they indicate different levels of importance of different combinations of countries and sectors as sources and destinations of shocks in terms of explaining the size of responses to shocks.

Two examples can be given to illustrate the quantitative importance of the fixed effects results. For instance, under the assumption of mobile factors, the results suggest that output declines occurring in China (in any sector) are on average associated with larger negative output responses in affected sectors as compared to output declines occurring in India (0.06 percentage point difference).[29] In another example that can be given for results obtained under the immobile factors assumption, output declines originating in the chemicals sector (in any country) are on average associated with somewhat more negative output responses than shocks originating in the non-ferrous metals sector (0.003 percentage point difference).

[25] This is intuitive as the results generated under the assumption of factor immobility increase the relative importance of vertical transmission by making the general equilibrium adjustments less strong.

[26] The interpretation of the statistical significance of the estimated fixed-effects coefficients is that, for those effects for which coefficients are statistically significant, it is highly unlikely that the production shocks originating in (or affecting) the corresponding countries, sectors or their combinations will have no effect on average, on top of what would be implied by the above-discussed estimated input-output effects discussed above.

[27] Coefficients estimated on dummy variables have to be interpreted relative to the model's estimated intercept which, in the case of a fixed effects regression with dummy variables, has a specific interpretation. In particular, the coefficient of the intercept captures an average effect for the observations for which the fixed effects are chosen arbitrarily and omitted from the regression in order to eliminate multicollinearity, along with some others which are dropped from the regression automatically because of, for example, little variation in output responses, and the coefficients on the remaining fixed effects have to be interpreted relative to the intercept. A key implication is that the differences between the estimated coefficients have more meaning than their actual sizes.

[28] This is also consistent with the relative size of the effects estimated for input-output linkages which are larger under the immobile factors assumption.

[29] This is calculated as the difference between the fixed effect coefficient for China as an origin of shock (-0.07) and the corresponding fixed effect coefficient for India (-0.01).

The qualification ‘on average’ attached to these results should be emphasised because it implies a specific interpretation in a policy context. The estimated fixed effects allow identifying the sources of shocks which generate more volatility across the global economy on average in the case of randomly occurring production shocks (or, where relevant, they allow identifying sectors and countries with potential to be on average more affected by such volatility). This global perspective is pertinent from a systemic point of view as it can inform international and industry co-operation initiatives, for example on how to jointly improve stability of certain globally important sectors or how to address systemically important volatility originating from specific countries, However, the properties of global distributions of shock responses may also mask heterogeneity which may be more relevant from specific national or national industry perspectives, especially since many of the policy instruments that might be used to address exposure to shocks are determined at the national level. The national perspective is explored in the following section.

3.2. Assessing exposure to GVC shocks from a national and industry perspective

The analysis of global distributions of responses to GVC shocks reveals that average responses to output declines in foreign vertically-linked sectors tend to be two magnitudes lower than the original shocks, that is very low (recall Figure 3.1 above). In addition, positive production shocks can also occur and in the model at hand, responses to output increases are the mirror image of responses to declines (i.e. they are of the same order of magnitude but have opposite signs). However, the global results also reveal the existence of some relatively large responses. This suggest that the main interest is in exploring the possible deviations from small average impacts.

It is not immediately obvious what summary statistics should be used to assess the exposure to shocks of specific national sectors or countries. Various businesses and policy makers may be interested in consequences of different shocks or shock patterns and different constellations of shocks can occur with different probabilities. Assessment of such risk profiles goes beyond the scope of this work even though the simulation results presented in this work allow for bespoke investigations of possible consequences of specific shocks and patterns of shocks.

The objective of the analysis presented in this section is to use three summary statistics to condense some broad implications of possible deviations from average shock responses for individual countries and sectors: *standard deviation*, *‘maximum impact’* and ‘*exceedance probability*’.

3.2.1. ‘Typical exposure’ to GVC shocks

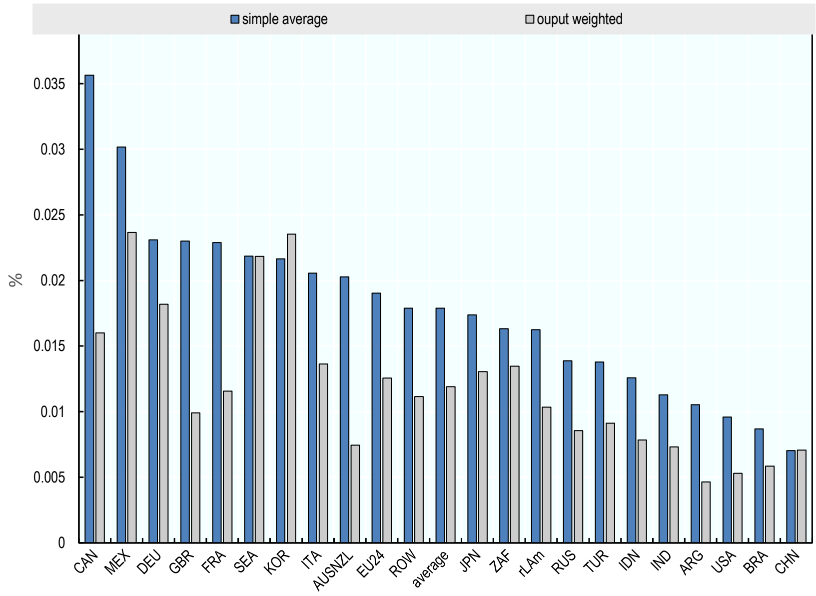
The *standard deviation* of output responses across all the *GVC shocks* captures the degree of a typical deviation of output in response to random (i.e. equally probable) *GVC shocks*. Calculated for each affected country-sector (see Annex Figure A B.4), it can be averaged across countries (Figure 3.2) and sectors (Figure 3.3) to gauge their ‘typical exposure’ to shocks.

Typical exposures to shocks for each affected country, averaged across all corresponding national sectors (Figure 3.3), confirm that exposure to GVC shocks is relatively low. Deviations of responses to random 1% production shocks are of two orders of magnitude lower than the original shocks and normally do not exceed 0.04%.

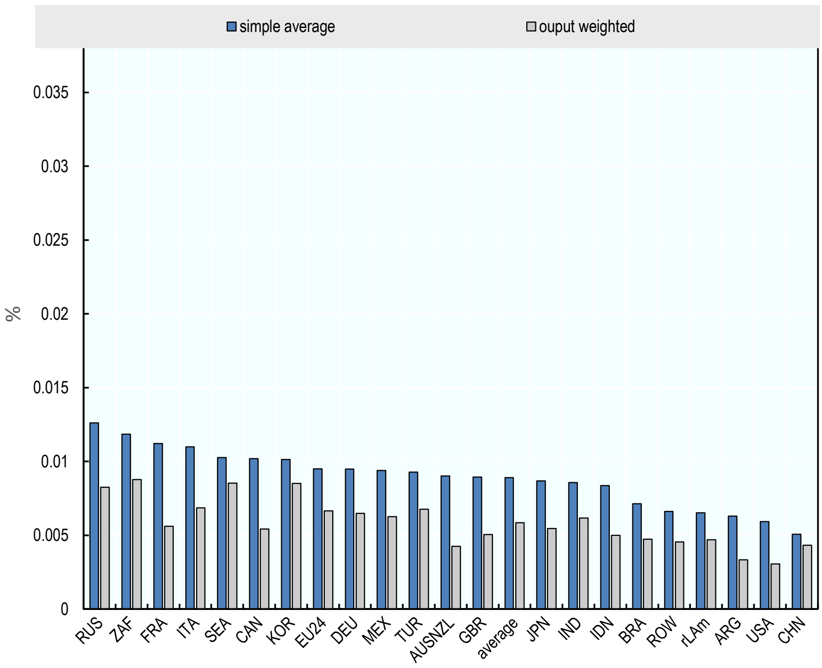
The exposure is even lower (typically not exceeding 0.0015%) when factors of productions are assumed immobile, showing again that some of impacts of shocks transmitted through GVCs are associated with secondary factor market impacts rather than the direct impacts through sourcing or supply of intermediate inputs.

Figure 3.2. *Typical exposure* to GVC shocks across countries

Panel A. Standard deviation of responses to 1% shocks – mobile factors of production



Panel B. Standard deviation of responses to 1% shocks – immobile factors of production



Note: Value of output at the starting point of the simulation are used as weights to produce weighted averages. Intra-EU shocks are included - for a discussion of *typical exposure* when intra-EU shocks are excluded see Section 3.2.4.
Source: OECD METRO model simulations.

There is some variation across countries, and the rankings of *typical exposure* also change somewhat depending on whether simple or output-weighted averages are used. Results using simple averages give a sense of overall exposure when all individual national sectors are given equal weight and can be dubbed as 'microeconomic' or 'structural' indicators of exposure. The output-weighted averages in turn capture the aggregate implications of exposure to shocks, because sectors which contribute more to national output are given more importance in the assessment of exposure. They can be interpreted here more as indicators of 'macroeconomic' exposure to shocks. For most countries, the microeconomic (simple average) indicator suggests a higher exposure than the macroeconomic indicator, and for some countries, such as, for example, Canada, the United Kingdom, France and Australia and New Zealand, this distinction is particularly important. This underscores that some of the small—but perhaps otherwise important—sectors are relatively more exposed to shocks than large sectors.

The country ranking of *typical exposures* depends also to some extent on the factor market assumption. Several countries which record some of the highest *typical exposures* under the mobile factors assumption, such as Canada, the United Kingdom or Mexico (Figure 3.2, Panel A) are closer to the average with immobile factors (Figure 3.2, Panel B).

Detailed results showing the *typical exposure* at the country-sector level (Annex Figure A B.4) suggest that in the case of Canada for example, the high *typical exposure* score under the assumption of mobile factors of production is explained by relatively high exposures across many manufacturing sectors (e.g. electronics, metals, irons and steel, chemicals and textiles). Furthermore, decompositions of typical impacts for these Canadian sectors (not shown in this report) indicate that the high exposure across the different manufacturing sectors is at least partially explained by strong links to two of the world's largest economies: United States and China. Canada and Mexico tend to rank similarly high on all different metrics used in this report, while the USA tends to be ranked at low end of exposures. The three economies have close supply chain linkages that are facilitated by the United States-Mexico-Canada Agreement (USMCA), the successor to NAFTA, but the United States has such a large domestic market and diverse trade links that it is less impacted by the type of shocks considered here.

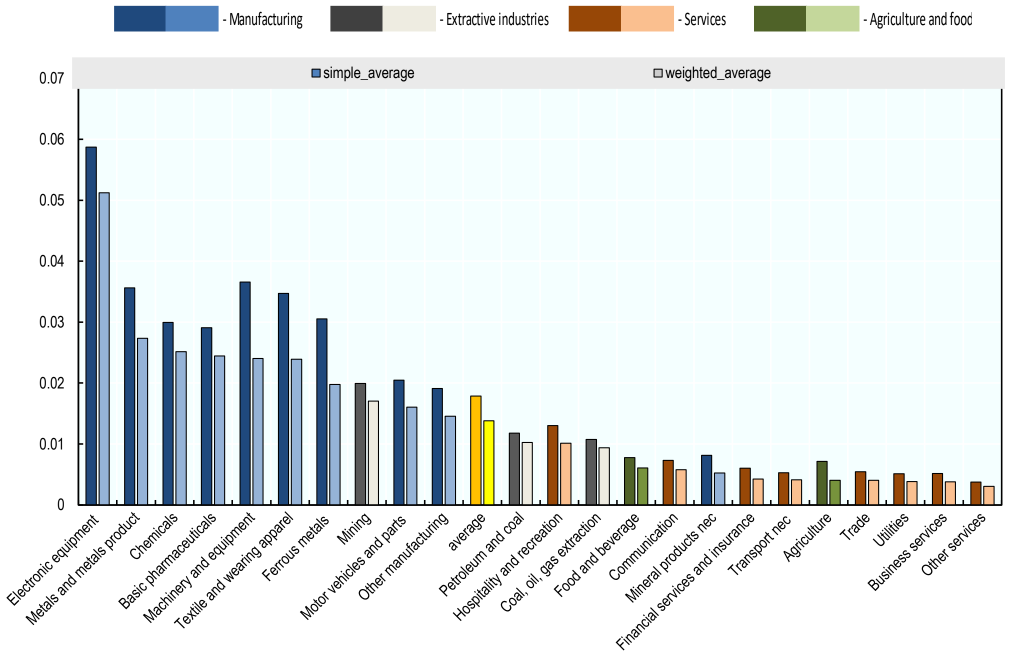
At the same time, Russia and South Africa are some of the countries that move to the top of the ranking of exposed countries under the assumption of immobile factors. These differences in rankings for the different factor market assumptions can best be explained by some examples. In the cases of Canada, the United Kingdom, and Mexico, the manufacturing sectors affected the most by GVC shocks (e.g. *electronic equipment* and *machinery*) account for relatively large shares of domestic factors of production. In Russia and South Africa, on the other hand, the sectors affected the most (e.g. *petroleum and coal*, *mining* and *chemicals*) have smaller shares in domestic factors markets which means that the direct results of shocks can be more easily absorbed in these markets.

Typical exposure can also be summarized across global economic sectors (Figure 3.3). There is more variation in *typical exposure* across sectors than there is across countries and the most exposed sectors are exposed more on average than the most exposed countries. This suggests a potential for sectoral initiatives to address exposure to shocks. Sector exposures calculated under the assumption of mobile factors are also higher that those calculated under the assumption of immobile factors. Rankings of the most exposed sectors also change somewhat between these two assumptions but there are also some features that are present irrespective of whether factors are mobile or not.

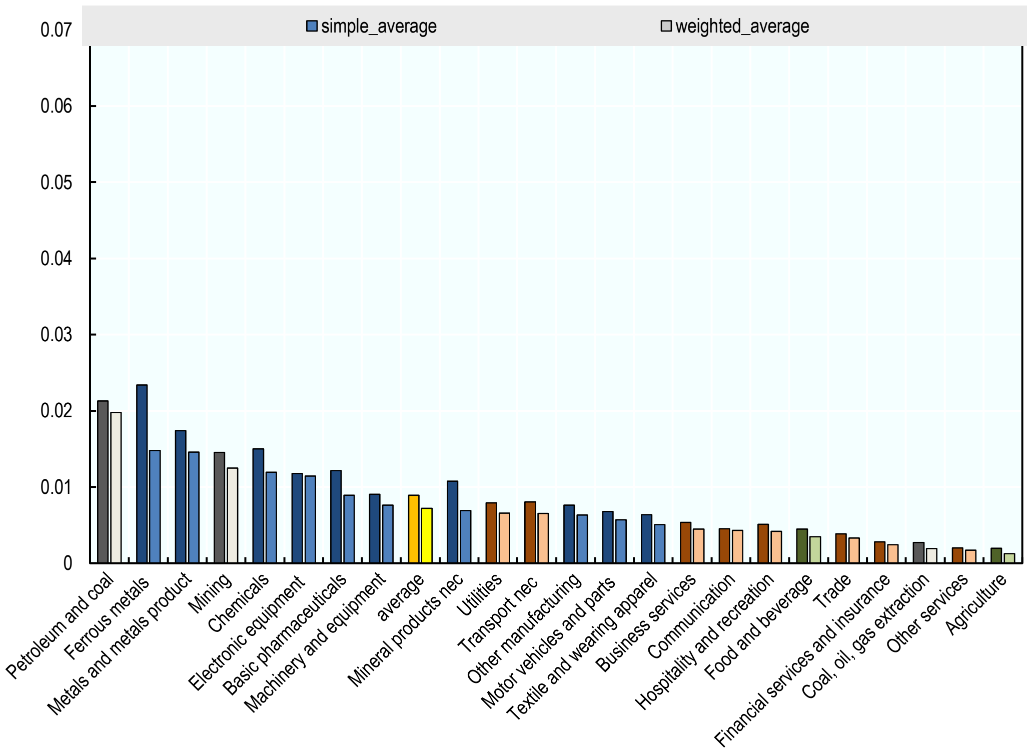
One of such common features is that manufacturing sectors in general tend to be exposed more than services and agriculture and food sectors. It is not surprising to see some of these sectors on top of the ranking because they are widely known to be some of the most internationalised ones in terms of destination of output as well as sourcing of intermediate inputs. Services sectors on the other hand are less traded and still source relatively few intermediate inputs from abroad. They also rely a lot more on domestic resources and account for large shares of domestic capital and labour markets.

Figure 3.3. *Typical exposure* to GVC shocks across global economic sectors

Panel A. Standard deviation of responses to shocks – mobile factors of production



Panel B. Standard deviation of responses to shocks – immobile factors of production



Note: Value of output at the starting point of the simulation are used as weights to produce weighted averages.
Source: OECD METRO model simulations.

When it comes to differences due to factor market assumptions, the most visible one is the relatively higher exposure to shocks of *extractive industries* under the assumption of immobile factors (Figure 3.3, Panel B). This is consistent with the above described relatively higher exposure of Russia and South Africa which tend to specialise in these industries. There are also some shifts in rankings within the broad industries. In manufacturing, it is the *ferrous* and *non-ferrous metals* industries as well as *chemicals* which are relatively more exposed under the immobile factors assumption, while the advanced manufacturing industries such as *electronic equipment* and *machinery and equipment* are relatively more exposed when factors are mobile. The latter finding is also consistent with the relatively higher exposures under the mobile factors assumption of some of the countries specialising in advanced manufacturing, as discussed above.

3.2.2. 'Maximum exposure' to GVC shocks

The use of standard deviation to capture *typical exposure* to shocks implicitly assumes that they occur independently and with an equal probability. However, shocks originating from different regions and sectors may occur simultaneously, and they can either counterbalance or reinforce each other. The second summary measure used here to condense the simulation results—called '*maximum exposure*'—focuses on the combinations of shocks which would result in the most extreme pooled output responses. Linked to the concept of a minimax decision criterion—a decision rule for minimising the possible loss for a worst case (maximum loss) scenario[30]—the *maximum exposure* for a given affected country-sector is defined as the sum of all the negative output changes of the affected sector that result from the whole range of positive and negative production shocks and therefore interpreted as the total output change or *maximum exposure*.

For example, if a negative output shock in the *electronic products* sector in Korea results in a decline of Germany's *motor vehicle* sector's output, then this impact is included in Germany's *maximum exposure* indicator for the *motor vehicles* sector. Similarly, if a positive output shock in the *non-ferrous metals* sector in China results in a decline in Germany's *motor vehicles* (as discussed above, this may materialise indirectly through a positive impact on China's *motor vehicles* production) then it is also included in Germany's *maximum exposure* indicator for motor vehicles. This reflects the possibility that the negative shock to *electronic products* in Korea can in principle combine with a positive shock to China's *non-ferrous metals* and deepen an output decline in Germany's *motor vehicle* sector. This is what is captured by the *maximum exposure* measure which combines the impacts of all such shocks which results in an output decline in a specific affected country-sector.[31]

Maximum exposure for all affected country-sectors is summarized in Annex Figure A B.5 for both assumptions regarding factor mobility. Similar to *typical exposure*, country-sector specific *maximum exposure* can be averaged across countries (Figure 3.4) and sectors (Figure 3.5) in order to establish exposure rankings.

[30] Minimax has been applied in artificial intelligence, decision theory, game theory, statistics, and philosophy (see https://en.wikipedia.org/wiki/Minimax).

[31] Specifically, if all possible shocks are considered (where shock country-sectors increase or decrease production by 1%), the maximum impact measure for an affected region's sector is calculated as the sum of the absolute values of all output declines across all foreign vertical shocks across. Summing over the absolute values follows from the fact that we are potentially concerned by both positive and negative output shocks and from the linearity of the model as discussed in Section 2. The definition of GVC shocks as 'foreign vertical shocks' (see Section 2) excludes domestic shocks and horizontal shocks. For example, in Panel A of Annex Figure A.7 the impact on Germany's *motor vehicles* of domestic shocks are presented in the row for Germany and the impact from horizontal shocks is the column for electronics. Both would be excluded from the maximum impact measure for Germany's electronic sector.

