Covid-19 and industrial restructuring: what future for transnational value chains?

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Table of contents

Abstract

The economic and health crisis triggered by the Covid-19 pandemic leaves the European Union facing the steepest decline in production and employment since the Second World War, on top of economic fundamentals that are already fragile as a result of the disastrous effects of the double fall associated with the great financial crisis and the sovereign debt crisis.

This paper shows that, in the absence of an industrial policy aimed at changing the structure of the EU's productive system, the transformation of global demand currently taking place will mostly benefit the Asian economy with China increasingly assuming industrial supremacy to the detriment of the US. The EU, in its turn, is going to accumulate growing gaps in terms of productive capacity within different supply chains – with the partial exception of Germany.

In order to achieve a transition that is not only environmental but also social, a European industrial policy is needed for the creation and public management of at least four industrial sectors, broadly defined: semiconductors – whose production is triggered by final demand for an extremely broad range of commodities, in particular TLC devices and personal computers; hydrogen electrolysers, solar panels and wind turbines; TLC equipment such as personal computers, smartphones, tablets – and in general connectivity devices; and public transport equipment.

1. Introduction

Capitalist dynamics have always been characterised by spatial reconfigurations and reshuffles, necessary to circumvent obstacles to the extraction of surplus value and to overcome crises. So-called 'global capital' – and its spatial configuration – is thus constantly changing shape.

The most evident phenomenon of recent decades is undoubtedly the acceleration of the international division of labour, which has radically changed internal relations on the European continent, generating a clear division between the centre – lying at the head of the production chains – and the periphery. The central countries, especially Germany, have increasingly concentrated their control over the heads of these supply chains while, at the same time, progressively relocating the most labour-intensive phases of production to peripheral countries – particularly eastern Europe.

Technological change, new business models, the liberalisation of financial flows and institutional asymmetries have been the driving forces behind this change, aimed at removing all barriers to the freedom of capital itself to go in search of the best opportunities for profit.

In the past, the processes of decentralisation have been expressed both in the form of supply relationships with foreign firms – with forms of monopsony by the 'leaders' – and through the control of firms in particular through mergers and acquisitions but also by creating new firms.

The increasingly pervasive diffusion of the models of lean production, just in time and just in sequence has the common objective of cost reduction in logistics and warehousing through the meticulous synchronisation of all the phases of production. In the presence of an increasing geographic fragmentation of production chains, Industry 4.0 technologies – in particular the Internet of Things (IoT) and Big Data – respond to this need for synchronisation, making it possible to connect machines, workers and plants located even in different geographic areas. How much of an impact does the healthcare crisis have on this synchronisation and on transnational value chains (GVCs)?

If the great crisis of the last decade seemed epochal, the current one in fact promises to be even more profound as simultaneous lockdowns in several countries have certainly produced disruptions and bottlenecks in supply chains.

We speculate that this will represent a temporary setback, destined to be gradually reabsorbed as restrictions are loosened; however, it will trigger profound structural changes.

First, thanks to Industry 4.0 technologies, large multinationals are developing business continuity plans.

How will supply relationships change in the face of these? Greater use of just in time and just in sequence will, in order to avoid any new bottlenecks, render GVCs much more flexible, creating further competition between suppliers located in different places.

Second, given that the lockdowns imposed to counter the spread of the Covid-19 pandemic have also accelerated the adoption of 'agile working', which does not seem likely to go away, to what extent will 'collaborative working' methods and tools spread? What will be the consequences for relocation processes? What will be the impact on working conditions and gender inequality?

Third, health security will also require some changes in urban and suburban mobility.

All these changes will imply changes in the structure of final demand – for example, smart working will increase the demand for electronic devices and connectivity.

This paper aims at investigating the effects of these changes in the structure of final demand on gross production and hence on employment. It emerges that the lion's share will be taken by Asia (especially China) and, to a lesser extent, by Germany. The peripheral countries in the EU, on the other hand, will only marginally benefit from the massive investment plans put in place to bring about these structural changes. In order to achieve a transition that is not only environmental but also social – reducing unemployment and creating new, good jobs where needed – a European industrial policy is required for the creation and public management of at least four industrial sectors, broadly defined: semi-conductors; hydrogen electrolysers, solar panels and wind turbines; TLC equipment; and public transport equipment.

In particular the first of these – and their shortage – are at the centre of policy debate given their relevance to many manufacturing sectors – see section 2 below detailing the example of the automotive industry. In a nutshell, the debate revolves around one question: does the EU need a semiconductor industry or should it focus on design and resign itself to an unbridgeable structural gap?[1] It is important to stress that the relevance of the chip industry was not lost on European authorities even before the pandemic: at the beginning of November 2019, the European Commission published a report by a group of experts – the Strategic Forum for Important Projects of Common European Interest (2019) – to boost Europe's competitiveness and global leadership in six strategic and future-

1. See for example Mollet (2021) and Poitiers (2021).

oriented industrial sectors: connected, clean and autonomous vehicles; hydrogen technologies and systems; smart health; the industrial Internet of Things; the low-carbon industry; and cybersecurity. To a large extent, these are value chains involving a high use of semiconductors.

The report explicitly recognises that there are situations in which the market alone cannot deliver efficient investment outcomes. This clearly calls for industrial policies at European level, despite dominant policy thinking according to which the public sector should limit itself to providing the correct set of incentives for private companies. This is the so-called 'horizontal approach' to industrial policy, as adopted by the EU. Indeed, according to the Treaty on the Functioning of the European Union (European Union 2007; Art. 173), industrial policy is specifically aimed at: (1) 'speeding up the adjustment of industry to structural changes'; (2) 'encouraging an environment favourable to initiative and to the development of undertakings throughout the Union, particularly small and medium-sized undertakings'; (3) 'encouraging an environment favourable to cooperation between undertakings'; and (4) 'fostering better exploitation of the industrial potential of policies of innovation, research and technological development.'

Industrial policy of this kind merely seeks to provide economic incentives to private companies that retain full control over the management of their economic activity, with the obvious aim of profit maximisation. In contrast, industrial policy should promote a fully-fledged structural change in the economic system according to an idea of society to be realised. The very first aim of such a policy should be the creation of good employment, working and living conditions – not the intensification of global competition and the achievement of higher competitiveness by private enterprises.

Moreover, the Covid-19 crisis has shown all too well that 'the market' cannot coordinate automatically;[2] without careful planning, bottlenecks are bound to emerge and supplies risk being blocked while material shortages result. This is exactly what is happening not only with chips but also in other manufacturing sectors. For example the constraints on the supplies of polyethylene, polypropylene and monoethylene are affecting a wide range of industries using plastics made from these raw materials (see Vakil 2021). In fact, supply chains are now so branched and complex that they cannot be expected to coordinate *ex post; ex ante* planning is required. Supply chain management is one of the main challenges facing large multinational companies. It will also be necessary to provide for production capacity that exceeds ordinary needs in order to be able to cope with emergency periods such as the one we have just experienced. This necessarily reduces profit margins and is the exact opposite of lean production – the business model to which big companies have, in general, been committed.

Only public investment, coordinated at European level and implemented through publicly owned and managed enterprises, can overcome these shortage issues and distribute productive effort – and hence employment – across the continent

2. See for example Stiglitz (2021) and Williams (2020).

as a whole. Strategic autonomy surely also goes in the direction of partial de-globalisation, i.e. a reduction in trade – which should be considered an extremely effective way of reducing the emissions associated with intermediate deliveries.

A preliminary analysis of monthly trade flows[3] shows that intermediate trade collapsed in March 2020,[4] only to recover within a couple of months or so. In other words, after the hard lockdowns that physically stopped trade, the latter resumed without any particular disruption. Reshoring, despite extensive rhetoric on the subject, does not yet appear to be a particularly widespread phenomenon, as shown by a recent note by the Bank of Italy: 'The pandemic shock has renewed the debate on the possibility that the repatriation of productive activities previously located abroad (reshoring) is contributing to a broader process of de-globalisation. The results of the survey of industrial and service companies, conducted by the Bank of Italy between September and October 2020, suggest that, in line with what has been recorded in other advanced countries, Italy too is not experiencing widespread reshoring phenomena.'[5] This appears to be in line with what is happening at international level: the note by the Bank of Italy also cites a survey carried out by Allianz involving around 1200 multinationals according to which less than 15 per cent are considering the possibility of reshoring while about 30 per cent could relocate some plants in neighbouring countries (so-called nearshoring).

The data in the Bank of Italy survey, collected through interviews with companies, indicate that more than 60 per cent of companies with plants abroad had not reduced their international presence in the last three years and neither did they intend to reduce it in the future; while 78 per cent of companies with foreign suppliers did not intend to reduce their number. With regard to the closure of foreign plants, 5.7 per cent of companies stated that they would consider this strategy; however, only 1.9 per cent had carried out reshoring in the last three years. Reshoring, therefore, is an operation that must be specifically constructed through industrial policies aimed at rebuilding production cycles within the territory.

This does not mean that structural changes are not taking place; on the contrary, as we will see in the next section, they are taking place and are also quite advanced. What is triggering them, however, is not the objective impossibility of taking advantage of 'old' supply chains. The main determinant seems, at the moment, to be the strong change that is characterising the composition of global demand – and thus, in a chain reaction, the relative weight of the corresponding GVCs.

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3. See Methodology for details.

4. We examined the monthly trend of trade for 57 countries and 5279 commodities (HS classification, AG6). All graphs are available upon request.

5. 'Lo shock pandemico ha rinnovato il dibattito sulla possibilità che il rimpatrio di attività produttive prima localizzate all'estero (reshoring) stia contribuendo ad un più ampio processo di de-globalizzazione. I risultati del Sondaggio congiunturale sulle imprese industriali e dei servizi, condotto dalla Banca d'Italia tra settembre e ottobre del 2020, suggeriscono che, in linea con quanto registrato in altri paesi avanzati, anche in Italia non siano in atto diffusi fenomeni di reshoring.' (Mancini 2021). Translated from the original Italian by the authors.

Hence we are focused on the consequences of changes in the structure of final demand, particularly as regards those trends that seem to be long-term in nature and therefore destined to last. More specifically, we are concerned with personal computers and other devices necessary for remote schooling and working, including household appliances; on storage devices (servers) for big data; and on devices for the production of renewable energy, such as solar panels and wind turbines.

The paper is organised as follows. Section 2 provides an example of the effects of the chip shortage in the automotive sector. Section 3 and Appendix A explain our empirical strategy and its theoretical and analytical groundwork, while Section 4 shows the main results of the empirical analysis. Section 5 provides some concluding remarks.

2. Chip shortage: the case of the automotive industry

As an example of how strong the global impact of changed demand structures is, we can consider the example of what is happening in the automotive sector due to the chip shortage resulting from the strong increase in final demand for connectivity devices. The facts and figures below come from the daily newsletter of Automotive News and from Olivieri (2020).