Unsurprisingly, *maximum exposures* are much higher than *typical exposures* –in specific country-sectors, they can exceed 10% of output (Annex Figure A B.5). In Canada's *electronic products* sector, for example, the industry's output could decline by as much as 9.7% if all the possible 1% negative and positive output shocks that can occur in foreign country-sectors which individually trigger an output decline in Canada's electronics coincide with each other. Averaged across national sectors, *maximum exposure* to GVCs shocks can reach 4% in the most exposed countries (Figure 3.4). They are thus two to three orders of magnitude higher than the *typical exposures* discussed above. Nevertheless, the differences between *maximum* and *typical exposures* have to be interpreted in probabilistic terms: the likelihood of all the country-sector shocks combining to produce the worst-case scenario for a given country-sector is much smaller than the likelihood of occurrence of an individual country-sector shock.

Interestingly, the rankings of the most exposed countries and global sectors established for *maximum exposure* are very similar to those established for *typical exposure*. For example, when factors are mobile, Canada and EU Members record both some of the highest *typical* and *maximum exposures*, while China and the United States are among countries which are relatively less exposed. Russia and South Africa are also the most typically and maximum exposed under the assumption of immobile factors of production while China and the United States are relatively less exposed (compare Figures 3.2 and 3.4). The same applies to the sectoral rankings which are also similar in the two approaches (compare Figures 3.3 and 3.5).

Countries for which the *typical* and *maximum exposure* approaches generate markedly different rankings[32] under the assumption of mobile factors of production include Mexico, Japan, and Korea. These countries tend to be exposed relatively more in terms of *maximum impacts* than in terms of *typical impacts*, while France, EU24, South Africa and Italy tend to be exposed relatively more in terms of typical impacts. Under the assumption of immobile factors, Canada, Australia and New Zealand, Japan and the aggregate region of the Rest of the World tend to be exposed relatively more in terms of maximum impacts, while the United Kingdom, Türkiye, Indonesia, India and Argentina tend to be exposed relatively more in terms of typical impacts.

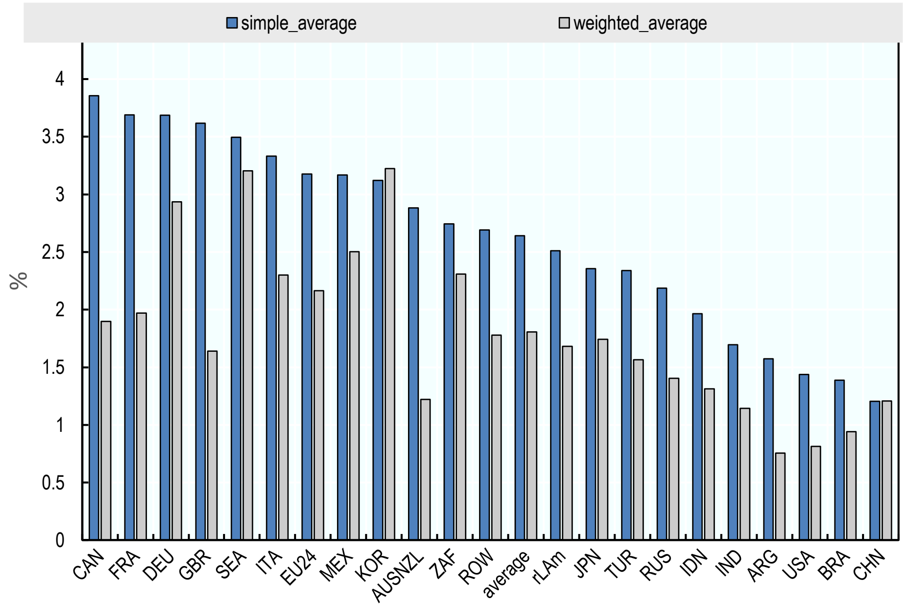
Especially for the countries exposed relatively more in terms of *maximum impacts*, there may be interest in exploring the results further and identifying which shocks in which foreign country-sectors are associated with the largest impacts. How this can be done is briefly shown in the next subsection, using examples of three manufacturing industries (*electronic equipment*, *iron and steel* and *motor vehicles*) in Germany, Japan and the United States.[33]

[32] Defined here as a difference between the two rankings by at least two positions.

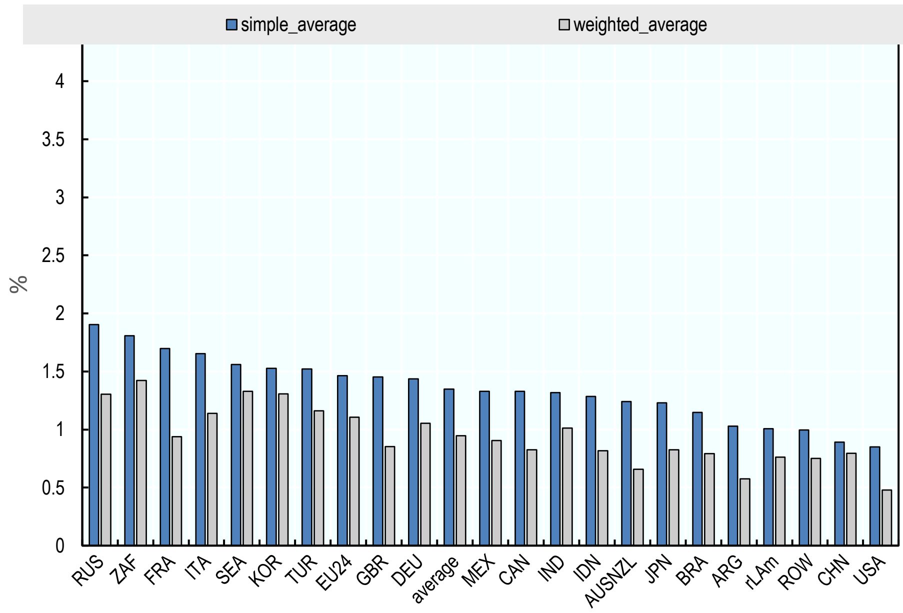
[33] While this is not done in this paper, note that the same exercise can be performed for the standard deviation measure of typical exposure discussed above.

Figure 3.4. *Maximum exposure* to GVC shocks across countries

Panel A. Maximum % impact of all possible 1% shocks -mobile factors of production



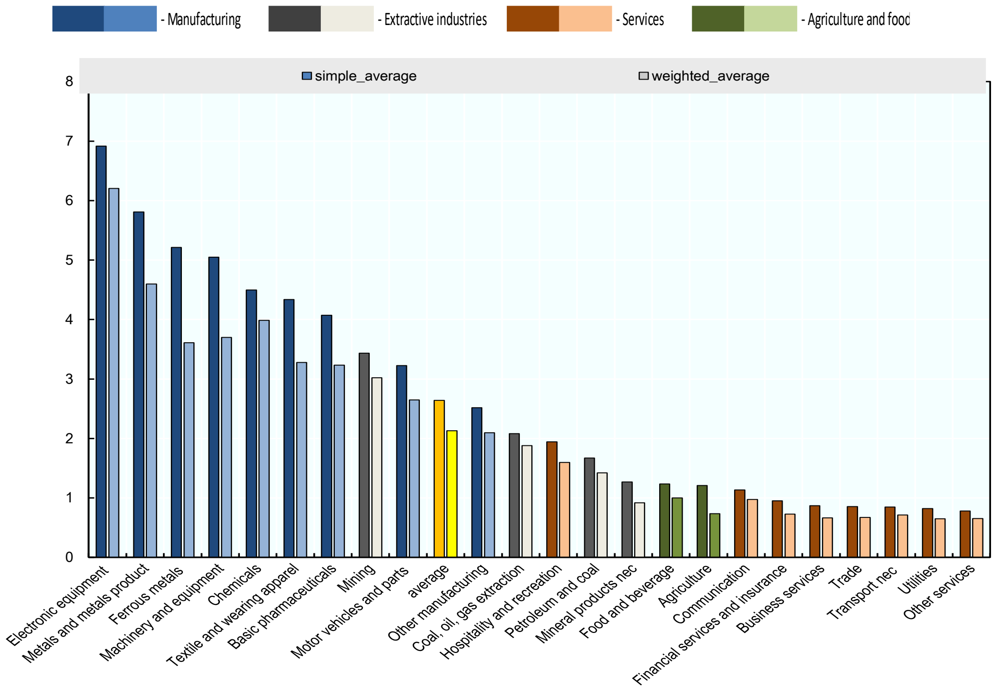
Panel B. Maximum % impact of all possible 1% shocks -immobile factors of production



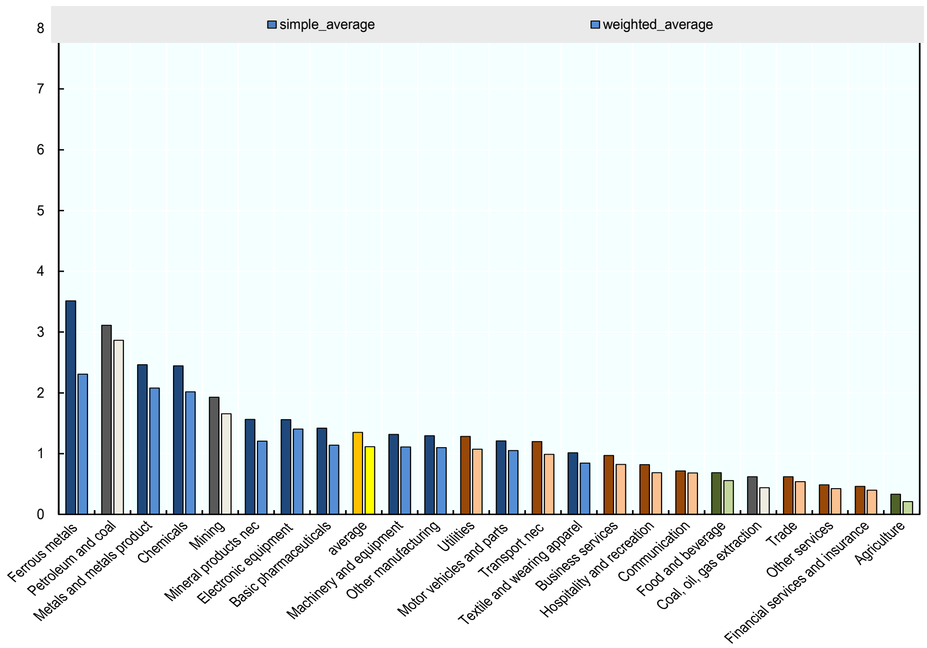
Note: Value of output at the starting point of the simulation are used as weights to produce weighted averages.
Source: OECD METRO model simulations.

Figure 3.5. *Maximum exposure* to GVC shocks across global sectors

Panel A. Maximum % impact of all possible 1% shocks -<u>mobile</u> factors of production



Panel B. Maximum % impact of all possible 1% shocks -<u>immobile</u> factors of production



Note: Value of output at the starting point of the simulation are used as weights to produce weighted averages.
Source: OECD METRO model simulations.

3.2.3. Decomposing maximum exposure for specific affected country-sectors

Examples of electronic equipment, iron and steel and motor vehicles in Germany, Japan and the United States

The *maximum exposure* of each affected country-sector is composed of different individual *vertical foreign* shocks depending on where the shocks occurred. An example of this in shown in Annex Figure A.6 depicting the simulated output responses of *electronic equipment* sectors of Germany, Japan and the United Stated and Japan to various shocks. For each of these three national *electronic equipment* sectors represented in a separate panel, the values of cells show the size of output responses associated with output declines occurring in different shock sectors (columns) and countries (rows).[34] The corresponding Figure 3.6 below summarises the extent to which shocks originating in different countries contribute to *maximum exposures* of these sectors[35], while Annex Figures A B.6 and A B.7 do so for Germany's, Japan's and United States' *iron and steel* and *motor vehicles* sectors.

In the *electronic equipment* sector, the 9.8% *maximum exposure* for Germany calculated under the mobile factors assumption, is almost twice as large as the one for the United States (5.1%) while Japan is in the middle (8%) (Figure 3.6, Panel A). Germany's exposure is less concentrated across country origins of shocks as compared to those for Japan and United States.[36] There are also interesting differences when it comes to exposure to shocks occurring in specific countries. For example, shocks originating in different economic sectors of China account for 52% of the *maximum exposure* in the United States and 50% in Japan, while in Germany they account for 38%. Russia on the other hand accounts for 2% of *maximum exposure* in the *electronic equipment* sector of Germany, while it accounts for 1% in the United States and for less than 1% in Japan.

Under the immobile factors assumption (Figure 3.6, Panel B), *maximum exposures* are much lower, and Japan turns out to be marginally more exposed than Germany and the United States. Differences in geographical concentrations of where negative shocks originate are also somewhat smaller although Germany's *maximum exposure* remains more geographically diversified than that of Japan and the United States.[37]

The corresponding figures for *iron and steel* (Annex Figure A B.6) show, among others, Germany's higher *maximum exposure* to shocks, but also a relatively lower geographic concentration as compared to Japan and the United States, and a lower exposure to shocks originating in China. In contrast to *electronics*, however, *maximum exposure* is not so much smaller under the assumption of immobile factors and the relative ranking of exposure across these countries does not change as much: Germany remains almost twice as exposed as the United States.

In the *motor vehicles* industry (Annex Figure A B.7), Germany is more than three times as exposed as the United States in *maximum exposure* terms under the assumption of mobile production factors and only somewhat more exposed under the assumption of immobile factors. Geographical concentrations of *maximum exposures* are generally lower in this sector than the *electronic equipment* and *iron and steel,* but Germany is more exposed than the United States to shocks originating China under the mobile factors assumption.

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[34] The corresponding Annex A. 4 explains in more detail how to read these matrices and discusses some of results for these three national electronics equipment sectors.

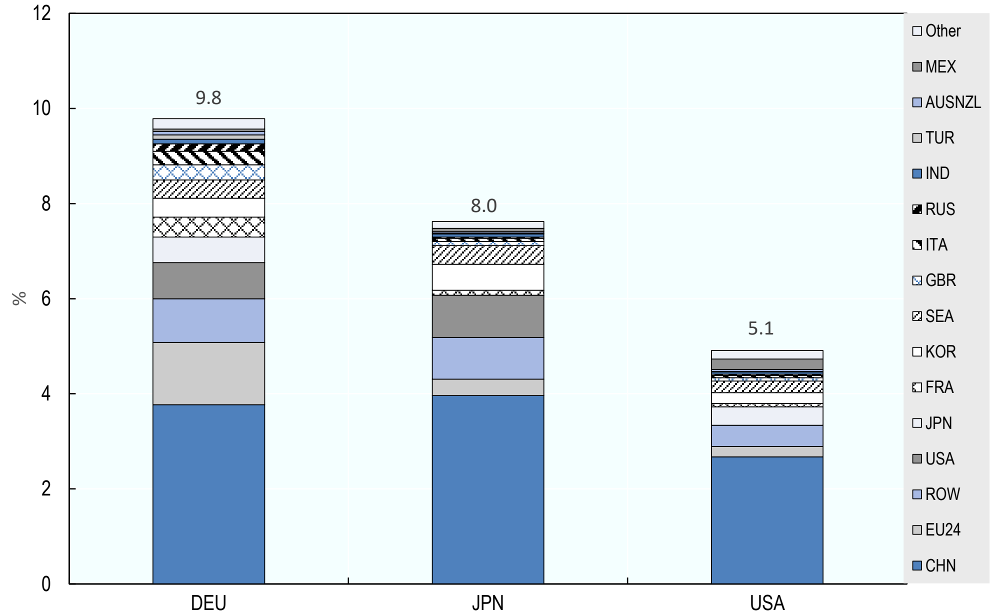
[35] Note that a further, or alternative, distinction can be made by the sector origin of shocks.

[36] The corresponding Herfindahl-Hirschman Indices of concentration are, respectively, 0.19 for Germany, 0.28 for Japan and 0.30 for the United States.

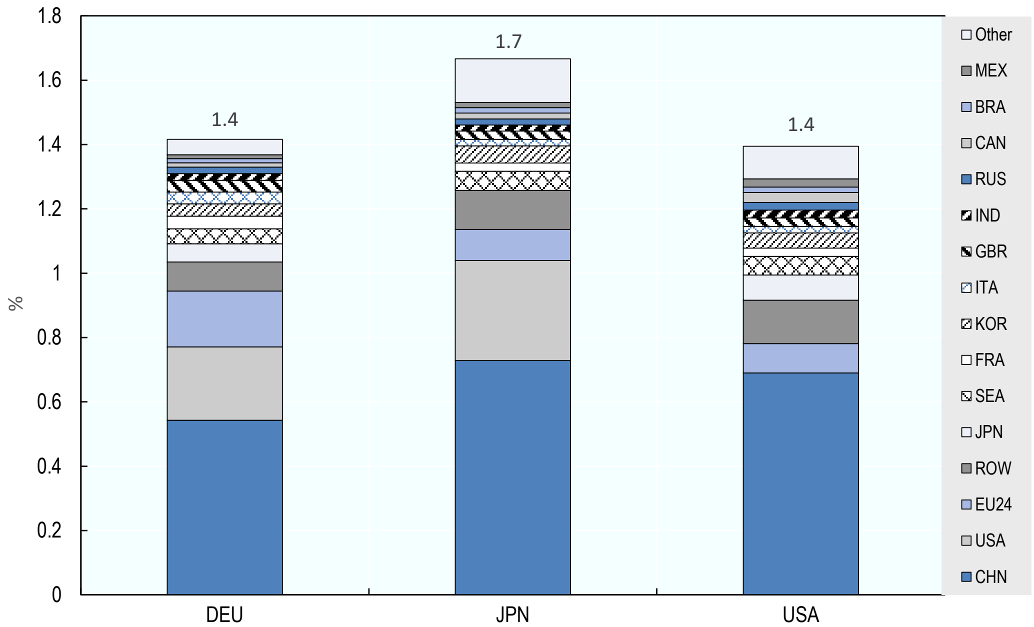
[37] The corresponding Herfindahl-Hirschman Indices of concentration are, respectively, 0.20 for Germany, 0.24 for Japan and 0.27 for the United States.

Figure 3.6. Decomposition of *maximum exposures* in electronics products in Germany, Japan and the United Sates, by country origin of shocks

Panel A. Maximum % impact of all possible 1% shocks -mobile factors of production



Panel B. Maximum % impact of all possible 1% shocks -immobile factors of production



Source: OECD METRO model simulations.

3.2.4. Typical and maximum exposures to GVC shocks when intra-EU shocks are excluded

The preceding examples involving Germany show that a significant part of its exposure can be attributed to shocks originating in France, Italy and other EU countries (EU24). This is an illustration of a more general finding that in regard to idiosyncratic shocks, the EU tends to be exposed more to shocks that originate in other EU countries.

These findings of course reflect the high levels of trade integration in the European single market. At the same time, the findings do not take into account that some types of idiosyncratic shocks are less likely within the European single market precisely due to its existence.[38] Furthermore, neither the *typical* nor the *maximum exposure* measures capture the extent to which the European single market may be helping with adjustment to shocks through provisions aiming to establish free movement of goods, services, people and capital between participating countries.[39]

When intra-EU shocks[40] are excluded from the calculations of *typical* and *maximum exposures* (see Annex Figures A B.8 and A B.9 which correspond to Figures 3.2 and 3.4 shown above) exposures of EU countries indeed go down and the countries move down the rankings of exposure, although more so for the *maximum exposure* and under the assumption of mobile production factors.[41]

However, even when intra-EU shocks are excluded, and depending on the exposure measure used and factor market assumptions made, the EU countries tend to remain exposed more than an average country, and in all cases they are exposed more than China, the United States or other relatively unexposed countries such as Brazil, India or Indonesia.