It is clear that a major problem has affected the automotive industry due to the lack of chips which are increasingly required as new car models become more and more electrified and digitalised. There are more than 100 types of chips in cars, used for a variety of functions ranging from speed control to communications, power transmission to control systems, etc.

In December 2020, original equipment manufacturers and major suppliers raised the first alarms about the semiconductor shortage, announcing that it would have a major impact on planned vehicle production.

During the lockdowns, carmakers closed their factories and demand for cars fell but then recovered much faster than expected. The reduction in semiconductor orders was significant and so, when automotive demand picked up again, carmakers did not have the volumes of chips needed to cope with increased production volumes.

Growing demand for personal electronics products such as tablets, computers and smartphones has absorbed an increasing share of semiconductors, making them less available to the automotive industry. Companies such as Apple and Samsung increased their demand for chips during the lockdowns to produce their smartphones.

In addition, a fire at the Asahi Kansei Microdevices factory in southern Japan in October 2020 affected the supply chain.

Several major European car plants have had to reduce production volumes. VW, which said it had lost production of 100 000 cars, had reduced production volumes at its Wolfsburg and Emden plants and at a component plant in Brunswick, and also called in its main suppliers, Bosch and Continental, because they had allegedly ordered insufficient volumes of chips in the previous months. Ford (the Saarlouis plant, where the Focus is produced), Daimler (in the Bremen and Rastatt plants in Germany and at Kecskemet in Hungary) and Audi (workers put on short-time working at Ingolstadt and Neckarsulm) were also forced to cut production. BMW seems to have been less affected by this phenomenon, although it is worth mentioning that it had previously experienced a similar situation: in 2017 it sued Bosch when it was forced to halt production due to a bottleneck in an Italian company producing castings for Bosch.

The chip chain has a number of particularities, including product features.

Table 1 **Number of vehicles lost, current and expected**

	Announced	Projected
North America	239 000	402 000
Europe	210 000	520 000
China	128 000	247 000
Rest of Asia	105 000	192 000
Middle East/Africa	8 000	16 000

Source: Automotive News

The chips used in cars are different from those used in smartphones because they have to be more robust and have a high degree of reliability as the life of a car is longer. The development of a chip for a car can take up to five years while the production of a few batches of chips takes up to three months.

Thus, the chip supply chain has elements of fragility as we move from link to link. For example, one of the carmakers' first-tier suppliers is Continental, whose main chip suppliers are NXP, Infineon and Nvidia which – in turn – are supplied by a Taiwanese foundry called TSMC which is restricting its supplies.

Semiconductor manufacturers are not integrated and the production of electronic elements is spread across the world. Bosch in Reutlingen, for example, has its own semiconductor production facility and it is opening a second chip factory in Dresden but, like other manufacturers, procures standardised integrated switching circuits (Asics) and microcontrollers on the world market. The Dresden factory only came on stream in July, demonstrating how long it takes to add manufacturing capacity.

Autoforecast Solutions has estimated the impact on vehicle production globally as a result of these factors (see Table 1), with more than 705 000 vehicles being lost while the overall impact is expected to be 1.4 million vehicles.

The situation is just as worrying in the plastics sector, as can be seen from the warnings issued in January 2021 by the Polymers for Europe Alliance. Its website states that 'The European market for polymers has been under pressure for several months and the negative consequences of raw material shortages and price increases are seriously impacting the production of plastic products in the EU. Plastic converting companies all over Europe report difficulties in getting the necessary raw materials to keep their production running, and alarmingly low stocks'.

In fact demand for polymers had recovered in Europe in the second half of 2020 after a strong drop in production due to the Covid-19 pandemic and the lockdowns. There is a similarity with the automotive sector in this area: plastics converters have re-increased their production but the supply of raw materials has not been able to cope with this increase in demand.

The situation is particularly worrying for the supply of polyolefins and PVC. According again to the Polymers for Europe Alliance 'With some polymer supplies getting very tight, plastics converters have difficulties to purchase the needed raw materials at reasonable prices and passing on the large price increases to their customers. In addition, European producers have also been declaring increased numbers of Force Majeure cases in the past months'.

The situation is further aggravated by shortages in shipping containers and by a frost wave in Texas which brought petrochemicals to a standstill; but this was only one further cause of the shortage.

3. Methodology

The columns of matrix L[6] show the quantity of the inputs directly and indirectly needed in order to produce the output of each industry in each country:

$\mathbf{L} =$

	E,d	E,p	E,b	M,d	M,p	M,b	S,d	S,p	S,b
Ed	1.08	0.00	0.00	0.65	0.00	0.00	0.65	0.00	0.00
Ep	0.00	1.18	0.00	0.00	0.59	0.00	0.00	0.59	0.00
Em	0.49	0.53	1.89	0.43	0.44	0.18	0.43	0.63	0.18
Md	0.00	0.00	0.00	1.10	0.00	0.00	0.00	0.00	0.00
Mp	0.00	0.00	0.00	0.00	1.25	0.00	0.00	0.00	0.00
Mm	0.11	0.12	0.18	0.65	0.79	1.89	0.20	0.20	0.18
Sd	0.00	0.00	0.00	0.00	0.00	0.00	1.10	0.00	0.00
Sp	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.17	0.00
Sm	0.11	0.12	0.18	0.20	0.23	0.18	0.65	0.57	1.89

Table 2 **Three countries, three industries example**

		E			*M*			*S*				
		d	*p*	*b*	*d*	*p*	*b*	*d*	*p*	*b*	*d*	*g*
E	*d*	5	0	0	30	0	0	30	0	0	0	65
	p	0	10	0	0	20	0	0	30	0	5	65
	b	15	15	50	2	2	5	2	10	5	2	108
M	*d*	0	0	0	5	0	0	0	0	0	50	55
	p	0	0	0	0	10	0	0	0	0	40	50
	b	2	2	5	15	15	50	2	2	5	10	108
S	*d*	0	0	0	0	0	0	5	0	0	50	55
	p	0	0	0	0	0	0	0	10	0	60	70
	b	2	2	5	2	2	5	15	15	50	10	108

Source: Authors' elaborations based on Figaro (Eurostat) IO tables

6. For details of the input-output framework, see Appendix A.

Table 3 **Net and gross quantities before and after a 50% increase in demand for photovoltaic panels**

Country	Industry	d	$\tilde{d}$	q	$\tilde{q}$	$q^{(\%)}$	$\tilde{q}^{(\%)}$	$\Delta q^{(\%)}$
E	d	0	0	65	65	9,5	7,65	-1,85
	p	5	7,5	65	97,5	9,5	11,48	1,97
	b	2	2	108	136,95	15,79	16,12	0,33
M	d	50	50	55	55	8,04	6,47	-1,57
	p	40	60	50	75	7,31	8,83	1,52
	b	10	10	108	130,09	15,79	15,31	-0,48
S	d	50	50	55	55	8,04	6,47	-1,57
	p	60	90	70	105	10,23	12,36	2,12
	b	10	10	108	130,09	15,79	15,31	-0,48

Source: Authors' elaborations based on Figaro (Eurostat) IO tables

For instance, looking at the first column, we can see that, for each euro of output, industry d in Europe uses 80 cents of its own output and 49 cents of output from basic industry. In addition, it imports American and Asian basic industry output to the tune of 11 cents, respectively.[7] What happens if the world final demand for photovoltaic panels suddenly increases by 50 per cent? The new quantities $\tilde{g}$ will be given by $L\tilde{d}$. Net and gross quantities are summarised in Table 3.

As can be seen, the weight of the different industries and countries in gross production changes as a consequence of the change in final demand. Obviously, there is an increase in the weight of industry p in all countries and a reduction of that of other industries, with one exception: European basic industry becomes more important, being a supplier of the Asian panels industry. Clearly this is an oversimplified example, but it should clarify that a change in the structure of final demand can change the structure of international trade even if the techniques in use do not change at all.

The aim of this paper is precisely that of exploring the possible effects of demand shocks generated by Covid-19 and their transmission throughout the input-output network. In order to do so, we have to estimate the vector of additional final demand $\tilde{d}$. This implies choosing not only the sectors potentially affected by demand shocks but also the proportion of final output produced by each country.

The choice of the sectors on which to focus was simply dictated by an analysis of what has been happening globally which is at the forefront of current trends – the spread of distance learning and smart working; the sizable increase in the use of digital channels for social life and shopping; the unprecedented spread of supply chain management software capable of bypassing temporary bottlenecks, even by small and medium-sized enterprises; etc. We have chosen to focus above all on personal computers and related peripheral units: due to remote working and

7. Since Europe does not produce devices for final demand, this column does not actually define a GVC.

schooling, demand for these devices has boomed over the last year, a tendency which is here to stay, even if on a lower scale. Moreover the phenomenon – already in existence – of migrating enterprise data to the (public or private) cloud has accelerated, implying a sharp increase in the demand for storage units (such as servers). Spending more time at home and the increased focus on health and wellbeing have also increased the demand for household appliances, particularly for food preparation, cooking and storage. Finally Europe's recovery and resilience programmes do and will rely heavily on renewable energies: the production of solar panels and wind turbines is therefore set to increase to meet growing demand.

Table 4 lists final commodities and the corresponding Comtrade (HS – Harmonized System Codes 2017) and Figaro (Isic Rev. 4) sectors.

In order to estimate the vector of additional final demand for each selected commodity, we adopted the following procedure. For each commodity in our basket, we obtained from Comtrade 2020 total export data for all world countries. Countries not explicitly considered in the Figaro database have been correspondingly aggregated into 'Rest of the World'.

We then normalised this vector to 1, obtaining each country's participation in world exports.

Unfortunately we do not have gross production data with this same level of disaggregation so we have to use this vector as a proxy for world gross production of each commodity. This is therefore the resulting vector as $\tilde{d}$ which we are using as the final demand vector in our estimates.

In other words we are asking ourselves: for every euro of additional demand for this commodity, what is the value of total additional production and how is this distributed among the various countries?

4. Results

4.1 Personal computers

A commodity demand strongly stimulated by the pandemic crisis is that of personal computers and storage devices. These production chains have been significantly enhanced by Covid-19 given the exponential spread of smart working in the labour market and digital distance learning within the education system. If this trend were to be confirmed – perhaps with smaller numbers, but still significant – the demand for electronic devices would continue to be strong.

Table 4 **Commodities, HS commodity codes and corresponding MRIO industry**

Commodity	HS 2017	Isic Rev.4
Personal Computer	8471	C26
Refrigerators	8418	C27
Washing machines	8450	C27
Dishwashers	8422	C27
Microwave ovens	851650	C27
Ovens	851660	C27
Solar panels	8541	C27
Wind turbines	850231	C28
Trains	86	C30

Source: Authors' elaborations based on Figaro (Eurostat) IO tables

Figures 1 and 2 (p. 18-19) show the international implications of this demand growth, respectively in terms of the country and sectoral distribution of additional gross output.