3.2.5. Preparing for large impacts: The tail of the distribution and exceeding the threshold

While average impacts of the simulated production shocks are small as shown in the results for the *typical exposure* to shocks, the interest from a resilience perspective is typically in large impacts which are potentially of bigger concern for policy making. To help inform polices to improve resilience, questions such as the following need to be addressed: 'what can we expect if several shock events in the world combine'? Or 'what is the probability of an impact greater than a given threshold'? To address those questions using the large set of simulated impacts of output shocks, this subsection explores the tail of the distribution of output impacts. The tail contains the small proportion of simulated output responses that are high impact events. These 'extreme values' of impacts of the simulated shocks can be characterized statistically, analogous to the analysis of extreme returns on financial assets, or the value at risk in insurance, or extreme temperatures impacting crop yields. Figure 3.7 shows the probabilities of output impacts exceeding the threshold of 0.1% (referred to as the '*exceedance probabilities*') from the estimated generalized Pareto distribution, a statistical model that is well suited for this type of analysis [(Coles, 2001[14]) (R.Reiss, 2007[15])].[42]

The *exceedance probabilities* are calculated for *GVC shocks*, as done above for *typical* and *maximum exposures*. Only the relatively large output responses, i.e. those exceeding the bound of 0.1%, are used for the estimations, while the probabilities in the figure also make adjustments for the country-specific proportion of observations exceeding this bound. Plotting probabilities of exceeding the mean value of impacts found in the data above the given bound results in a similar ranking of risk exposure as found earlier when using alternative the *typical* and *maximum exposure* metrics. When a higher threshold is chosen, the ranking changes somewhat. The difference in *exceedance probabilities* and the rankings reflect the structural aspects of each economy and their trade linkages in the model. For example, the UK,

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[38] The European single market strives to establish free movement of goods, capital, services and people. It severely constrains the ability of individual EU Members of adopting economic policies that may have beggar-thy-neighbour effects on other EU Members.

[39] The trade and substitution elasticities used in the METRO model are differentiated by sector and not by region, so the model does not capture any preferences in the European Union for other EU goods. Or how EU goods might be more substitutable than non-EU goods in EU countries in terms of intermediate inputs into production.

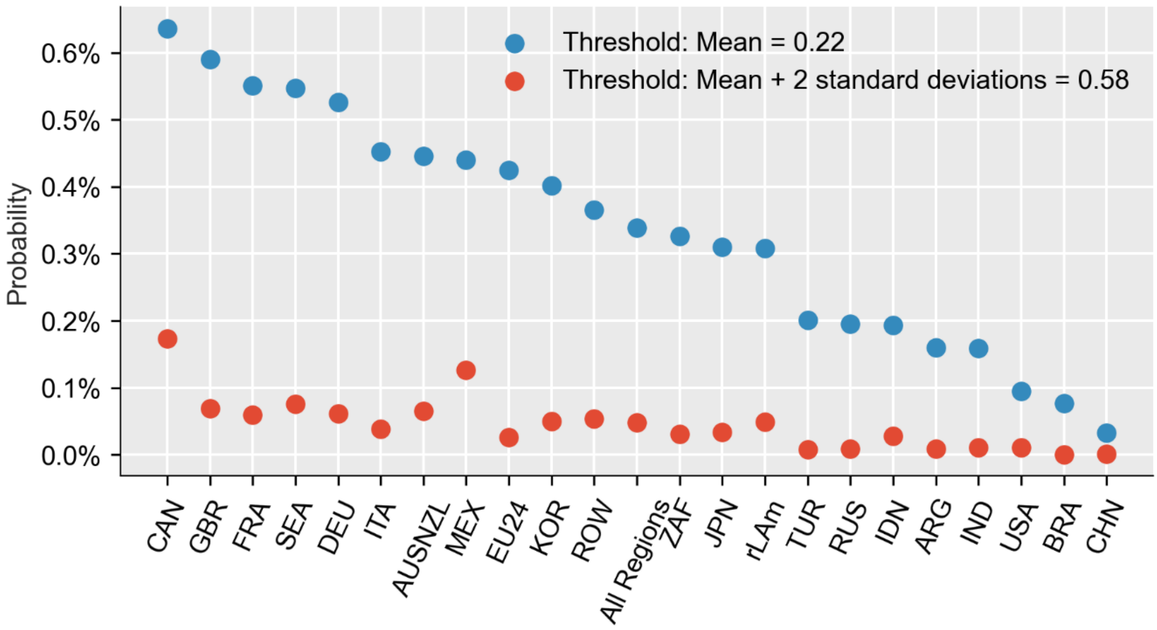
[40] Here these are defined as the output shocks that originate in any sector of Germany, France, Italy, or the aggregated EU24 region, and cause responses in any of these regions.

[41] This reflect the fact that the levels of European trade integration are particularly high in manufacturing which account for relatively large shares of domestic factor markets.

[42] The parameters of the generalised Pareto distribution are estimated by maximum likelihood. The data are all simulated output changes resulting from foreign negative vertical GVC shocks above the cut off set to 0.1 (i.e. the impact of an initial shock of 1% greater than 0.1%). The mean value of data above that threshold across all regions and sectors equals 0.22, with a standard deviation of 0.18.

France, Germany, Italy and the EU24 tend to show similar risk exposure to *GVC shocks* with more extreme impacts.

Figure 3.7. Regions ranked by probability of threshold exceedance



Note: The Mean is the conditional mean of data values above the bound of 0.1.
Source: OECD METRO model simulations.

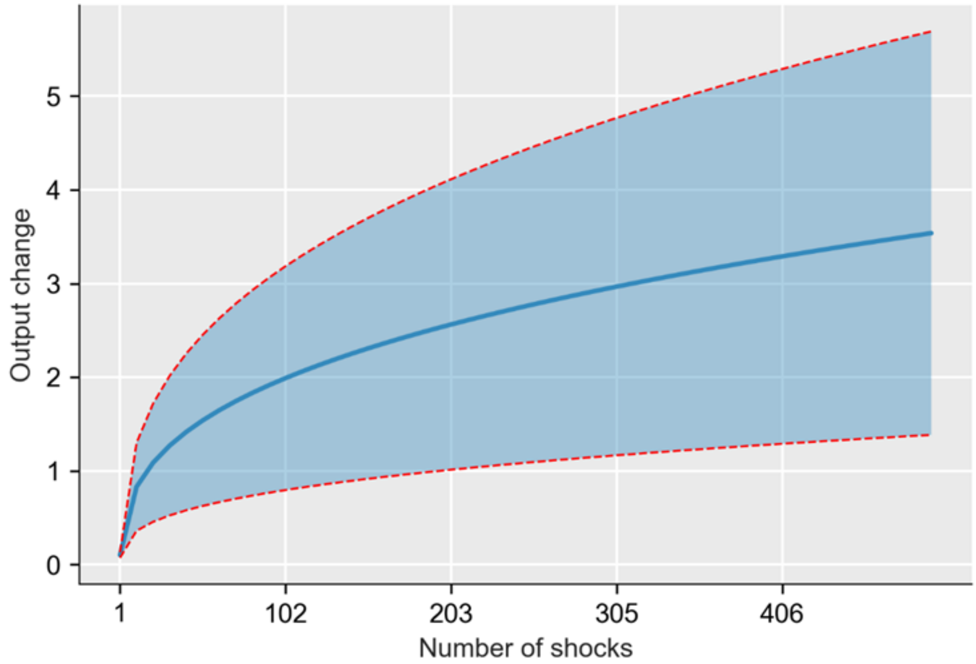
A potentially more revealing insight from this statistical approach comes from the examination of expected extremes when multiple shocks can occur simultaneously. Figure 3.8 shows what maximum impact can be expected anywhere in the world economy as a function of the number of coinciding shocks.[43] When there is only one shock in some country and some sector, leading to 462 impacts[44] in all foreign vertically-linked affected country-sectors, the expected maximum impact is found to be 0.1%. However, when the number of shocks increases, the *expected maximum* increases as well. The estimated 95% confidence level increases with the number of shocks and is quite wide. For example, when 100 shocks can occur together, which could be an event touching 10 sectors in 10 economies, the expected maximum impact equals approximately 1.98 with a 95% confidence interval [0.79, 3.18]. When all the possible 506 shocks would occur together, the expected maximum impact is 3.5, with a confidence interval [1.4, 5.7].

This variability reflects the heterogeneity of economic conditions and the different ways in which *GVC shocks* are transmitted between economies and sectors. The calculations that underly Figure 3.8 can be performed for each economic region and each sector in the model to gauge the exposure to events with small probability and high impacts. This in turn can be an input into policy decision making to clarify under what circumstances an expected maximum impact of a certain magnitude is acceptable, and how exposure would change if certain policy actions were followed.

[43] In the literature on extreme value statistics this is known as the return level.

[44] This number is obtained as follows (22 countries x 23 sectors) less 23 sectors in the country in which the shocks occurs (including the shocked sector) and less 21 country-sectors which are linked to the shocked sector horizontally (foreign competitors from the same industry).

Figure 3.8. Global perspective: The expected maximum impacts when random shocks occur together



Note: The dashed lines represent 95% confidence intervals around the expected maximum. The standard deviations are obtained from the variance -covariance matrix of three estimated parameters: the estimated shape and scale parameters of the generalized Pareto distribution, and the variance of the sample proportion above the threshold. The variance-covariance matrix for the Pareto parameters is based on the observed information matrix, i.e. the Hessian matrix of the log-likelihood evaluated at the estimated parameter values. To obtain the standard deviation around the mean return level, the variance-covariance matrix is pre- and post-multiplied by the vector of first derivatives of the three-parameter (return level) function that links shocks to expected maximum impacts. This so-called ‘ delta method' is outlined in (Grimshaw, 1993[16]) and (Coles, 2001[14])
Source: OECD METRO model simulations.

4. Conclusions

The work presented in this report uses the OECD CGE model METRO to investigate how production shocks are transmitted throughout the global economy. The model accounts for some of the traditional features of international trade, such as competition in international markets and allocation of resources in line with comparative advantage and international prices, as well as for the main characteristics of GVC integration, such as the international sourcing and provision of inputs used in production. As such, the model can be readily used to study the international transmission of different shocks operating through international supply chains and other channels. This report focuses on production shocks which can occur in, and can be transmitted to, any sector and geographical location that can be reasonably accounted for in the context of this exercise. Focusing on sectoral output responses as the key variable of interest, and differentiating across countries and sectors where the shocks occur and where their effects are felt, the work develops an approach to studying the effects of production shocks and identifying the key transmission channels. Notwithstanding many caveats[45] associated with modelling, several broad findings emerge.

[45] The model relies on simplified assumptions that only imperfectly capture the reality of complex linkages in trade and production systems. As discussed in Section 2.1, the transmission of the shocks depends on several shares and parameters, particularly substitution elasticities. The key sensitivity checks with respect to production factor mobility and trade elasticities have been performed but the results may still be sensitive to other assumptions. Due to

Considering the global distribution of responses to all production shocks, most of them are one to two orders of magnitude smaller than the original shocks. This suggests a generally small international transmission of production shocks. However, the distribution is also 'fat-tailed' which means that there are quite a few shocks which have more consequential effects.

Impacts of output declines that originate in foreign locations of the same sector (dubbed horizontal shocks in this analysis) tend to be positive and in some cases their magnitude is larger than the magnitude of the initial shocks. This is foreseeable because declines in output of competitors are expected to create new production opportunities.

Responses to output declines in vertically linked domestic sectors can be both negative and positive although the distribution is also skewed towards positive values. This indicates that general equilibrium effects related to resource allocation are relatively strong: resources which are freed from the declining sectors are absorbed in other sectors and this boosts output. The latter suggests the need to consider alternative modelling setups where these adjustments, particularly in factor markets, are more constrained. The effects of vertical domestic shocks are also characterised by a higher dispersion than shocks transmitted via other channels: in the most extreme cases, the magnitude of output responses to domestic shocks can be from two to four times larger than that of original shocks.

Effects of output declines in foreign vertically-linked sectors—the kind of shocks that are at the centre of the debate on transmission of shocks in GVCs—tend to be smaller and they are negatively skewed. The latter confirms the intuition that negative output shocks upstream in the value chain constrain access to intermediate inputs and negative shocks downstream lower the demand for inputs. Most of the negative impacts are of one to two magnitudes smaller than the original shocks. This would indicate a relatively small transition of shocks through GVCs and is consistent with the fact that in most national sectors reliance on foreign inputs and foreign markets for final products is still smaller than reliance on domestic inputs and markets. In addition, in the face of shocks, sourcing in GVCs offers opportunities for substitution towards suppliers and markets which are unaffected. Having said that, in some cases, the detected negative responses can be large.

The results suggest that a wide variety of economic adjustment mechanisms is at play. Price signals leading to substitution towards other suppliers or other market outlets, and responses of labour and capital markets play an important role in shaping responses to shocks and should be part of an overall assessment of resilience to shocks. The analysis presented thus considers sensitivity checks with respect to key model parameters driving substitution in international markets and adjustments in domestic factor markets.

The degree of factor markets adjustment in particular can significantly affect the transmission of shocks. The analysis considers different degrees of adjustments to shocks in domestic factor markets. Impacts of shocks transmitted through the GVC channel tend to be smaller when factors of production cannot move across sectors (short term) then when they can move freely (medium to long term). The differences in impacts in different time horizons are nevertheless sector-specific and depend also on whether the given sector is an important employer or user of capital.

A more detailed analysis of exposure to different vertical foreign shocks affecting specific sectors and countries reveals among others that averages and global distributions mask some important heterogeneity. A broad distinction can be made between shocks originating in and impacting services and manufacturing sectors. Large services sectors, which employ large shares of labour resources, can be sources of shocks which can have relatively big impacts across the global economy, but these are not transmitted vertically through constrained access to intermediate inputs, or vertical demand effects, but rather through general equilibrium impacts on factor markets. When modelling assumptions used allow factor mobility, an output reduction in those sectors is associated with a release of labour and capital that finds employment in other parts of the economy, possibly at lower remuneration rates. These effects are thus distinct from the vertical transmission of shocks in GVCs through input-output or demand links and turn out to be relatively large. The more classical transmission of vertical foreign shocks through GVCs is more visible in the case of

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computational constraints characterising this type of model, economic activity is relatively highly aggregated (23 sectors). One implication is that the approach may not capture well the potential heterogeneity of exposures of less aggregated sectors (more exposed small sectors are aggregated with less exposed small sectors).

shocks occurring in manufacturing sectors—but also business services—which have strong backward and forward linkages to other manufacturing sectors.

Another finding is that output declines in some foreign sectors depress national industry outputs while output declines in other foreign sectors boost them. On the one hand this means that some of the negative output shocks occurring in the global economy may work in opposite directions and counterbalance each other, stabilising these national industries' outputs when they coincide. On the other hand, and also since the shocks can in principle be both positive and negative, the different shocks can also significantly reinforce each other if they occur in certain worst-case constellations. An approach developed to rank sectors and countries with the highest potential to be impacted by such worst-case shock scenarios indicates that some sectors and countries are exposed more than others.

Economies with strong intermediate input links to major economies such as China and the United States tend to be more exposed to foreign vertical shocks, with Canada, France, Germany and the United Kingdom leading the ranking, and the United States, Brazil and China appearing relatively unexposed. Russia and South Africa move to the top of the ranking of exposed countries under the assumption of immobile factors and this is related to how petroleum and coal, mining and chemicals sectors are exposed to shocks transmitted through GVCs and what role they play in domestic factors markets.

The corresponding ranking of sectors reveals that manufacturing sectors are on average a lot more exposed to output shocks than services sectors and agriculture and food, with electronics metals, iron and steel, machinery and equipment, and chemicals exposed the most. When production factors are immobile in short term, extractive industries, as well as some of the manufacturing sectors linked to them. such as metals, iron and steel and chemicals, move towards the top of shock exposure rankings.

Irrespective of factor market assumptions, or which exposure measure is used, there is more variation in the measures of exposure across sectors than there is across countries, suggesting a potential for sectoral initiatives to address exposure to shocks.

Overall, this exploratory modelling analysis shows how the OECD METRO model can be used in support of government efforts to identify some of the risks inherent in the interlinked global economy. The analysis can be developed in several directions in follow up work.

In a longer term, the presented approach could be used to build also on the work developed in (Arriola et al., 2020[1]) which would consider how transmission of production and other shocks is altered by different policy-driven scenarios of global fragmentation, as reflected in a rapidly emerging literature (e.g. WTO (2022[17]) and IMF (2023[18]).

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Annex A. Methodological annex

A.1 The OECD METRO Model

The METRO model (OECD, 2023[19])is a multi-country, multi-sector computable general equilibrium (CGE) model that traces international interdependencies in a theoretically and empirically consistent framework, and incorporates several features of GVC participation such as trade of intermediate and final products and trade in value added (TiVA) concepts.

The model builds on the GLOBE model developed by McDonald and Thierfelder (2013[20]). The novelty and strength of METRO lies in the detailed trade structure and the differentiation of commodities by end use. Specifically, commodities and thus trade flows are distinguished by whether they are destined for intermediate use, for use by households, for government consumption, or as investment commodities.

The underlying framework of METRO consists of a series of individually specified economies interlinked through trade relationships. As is common in CGE models, the price system is linearly homogeneous, with a focus on relative, not absolute, price changes. Each region has its own numeraire, typically the consumer price index, and a nominal exchange rate (an exchange rate index of reference regions serves as model numeraire). Prices between regions change relative to the reference region.

The database of the model relies on the GTAP v11 database pre-release version 2 (Aguiar et al., 2022[21]) in combination with the OECD Inter-Country Input-Output Tables, which are the main source of the OECD Trade in Value Added Indicators and allows the model to distinguish trade for use in intermediate production or final demand. Policy information combines tariff and tax information from GTAP with OECD estimates of non-tariff measures on goods (Cadot et al, (2018[22]); Gourdon et al, (2020[23])), services (Benz and Gonzales, (2019[24]); Benz and Jaax, (2020[25]); Benz and Jaax, (2022[26])), trade facilitation (OECD, 2018[27]) and export restricting measures. The METRO database contains 151 countries and regional aggregates and 65 sectors. For this analysis the database as aggregated to 23 regions and 23 sectors based on the definition presented in Table A B.1. Model database aggregation

The model is firmly rooted in microeconomic theory, with firms maximising profits and creating output from primary inputs (i.e. land, natural resources, labour and capital), which are combined using constant elasticity of substitution (CES) technology, and intermediate inputs in fixed shares (Leontief technology). Households are assumed to maximise utility subject to a Stone-Geary utility function, which allows for the inclusion of a subsistence level of consumption. Substitution elasticities are sourced from GTAP, while the income elasticity used in the Stone-Geary utility function is based on USDA estimates (Muhammad et al., 2011[28]) and (Seale, Regmi and Bernstein, 2003[29])). All commodity and activity taxes are expressed as *ad valorem* tax rates, and taxes are the only income source to the government.

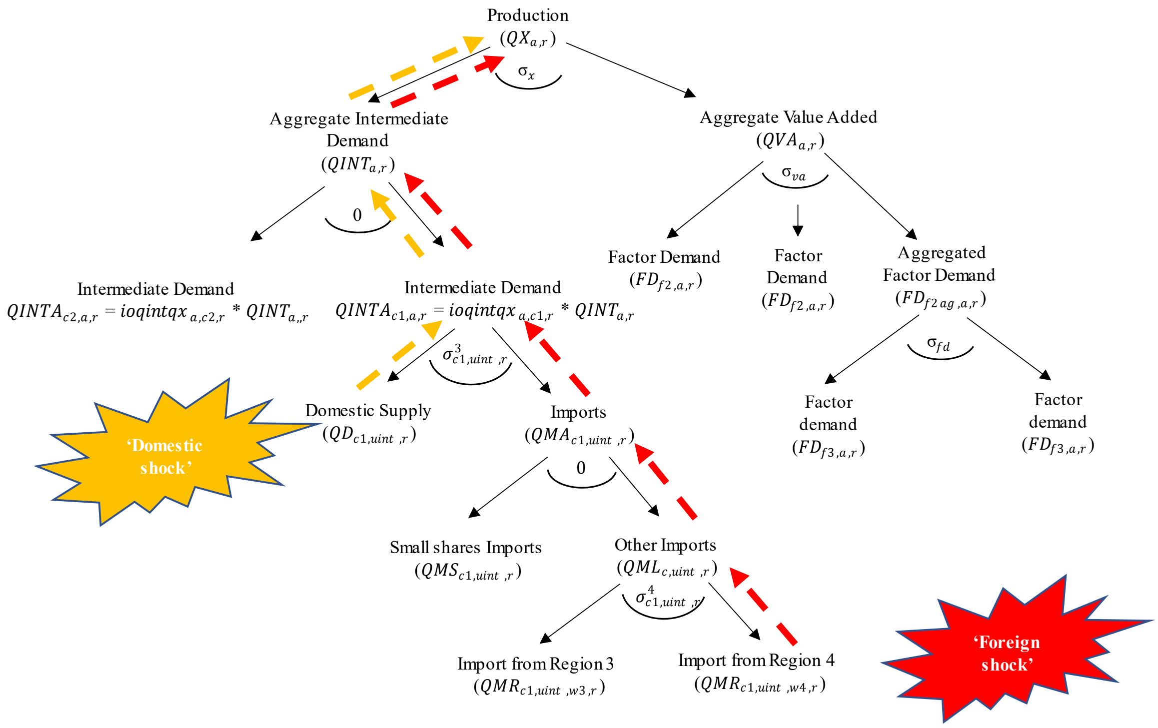
In the configuration of the model used for the simulations capital and labour stocks are assumed fixed, and factors are mobile between industries, but not between economies. All factors, including capital and labour, are fully employed and returns to land and capital and wage rates are flexible. Tax rates are fixed. Government expenditure is fixed in volume terms at base levels while the government balance is allowed to adjust. The trade balance is assumed flexible. Investment as share of total final demand is remains fixed, but the household savings rate can adjust.

A.2 Factors influencing the degree of transmission of vertical foreign shocks in the METRO model

The magnitude of transmission of specific shocks in the model's international supply chains depends on several shares and parameters. This can be illustrated using a simplified graphical representation of the METRO's model production structure (Figure A A.1). Starting from the top of the 'production tree', sectors are assumed to use two inputs for production: domestic primary factors of production ('aggregate value added' in Figure A A.1); and intermediate inputs ('aggregate intermediate demand'). Here the choice between the value added and intermediates is governed by the constant elasticity of substitution (CES) function with σ_x as the elasticity of substitution. Value added is composed of different domestic primary factors of production such as capital, land and labour (of which there are different kinds according to skill level) and these factors can be substituted one for another within another CES 'nest' with elasticities σ_{VA}

on one level of the nest and σ_{fd} in the level below where factors within an aggregate factor, for example skilled and unskilled labour, are substituted amongst each other. The aggregate intermediate demand is in turn composed of different types of intermediate inputs (intermediate demand in Figure A A.1) such as, for example, metal and chemical products which are used as intermediate inputs into production of, say, electronics. In line with standard conventions of the ICIO approach, in the current version of the METRO model (OECD, 2023[19]), the different intermediate inputs are sourced according to the Leontief production function in fixed proportions (i.e. with an elasticity of substitution of 0) meaning that if the use of one input is reduced for some reason, others have to be reduced by the same proportion.[46] The different intermediate inputs are sourced either domestically (domestic supply) or from abroad (imports) from different regions. These latter choices are governed by two further CES function nests, which are referred to in the applied trade modelling literature as the Armington functions. One such function determines the substitution between domestic and imported inputs (with elasticity of $\sigma^3_{c,uint,r}$) and one determines the substitution between different origins of foreign intermediates (elasticity of $\sigma^4_{c,uint,r}$).[47]

Figure A A.1. METRO's production structure and transmission of 'foreign' and 'domestic' intermediate input production shocks



Source: simplified version adapted from the METRO model's documentation, version 4 (OECD, 2023[19]).

[46] On the one hand this assumption may be seen as overly restrictive as no substitution between the different intermediate inputs is allowed. On the other hand, it emphasises the complementarity that may well characterise production in GVCs (e.g. one engine and one set of tyres are needed for a production of a car and they cannot be substituted for each other) and, as a relatively conservative one, it brings the results of the simulations closer to a 'worst case' scenario.

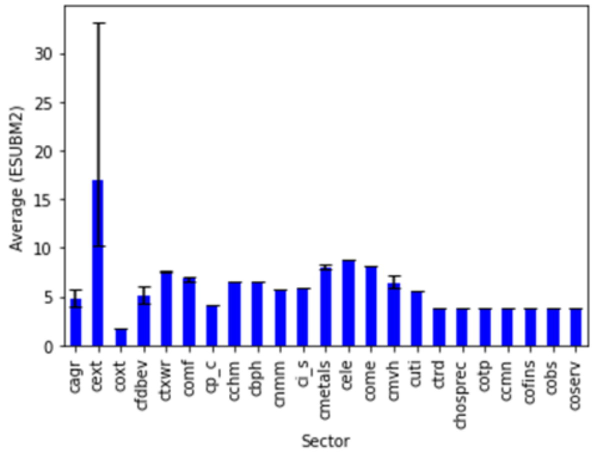
[47] See the model documentation for more detail TAD/TC/RD(2023)1/FINAL.

Model substitution and supply elasticities

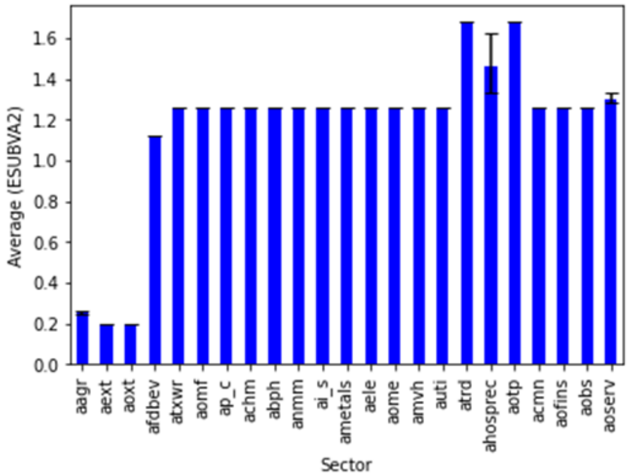
Production and Armington (trade) elasticities are sourced from GTAP. In the GTAP database, the Armington elasticities of substitution among imports from different sources ($\sigma^4_{c,u,r}$) are econometric estimations from Hertel et al (2003[30]) with one elasticity estimate for each GTAP sector. The elasticities in the model database used in the analysis, which is an aggregation of the full database, uses a trade weighted average of these elasticities for each commodity-use-region. Average sectoral Armington elasticities (Figure A A.2. Panel A) in the analysis database range from 1.8 (coxt – *mining*) to 17.0 (ext – *coal, oil, and gas extraction*).

Figure A A.2. METRO Elasticities

Panel A. Armington elasticities $\sigma^4_{c,u,r}$, averaged across uses and regions



Panel B. CES elasticities on second level of production nest (σ_{va}), averaged across regions



Note: Whiskers indicate the range of values.
Source: OECD METRO Model.

As a rule, elasticities in the lower level of a nest (e.g. where activities substitute among imports from different regions) are typically larger than the elasticities in the upper level (where activities substitute between domestic and imported commodities). As a consequence, activities (as well as households, government, and investment) are more sensitive to relative prices change across source regions within imported commodities than they are to relative price changes between imported and domestic sources. Accordingly, the substitution elasticities between domestic and imported goods ($\sigma^3_{c,u,r}$) is calibrated using a common assumption, “the rule two” (Aguiar et al., 2022[21]), such that it is double the Arlington elasticities.[48]

GTAP is also the source for the elasticities used in the first and second level of the value-added portion in the production structure show in Figure A A.1. GTAP elasticities are used in the second level where factors and aggregated factors such as skilled and unskilled are substituted for each other (σ_{va}). These elasticities are taken from the SALTER model parameter file (estimates for the medium run) which are based on a synthesis of estimates from other studies (Aguiar et al., 2022[21]). The GTAP level elasticities vary across sectors, but not regions. In order to aggregate these elasticities to the METRO analysis level, factor demand in each sector and region is used as weights to produce weighted averages for the analysis database and range from 0.20 (oxt- *mining* and ext- *coal, oil, and gas extraction*) to 1.68 (otp – *transportation services* and trd - *trade*). Elasticities at the top level of the production tree (σ_x) is scaled to be half of the elasticities in the preceding level (σ_{va}), using the “rule of two”. Substitution between the labour categories forming aggregate factors is governed by the labour elasticity (σ_{fd}) is set to a value of 3.

Analysis of sensitivity with respect to trade elasticities

The degree of transmission of foreign and domestics shocks through the supply chain are affected by model parameters – particularly the substitution elasticities on the import and demand side as well as the transformation elasticities on the supply and export side. To assess how sensitive the model results are to changes in these parameters, a sensitivity analysis is performed. Specifically, the same set of single country-sector production shocks that increases (and decreases) the production tax 10 percentage points are simulated using the METRO model, where substitution elasticities i) between imports from different regions and ii) between domestic and imported commodities, as well as supply elasticities iii) between domestic and foreign markets and iv) across various export markets are reduced 10% making substitution harder and more expensive.

The analysis shows that using lower trade elasticities has only small effects on the results Figure A A.3. The results under the two different sets of trade elasticities are largely the same with marginal output changes from production shocks, positive or negative, slightly less pronounced with lower trade elasticities where increases in marginal output are not as large and declines are not as deep.

Average and standard deviation of the results are also similar under the two set-ups (Table A A.1.). Focusing on negative production shocks, the marginal output change averaged across all types of shocks are slightly lower using the elasticities from the main report. However, examining the effects based on the type of shock shows that the magnitude of both the average and spread of impact are slightly smaller under lower trade elasticities.

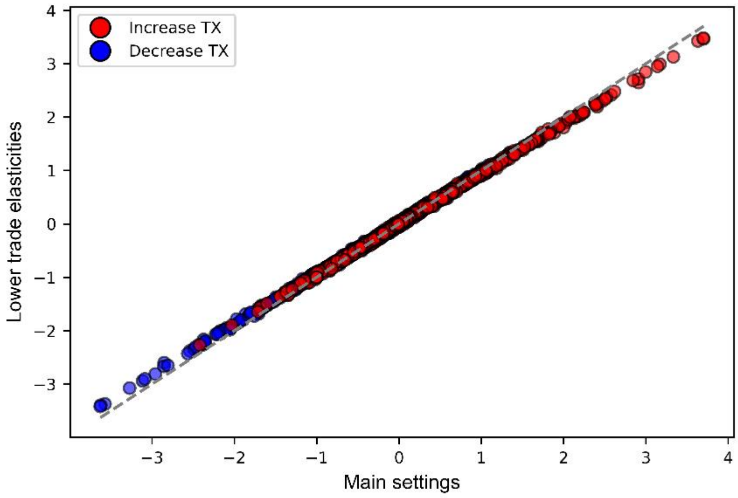
The average and standard deviation by region and by sector show a similar pattern (Figure A A.4 Part A). While the average impact on output is lower across regions and sectors with the main elasticities, the relative impacts and variation are the same under the two setups.

Comparing across regions and sectors by the different types of shocks also show small differences in magnitude of the average and standard deviation of the output changes (Figure A A.4 Part B). Relative impacts are similar under the two different sets of elasticities. The average output declines when negative production shocks come from vertical domestic sectors are deeper when trade elasticities are lower (Figure A A.4 Part B Panels A). However, the effects from negative productions shocks on vertical foreign sectors are less pronounced (output declines are not as deep, output increases are much) (Figure A A.4 Part B Panels B). With lower trade elasticities, substitution is harder. When a negative production shock occurs, it is more difficult to substitute away from domestic towards foreign sources. Lower trade elasticities keeps more of the shock domestically. These results hold when examining the output declines by sector or by region (region not shown).

[48] The model has a similar nesting structure on the supply and export side assuming imperfect transformation between domestic and export market (a Constant Elasticity of Transformation). GTAP provides elasticities on the import side only and as no other estimates are available, therefore the import substitution elasticities from GTAP are also used on the export side in the METRO database.

Lastly, the rankings of most exposed regions and sectors based on the maximum negative exposure metric, do not change when using lower trade elasticities. The average maximum negative exposure metric is on average consistently lower with the lower elasticities, but the ordering remains the same.

Figure A A.3. Marginal output results do not change significantly with lower trade elasticities



Note: An increase in the production tax (TX) on a sector- region lowers production of that sector-region while a decrease in TX increases production. Grey dashed line represents equality.
Source: OECD METRO model simulations.

Table A A.1. Compare distribution of marginal output changes when there is a negative production shock

Average and Standard deviation by type of shock

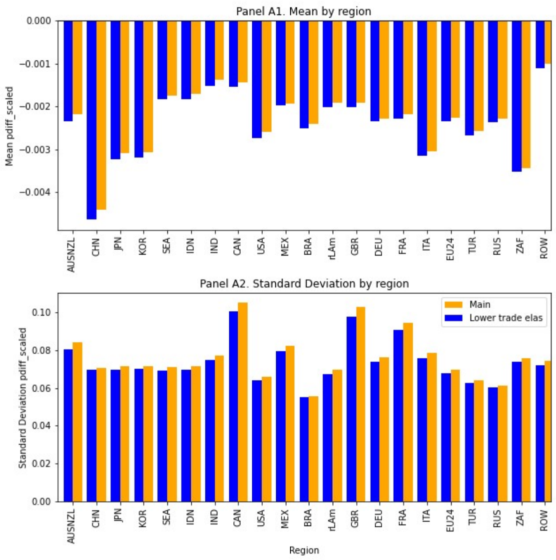
	Mean		Standard deviation	
Type of shock	Main settings	Lower trade elasticities	Main settings	Lower trade elasticities
Own	-1.0000	-1.0000	0.0000	0.0000
Vertical domestic	**0.0261**	0.0210	**0.2551**	0.2429
Vertical foreign	**-0.0032**	-0.0031	**0.0267**	0.0252
Horizontal	**0.0369**	0.0359	**0.0864**	0.0843
Overall	-0.0023	-0.0024	**0.0765**	0.0741

Source: OECD METRO model simulations.

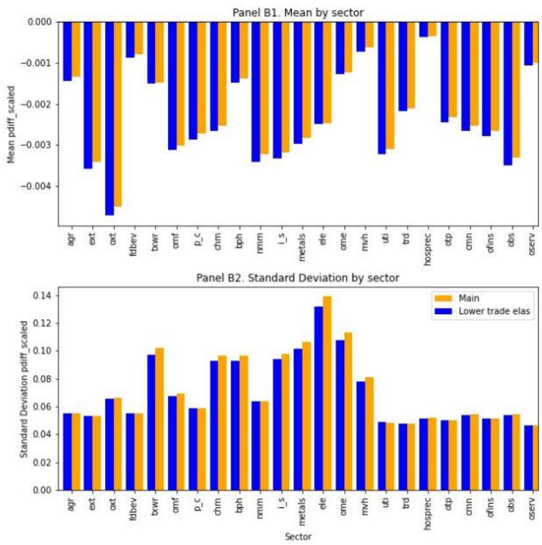
Figure A A.4.Relative changes across regions and sectors remain the same (Part A) and Lower elasticities "keeps" the impact domestically (Part B)

Part A

Panels A. By region



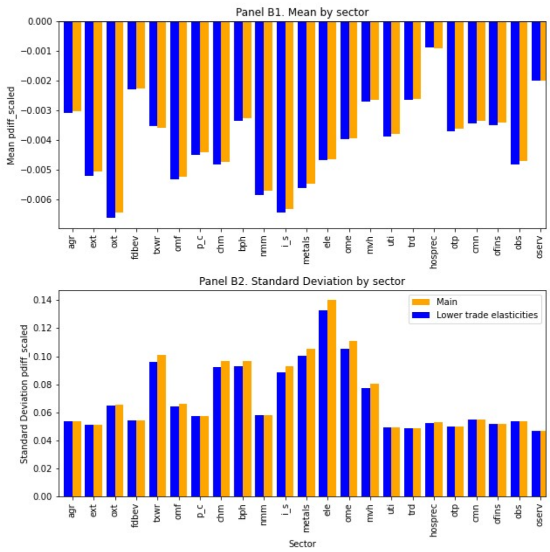
Panels B. By sector



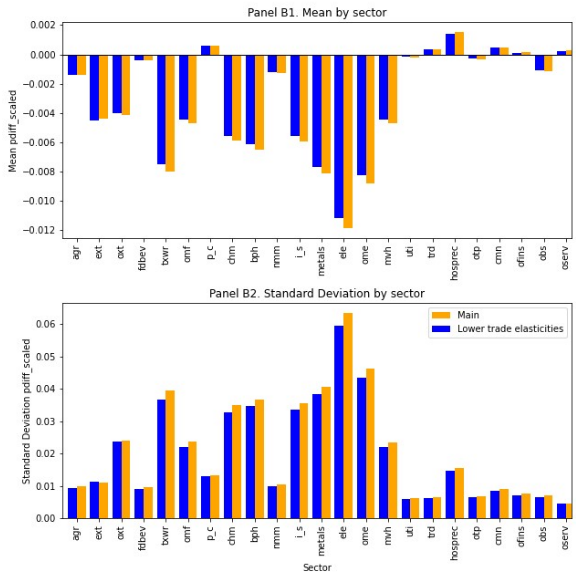
Note: Results based on a negative production shock (an increase TX). Analyses based on a positive production shock would produce the same standard deviation, and the same absolute average marginal output but with an opposite sign.
Source: OECD METRO model simulations.

Part B

Panel A. Vertical domestic shocks

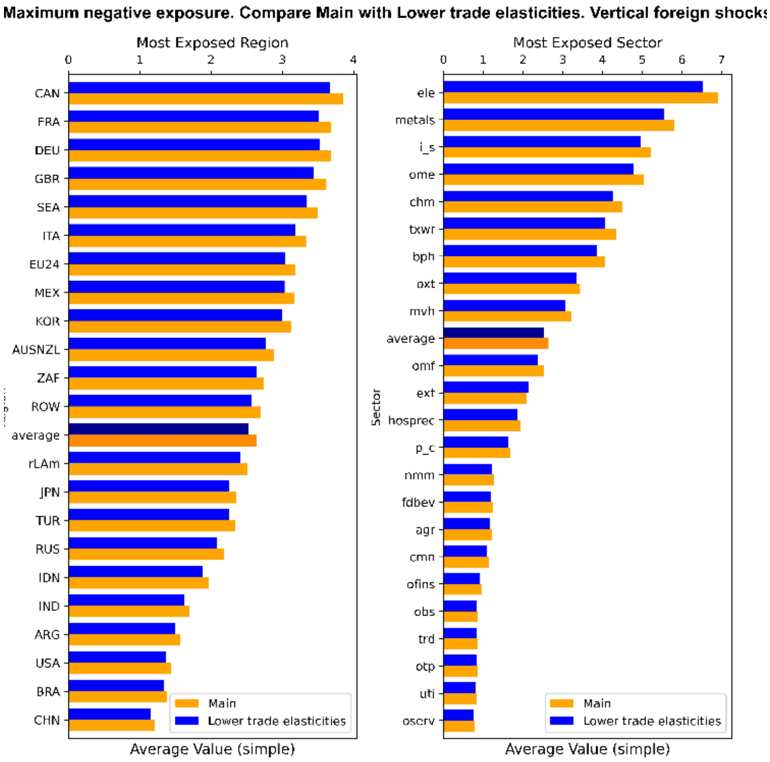


Panel B. Vertical foreign



Note: Simple average of maximum negative exposure metric across vertical foreign shocks.
Source: OECD METRO model simulations.