China accounts for the lion's share of the increase in production considering both direct, indirect and total production (in all three cases, China is well above 40 per cent). From the point of view of direct production, China exceeds 40 per cent of gross additional production followed by Rest of the World with almost 20 per cent. To find the first European country, we have to go down to fifth place with Germany which has a share of less than 5 per cent. In addition to Germany, the top European countries, with figures well below those of China and Rest of the World, also include a number of 'satellites' of German industrial chains such as the Czech Republic, Poland and Hungary. But undoubtedly, in these cases, we are a long way from the numbers of German automotive chains as the gap from these countries to China and Rest of the World is significant.

Considering indirect impact (Figure 1), China reaches nearly 50 per cent of additional global production, while Rest of the World again follows (slightly more than 15 per cent) and then we find the US in a distant third place (about 5 per cent), preceding Korea (another Asian country), Germany and Japan (both below 5 per cent). These pictures signal an unprecedented amount of industrial power being concentrated in the far east. Even if the actual structure of multinational corporations makes it difficult to establish a clear connection between each manufacturing activity and a specific country, the productive capacity of the 'world's factory' cannot be underestimated.

Even in these strategic sectors, the EU needs to increase public investment significantly to attain digital independence. The amount of the resources provided together by the Multiannual Financial Framework (MFF) and the Next Generation EU fund (NGEU) – which will bring around €150 billion to digital transition in the next six years (2021-2026) – alongside national policies do not seem sufficient. Furthermore, any result will take a long time to materialise.

Looking at the sectoral impact (Figure 2), a positive demand increase for medical instruments and personal computers mainly affects the same sector in which these commodities are classified, including the Manufacture of computer, electronic and optical products. Beyond that, demand growth mostly reverberates in Wholesale trade (G), Manufacture of basic metals (C24) and Manufacture of electrical equipment (C27), among which the production of batteries assumes considerable importance.

The topic of batteries and energy accumulators, which can be used (obviously with different products and sizes) in both the ICT and medical industries (as well as in means of transport), cannot be dealt with here but it is worth emphasising that, in this sector too, Europe is lagging far behind other areas of the world, especially Asia.

The macro-phases in the battery cells supply chain can be highlighted as follows: raw materials; processed materials; components; cells; and assembly pack. The supply chain for the production of lithium batteries for vehicles is made up of several phases among which the primary is obviously the extraction of raw materials, followed by their processing, which involves dedicated industrial activity. The chemically active materials thus obtained are used in the production of components and cells (assembly cells) that make up the parts of the modules (assembly modules) that, in turn, constitute the complete battery (assembly pack). In each of these phases, Europe proves to be very weak (Gaddi and Garbellini 2021).

Figure 1 **Personal Computer. Additional quantities by country**

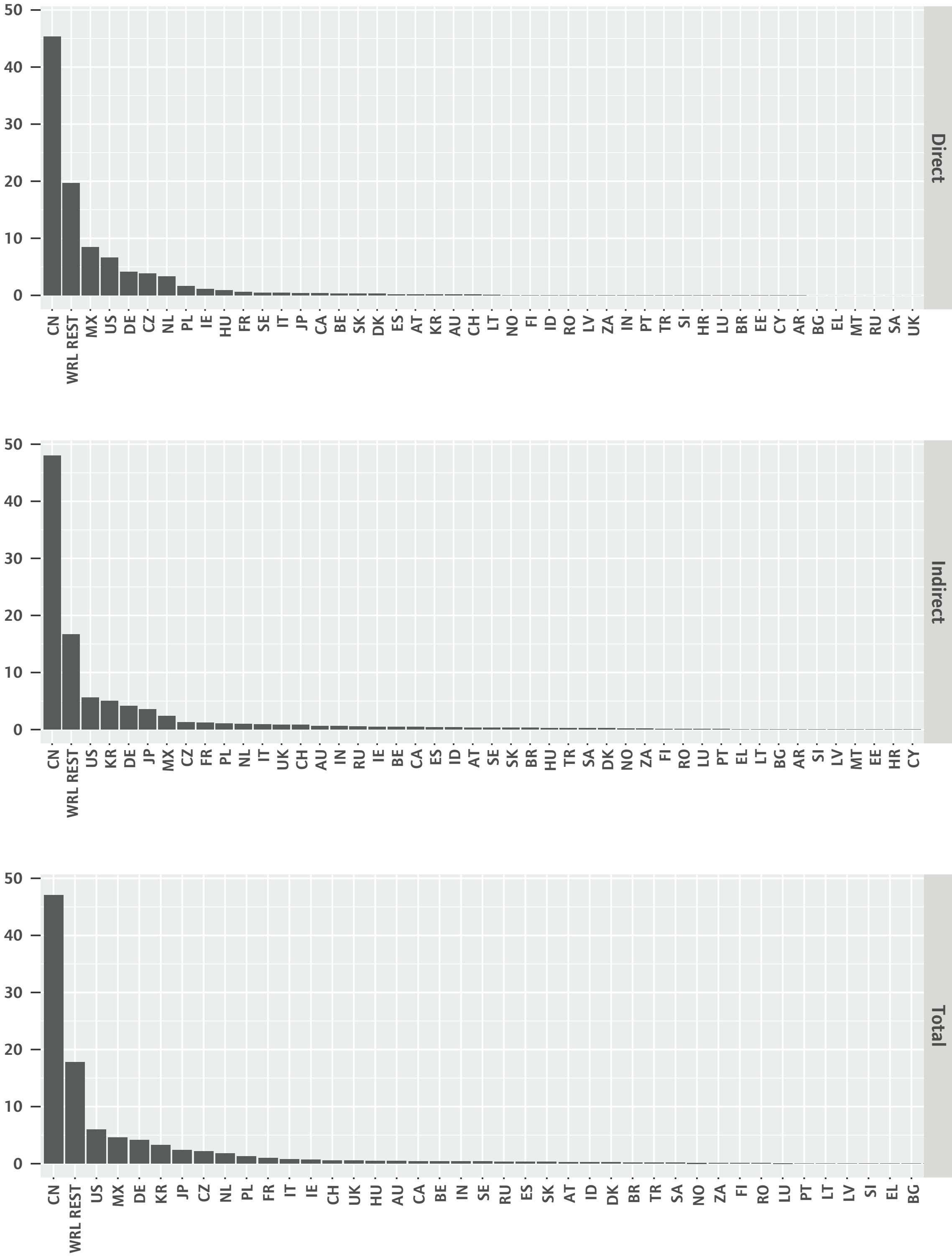
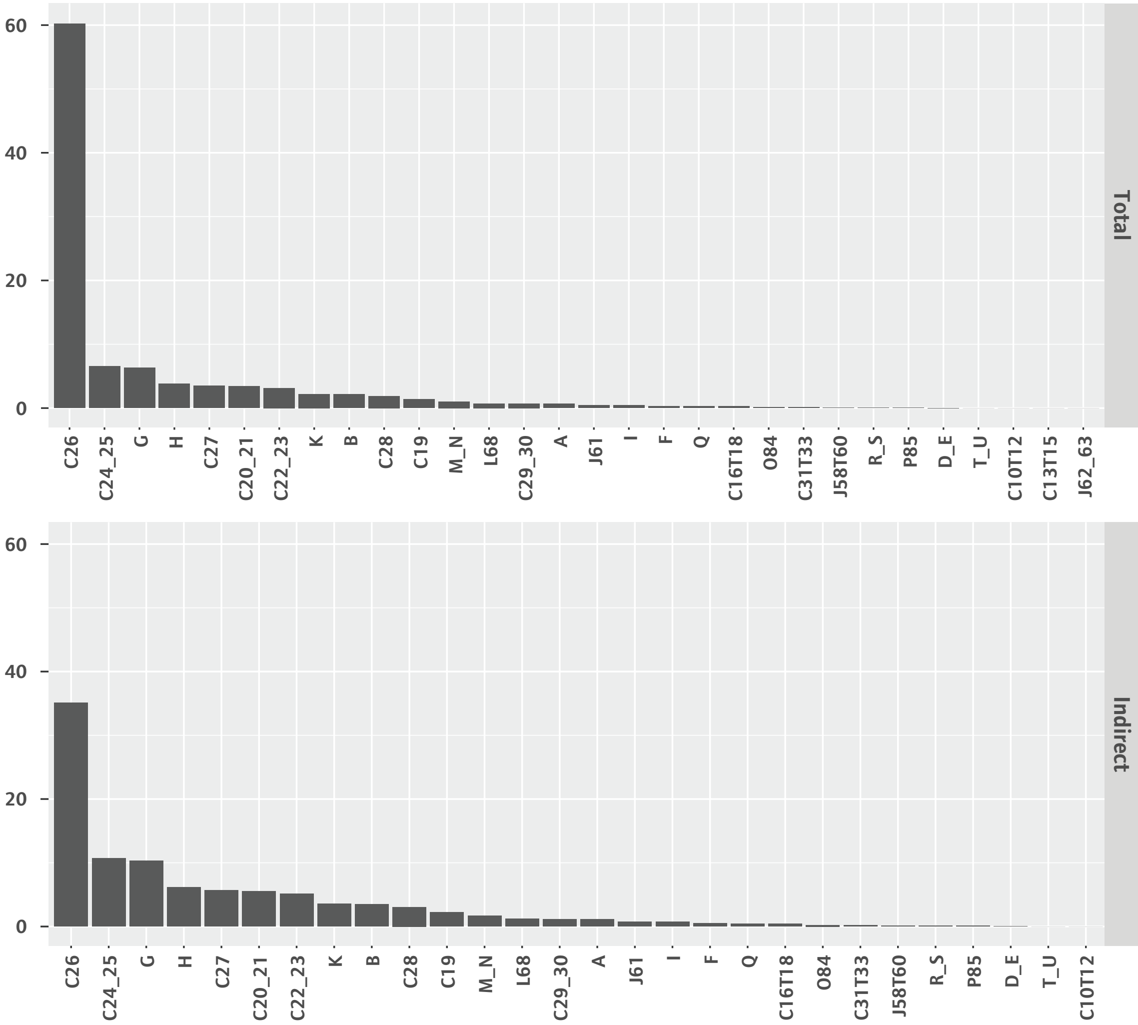


Figure 2 **Personal Computer. Additional quantities by industry**



Source: Authors' elaborations based on Figaro (Eurostat) IO tables

4.2 Trains and buses

The production of trains and buses is also interesting for at least two reasons.

On the one hand, the Covid-19 pandemic has highlighted the need to adapt public transport systems by increasing the number of vehicles and their safety; while, on the other, a significant proportion of public funding (both national and European) will be used in this sector to contribute to the green transition.

Many European countries have obsolete fleets of buses and trains which need to be renewed for both safety and environmental reasons. In addition the move towards new and less polluting forms of mobility could result in an increase in public transport services and therefore in the need for new vehicles.

In this sector too, although to a lesser extent than in the case of computers, it is China that occupies first place with percentages either close to (in the case of direct production) or above (in terms of indirect and total production) 30 per cent of the additional gross production expected. Europe seems to be in a better position but there are strong imbalances between member countries.

Germany, in fact, is in second place in both direct and indirect production (both more than 10 per cent) thanks, for example to Daimler's production of brands such as Mercedes, Setra and Evobus in the bus sector, and in the train sector thanks to the presence in Germany of Germany's Siemens but also of foreign groups such as Bombardier and Alstom. Germany is therefore not only the leading producer of cars but also of public transportation systems.

Focusing on direct production third, fourth and fifth places are occupied by USA, Mexico and Rest of the World, respectively, followed by other European countries such as Austria and Spain, and then by Poland and the Czech Republic. In Poland, bus production takes place in four plants, all of which are foreign-owned: two sites of Volkswagen (which produces the Scania, Man and Neoplan brands); one of Volvo; and one of Solaris which has been acquired by the Spanish company CAF. In the Czech Republic, buses are produced in two plants: one by the Italian company CNH-Iveco (created by the split within FCA Group); and the other by the Czech company Sor. Only one plant out of the six, therefore, is 'local' from the point of ownership; the others are owned by foreign groups.

In Italy, bus production has collapsed dramatically over the years due to: a) the closure of the Iveco plant which, however, only maintained production abroad, in France and the Czech Republic; and b) the progressive disengagement of the public company Breda which has led to a drastic reduction in production volumes; only recently, with the birth of Industria Italiana Autobus, has a project been defined which will partly contribute to a relaunching of the sector.

From the point of view of train construction, the situation in Europe also appears to be affected by the imbalances highlighted in the case of buses.

In Germany there are plants of all the major manufacturers: Alstom; Siemens; and Bombardier.

In addition to Germany, Siemens also has a significant presence in Austria which could explain the good positioning of this country. France is strong in train production thanks to the presence of Alstom (this country is the group headquarters) whose plants cover almost all types of vehicles (regional, metro, etc.).

There is no doubt that changes taking place in the train sector will have major consequences in Europe, such as the merger between Alstom and Bombardier which led the European Commission to impose certain conditions including the sale of some plants due to competition issues.

But, above all, it is the production strategies of these major players that could lead to further changes through a different distribution of their production at international level. For example, Alstom has decided to apply a strategy of locating an important part of its manufacturing production in so-called 'best cost countries', i.e. countries with low labour costs. In fact, Alstom has announced a reorganisation of its global train production that envisages 60 per cent of rolling stock being manufactured outside western Europe (in this sense, the Polish site is considered to be external); in 2014/15, this volume was 33 per cent. The 'best cost countries' strategy will encompass local suppliers: this means not only that the construction of trains will be located in countries with low labour costs but also parts and components.

With regard to European countries with low labour costs, we have previously highlighted the presence of countries such as Poland and the Czech Republic in the top places in the ranking: in these countries, in addition to foreign-owned bus plants, it is worth highlighting the presence of the production sites of the main players in the train sector, such as Alstom and Bombardier, which are the result of the location choices described above.

In terms of indirect production, the leading positions are essentially the same as those seen in the case of direct production: China (almost 40 per cent); Germany (over 10 per cent); and the USA (just under 10 per cent). Among European countries, Germany is again therefore in first place followed by Spain, France, Poland and Italy.

China, which ranks first in direct, indirect and total production, has large manufacturers of these vehicles; for example, in the train sector, the Chinese company CRRC, in addition to producing for the domestic market, is adopting a very aggressive strategy in European markets, taking part in many tenders for the construction of trains.

CRRC, but also Alstom, Bombardier and Siemens, are free to decide where to allocate the production they win through the public tenders issued by the various European authorities. This is a major problem for European industry. According to the EU's neoliberal approach, governments become customers and must procure public transport equipment through competitive procedures. In drawing up calls for tender, governments cannot include clauses guaranteeing that production takes place at least partially on national territory; EU procurement rules prohibit customers from disqualifying bidders that do not have local production assets. In this way, multinational companies can take part in the public tenders launched by European governments for the construction of public transport vehicles and, if they win the tender, can decide to locate production wherever they like – usually in low labour cost countries.

This legal framework can lead to a paradoxical outcome: a country can invest billions of euros in building new public transport vehicles without creating a single job domestically.

Figure 3 **Train and buses. Additional quantities by country**

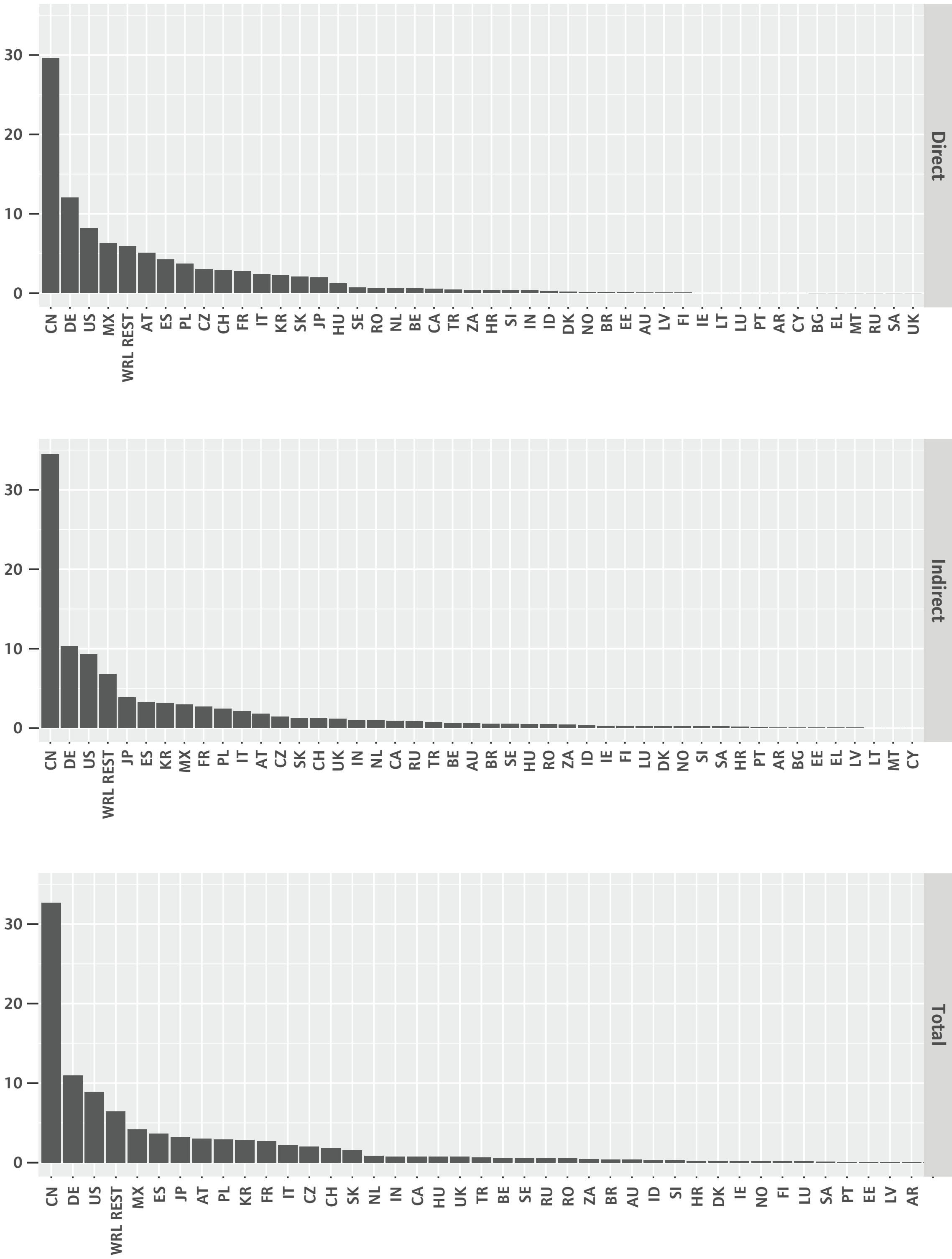
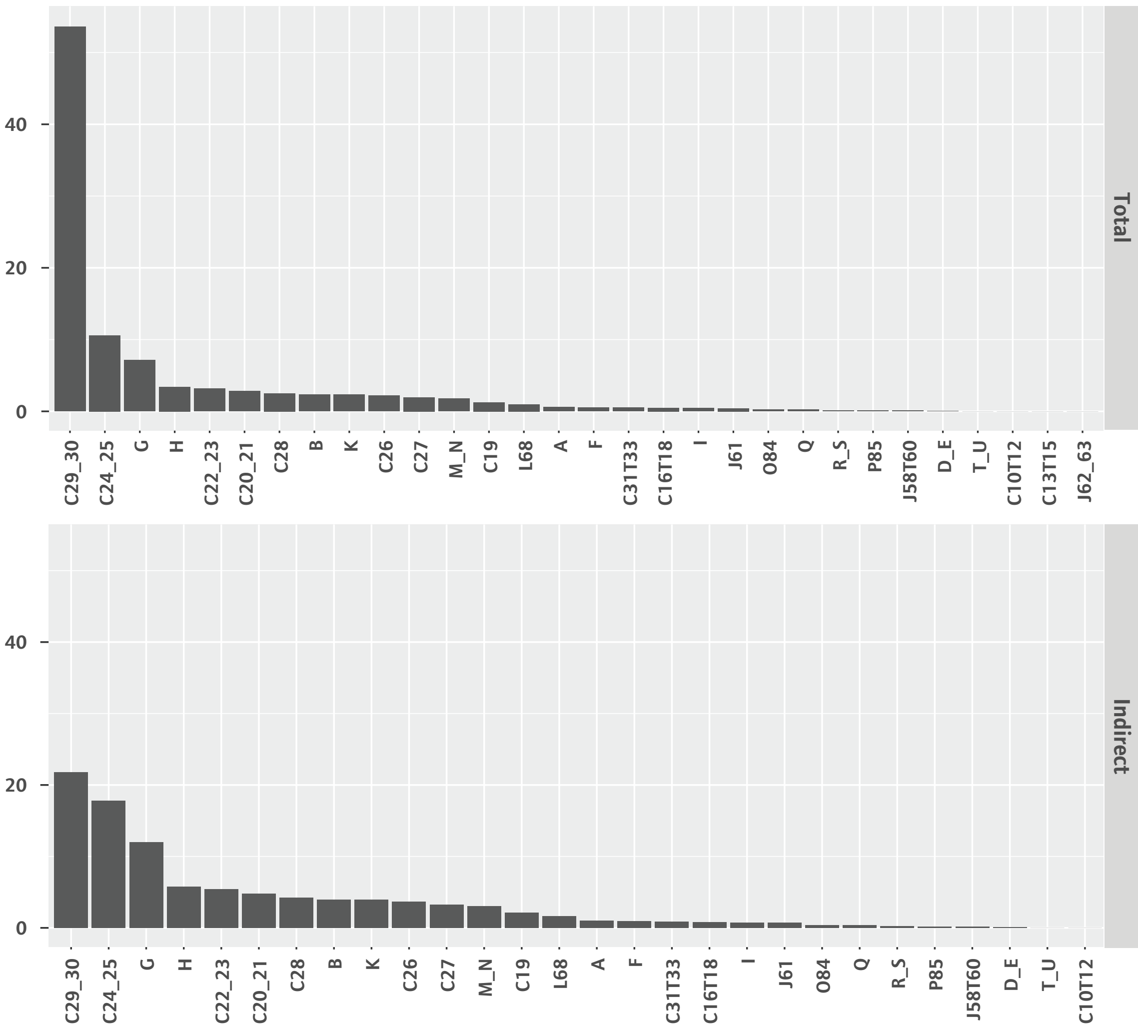


Figure 4 **Train and buses. Additional quantities by industry**



Source: Authors' elaborations based on Figaro (Eurostat) IO tables

4.3 Household appliances; solar panels

China also leads in this sector in terms of direct, indirect and total production. However, while direct production is below 30 per cent, its indirect production is almost 40 per cent.