Figure A A.5. Maximum negative exposure rankings, sensitivity analysis



Note: Simple average of maximum negative exposure metric across vertical foreign shocks.
Source: OECD METRO model simulations.

A.3 A regression analysis of factors influencing the size of impacts of GVC shocks

Dummy variable fixed effects regression models, augmented with input-output-based measures of channels of downstream and upstream propagation of shocks, were used to ‘decompose’ the values of the observed output responses into average effects which can be statistically associated with the fact that shocks are originating in a specific country or sector or are being felt in a specific country or sector and to isolate the effects which are associated with input-output network spillover effects.

This has been accomplished by estimating the following regression models for the two sets of results under the assumptions of mobile and immobile production factors:

$$\Delta \mathrm{Q_{ijkm}} = \alpha + \delta_{\mathrm{i}} \mathrm{D}_{i} + \delta_{\mathrm{j}} \mathrm{D}_{j} + \delta_{\mathrm{k}} \mathrm{D}_{k} + \delta_{\mathrm{m}} \mathrm{D}_{m} + \delta_{\mathrm{ij}} \mathrm{D}_{ij} + \delta_{\mathrm{km}} \mathrm{D}_{km} + \partial_{\mathrm{ik}} \mathrm{D}_{ik} + \delta_{\mathrm{jm}} \mathrm{D_{jm}} + \beta\ \mathrm{DLTFINV}_{ijkm} + \mu \mathrm{ULTFINV}_{ijkm} + \mathrm{e_{ijkm}}$$

where ΔQ_{ijkm} is the percentage change in output in affected country-sector *ik* as predicted by the METRO model simulations and resulting from a 1% decline in output in shock country-sector *jm*, and where it is assumed that $\mathrm{k} \neq \mathrm{m}$ and $\mathrm{i} \neq \mathrm{j}$ (denoting the subset of vertical foreign shocks). α is the intercept and the different δs are the coefficients on dummy variables corresponding to the included fixed effects. The latter comprise the main fixed effects which denote the shock country ($\delta_{\mathrm{i}}\mathrm{D}_{i}$) and shock sector ($\delta_{\mathrm{k}}\mathrm{D}_{k}$), the affected country ($\delta_{\mathrm{j}}\mathrm{D}_{j}$) and affected sector ($\delta_{\mathrm{m}}\mathrm{D}_{m}$) as well as some of the main interactions (e.g. $\delta_{\mathrm{ij}}\mathrm{D}_{ij}$ which denotes a bilateral fixed effect for the affected country *i* and shock country *j* which can for example be due to a close geographical distance or a preferential trade agreement between *i* and *j;* or $\delta_{\mathrm{ik}}\mathrm{D}_{ik}$ which denotes an effect specific to the affected country-sector *ik*).

Following the insights from (Acemoglu, Akcigit and Kerr, 2015[13]) the corresponding elements of the Leontief inverse matrix were included to measure downstream and upstream propagation of shocks in the input-output network underlying our modelling framework. $\mathrm{DLTFINV}_{ijkm}$ are the corresponding elements of the Leontief inverse matrix which can be interpreted in the context of this study as coefficients measuring the extent of dependence of sector *k* in country *i* on inputs of industry *m* in country *j* when all the direct and indirect input-output linkages have been accounted for.[49] $\mathrm{ULTFINV}_{ijkm}$ are in turn coefficients measuring the extent of dependence of sector *m* in country *j* on inputs of industry *k* in country *i.* Because sector *m* of country *j* is the shocked sector in our definition of ΔQ_{ijkm}, $\mathrm{DLTFINV}_{ijkm}$ can be interpreted as a measure downstream channels of propagation of production shocks while $\mathrm{ULTFINV}_{ijkm}$ can be interpreted as a measure of upstream channels of propagation.

A.5 How to read the *maximum exposure* table for individual affected country-sectors

An example of the electronics equipment in Germany, Japan and the United States, under the assumption of mobile factors of production

The contributions of different vertical foreign shocks to the maximum exposure measure are specific to each affected country-sector. Annex Figure A A.6 below presents output responses to shocks in the *electronic equipment* sectors of Germany, Japan and the United States. For each national *electronic equipment* sector represented in a separate panel, the values of cells show the size of output responses associated with output declines occurring in different shock sectors (columns) and countries (rows).

As far as the 'horizontal shocks' are concerned (the outlined columns in Panels A to C in Figure A A.6), we see that the output declines in competing foreign electronics industries tend to be associated with significant positive effects. In the case of Germany's electronics sector, for example, a 1% decrease in electronics' output in China results in 0.46% increase in production while a similar decrease in the United States results in 0.15% increase. Japan's electronics industry is even more exposed to horizontal shocks originating in China (0.48%) and the United States (0.17%). The United States' electronics industry is mainly exposed to horizontal shocks originating in China (0.33%) while exposure to shocks occurring in other origins is smaller. As discussed above, the impacts grouped in the 'horizontal' category capture also the effects of negative impacts of output declines on sourcing of inputs from foreign electronics industries. In this context, the overwhelmingly positive output responses suggest that the competitive effects dominate the intermediate sourcing effects.[50]

'Vertical domestic' shocks tend to be associated with relatively large output responses and here a distinction can be made between shocks occurring in services and manufacturing sectors. In all the three countries considered here, negative output shocks in large services sectors tend to boost output in the electronics industry. For example, a 1% decline in the output of the other services (*oserv*) sector in Germany, is found to result in 2.35% increase in Germany's electronics and large effects are detected also for the hospitality and recreation (*hosprec*, 0.58%) and communication services (*cmn*, 0.34%). A more detailed analysis of the possible linkages through which domestic shocks affect the output of the electronics industry also acutely reveals that these shocks do not propagate so much through domestic backward or forward value chain linkages (i.e. sourcing of inputs, or relying on demand from, these services industries) but through general equilibrium effects. For example, the other services, which is an aggregated sector collecting a large number of individual services sectors[51], accounts for some 32% of the German capital base, for 40 to 50% of the domestic skilled labour force and for 20 to 30% of unskilled labour force. A negative shock to this sector frees the relatively large quantities of capital and labour which are absorbed by other sectors, under the factor mobility assumption, particularly the sectors like electronics which significantly rely on similar factors of production. It is this resource reallocation effect that underlies the large responses of electronics output to shocks in services sectors. In reality this, may not materialise if the shocks are short-lived or if the factor markets are sticky, and, again suggests the importance of considering alternative modelling setups where mobility of resources is more constrained.

[49] Strictly speaking each of these elements measure the impact of a unit change in the exogenous final demand of sector *k in* country *i* on the output of the industry *m* in country *j*.

[50] See the discussion in footnote 11 above.

[51] Other services includes: construction; warehousing and support activities; real estate activities; public administration and defense; education, human health and social work activities and dwellings.

Vertical domestic shocks originating in manufacturing industries on the other hand tend to be propagated through vertical GVC channels, and these impacts are particularly visible in the United States and Japan. In the United States, for example, a negative 1% shock to the output of the metals or iron and steel industry (*metals* and *i_s* in Figure A.6), lowers the electronics output by, respectively, 0.24% and 0.11%, while the corresponding effects for Japan are 0.23% and 0.19% and for Germany 0.06% and 0.03%. The business services sector (*obs* in Figure A.6) is similar in this respect, and this can be explained by the fact that its products are used intensely in the electronics industry as inputs (Figure A A.7).

As already discussed in the global analysis of impacts in Section 3.1, the impacts of 'vertical foreign shocks (which can be identified in Figure A.6 in cells which lie outside the outlined columns and rows) tend to be smaller but there are also some notable exceptions. Here, a distinction between shocks originating in foreign services sectors and foreign manufacturing sectors should also be made, again because of the apparent different transition mechanisms.

First, declines in large foreign services sectors, such as the above discussed other services, tend to have relatively large negative impacts on the electronics sectors in the three countries (*oserv* columns in the three panels). These impacts are however again explained by an indirect transmission, first through resources reallocation within the foreign economies where these shocks are originating and the associated positive impacts they have on foreign electronics sectors and, second, through the negative competition effects these increases in foreign electronics output have on the output of the electronics sectors in the three countries considered here. These effects are thus distinct from the more classical vertical transmission of shocks in GVCs through input-output or demand linkages, but they coincide with the latter and their effects turn out to be relatively large.

A classical transmission of vertical foreign shocks through GVCs would be expected in case of transmission of shocks from sectors with strong backward and forward links to electronics, such as, for backward linkages, retail trade (trd), business services (obs), and metals (Figure A A.7, Panel A), and, for forward linkages, motor vehicles (mvh), machinery and equipment (ome), other manufacturing (omf) and business services (obs) (Figure 3.5, Panel B). For Germany's electronics we indeed see the negative foreign backward linkage effects for shocks in retail trade, metals and chemicals originating from the other European countries EU24) and for business services originating also from other major European economies such as France and the United Kingdom, but also from other regions. We also see some negative forward linkage effects, for example with China's motor vehicle sector where a decline in China's motor vehicle production is found to depress electronics production in Germany. For the United States' electronics sector, the negative foreign backward linkage effects seem to be concentrated in the retail trade and business services originating in Canada, Korea and Mexico (columns *trd* and *obs* in Figure 3.4, Panel B) and there is a negative forward linkage with China's motor vehicle sector. For Japan, similarly for the United States, the negative backward linkage effects are mainly associated with business services sourced from Korea and other countries in Southeast Asia.

Overall, we see that many effects associated with more typical channels of transmission of vertical foreign shocks in GVCs are relatively small and that some of the larger effects that have been categorised as foreign vertical shocks seem to operate through indirect channels. The latter seem to involve not so much transmission through a constrained access to intermediate inputs but general equilibrium and competition effects.

Figure A A.6. Impacts of negative output shocks on three national electronics sectors

Panel A. Germany: % impact on output in Germany's electronics industry, by shocks country and sector

shock sectors

shock regions	agr	bph	chm	cmn	ele	ext	fdbev	hosprec	i_s	metals	mvh	nmm	obs	ofins	ome	omf	oserv	otp	oxt	p_c	trd	txwr	uti	avg sec
arg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ausnzl	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	-0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00
bra	-0.01	0.00	0.00	0.00	0.01	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
can	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
chn	-0.83	-0.05	0.01	-0.11	0.46	0.00	-0.49	-0.21	0.11	0.19	-0.07	0.05	0.05	-0.23	0.04	0.03	-0.94	-0.10	0.06	-0.07	0.03	-0.03	-0.05	-0.09
deu	0.12	0.02	0.03	0.34	-1.00	0.01	0.32	0.58	-0.03	-0.06	0.07	0.01	-0.06	0.38	0.03	0.03	2.35	0.18	0.00	0.17	0.56	0.02	0.71	0.21
eu24	0.00	0.00	-0.01	-0.10	0.21	0.00	-0.05	-0.09	-0.01	-0.02	-0.05	-0.01	-0.07	-0.04	-0.03	-0.02	-0.50	-0.04	-0.01	0.00	-0.12	0.01	-0.09	-0.05
fra	-0.01	0.00	0.00	-0.04	0.05	0.00	-0.02	-0.03	0.00	0.00	-0.01	0.00	-0.03	-0.03	0.00	0.00	-0.17	-0.01	0.00	0.00	-0.03	0.00	-0.02	-0.02
gbr	0.00	0.00	0.00	-0.04	0.03	0.00	-0.01	-0.03	0.00	0.00	0.00	0.00	-0.02	-0.02	0.00	0.00	-0.14	-0.01	0.00	-0.01	-0.03	0.00	-0.01	-0.01
idn	-0.01	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ind	-0.03	0.00	0.00	0.00	0.02	0.00	-0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	-0.01	0.00	0.00	0.00	0.00
ita	0.00	0.00	0.00	-0.02	0.04	0.00	-0.01	-0.03	0.00	0.00	0.00	0.00	-0.01	-0.02	0.00	0.00	-0.11	-0.01	0.00	-0.01	-0.03	0.00	-0.01	-0.01
jpn	-0.02	0.00	0.00	-0.03	0.07	0.00	-0.04	-0.05	0.02	0.02	0.00	0.01	-0.01	-0.03	0.00	0.01	-0.19	-0.02	0.00	-0.01	-0.06	0.00	-0.01	-0.01
kor	-0.02	0.00	0.00	-0.03	0.06	0.00	-0.02	-0.04	0.00	0.01	-0.01	0.00	-0.02	-0.03	0.00	0.01	-0.13	-0.01	0.00	-0.01	-0.05	0.00	-0.01	-0.01
mex	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	-0.01	0.00	0.00	0.00
rlam	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
row	-0.15	0.00	0.00	-0.03	0.09	0.04	-0.09	-0.06	0.00	0.01	0.00	-0.01	0.00	-0.04	0.00	0.00	-0.31	-0.04	0.00	-0.02	-0.07	0.00	-0.01	-0.03
rus	-0.01	0.00	0.00	0.00	0.02	0.03	-0.02	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.04	-0.01	0.00	0.00	-0.02	0.00	0.00	0.00
sea	-0.07	0.00	0.00	-0.02	0.08	0.00	-0.04	-0.03	0.00	0.00	-0.01	0.00	-0.01	-0.03	0.00	0.00	-0.10	-0.01	0.00	-0.01	0.03	0.00	-0.02	-0.01
tur	-0.01	0.00	0.00	0.00	0.01	0.00	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.03	0.00	0.00	0.00	-0.01	0.00	0.00	0.00
usa	-0.03	-0.01	0.00	-0.01	0.15	0.01	-0.06	-0.06	0.02	0.03	0.00	0.00	0.01	-0.06	0.00	0.01	-0.36	0.00	0.00	-0.01	0.05	0.00	-0.02	-0.02
zaf	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
avg cnty	-0.05	0.00	0.00	0.00	0.01	0.00	-0.03	0.00	0.01	0.01	0.00	0.00	-0.01	-0.01	0.00	0.00	-0.04	0.00	0.00	0.00	0.01	0.00	0.02	0.00

Panel B. United States: % impact on output in Germany's electronics industry, by shocks country and sector

shock sectors

shock regions	agr	bph	chm	cmn	ele	ext	fdbev	hosprec	i_s	metals	mvh	nmm	obs	ofins	ome	omf	oserv	otp	oxt	p_c	trd	txwr	uti	avg sec
arg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ausnzl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
bra	-0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
can	0.00	0.00	0.00	-0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	-0.03	0.00	0.00	0.00	-0.01	0.00	0.00	0.00
chn	-0.64	-0.03	0.00	-0.07	0.33	-0.01	-0.35	-0.14	0.09	0.14	-0.04	0.04	0.07	-0.14	0.04	0.02	-0.61	-0.06	0.05	-0.04	0.04	-0.03	-0.02	-0.06
deu	0.00	0.00	0.00	-0.01	0.03	0.00	-0.01	-0.02	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	-0.07	0.00	0.00	-0.01	-0.02	0.00	-0.02	-0.01
eu24	-0.02	0.00	0.00	-0.01	0.04	0.00	-0.02	-0.02	0.00	0.01	0.00	0.00	0.00	-0.01	0.00	0.00	-0.08	0.00	0.00	-0.01	-0.01	0.00	-0.01	-0.01
fra	0.00	0.00	0.00	0.00	0.01	0.00	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
gbr	0.00	0.00	0.00	-0.01	0.01	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	-0.03	0.00	0.00	0.00	-0.01	0.00	0.00	0.00
idn	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ind	-0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ita	0.00	0.00	0.00	0.00	0.01	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
jpn	-0.02	0.00	0.00	-0.02	0.05	0.00	-0.03	-0.04	0.01	0.01	0.00	0.01	0.00	-0.02	0.00	0.01	-0.14	-0.01	0.00	-0.01	-0.04	0.00	-0.01	-0.01
kor	-0.01	0.00	0.00	-0.02	0.03	0.00	-0.01	-0.02	0.00	0.00	0.00	0.00	-0.01	-0.02	0.00	0.00	-0.08	0.00	0.00	0.00	-0.03	0.00	-0.01	-0.01
mex	-0.01	0.00	0.00	-0.01	0.04	0.00	-0.02	-0.01	0.00	0.00	-0.01	0.00	-0.01	-0.01	0.00	0.00	-0.07	-0.02	0.00	0.00	-0.04	0.00	0.00	-0.01
rlam	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
row	-0.08	0.00	0.00	-0.01	0.05	-0.04	-0.04	-0.03	0.00	0.01	0.00	0.00	0.00	-0.02	0.00	0.00	-0.13	-0.01	0.01	0.00	-0.03	0.00	0.00	-0.01
rus	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
sea	-0.05	0.00	0.00	-0.01	0.05	0.00	-0.02	-0.02	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	-0.06	-0.01	0.00	0.00	0.02	0.00	-0.01	-0.01
tur	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
usa	0.09	0.02	0.00	-0.06	-1.00	0.01	0.33	0.44	-0.11	-0.24	-0.01	-0.03	-0.43	0.29	-0.05	-0.11	2.23	-0.02	-0.05	0.03	-0.51	0.02	0.10	0.04
zaf	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
avg cnty	-0.04	0.00	0.00	-0.01	-0.02	0.00	-0.01	0.01	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.04	-0.01	0.00	0.00	-0.03	0.00	0.00	0.00

Panel C. Japan: % impact on output in Germany's electronics industry, by shocks country and sector