The likely driver of this difference is components for household appliances – for example compressors for refrigerators and chillers.

The number of compressor manufacturers has halved in the last twenty years while, over the same period, large companies have emerged in China such as Jiaxipera (35 million pieces), GMCC (30 million), Donper (20 million) and Wanbao (15 million). The entire production of these companies is located in China. Furthermore, companies from other Asian countries, i.e. Japan and Korea, have also located large volumes of production in China: these include Samsung, LG and Panasonic. In addition, Japan's Nidec is another major company in the sector worldwide with around 35 million units and production located in Brazil, Slovakia and also China.

At EU level, only two European manufacturers are still active: ACC (Italy); and Secop which has production facilities in Slovakia – and in China.

Taking into account Chinese manufacturers and Asian and European manufacturers with plants in China, a total of at least 140 million compressors (out of a worldwide total of 170 million) are produced within Chinese borders. It should be borne in mind that Chinese demand for compressors is around 76 million units, i.e. around 58 per cent of the production located in China.

A similar situation exists for the production of electric motors for washing machines and dryers. It should be pointed out that Korean (Samsung and LG) and Chinese (Midea) manufacturers produce motors in-house; moreover, among the manufacturers of electric motors for washing machines and dryers, only Nidec and Askoll have plants in Europe and they make products for niche segments. The rest of the electric motors are made by Chinese manufacturers.

This is particularly important in the light of the supply chain debate: with the production of parts and components concentrated in Asia, Europe's industrial structure shows a further element of fragility.

Among European countries, Germany is in first place (and third in the overall ranking) in terms both of direct and indirect production (in both cases just over 5 per cent) while Italy is the second European country (fourth in the overall ranking in direct production and seventh in indirect production). It is surpassed by other Asian countries such as Japan and Korea in both direct and indirect production (in both cases less than 5 per cent).

Poland and Turkey are among the top ten countries in both direct and indirect production, probably due to the relocation of production from western European countries which have progressively shifted household appliance production volumes to these countries (and due also to Arcelik's presence in Turkey).

Italy's position in this sector seems to be entirely due to the production of household appliances and their parts as its production of solar panels is very low. More generally, the whole of Europe, with the partial exception of Germany, is seriously lagging behind in the production of photovoltaic panels. Installed photovoltaic capacity in Europe is expected to increase from 152 gigawatts to 442 by 2030 – with Italy, for example, rising from its current 21 gigawatts to over 52. The current market is dominated by Asian and Chinese producers with over 70 per cent of production while Europe is reduced to a share of 5 per cent in the production of panels (among the top ten world producers of panels seven are Chinese companies, one is South Korean, one is from the US and one is Canadian).

This lack of European production capacity is particularly relevant in view of the significant investments that will be made in the photovoltaic sector in the light of the environmental and energy policy guidelines decided by the EU under the Green Deal, the Recovery and Resilience Plan and the latest decisions on pollutant emissions.

To support the green transition, the European Commission has established that national plans must explain their consistency with the European Green Deal and with the objectives set out in 'Shaping Europe's Digital Future'. In particular they must highlight how they intend to support initiatives in full compliance with the EU's climate, environmental, social and digital priorities.[8]

Essentially the European Commission is requiring member states to ensure that at least 37 per cent of the resources made available through the Recovery Fund are used to achieve climate and environmental objectives.

Obviously not all the resources will be devoted to photovoltaics, as environmental and climate policies cover a very wide range of actions (transport, energy saving and efficiency, etc.). Undoubtedly, however, the share of resources will be important. Without their own photovoltaic panel industry, most European countries will use these resources to buy imported goods – in other words, they will create jobs elsewhere.

The sector most involved in indirect production is Manufacture of basic metals and fabricated metal products (C24 C25, with almost 25 per cent), followed by Manufacture of electrical equipment (C27, with over 10 per cent).

In addition to services such as Wholesale and retail trade (G) and Transport and storage (H), other industrial sectors have a share of more than 5 per cent: Manufacture of computer, electronic and optical products (C26); Manufacture of chemicals and chemical products (C20 C21); and Manufacture of rubber and plastic products and other non-metallic mineral products (C22 C23).

8. See for example: COM (2020) 562 final; European Council Conclusions 10-11 December 2020 EUCO 22/20 CO EUR 17 CONCL 8; Regulation (EU) 2021/783) of the European Parliament and of the Council of 29 April 2021 establishing a Programme for the Environment and Climate Action (LIFE) and repealing Regulation (EU) No 1293/2013 (OJ L 172, 17.5.2021, p. 53-78); Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law') (OJ L 243, 9.7.2021, p. 1); Proposal (14.7.2021 COM(2021) 551 final) of the European Commission amending Directive 2003/87/EC establishing a system for a greenhouse gas emission allowance trading within the Union, and Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and Regulation (EU) 2015/757.

Figure 5 **Household appliances; solar panels. Additional quantities by country**

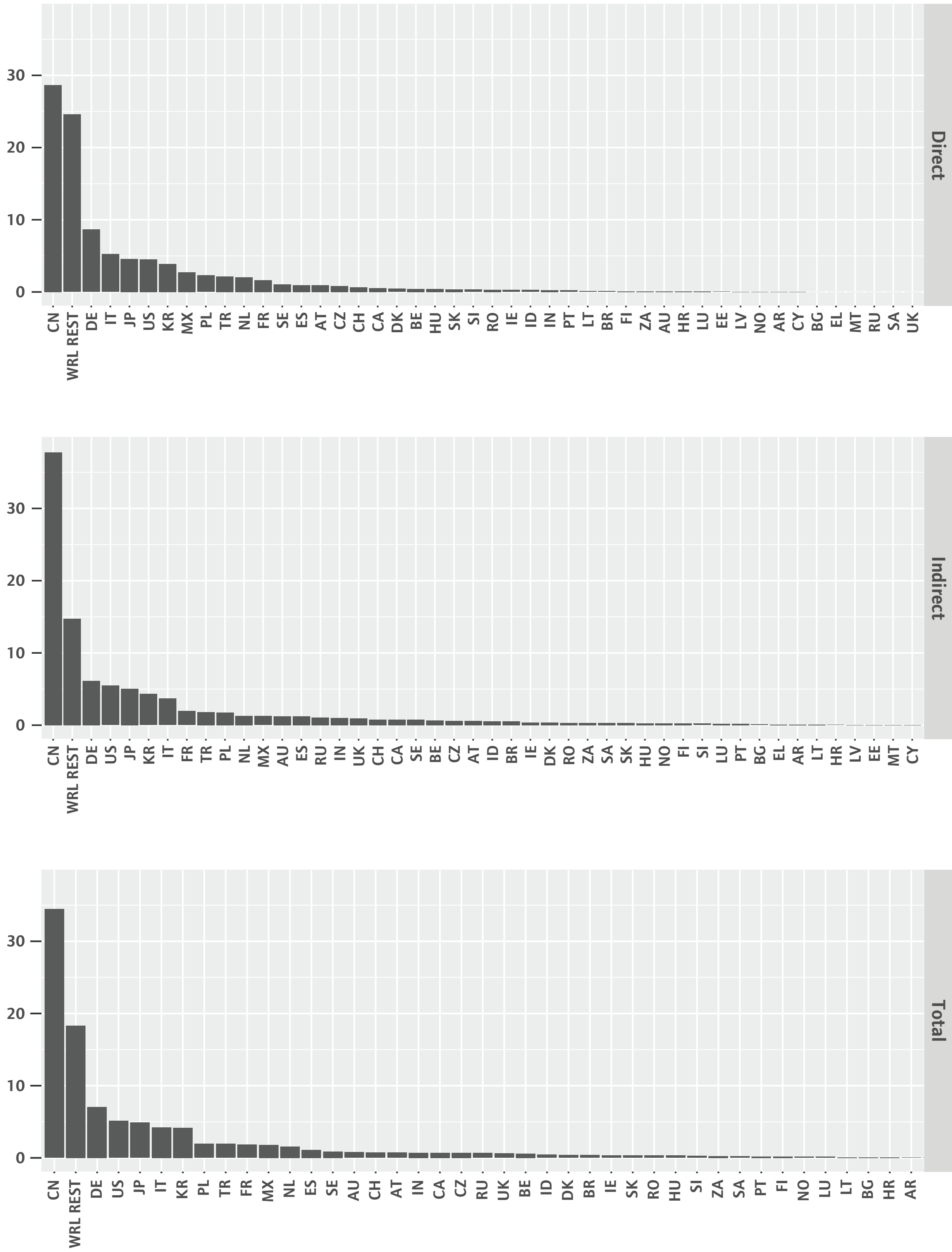
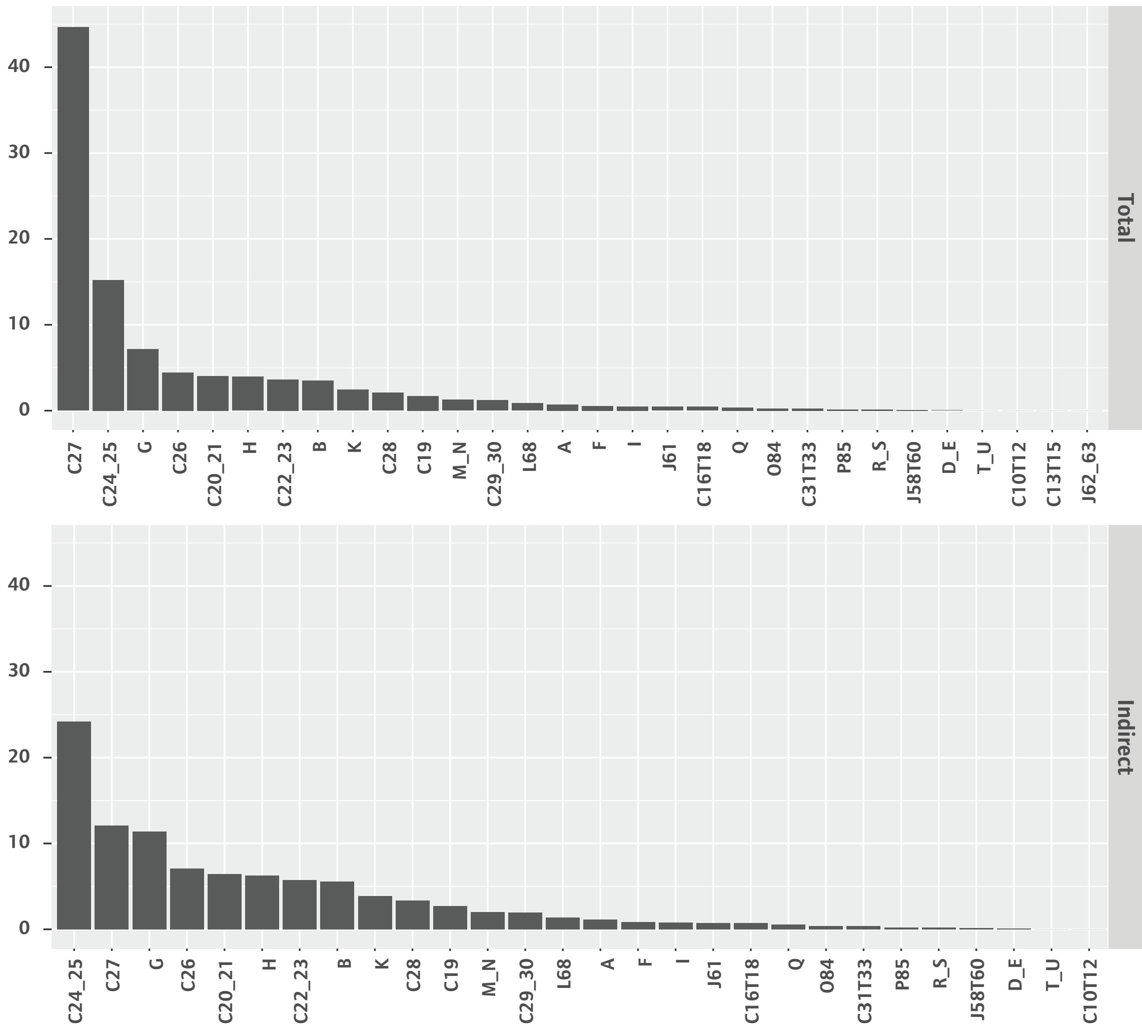