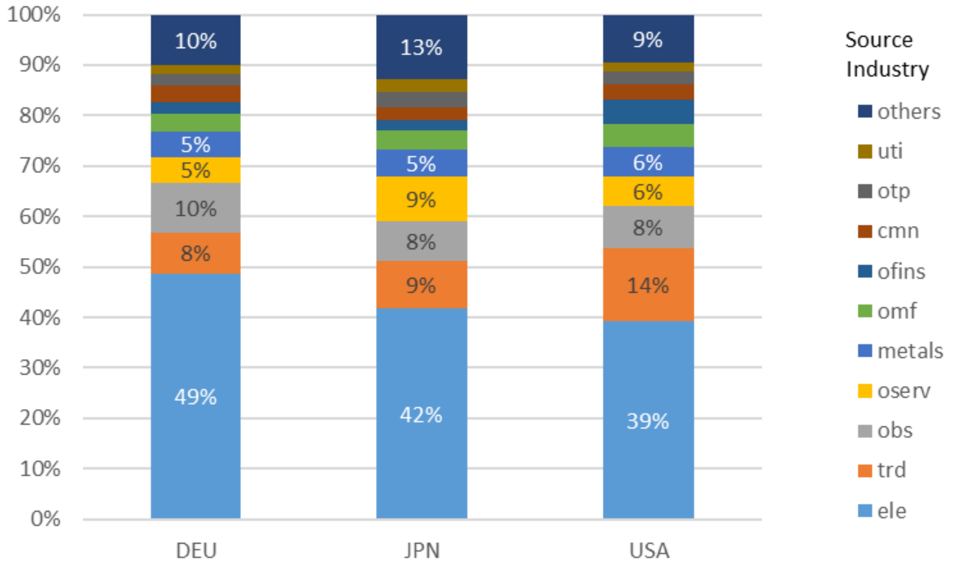
shock sectors

shock regions	agr	bph	chm	cmn	ele	ext	fdbev	hosprec	i_s	metals	mvh	nmm	obs	ofins	ome	omf	oserv	otp	oxt	p_c	trd	txwr	uti	avg sec
arg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ausnzl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00
bra	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
can	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
chn	-0.84	-0.05	0.01	-0.13	0.48	-0.01	-0.50	-0.23	0.10	0.19	-0.08	0.03	0.00	-0.27	0.04	0.03	-1.05	-0.13	0.06	-0.08	-0.01	-0.02	-0.08	-0.11
deu	-0.01	0.00	0.00	-0.02	0.04	0.00	-0.02	-0.03	0.00	0.01	0.00	0.00	0.00	-0.02	0.00	0.00	-0.12	-0.01	0.00	-0.01	-0.03	0.00	-0.04	-0.01
eu24	-0.02	0.00	0.00	-0.02	0.05	0.00	-0.03	-0.03	0.00	0.01	0.00	0.00	0.00	-0.01	0.00	0.00	-0.12	-0.01	0.00	-0.01	-0.03	0.00	-0.02	-0.01
fra	-0.01	0.00	0.00	-0.01	0.01	0.00	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	-0.04	0.00	0.00	0.00	-0.01	0.00	0.00	0.00
gbr	0.00	0.00	0.00	-0.01	0.01	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	-0.04	0.00	0.00	0.00	-0.01	0.00	0.00	0.00
idn	-0.01	0.00	0.00	0.00	0.01	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	-0.01	0.00	0.00	0.00	0.00	0.00
ind	-0.02	0.00	0.00	0.00	0.01	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ita	0.00	0.00	0.00	0.00	0.01	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	-0.01	0.00	0.00	0.00
jpn	0.27	0.04	-0.01	0.32	-1.00	0.00	0.59	0.70	-0.19	-0.23	0.02	-0.22	-0.06	0.37	-0.03	-0.14	2.47	0.23	-0.03	0.19	0.80	0.00	0.16	0.18
kor	-0.02	0.00	0.00	-0.04	0.08	0.00	-0.03	-0.05	0.00	0.00	-0.01	0.00	-0.03	-0.04	0.00	0.01	-0.17	-0.01	0.00	-0.01	-0.07	0.00	-0.03	-0.02
mex	0.00	0.00	0.00	0.00	0.01	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	-0.01	0.00	0.00	-0.01	0.00	0.00	0.00
rlam	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00
row	-0.16	0.00	0.00	-0.03	0.10	0.01	-0.08	-0.07	0.00	0.01	0.00	0.00	0.00	-0.03	0.00	0.00	-0.29	-0.05	0.00	-0.01	-0.07	-0.01	-0.03	-0.03
rus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
sea	-0.06	0.00	0.00	-0.02	0.07	0.00	-0.03	-0.03	0.00	0.00	-0.01	0.00	-0.01	-0.03	0.00	0.00	-0.11	-0.01	0.00	-0.01	0.02	0.00	-0.03	-0.01
tur	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
usa	-0.02	0.00	0.00	-0.02	0.17	0.00	-0.06	-0.08	0.02	0.04	-0.01	0.00	0.02	-0.06	0.01	0.01	-0.44	-0.01	0.00	-0.01	0.04	0.00	-0.03	-0.02
zaf	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
avg reg	-0.04	0.00	0.00	0.00	0.00	0.00	-0.01	0.01	0.00	0.00	0.00	-0.01	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00

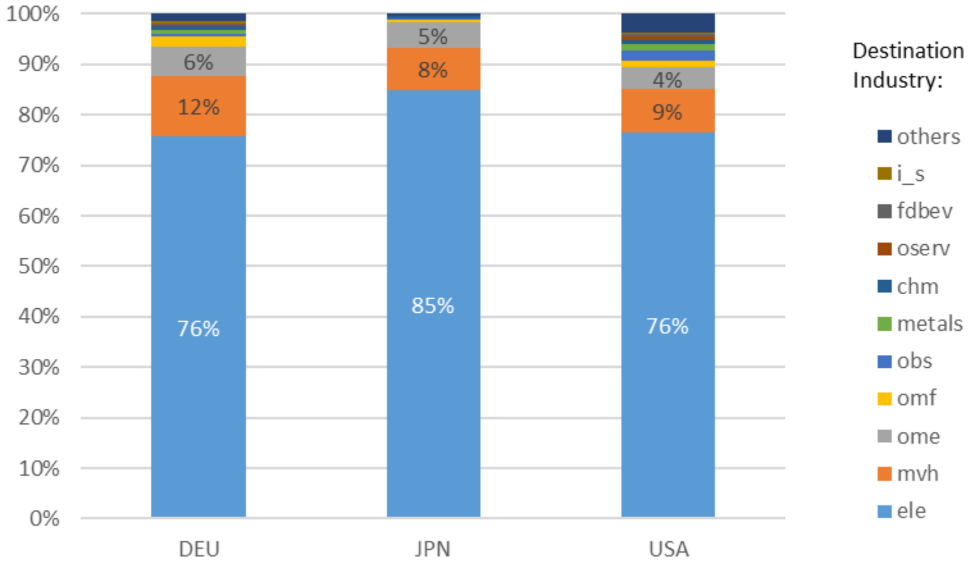
Note: The values of the cells are conditionally formatted with the size of bars indicating the direction and relative size of the impact of 1% output decline in the shock sector and country.
Source: OECD METRO model simulations.

Figure A A.7. Industry origin of value added in the electronics sector

Panel A. The backward linkage: industry origin of value added in gross exports for electronics as the exporting industry



Panel B. The forward linkage: electronics as origin of value added in gross exports for export industries



Note: See Annex Table A A.1 for a description of the industries presented in the figures.
Source: OECD METRO Model ICIO module based on the analysis database.

Annex B. Tables and figures

Table A B.1. Model database aggregation

Sector aggregation

	Sectors (23)
agr	Agriculture
ext	Coal, oil, gas extraction
oxt	Mining
fdbev	Food and beverage
txwr	Textile and wearing apparel
omf	Other manufacturing
p_c	Petroleum and coal
chm	Chemicals
bph	Basic pharmaceuticals
nmm	Mineral products nec
i_s	Ferrous metals
metals	Metals and metals product
ele	Electronic equipment
ome	Machinery and equipment
mvh	Motor vehicles and parts
uti	Utilities
trd	Trade
hosprec	Hospitality and recreation
otp	Transport nec
cmn	Communication
ofins	Financial services and insurance
obs	Business services
oserv	Other services

Source: Authors’ compilation.

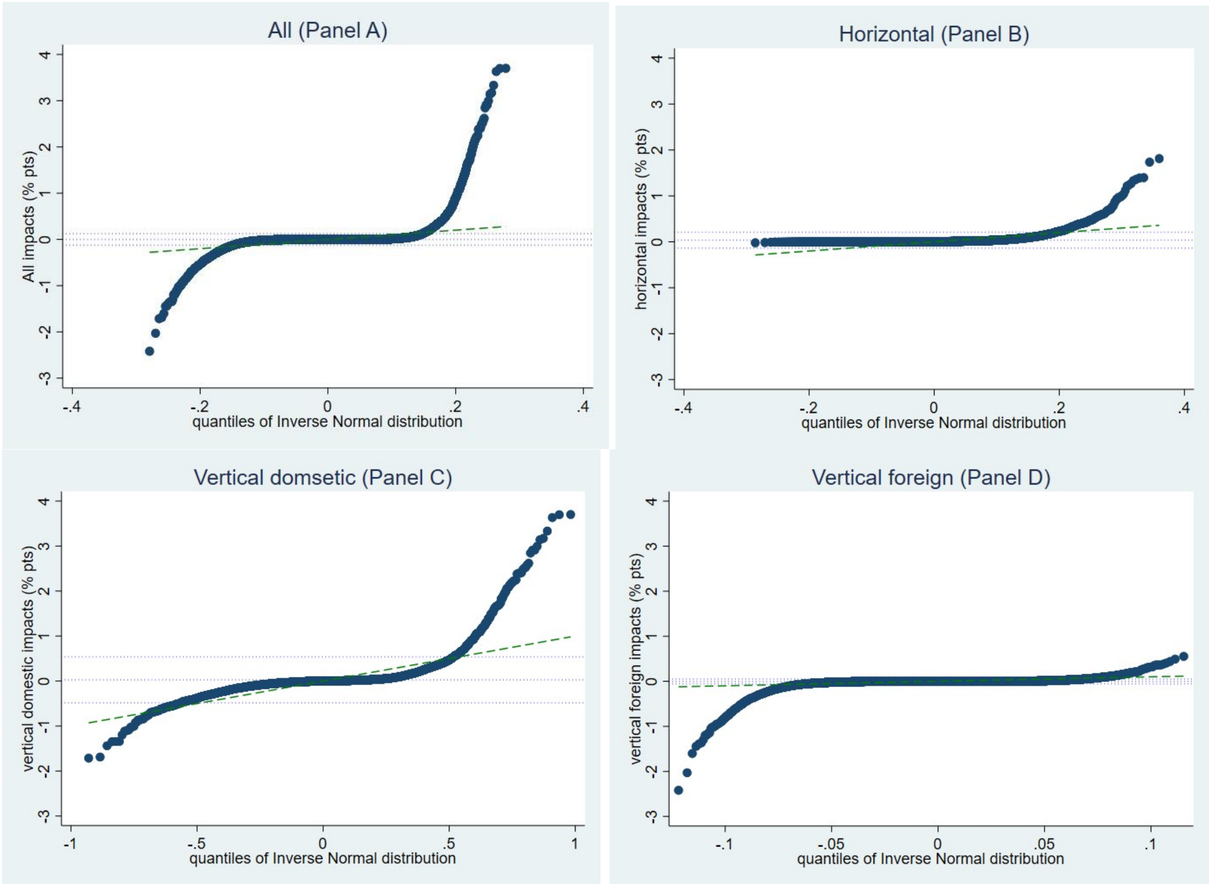
Country aggregation

	Countries (22)
ARG	Argentina
AUSNZL	Australia and New Zealand
BRA	Brazil
CAN	Canada
CHN	China
FRA	France
DEU	Germany
GBR	United Kingdom
ITA	Italy
EU24	European Union (24)
IDN	Indonesia
IND	India
JPN	Japan
KOR	Korea
MEX	Mexico
RUS	Russian Federation
ZAF	South Africa
TUR	Türkiye
USA	United States
rLAm	rest of Latin America
SEA	South East Asia
ROW	Rest of the world
glo	Globe

Source: Authors’ compilation.

Figure A B.1. Distribution of effects of global production shocks (mobile factors assumption)

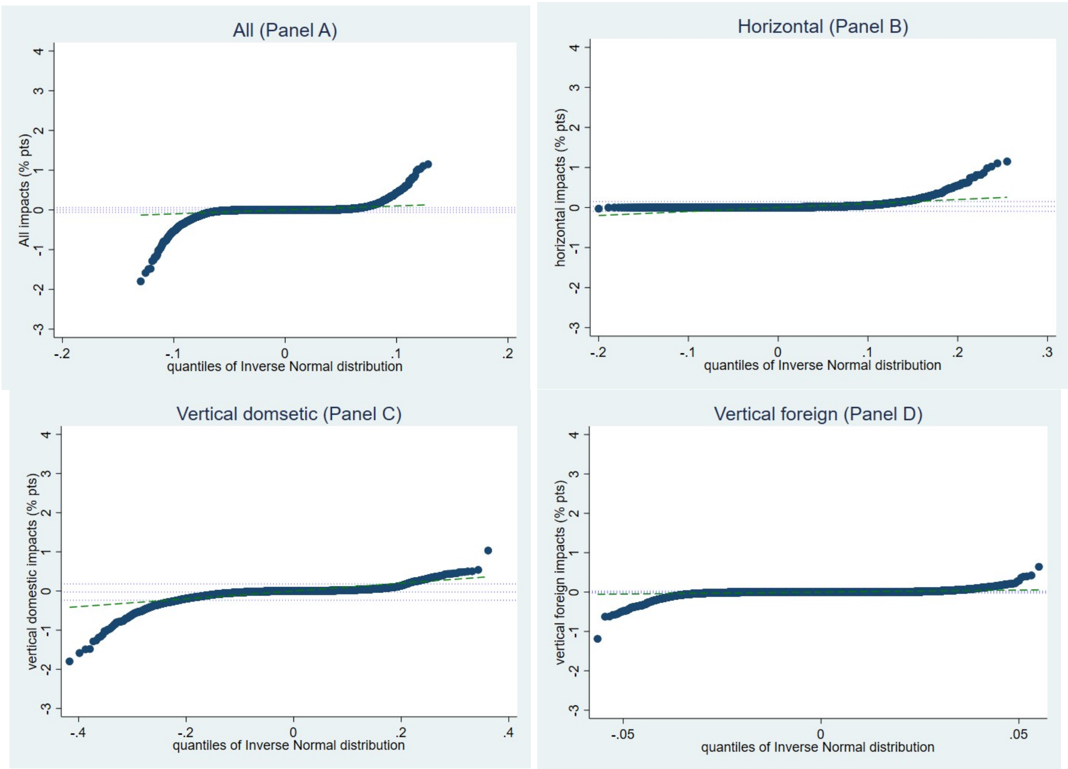
% impacts of global output shocks, by transmission channel



Note: Vertical axes show the size of the observed impacts (i.e. the quantiles of the observed impacts). The horizontal axes show the theoretical quantiles of the observed data if it follows a normal distribution with the same mean and standard deviation. The dashed green line is the normal distribution line, meaning if the plotted observations fall on this line, the observed values follow a normal distribution. The larger the difference between the observed impacts and the dashed green lines, the more the observations deviate from a normal distribution. Lastly, in each panel there are three dotted blue lines, the middle line shows the average marginal observed output change and, the two other blue lines show + and – two standard deviations from the average.
Source: OECD METRO model simulations.

Figure A B.2. Distribution of effects of global production shocks (immobile factors assumption)

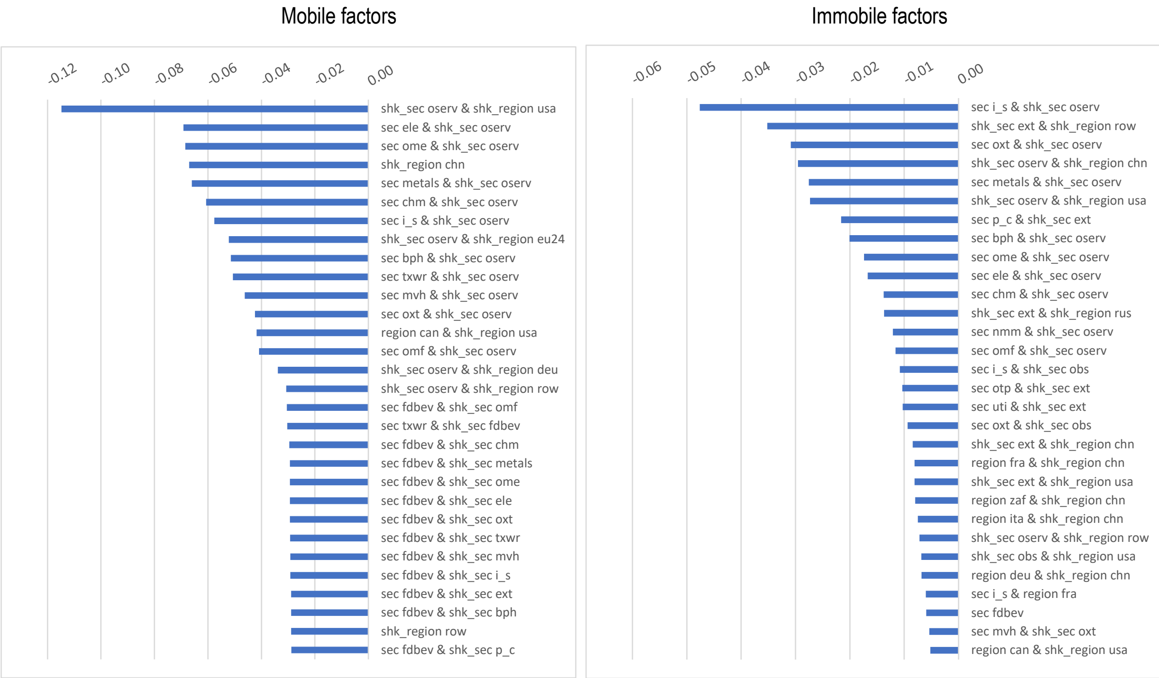
% impacts of global output shocks, by transmission channel



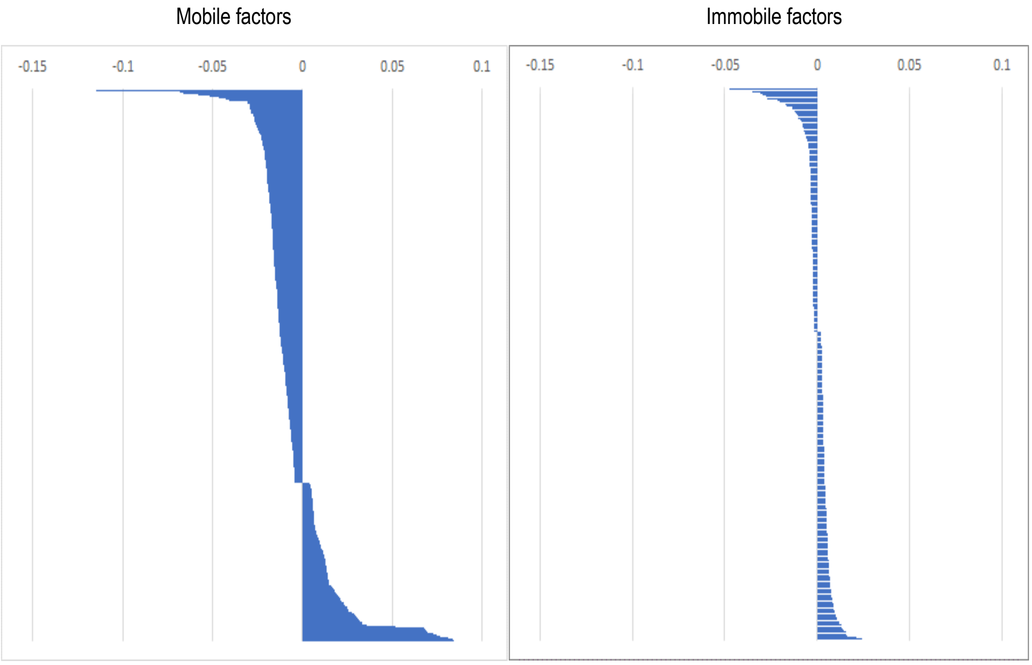
Note: Vertical axes show the size of the observed impacts (i.e. the quantiles of the observed impacts). The horizontal axes show the theoretical quantiles of the observed data if it follows a normal distribution with the same mean and standard deviation. The dashed green line is the normal distribution line, meaning if the plotted observations fall on this line, the observed values follow a normal distribution. The larger the difference between the observed impacts and the dashed green lines, the more the observations deviate from a normal distribution. Lastly, in each panel there are three dotted blue lines, the middle line shows the average marginal observed output change and, the two other blue lines show + and – two standard deviations from the average.
Source: OECD METRO model simulations.

Figure A B.3. Regression results for foreign vertical shocks

Panel A: thirty largest statistically significant coefficients on fixed effects



Panel B. All statistically significant coefficients on fixed effects



Note: Only coefficients statistically significant at the 5% or higher level of significance are shown. Sector and country abbreviations correspond to those listed in the Annex Table A A.1. Model database aggregation. In Panel A, not all labels are displayed on the horizontal axis.
Source: OECD METRO model simulations.