Figure 6 **Household appliances; solar panels. Additional quantities by industry**



Source: Authors' elaborations based on Figaro (Eurostat) IO tables

4.4 Wind turbines

Wind turbines are also one of the decisive technologies for changing the energy paradigm so their production is likely to receive a major boost in the coming years for the same reasons as those given for solar panels.

The wind power sector is the one that has seen the largest investments by the oil and gas majors – Total, Equinor, Shell, Repsol, etc. – in the period 2015-2020 at almost $25 billion and this is expected to receive a major boost in the next few years; see GWEC (2021).

There is a fairly significant difference between direct and indirect production.

Figure 7 **Wind turbines. Additional quantities by country**

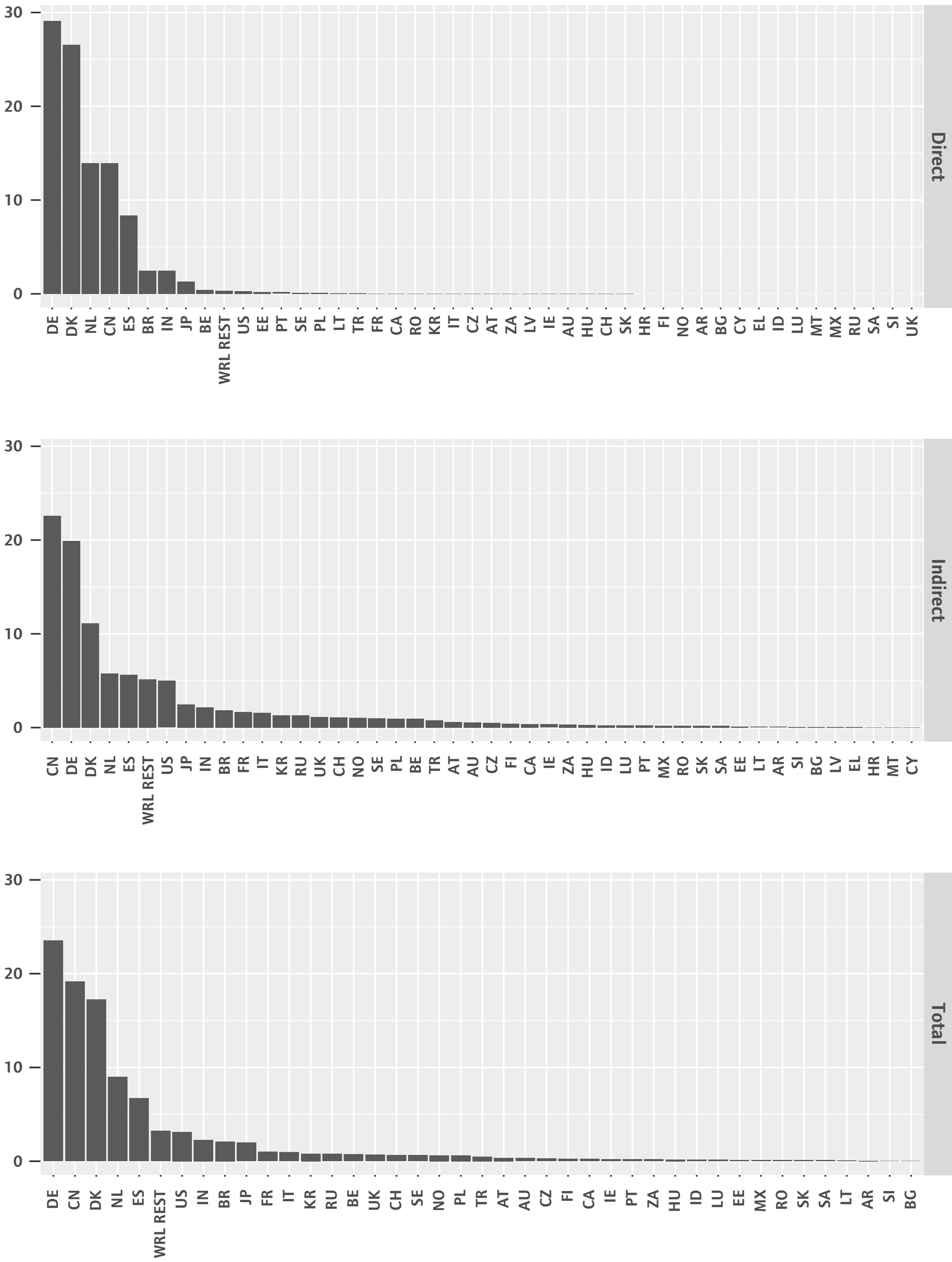
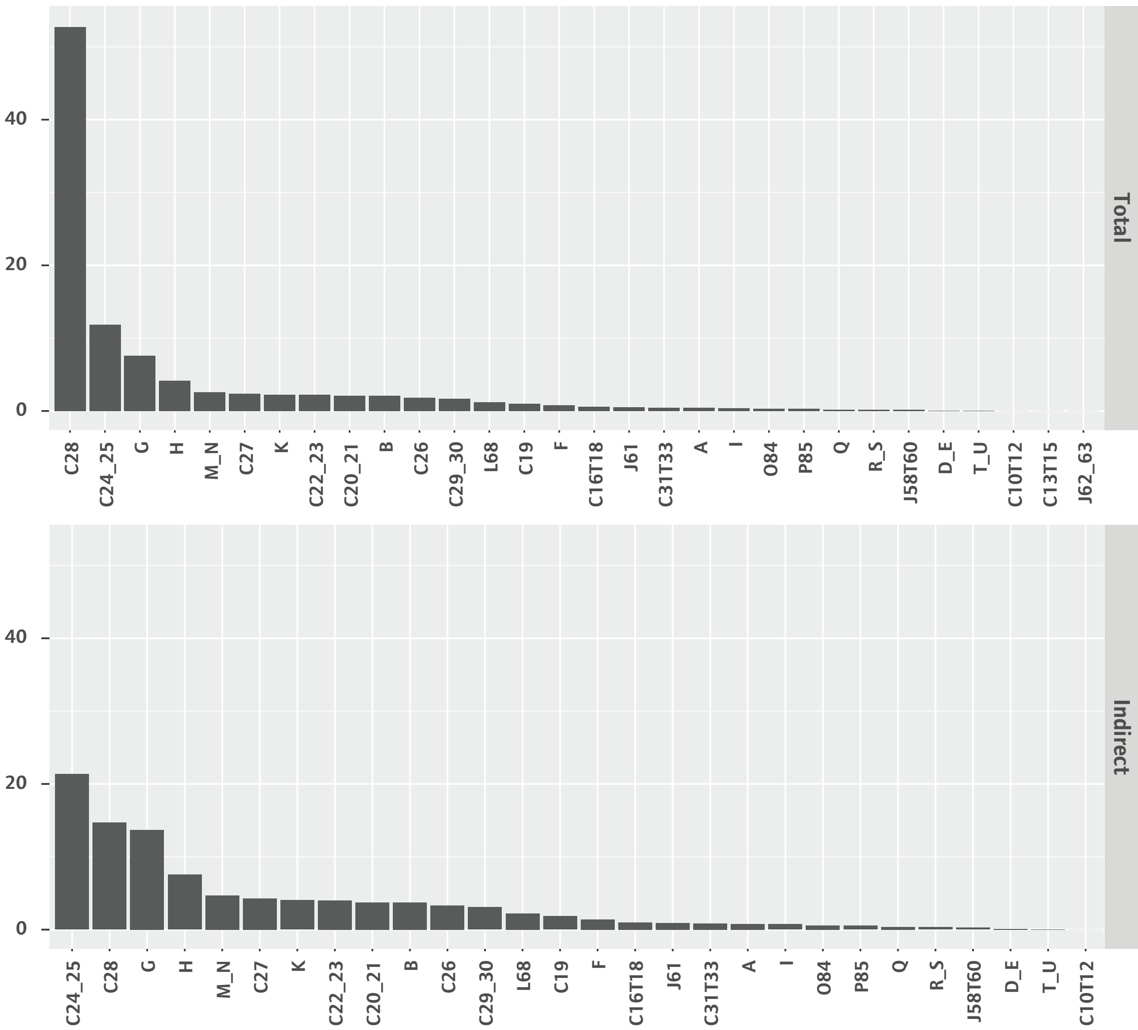


Figure 8 **Wind turbines. Additional quantities by industry**



Source: Authors' elaborations based on Figaro (Eurostat) IO tables

In terms of direct production, Germany is in first place with almost 30 per cent followed by Denmark (over 25 per cent), the Netherlands and China (both just under 15 per cent) while Spain is in fifth place (less than 10 per cent). Italy, on the other hand, has a very low share which puts it in 22nd place. On the other hand, from the point of view of indirect production, China is in first place with over 20 per cent followed by the European countries mentioned above: Germany; Denmark; Holland; and Spain. From the point of view of total production, therefore, Germany remains in first place with almost 25 per cent of the share of additional production followed by China (just under 20 per cent), Denmark (around 15 per cent), Holland and Spain (less than 10 per cent).

In this sector, Europe seems to be less dependent on other geographical areas, although we should not lose sight of China's first place in indirect production. This signals the presence of a supply chain that is also global in scale with the corollary risks that a possible interruption in supplies may entail.

From the point of view of the sectoral breakdown of indirect production (where China excels), in first place we find Manufacture of basic metals and fabricated metal products (C24 C25) with over 20 per cent followed by Manufacture of machinery and equipment n.e.c. (C28) with about 15 per cent. C28, on the other hand, leads in direct production with over 45 per cent.

These figures may highlight China's overcapacity in the steel sector which places it among the world's leading producers and suppliers.

The world's top 15 manufacturers include eight Chinese companies (Goldwind, Envision, Mingyan, etc.), the American giant General Electric, the Danish company Vestas (world leader in onshore installations), two German companies (Enercon and Senvion), two German-Spanish companies (Siemens-Gamesa and Nordex-Acciona) and one Japanese-Danish company (MHI-Vestas).[9]

Of course, the production capacities of each differ, just as the location of their plants does not necessarily correspond to the nationality of the company: the four German-owned companies thus justify Germany's first place in direct production while the size of Denmark's Vestas explains Denmark's excellent ranking.

9. See GWEC (2020).

5. Conclusions

The economic and health crisis triggered by the Covid-19 pandemic leaves the European Union in the face of the steepest decline in production and employment since the Second World War, on top of economic fundamentals that were already fragile as a result of the disastrous effects of the double fall associated with the great financial crisis and the sovereign debt crisis.

The management and the long-run impact of this crisis will greatly depend on the fiscal reaction that will be put in place by member state governments and by the European institutions within the problematic European fiscal regime, temporarily suspended by the activation of the general escape clause of the Stability and Growth Pact. Looking at the global fiscal response to the pandemic, direct budgetary support in 2020 amounted to €6 trillion (7.5 per cent of world GDP), with most support coming from the G20 countries (IMF 2021).

Unfortunately the support measures have been heterogeneous in size and the EU is characterised by a much smaller fiscal response than other international actors. In particular, as regards the Eurozone, the additional gross borrowing requirements associated with Covid-19 (6 per cent of GDP) was approximately equal to that recorded in response to the great financial crisis in 2008-2010. In relative terms, this figure was less than half the response among G7 (14 per cent of GDP) and OECD (12 per cent) countries (OECD 2021). In 2020, the United States adopted fiscal measures of 17 per cent of GDP and liquidity support for 2.4 per cent of GDP while a new $1.9 trillion (10 per cent of GDP) package is under discussion. Japan used a relatively large stimulus of 16 per cent of GDP in direct fiscal support and over 28 per cent of GDP in liquidity support. In the UK, fiscal measures and liquidity measures each amounted to over 16 per cent of GDP (European Commission 2021).

Within the EU, the fiscal response of each member country has been diverse and not always adequate while the common stimulus implemented through the NGEU fund is too small when diluted over the expected time frame and too slow in its actual realisation.

Ultimately the European fiscal reaction to the economic crisis triggered by Covid-19 has been insufficient.

In addition to the total amount of public intervention, the composition of that expenditure also matters. Our analysis in this paper provides an important contribution as it identifies the countries that are likely to benefit most from the transformation of global demand as a result of which some specific commodities are recording significant growth. Input-output analysis provides a contribution in this sense by allowing an in-depth scrutiny of the various sectoral requirements associated with different production processes considered at international level. Although it is too early to assess the structural change which has been triggered by the pandemic, and as a result of the acceleration of the digital and green transitions, the explosion of demand for such goods and the overall transformation of global demand do allow the identification of some interesting dynamics including the emergence of new strategic sectors. This has deep consequences with respect to the international structure of production and the various production chains.

The transformation of global demand will mostly benefit the Asian economy with China increasingly assuming industrial supremacy in these sectors to the detriment of the US. On the other side, the EU is generally accumulating growing gaps in terms of productive capacity within the different supply chains so – with the exception of Germany and some other specific cases – its ability to seize these industrial opportunities is relatively limited.

The sectoral snapshot of the complex reorganisation of international industrial processes shows that the EU is running into an ever-increasing industrial lag in terms of manufacturing capacity and global supply chains, even in strategic sectors. The elaboration of adequate public policies must necessarily consider these weaknesses. In other words, the EU clearly needs an industrial policy approach which is very different to that of recent decades and which is based on a return to long-term public planning. This means, above all, an adequate level of public investment to build a production capacity which is capable of guaranteeing the EU full autonomy in strategic sectors. It will therefore be critical properly to identify those sectors which extend not only to healthcare and digital equipment but also all of those which supply basic necessities (agri-food, distribution, essential infrastructure, energy). Self-sufficiency in essential goods should be one of the pillars of the new industrial policy and this entails a shortening and re-internalising of the supply chain in these sectors, rebalancing a European development model which has become excessively based on international trade.

Furthermore, to be effective, this new industrial approach has to be developed on a European scale if the gap with international competitors is to be bridged. Consequently European governance is more necessary than ever to ensure the various national industrial policies are consistent. From our point of view, an industrial change of this type requires an ad hoc European public institution with an adequate administrative structure and sufficient resources to put back on the table a planning and development horizon of at least twenty years.

The Multinational Annual Framework and the Next Generation EU fund represent respectively the ordinary and extraordinary fiscal tools that the EU has implemented to tackle the pandemic and even constitute a starting point from which we might adequately develop a real industrial planning strategy. Unfortunately, net of some positive update in the NGEU, the resources allocated to the strategic sectors are still insufficient and the overall strategic coherence of the set of individual national recovery and resilience plans is still to be verified.

The intense international economic interconnection that characterised neoliberal globalisation has, up to now, translated into long production chains but, for several years, the system has been in transformation, a process which the Covid-19 crisis has accelerated, triggering reorganisation on a macro-regional scale. The organisation of production and the international division of labour will undergo rapid evolution in the coming years. The EU urgently needs to return public planning and industrial policy to centre stage if it is to govern this process without passively surrendering to it.

In particular, as stated in the Introduction, there are four broad sectors which require public planning, investment and management. The aim must be to transform the structure of the European economy in a socially and environmentally sustainable direction. The environmental issue must be interpreted in a way that is consistent with trade unions' own class approach: consequently social production relations, and hence also technical relations, must be changed.

The gains from increased productivity should be distributed to workers while the productivity myth also needs to be debunked, at least to some extent. In general, productivity gains are ultimately increases in the rate of exploitation if they do not translate into a reduction in working time. Technological innovation should not be aimed at increasing productivity but at reducing fatigue, improving working conditions and reducing pollution and energy consumption. Productivity may well fall, but this would be a desirable process. However, this cannot happen in the presence of international competition and a management approach which is aimed exclusively at reducing unit costs.

That is why the optimal dimension for industrial policy is the European dimension: the EU is an economic area of the right size to be almost self-sufficient; for it to become so – and at the same time create a fairer and more inclusive society – its member countries need to show solidarity, not competition. Public enterprises are needed for an investment plan aimed at creating good jobs throughout the EU, especially where unemployment is highest.

We have discussed the semiconductors sector at length. The green transition would also require hydrogen electrolysers, solar panels and wind turbines which – as we have seen above – would mainly be imported from Asia. A European public company could play the dual role of research centre – in collaboration with the university system – and producer of these devices. Production units could then be located in each country or region in order to create jobs locally as well as to meet demand. Energy is a strategic sector not only in terms of the production system but also for security and its public management would therefore be highly desirable.

The same applies to the production of trains and buses: the pandemic has forced us to think about the mobility patterns of cities and connections with the suburbs. Public transport needs to be expanded to allow smooth travel without excessive crowding. In this context, a public company responsible for the construction and maintenance of the fleet could carefully monitor the vehicles in circulation and their obsolescence and allocate production to the various geographical areas.

Appendix A
Input-output framework

Input-output tables are an accounting device which can be used to quantify the material balance of an economic system in matrix terms and to derive synthetic measures at the level of single activities both at the industry level and at the subsystem one.

More specifically the material balance – i.e. the detailed account of commodities produced in a specific accounting period – can be written as:

$$\begin{cases} g_1 = x_{11} + x_{12} + \cdots + x_{1n} + d_1 = a_{11}g_1 + a_{12}g_2 + \cdots + a_{1n}g_n + d_1 \\ g_2 = x_{21} + x_{22} + \cdots + x_{2n} + d_2 = a_{21}g_1 + a_{22}g_2 + \cdots + a_{2n}g_n + d_1 \\ \vdots \\ g_1 = x_{n1} + x_{n2} + \cdots + x_{nn} + d_n = a_{n1}g_1 + a_{n2}g_2 + \cdots + a_{nn}g_n + d_1 \end{cases}$$

where g_i is industry i's gross (total) output, x_{ij} is the output of industry i purchased by industry j as an intermediate input, d_i is the output of industry i purchased by the final sector as final demand, and $a_{ij} = x_{ij} / g_j$ is the output of industry i purchased by industry j for each unit of its own gross output. In matrix terms:

$$\begin{bmatrix} g_1 \\ g_2 \\ \vdots \\ g_n \end{bmatrix} \equiv \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nn} \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{bmatrix} + \begin{bmatrix} d_1 \\ d_2 \\ \vdots \\ d_n \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \begin{bmatrix} g_1 \\ g_2 \\ \vdots \\ g_n \end{bmatrix} + \begin{bmatrix} d_1 \\ d_2 \\ \vdots \\ d_n \end{bmatrix}$$

or, more compactly:

$$\mathbf{g} \equiv \mathbf{Xe} + \mathbf{d} \equiv \mathbf{Ag} + \mathbf{d} \equiv \mathbf{Ag} + \mathbf{d}_D + \mathbf{d}_E$$

where g is the vector of gross output, X the inter-industry transactions matrix, $e = [1 \ldots 1]$ the sum vector, d net output, d_D domestic final demand, d_E exports, and $A = \hat{X}g{-1}$ the matrix of input coefficients.[10] Expression A.1 simply states that gross production in the reference year is given, for each activity, by the quantity of output sold as intermediate inputs for production – and stored in the inter-industry transactions matrix – plus the quantity sold to the domestic final sector as final demand (d_D) plus exports (d_E), the sum of these two components being total final demand or the net product of the economic system ($d \equiv dD + dE$).