Figure A B.4. Typical exposure to GVC shocks by affected country-sector

Panel A. Standard deviation of output responses across all relevant shock country sectors under <u>mobile factors</u> of production

affected countries (ordered by size of impact)	affected sectors (ordered by size of impact)																							average	
	Electronic equipment	Machinery and equip	Metals and metals pr	Textile and wearing a	Ferrous metals	Chemicals	Basic pharmaceutical	Motor vehicles and p	Mining	Other manufacturing	Hospitality and recre	Petroleum and coal	Coal, oil, gas extracti	Mineral products nec	Food and beverage	Communication	Agriculture	Financial services anc	Trade	Transport nec	Business services	Utilities	Other services	simp.	wghtd.
CAN	0.09	0.10	0.06	0.07	0.07	0.08	0.05	0.03	0.04	0.06	0.02	0.01	0.01	0.03	0.02	0.01	0.03	0.01	0.01	0.00	0.01	0.01	0.00	0.04	0.02
MEX	0.08	0.12	0.07	0.04	0.06	0.02	0.02	0.03	0.04	0.05	0.03	0.02	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.02	0.00	0.01	0.01	0.03	0.02
DEU	0.07	0.04	0.04	0.05	0.04	0.04	0.06	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.02	0.02
GBR	0.08	0.06	0.04	0.05	0.04	0.04	0.06	0.03	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.02	0.01
FRA	0.07	0.04	0.03	0.06	0.04	0.04	0.07	0.03	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.02	0.01
SEA	0.07	0.04	0.04	0.04	0.04	0.04	0.02	0.02	0.02	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.02	0.02
KOR	0.07	0.03	0.03	0.04	0.03	0.04	0.02	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02
ITA	0.06	0.04	0.03	0.06	0.03	0.03	0.06	0.03	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.02	0.01
AUSNZL	0.08	0.04	0.04	0.06	0.02	0.03	0.03	0.02	0.04	0.02	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01
EU24	0.06	0.03	0.03	0.04	0.03	0.03	0.05	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.02	0.01
ROW	0.08	0.04	0.04	0.03	0.02	0.03	0.05	0.01	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.01
JPN	0.08	0.02	0.03	0.03	0.03	0.03	0.01	0.03	0.03	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.02	0.01
ZAF	0.03	0.02	0.06	0.01	0.04	0.02	0.01	0.02	0.04	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.02	0.01
rLAm	0.05	0.02	0.06	0.02	0.03	0.03	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.02	0.01
RUS	0.04	0.01	0.03	0.03	0.02	0.04	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.01	0.01
TUR	0.05	0.03	0.03	0.03	0.03	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.01
IDN	0.06	0.03	0.01	0.03	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.01
IND	0.04	0.01	0.02	0.01	0.01	0.02	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.01
ARG	0.02	0.02	0.03	0.01	0.02	0.02	0.02	0.04	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00
USA	0.05	0.01	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
BRA	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01
CHN	0.03	0.01	0.02	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
avrg simp.	0.06	0.04	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00		
avrg wghtd.	0.05	0.02	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00		

Legend: Manufacturing; Extractive industries; Services; Agriculture and food

Panel B. Standard deviation of output responses across all relevant shock country sectors under <u>immobile factors</u> of production

affected countries (ordered by size of impact)	affected sectors (ordered by size of impact)																							average	
	Ferrous metals	Petroleum and coal	Metals and metals product	Chemicals	Mining	Basic pharmaceuticals	Electronic equipment	Mineral products nec	Machinery and equipment	Transport nec	Utilities	Other manufacturing	Motor vehicles and parts	Textile and wearing apparel	Business services	Hospitality and recreation	Communication	Food and beverage	Trade	Financial services and insurance	Coal, oil, gas extraction	Other services	Agriculture	simp.	wghtd.
RUS	0.03	0.03	0.01	0.07	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
ZAF	0.04	0.02	0.02	0.02	0.03	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01
FRA	0.04	0.03	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01
ITA	0.04	0.02	0.03	0.01	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
SEA	0.03	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01
CAN	0.03	0.01	0.02	0.01	0.01	0.02	0.01	0.03	0.01	0.01	0.00	0.02	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01
KOR	0.01	0.03	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.01	0.01
EU24	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01
DEU	0.02	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01
MEX	0.02	0.02	0.02	0.00	0.01	0.02	0.01	0.03	0.01	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01
TUR	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01
AUSNZL	0.01	0.01	0.05	0.01	0.02	0.02	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
GBR	0.04	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01
JPN	0.02	0.03	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
IND	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
IDN	0.03	0.04	0.01	0.01	0.00	0.00	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
BRA	0.01	0.02	0.01	0.01	0.02	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00
ROW	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
rLAm	0.03	0.01	0.01	0.01	0.03	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
ARG	0.02	0.02	0.02	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
USA	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
CHN	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
avrg simp.	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
avrg wghtd.	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		

Source: OECD METRO model.

Figure A B.5. Maximum exposure to GVC shocks by affected country-sector

Panel A. Maximum % impact of all possible 1% shocks -mobile factors of production

Legend: Manufacturing | Extractive industries | Services | Agriculture and food

affected sectors (ordered by size of impact); average

affected countries (ordered by size of impact)	Electronic equipment	Metals and metals product	Ferrous metals	Machinery and equipment	Chemicals	Textile and wearing apparel	Basic pharmaceuticals	Mining	Motor vehicles and parts	Other manufacturing	Coal, oil, gas extraction	Hospitality and recreation	Petroleum and coal	Mineral products nec	Food and beverage	Agriculture	Communication	Financial services and insurance	Business services	Trade	Transport nec	Utilities	Other services	average simp.	average wghtd.
CAN	9.7	7.7	7.7	8.8	7.6	7.0	5.8	4.8	3.4	5.1	2.2	1.8	1.2	2.6	2.2	3.9	1.2	0.8	0.8	1.1	0.8	1.6	0.8	3.9	1.9
FRA	10.9	6.4	7.5	7.3	6.3	8.2	9.2	3.2	5.3	3.6	2.4	1.8	2.3	1.9	1.4	1.5	1.1	1.1	0.5	0.8	1.0	0.6	0.8	3.7	2.0
DEU	9.8	7.0	7.1	6.6	6.1	7.2	7.5	3.5	4.3	2.8	2.1	3.7	2.1	2.0	2.0	2.2	1.9	1.8	0.7	1.4	1.1	0.8	1.2	3.7	2.9
GBR	10.5	7.0	7.8	10.3	6.9	7.5	7.1	2.4	5.4	3.2	2.5	1.8	1.7	1.2	1.2	1.3	0.8	0.9	0.8	1.1	0.9	0.4	0.7	3.6	1.6
SEA	7.8	7.7	6.9	6.2	6.7	5.4	4.6	3.2	3.5	4.4	2.1	3.8	2.3	1.6	1.6	0.8	2.2	1.9	2.4	1.0	1.7	1.1	1.5	3.5	3.2
ITA	8.3	6.3	6.7	7.3	4.4	8.0	7.6	2.2	5.4	2.9	2.1	2.6	1.5	2.1	1.4	1.5	1.0	0.7	0.6	1.2	0.8	1.0	0.9	3.3	2.3
EU24	8.5	6.0	6.4	5.6	5.3	6.1	6.6	3.6	3.6	3.0	2.1	2.4	1.9	1.6	1.4	1.4	1.2	1.2	1.0	1.2	1.1	0.8	0.9	3.2	2.2
MEX	7.6	7.2	6.0	9.0	2.2	4.5	3.5	5.1	3.9	4.7	2.0	2.5	2.1	2.0	0.9	0.9	1.5	1.4	0.4	1.0	1.9	1.3	1.1	3.2	2.5
KOR	8.2	4.8	5.4	4.8	6.1	4.1	3.3	4.0	4.4	3.4	2.2	3.0	3.1	1.6	1.7	0.9	2.4	1.9	1.0	1.2	1.4	1.3	1.5	3.1	3.2
AUSNZL	8.2	7.2	4.1	6.6	4.9	6.0	3.8	5.2	3.4	2.6	2.6	1.3	1.3	0.7	2.0	2.5	0.6	0.6	0.4	0.8	0.5	0.6	0.5	2.9	1.2
ZAF	4.0	10.3	7.0	3.0	3.4	2.3	2.9	6.0	3.3	2.2	2.1	2.2	1.9	0.9	2.4	1.3	1.4	1.7	0.6	1.2	0.6	1.4	1.2	2.7	2.3
ROW	9.3	7.4	4.5	5.4	5.2	3.9	5.2	2.5	2.5	2.5	1.8	2.0	1.2	0.9	1.0	0.5	1.1	0.9	1.2	0.6	0.8	0.7	0.8	2.7	1.8
rLAm	5.6	10.1	5.8	3.6	3.8	2.4	2.5	5.7	2.4	1.8	2.3	2.0	1.3	0.7	0.9	0.8	1.3	0.9	0.4	1.2	0.9	0.8	0.8	2.5	1.7
JPN	8.0	4.3	4.5	3.2	4.8	3.1	1.3	4.6	3.6	1.7	2.2	1.9	1.8	2.2	1.1	0.9	1.1	1.0	0.4	0.8	0.5	0.5	0.6	2.4	1.7
TUR	7.3	4.9	5.3	5.0	3.3	4.0	2.7	2.6	3.5	1.6	2.1	1.4	1.7	1.0	0.9	0.7	1.1	0.6	0.8	0.8	0.9	0.8	0.6	2.3	1.6
RUS	4.0	5.8	3.6	2.1	6.8	2.9	3.6	4.2	1.7	1.6	2.2	1.8	1.6	0.9	0.9	0.9	0.8	0.7	1.1	0.8	0.8	0.9	0.5	2.2	1.4
IDN	6.9	1.6	4.9	4.3	3.1	4.2	1.5	1.2	2.3	2.2	2.2	1.3	2.4	0.8	0.6	0.4	0.9	0.6	0.9	0.6	0.7	0.9	0.7	2.0	1.3
IND	4.3	3.1	2.0	1.9	3.1	1.7	3.4	2.4	1.4	1.8	1.8	1.5	1.3	1.0	0.5	0.3	1.3	0.5	3.1	0.6	0.6	0.6	0.6	1.7	1.1
ARG	2.5	4.8	4.1	3.3	2.6	1.2	2.7	1.7	3.7	0.6	1.5	0.6	1.0	0.5	0.9	1.2	0.5	0.4	0.5	0.4	0.5	0.6	0.2	1.6	0.8
USA	5.1	2.9	3.1	1.9	2.4	2.4	3.1	1.5	1.4	1.1	1.6	0.7	1.1	0.8	0.6	1.1	0.3	0.4	0.3	0.2	0.3	0.4	0.4	1.4	0.8
BRA	2.0	2.8	3.0	2.6	1.7	1.1	1.1	4.1	1.6	1.0	2.2	1.1	1.0	0.6	0.7	1.3	0.5	0.5	0.9	0.6	0.6	0.4	0.4	1.4	0.9
CHN	4.0	2.6	1.1	2.0	2.3	2.1	0.8	1.6	0.9	1.6	1.3	1.2	0.8	0.5	0.8	0.4	0.7	0.5	0.4	0.4	0.3	0.6	0.6	1.2	1.2
avrg simp.	6.9	5.8	5.2	5.1	4.5	4.3	4.1	3.4	3.2	2.5	2.1	1.9	1.7	1.3	1.2	1.2	1.1	1.0	0.9	0.9	0.8	0.8	0.8		
avrg wghtd.	6.2	4.6	3.6	3.7	4.0	3.3	3.2	3.0	2.6	2.1	1.9	1.6	1.4	0.9	1.0	0.7	1.0	0.7	0.7	0.7	0.7	0.7	0.7		

Panel B. Maximum % impact of all possible 1% shocks -immobile factors of production

Legend: Manufacturing | Extractive industries | Services | Agriculture and food

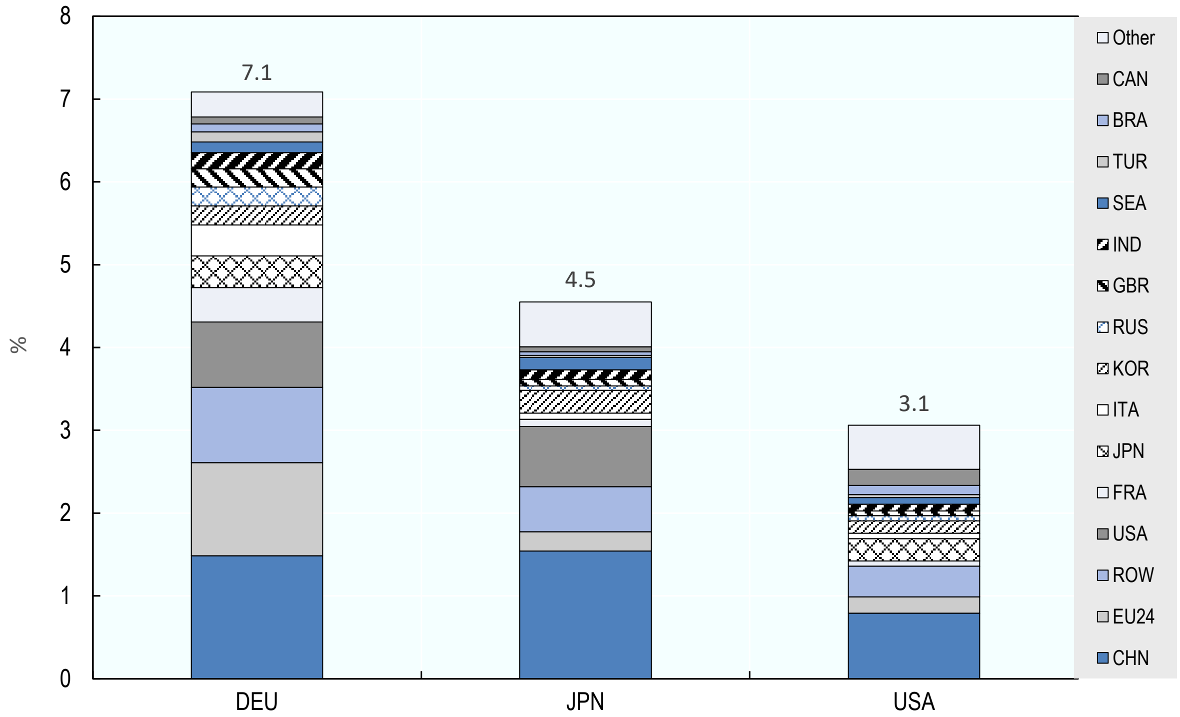
affected sectors (ordered by size of impact); average

affected countries (ordered by size of impact)	Ferrous metals	Petroleum and coal	Metals and metals product	Chemicals	Mining	Mineral products nec	Electronic equipment	Basic pharmaceuticals	Machinery and equipment	Other manufacturing	Utilities	Motor vehicles and parts	Transport nec	Textile and wearing apparel	Business services	Hospitality and recreation	Communication	Food and beverage	Coal, oil, gas extraction	Trade	Other services	Financial services and insurance	Agriculture	average simp.	average wghtd.
RUS	5.2	3.5	2.0	10.0	2.7	1.7	1.4	3.1	1.1	1.4	1.6	1.3	1.5	0.8	1.2	1.0	0.7	0.6	0.7	0.8	0.6	0.7	0.2	1.9	1.3
ZAF	5.4	3.6	3.2	3.3	3.3	1.7	2.4	1.6	2.0	1.5	1.4	1.5	1.2	1.4	0.8	1.0	1.2	1.2	1.1	0.8	0.7	0.6	0.7	1.8	1.4
FRA	6.7	3.8	3.5	2.3	2.6	2.2	1.5	2.2	1.4	1.5	0.7	1.5	1.6	1.3	0.7	0.8	0.8	0.5	1.2	0.7	0.4	0.8	0.3	1.7	0.9
ITA	5.6	2.6	3.9	2.5	2.8	2.1	1.8	2.3	1.8	1.5	1.1	1.4	1.3	1.3	1.0	1.0	1.0	0.7	0.4	0.7	0.5	0.6	0.2	1.7	1.1
SEA	4.3	3.0	2.2	2.2	2.0	1.7	1.9	1.1	1.6	2.0	1.5	1.7	1.2	1.2	2.2	1.5	1.0	0.9	0.3	0.9	0.8	0.6	0.2	1.6	1.3
KOR	2.7	3.7	1.6	3.4	1.8	1.2	1.3	1.5	1.4	1.2	1.9	2.0	1.2	2.3	1.1	1.2	1.0	0.9	1.3	0.9	0.6	0.5	0.3	1.5	1.3
TUR	3.6	3.4	2.7	1.7	1.5	2.3	2.9	1.0	2.2	1.2	1.8	1.9	1.8	0.9	1.2	0.8	0.8	0.9	0.5	0.7	0.7	0.3	0.2	1.5	1.2
EU24	3.6	3.4	3.1	2.2	2.3	1.8	1.6	1.2	1.4	1.5	1.2	1.3	1.4	1.2	1.2	1.0	0.9	0.8	0.6	0.9	0.6	0.4	0.3	1.5	1.1
GBR	5.8	3.1	2.5	2.8	1.1	1.6	1.3	0.8	1.8	1.1	1.1	1.3	1.7	0.9	0.9	0.7	0.8	0.7	1.0	0.8	0.4	0.6	0.6	1.5	0.9
DEU	3.9	3.0	3.2	2.3	1.5	1.9	1.4	1.9	1.4	1.4	1.0	1.1	0.9	1.6	0.8	0.8	0.9	0.9	1.0	0.8	0.5	0.7	0.4	1.4	1.1
MEX	2.4	3.7	2.4	1.0	1.1	2.8	1.5	3.3	1.0	2.0	2.2	1.7	1.2	0.7	0.5	0.4	0.5	0.7	0.3	0.3	0.4	0.3	0.2	1.3	0.9
CAN	3.9	2.0	2.7	2.2	1.4	2.0	1.2	1.5	1.1	2.1	0.7	1.1	1.4	1.2	0.7	0.8	0.6	0.8	0.6	0.6	0.4	0.4	0.9	1.3	0.8
IND	2.0	3.0	2.6	2.5	2.1	2.1	2.0	1.2	1.4	1.8	1.3	1.3	1.1	0.8	1.2	0.8	0.7	0.4	0.3	0.6	0.7	0.6	0.1	1.3	1.0
IDN	3.9	5.8	0.8	1.4	0.4	1.6	2.6	0.7	1.4	1.1	1.8	0.5	1.0	0.7	1.9	0.9	0.6	0.5	0.0	0.7	0.6	0.4	0.0	1.3	0.8
AUSNZL	2.2	2.0	5.3	1.9	1.9	0.8	1.1	1.7	1.3	1.4	1.2	1.4	0.7	1.0	0.5	0.9	0.3	0.7	0.5	0.4	0.3	0.3	0.6	1.2	0.7
JPN	2.4	3.5	1.6	3.4	2.8	1.3	1.7	1.0	1.0	1.0	1.3	1.1	0.7	1.1	0.7	0.6	0.6	0.5	0.8	0.3	0.3	0.3	0.3	1.2	0.8
BRA	1.9	3.2	2.0	1.4	3.1	1.0	1.1	0.7	1.2	0.7	0.9	1.3	1.3	0.6	1.1	0.7	0.6	0.9	1.3	0.5	0.3	0.4	0.3	1.1	0.8
ARG	3.1	3.3	2.3	1.1	1.1	0.8	1.1	0.6	1.2	0.6	1.9	0.8	1.8	0.5	0.8	0.4	0.3	0.6	0.2	0.4	0.2	0.2	0.3	1.0	0.6
rLAm	3.9	1.2	1.5	1.7	3.3	1.0	0.7	0.9	0.6	0.9	0.8	0.5	1.1	0.6	0.5	0.8	0.5	0.7	0.3	0.6	0.4	0.3	0.2	1.0	0.8
ROW	1.5	2.7	1.9	1.7	1.2	1.2	1.3	1.1	1.1	0.9	1.3	0.5	0.9	0.7	1.2	0.7	0.6	0.4	0.3	0.6	0.5	0.3	0.1	1.0	0.7
CHN	1.0	1.8	1.4	1.6	1.1	0.9	1.2	1.0	1.1	1.2	0.9	0.9	0.6	0.7	0.7	0.8	0.8	0.5	0.6	0.4	0.6	0.7	0.1	0.9	0.8
USA	2.3	3.0	2.0	1.1	1.4	0.6	1.4	0.7	0.6	0.5	0.6	0.7	0.7	0.7	0.5	0.4	0.4	0.3	0.4	0.3	0.2	0.2	0.5	0.8	0.5
avrg simp.	3.5	3.1	2.5	2.4	1.9	1.6	1.6	1.4	1.3	1.3	1.3	1.2	1.2	1.0	1.0	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.3		
avrg wghtd.	2.3	2.9	2.1	2.0	1.7	1.2	1.4	1.1	1.1	1.1	1.1	1.1	1.0	0.8	0.8	0.7	0.7	0.6	0.4	0.5	0.4	0.4	0.2		