10. Notice that bold letters indicate matrices (capital letters) and vectors. A vector with a hat denotes a diagonal matrix with the elements of the vector on its main diagonal. The symbol x(i) denotes a vector of zeros with the exception of the i-th element, given by the i-th element of vector x. Vectors are columns unless explicitly transposed.

Expression (A.1) can be re-written as:

$$\mathbf{g} = \mathbf{A}\mathbf{g} + \mathbf{d}$$
$$\mathbf{g} - \mathbf{A}\mathbf{g} = \mathbf{d}$$
$$(\mathbf{I} - \mathbf{A})\mathbf{g} = \mathbf{d}$$
$$\mathbf{g} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{d} = \mathbf{L}\mathbf{d}$$

where $L = (I - A)^{-1}$ is the so-called *Leontief inverse*.[11]

Matrix L is a linear operator which allows the reclassification of economic activities by shifting the unit of analysis from industry to subsystems[12] and vice versa. Such a reclassification implies a shift of the unit of analysis from the activities directly performed by one single industry to produce its gross output to the activities directly and indirectly performed by all industries for the production of each item of net output. In terms of labour, while an industry's employment (L_i) is given by the quantity of labour directly necessary for the production of its gross output, a subsystem's employment ($L^{(i}$, or vertically integrated labour) is the quantity of labour directly and indirectly necessary for the production of each item of final demand. In analytical terms, given the vector of direct labour requirements $a_n^T = [a_{ni}]$:[13]

$$l_i = a_{ni} g_i = \mathbf{a}_n^T \widehat{\mathbf{g}} \mathbf{e}_i$$
$$l^{(i)} = v_i d_i = \mathbf{a}_n^T \widehat{\mathbf{g}}^{(i)} = \mathbf{a}_n^T \mathbf{L} \mathbf{y}^{(i)} = \boldsymbol{\eta}^T \mathbf{y}^{(i)}$$

or, in matrix terms:

$$\mathbf{l} = \widehat{\mathbf{a}}_n \mathbf{g}$$
$$\mathbf{l}_v = \widehat{\boldsymbol{\eta}} \mathbf{y}$$

where L, i.e. total employment of the economic system, is given by:

$$L = \sum_{i=1}^{n} l_i = \sum_{i=1}^{n} l^{(i)} = \mathbf{e}^T \mathbf{l} = \mathbf{e}^T \mathbf{l}_v$$

When switching to a multi-regional framework such as Eurostat Figaro ('Full International and Global Accounts for Research in Input-Output Analysis') the logic of the model remains unchanged but the change in the geographical unit of analysis requires careful consideration of the redistribution of certain flows between final demand and circular flow.

In fact, the concept of GVC (global value chain) is nothing more than an extension of that of subsystems. Each GVC – or international vertically integrated sector (Pasinetti 1973, 1981, 1988) – is identified not only by the final good produced but also by the country where the last assembly takes place – the head of the chain. For example, the German and Italian automotive sectors are two distinct GVCs. Italian industries will participate in the German GVC (for example providing components for BMWs assembled in Germany) and vice versa.

11. See for example Leontief (1951).
12. See Sraffa (1960) and, for a formalisation, Pasinetti (1973).
13. Where a_{ni} is the quantity of labour directly required for the production of one unit of output in industry *i*.

All countries participate in GVCs, directly or indirectly. Continuing with the example above, Italian companies selling wipers directly to BMW go into direct participation; Portuguese companies selling wiper bodies to Italian ones, which will then be completed and sold to BMW, are an example of indirect participation.

Let us consider, to make things clear, a three countries (C_1, C_2, C_3), three commodities (*A, M, S*) example.

Figure A.9 shows the multi-regional input-output (MRIO) framework in the upper panel and the corresponding national tables in the bottom ones. The grey cells, i.e. diagonal inter-industry blocks, in the MRIO table correspond to national inter-industry transactions. Extra-diagonal blocks in the MRIO table (the pink cells) are dealt with as exports – i.e. as final demand, not part of the circular flow – in national tables. Hence in the latter case circularity breaks and extra-national links of GVCs cannot be traced back.

In the MRIO framework, final demand is a matrix where each row represents the country-industry combination delivering the item to final demand and each column represents the country of destination. Hence, each cell in the matrix identifies both the source of final demand – i.e. the recipients of final goods and services who are actually triggering the production of such item as well as the country from which they have come.

Whenever the structure of final demand – i.e. the relative weight of one or more item – changes, the whole structure of inter-industry flows changes as well, even if the technical coefficients (matrix *A* and hence matrix *L*) are unchanged. We can see this in our example. Figure A.10 shows the matrix of coefficients corresponding to our MRIO framework.

Let us assume that, total final demand being constant, the relative weight of the nine elements of the corresponding vector (stored in vector δ) change as in Figure A.10. Comparing X N with the inter-industry matrix in Figure A.9 should clarify the point at stake: a small variation in the relative weight of the different items of final demand is transmitted to the whole network.[14]

14. See Garbellini et al. (2014) for further details.

Figure 9 **The WIOD framework – a toy example**

	C_1^A	C_1^M	C_1^S	C_2^A	C_2^M	C_2^S	C_3^A	C_3^M	C_3^S	x	C_1^d	C_2^d	C_3^d	d	q
C_1^A	345	251	189	67	102	89	141	64	146	1394	96	85	120	301	1695
C_1^M	432	572	324	82	212	43	96	136	142	2039	102	98	115	315	2354
C_1^S	330	498	486	15	12	25	23	31	21	1441	99	74	112	285	1726
C_2^A	90	75	43	471	678	540	100	98	79	2174	101	142	236	479	2653
C_2^M	45	112	79	564	843	427	132	156	12	2370	123	165	248	536	2906
C_2^S	15	31	42	271	345	635	26	35	29	1429	96	112	154	362	1791
C_3^A	135	127	196	124	211	312	1250	987	841	4183	153	189	267	609	4792
C_3^M	99	134	76	132	144	213	2015	2475	1764	7052	256	843	1024	2123	9175
C_3^S	11	8	32	21	19	22	1864	2034	1896	5907	198	231	643	1072	6979
x	1502	1808	1467	1747	2566	2306	5647	6016	4930	27989	1224	1939	2919	6082	34071

C_1	A	M	S	x	f	Ex	d	g
A	345	251	189	785	96	814	910	1695
M	432	572	324	1328	102	924	1026	2354
S	330	498	486	1314	99	313	412	1726
x	1107	1321	999	3427	297	2051	2348	5775

C_2	A	M	S	x	f	Ex	d	g
A	471	678	540	1689	142	822	964	2653
M	564	843	427	1834	165	907	1072	2906
S	271	345	635	1251	112	428	540	1791
x	1306	1866	1602	4774	419	2157	2576	7350

C_3	A	M	S	x	f	Ex	d	g
A	1250	987	841	3078	267	1447	1714	4792
M	2015	2475	1764	6254	1024	1897	2921	9175
P	1864	2034	1896	5794	643	542	1185	6979
x	5129	5496	4501	15126	1934	3886	5820	20946

Source: Authors' elaborations based on Figaro (Eurostat) IO tables

Figure 10 **The MRIO framework – Matrix of inter-industry coefficients (A), old (_) and new (_N) vectors of final demand proportions, new vector of final demand (dN), the new vector of gross output (gN) and new matrix of inter-industry flows (XN)**

$$\mathbf{A} = \begin{bmatrix} 0.20 & 0.11 & 0.11 & 0.03 & 0.04 & 0.05 & 0.03 & 0.01 & 0.02 \\ 0.25 & 0.24 & 0.19 & 0.03 & 0.07 & 0.02 & 0.02 & 0.01 & 0.02 \\ 0.19 & 0.21 & 0.28 & 0.01 & 0.00 & 0.01 & 0.00 & 0.00 & 0.00 \\ 0.05 & 0.03 & 0.02 & 0.18 & 0.23 & 0.30 & 0.02 & 0.01 & 0.01 \\ 0.03 & 0.05 & 0.05 & 0.21 & 0.29 & 0.24 & 0.03 & 0.02 & 0.00 \\ 0.01 & 0.01 & 0.02 & 0.10 & 0.12 & 0.35 & 0.01 & 0.00 & 0.00 \\ 0.08 & 0.05 & 0.11 & 0.05 & 0.07 & 0.17 & 0.26 & 0.11 & 0.12 \\ 0.06 & 0.06 & 0.04 & 0.05 & 0.05 & 0.12 & 0.42 & 0.27 & 0.25 \\ 0.01 & 0.00 & 0.02 & 0.01 & 0.01 & 0.01 & 0.39 & 0.22 & 0.27 \end{bmatrix} \quad \boldsymbol{\delta} = \begin{bmatrix} 0.05 \\ 0.05 \\ 0.05 \\ 0.08 \\ 0.09 \\ 0.06 \\ 0.10 \\ 0.35 \\ 0.18 \end{bmatrix} \quad \boldsymbol{\delta}^N = \begin{bmatrix} 0.05 \\ 0.06 \\ 0.05 \\ 0.08 \\ 0.03 \\ 0.06 \\ 0.06 \\ 0.37 \\ 0.24 \end{bmatrix}$$

$$\mathbf{d}^N = \begin{bmatrix} 304.10 \\ 364.92 \\ 304.10 \\ 486.56 \\ 182.46 \\ 364.92 \\ 364.92 \\ 2250.34 \\ 1459.68 \end{bmatrix} \quad \mathbf{q}^N = \begin{bmatrix} 1636.855 \\ 2314.885 \\ 1714.582 \\ 2407.203 \\ 2258.476 \\ 1633.289 \\ 4369.011 \\ 9105.587 \\ 7252.117 \end{bmatrix} \quad \mathbf{X}^N = \begin{bmatrix} 333.17 & 246.83 & 187.75 & 60.79 & 79.27 & 81.16 & 128.55 & 63.52 & 151.71 \\ 417.18 & 562.50 & 321.86 & 74.40 & 164.76 & 39.21 & 87.53 & 134.97 & 147.56 \\ 318.68 & 489.72 & 482.78 & 13.61 & 9.33 & 22.80 & 20.97 & 30.77 & 21.82 \\ 86.91 & 73.75 & 42.72 & 427.36 & 526.93 & 492.45 & 91.17 & 97.26 & 82.09 \\ 43.46 & 110.14 & 78.48 & 511.75 & 655.16 & 389.40 & 120.35 & 154.82 & 12.47 \\ 14.49 & 30.48 & 41.72 & 245.89 & 268.13 & 579.08 & 23.70 & 34.74 & 30.13 \\ 130.37 & 124.89 & 194.70 & 112.51 & 163.98 & 284.53 & 1139.66 & 979.53 & 873.91 \\ 95.60 & 131.77 & 75.50 & 119.77 & 111.91 & 194.24 & 1837.14 & 2456.28 & 1833.03 \\ 10.62 & 7.87 & 31.79 & 19.05 & 14.77 & 20.06 & 1699.47 & 2018.61 & 1970.20 \end{bmatrix}$$

Source: Authors' elaborations based on Figaro (Eurostat) IO tables

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