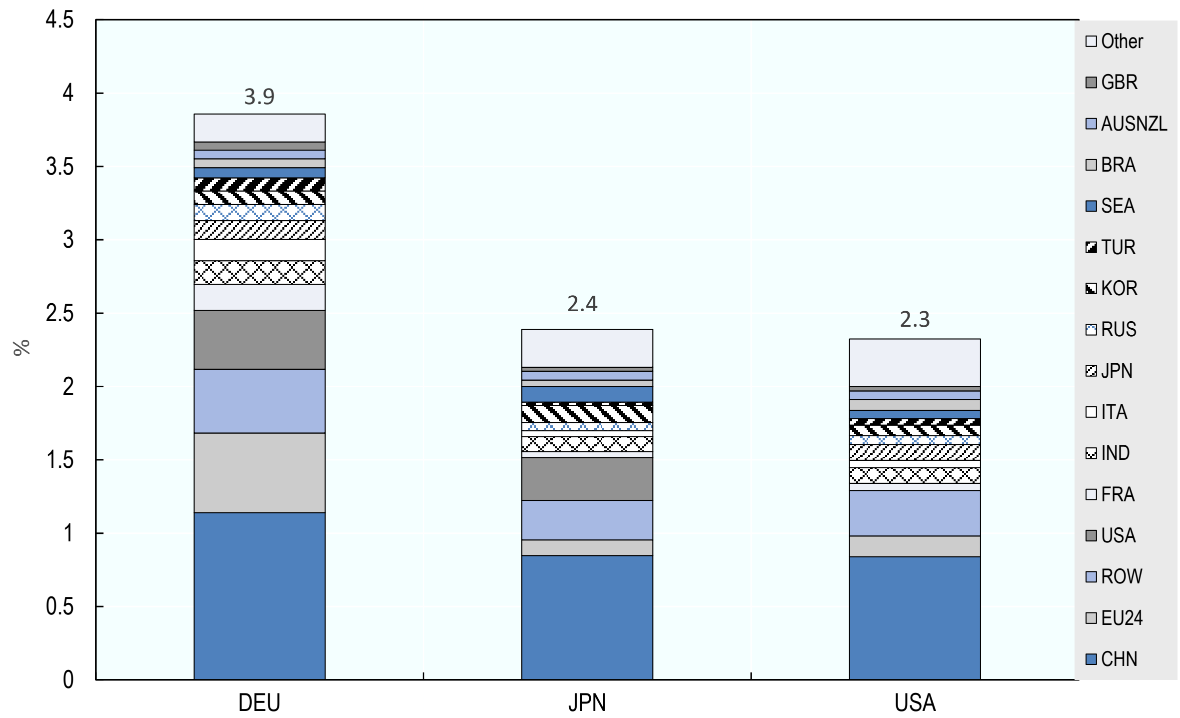
Source: OECD METRO model.

Figure A B.6. Decomposition of maximum exposures in *iron and steel* products in Germany, Japan and the United Sates, by country origin of shocks

Panel A. Maximum % impact of all possible 1% shocks -mobile factors of production



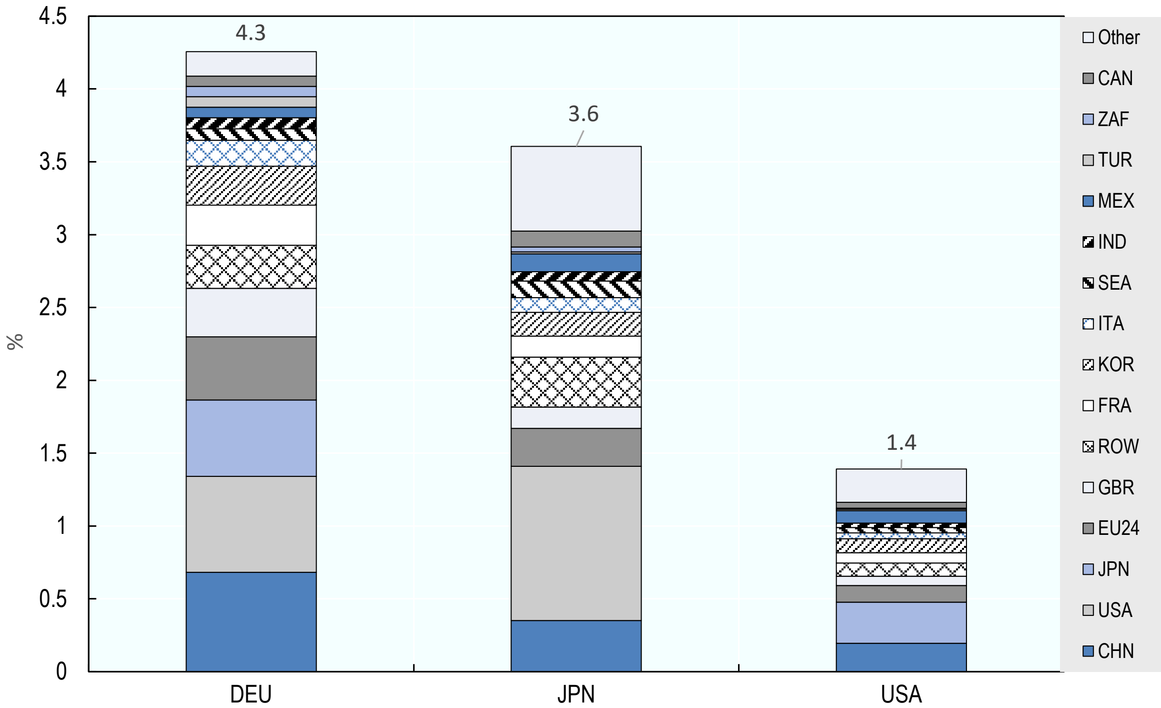
Panel B. Maximum % impact of all possible 1% shocks -immobile factors of production



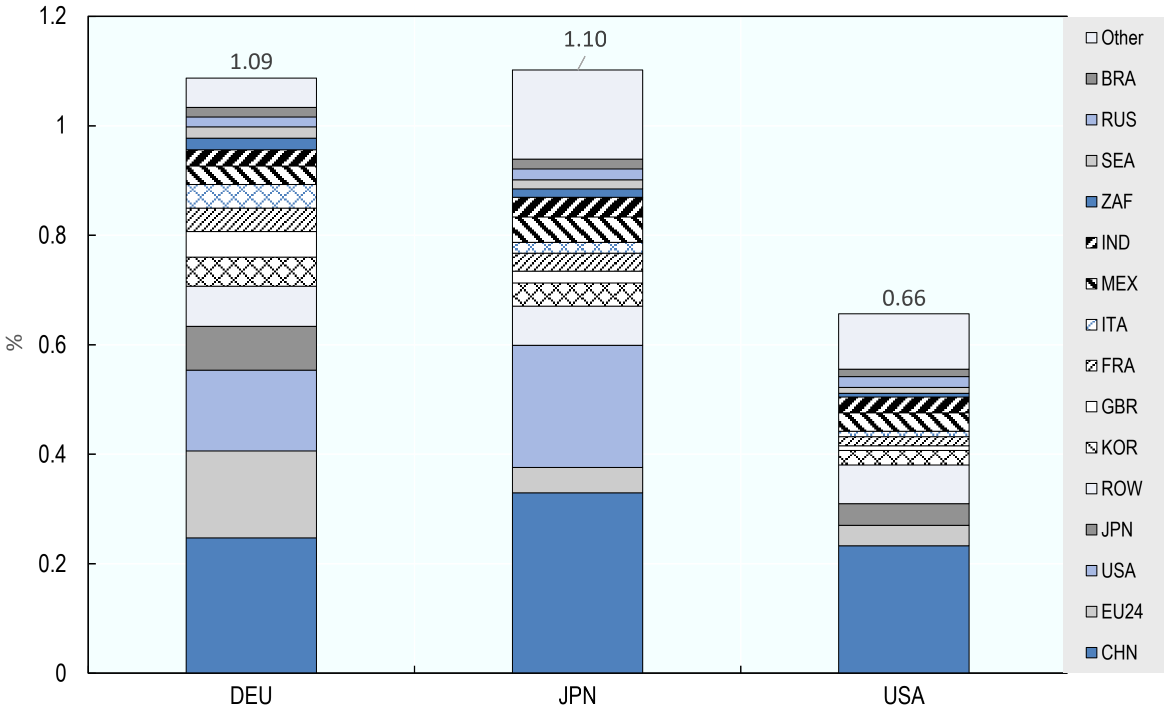
Source: OECD METRO model.

Figure A B.7. Decomposition of maximum exposures in *motor vehicles* products in Germany, Japan and the United Sates, by country origin of shocks

Panel A. Maximum % impact of all possible 1% shocks -mobile factors of production



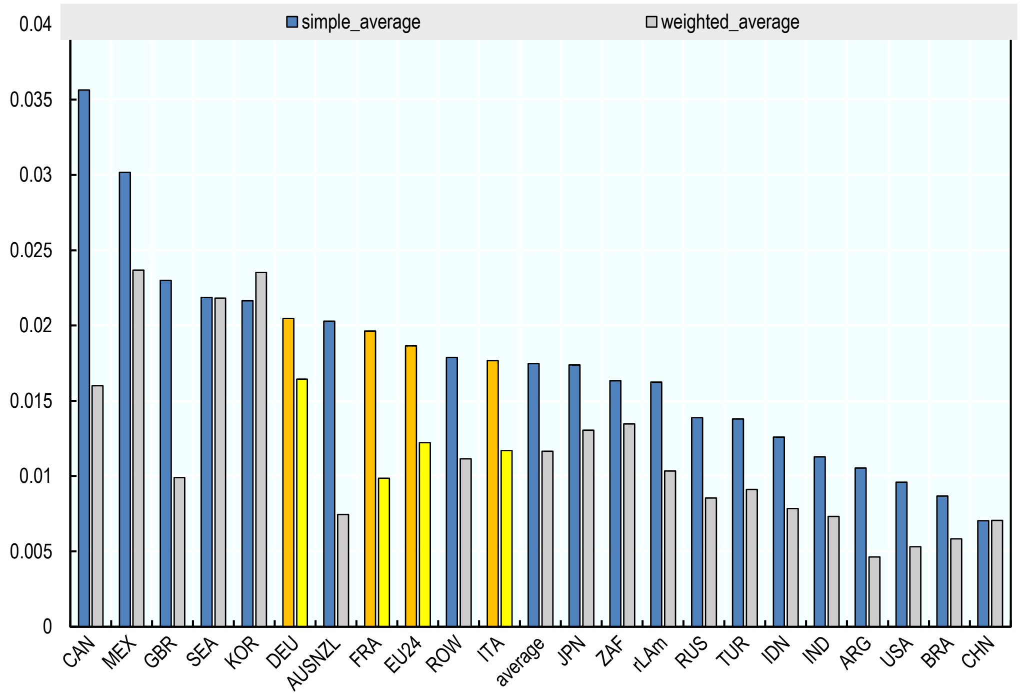
Panel B. Maximum % impact of all possible 1% shocks -immobile factors of production



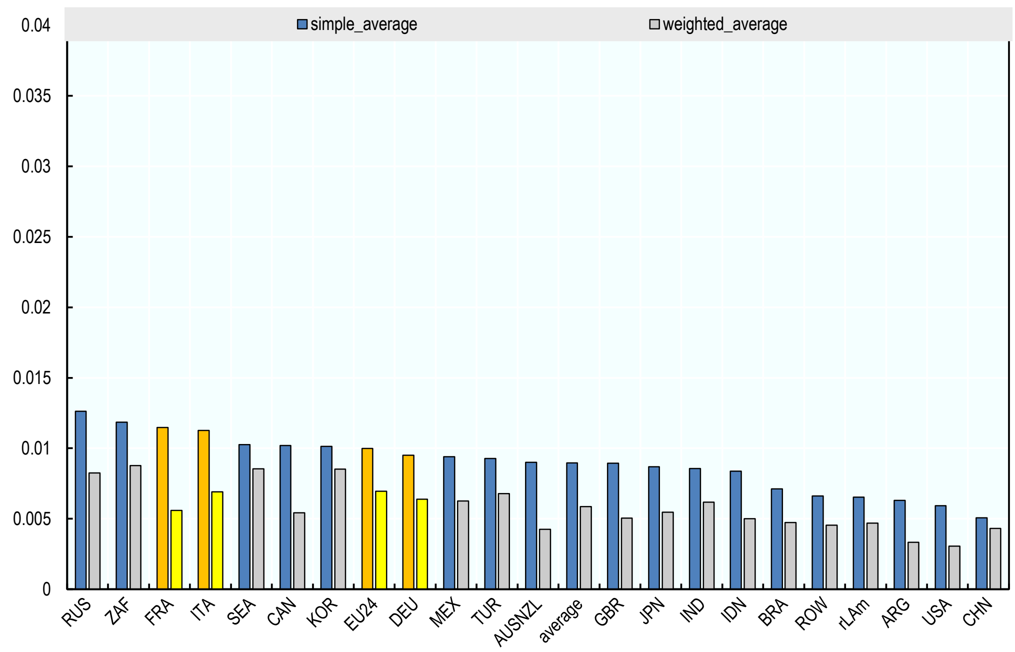
Source: OECD METRO model.

Figure A B.8. Typical exposure to GVC shocks across countries (intra-EU shocks excluded)

Panel A. Standard deviation of responses to shocks – mobile factors of production



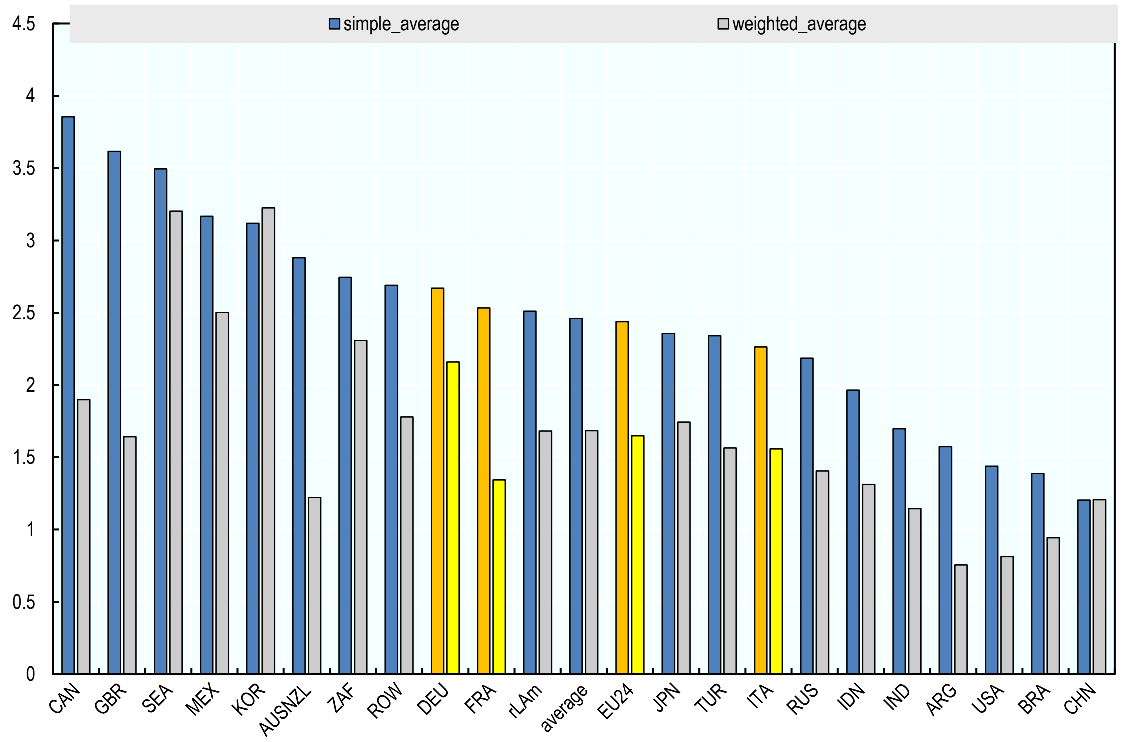
Panel B. Standard deviation of responses to shocks – immobile factors of production



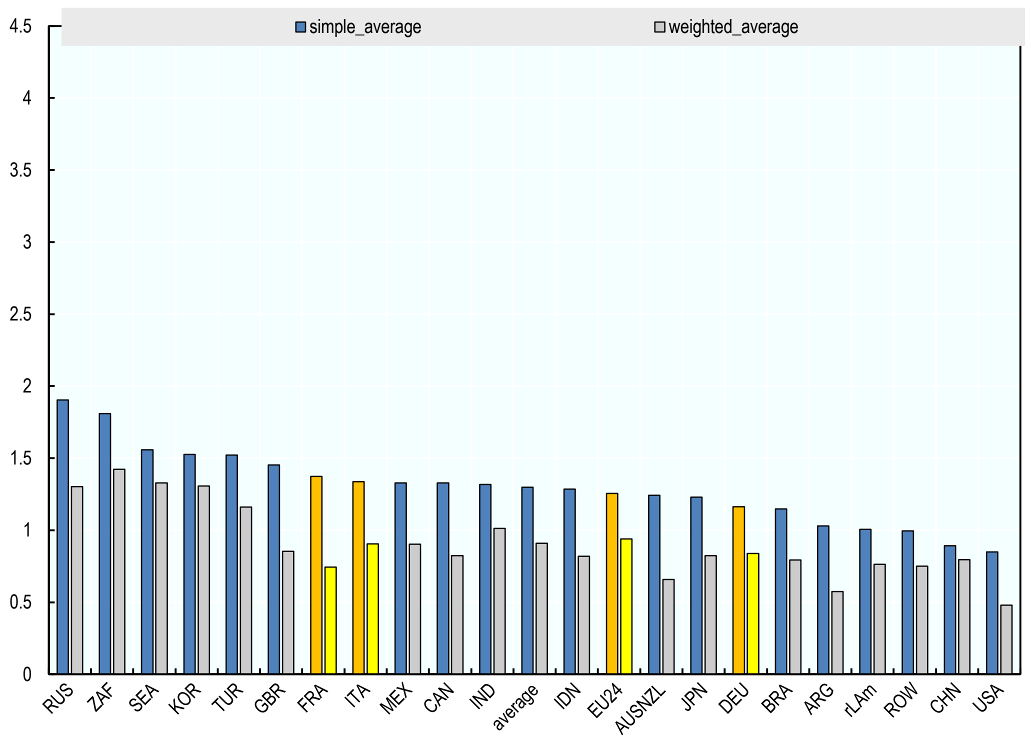
Source: OECD METRO model.

Figure A B.9 Maximum exposure to GVC shocks across countries (intra-EU shocks excluded)

Panel A. Standard deviation of responses to shocks – mobile factors of production



Panel B. Standard deviation of responses to shocks – immobile factors of production



Source: OECD METRO model.

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Comments are welcome and can be sent to tad.contact@oecd.org.