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Cars and the Green Transition: Challenges and Opportunities for European Workers

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ABSTRACT: Reducing transport sector emissions is an important pillar of the green transition. However, the transition to electric vehicles (EV) portends major changes in vehicle manufacturing activity, on which many livelihoods in Europe depend. Using the heterogeneity across European countries in the speed of transition to EV production and variation in sectoral and regional exposure to the automotive sector, this paper offers early evidence of the labor market implications of the EV transition. Our results suggest that the transformation of the auto sector is already having an adverse impact on employment in the affected sectors and regions, which can be expected to grow at least in the near term. Many of the affected workers will be able to retire and our analysis suggests that those who will have to transition to new "greener" jobs have a fair chance to do so when compared to other workers in the manufacturing sector. Furthermore, we find evidence that active labor market policies, specifically training, can help to reduce the adjustment costs for the affected workers.

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WORKING PAPERS

Cars and the Green Transition: Challenges and Opportunities for European Workers

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Contents

I. Introduction

Vehicle manufacturing is undergoing its most profound transformation in history. A combination of rising demand for environmentally friendly vehicles and regulatory restrictions on emissions is steering the industry to produce zero-emission vehicles, especially vehicles powered by electricity (EVs). With their paint, frames, wheels, steering systems and interiors, EVs may look similar to traditional internal combustion engine vehicles (ICEVs). However, EVs need batteries, more wiring, and simpler electric motors, while ICEVs have more complex engines and need starters, fuel tanks, exhaust pipes and gears. As a result, the amount of labor input and components required to produce an EV could be significantly lower from the requirements of traditional ICEVs—a product with one of the longest and most complex supply chains. EVs will also transform energy markets: EVs will increase demand for electricity, requiring more power plants and higher-capacity transmission lines, and will reduce demand for gasoline and diesel refining and filling stations. As Daniel Yergin notes, "Today, the EV has become an existential question for the global automotive industry."[1] And the EU automotive industry and consumers have responded in an astounding manner over the past 5-6 years to stricter regulatory requirements, shifting consumer preferences and evolving financial incentives. Registrations of new EVs rose from 150 thousand to nearly 2 million in the EU from 2015 to 2022. And most major automakers are phasing out new investment in ICE and announcing new, ambitious, targets for EV production in European markets.

In the European Union, the transformation of the automotive sector could have profound effects on employment. More than 14½ million people (or 7 percent of the workforce) depend on the automotive sector directly or indirectly for their livelihood. In several countries, the automotive sector is macro-critical. For instance, in Germany—the largest car producer in Europe—the sector constitutes about 20 percent of manufacturing, 12 percent of employment, and 10 percent of goods exports. In some countries in Central, Eastern, and Southeastern Europe, such as the Czech Republic and the Slovak Republic, it has an even larger footprint. To the extent that a reduced demand for workers in the automotive sector because of the technological transformation is not offset by higher labor demand in other parts of the economy and/or the displaced auto workers cannot easily reallocate to growing economic sectors or regions, the switch to EV production may bring significant adjustment costs, at least in the short to medium run.

To minimize the potential loss from the automotive sector's transition, many countries around the world are implementing policies to retain or attract EV manufacturers and EV components' suppliers, such as the Chips Act in the EU, the Inflation Reduction Act (IRA) in the US, and Production Linked Incentives Schemes in India among others. The 2022 US IRA, in particular, will provide subsidies for EVs that meet certain "domestic content" requirements, including assembly in the United States, likely putting EU firms at a cost disadvantage and triggering firms to relocate their production to the United States. The EU is considering adopting a "Green Industrial Plan" in response, which could relax competition rules temporarily to allow for expanded subsidies to firms, in part to neutralize the production-shifting incentives provided by the IRA.

Even though there is considerable concern about the labor market implications of the automotive transition, we still know very little about how this process might play out. As argued by Galgóczi (2019) regarding the employment effects of the auto sector transformation, "the only certainty is that the changes will be massive and that almost all jobs in the industry will be affected to some extent." Studies to date have modelled the

[1] Yergin, Daniel "The New Map: Energy, Climate and the Clash of Nations." Chapter 37 The Electric Charge.

potential employment effects of the transition to EVs through bottom-up or top-down approaches (explained below). These studies have presented a wide range of estimates of the potential job losses (or gains) from the automotive sector transition to EVs depending on assumptions about EV demand, the distribution of production of car parts and their assembly across countries, and policy responses. However, to the best of our knowledge, there is no empirical evidence thus far on the impact of the switch to EV production on automotive sector workers and regional labor markets, due not least to the relative newness of electric vehicle production in Europe.

This paper aims to fill this gap in the literature by examining empirically the link between employment and production of EVs using data from the EU. To do so, we take advantage of the rapid expansion of EV production since 2017 and the cross-country heterogeneity in the speed of expansion across EU countries in two simple and complementary difference-in-difference exercises. First, using sectoral employment data, we demonstrate that employment in sectors exposed to ICEV grew significantly slower than in other sectors in EU countries where the share of EV exports in total car exports grew relatively faster over the 2015-19 period.[2] While this first piece of evidence is suggestive of the drag the switch to EV production might have on employment in ICE-related sectors, it does not speak to the overall labor market consequences of the automotive sector's transformation. If workers that might have been employed in the automotive sector – were it not for the switch to EV production – can easily find jobs in other sectors (for example, in the expanding industries that provide EV use infrastructure), then overall employment might not be adversely affected. Our second empirical exercise, however, suggests this was not the case. Using sub-regional employment data across EU countries, we show that regions within a country that were more exposed to car manufacturing through their employment mix prior to the EV take-off experienced relative employment losses (or smaller employment gains) in countries where EV exports grew relatively faster. Encouragingly, there is suggestive evidence that labor market policies were able to offset some of these effects. The link between the potential exposure to electric vehicle production and regional employment is significantly smaller in countries with higher spending on workers' training. Moreover, using detailed data from Germany, we find that given their skills, workers in the automotive sector have a fair chance to reallocate to "green" sectors, those with a high share of green occupations, which are more likely to expand during the green transition.

Taken together, the results in this paper suggest that the transformation of the automotive sector may have adverse employment consequences for workers in vehicle manufacturing and ICEV related sectors. However, strong active labor market policies, particularly those focused on workers training, could ease the process, and help speed the adjustment to the profound transformation of the automotive sector.

Our paper contributes to several strands of literature. First, it complements existing studies on the ramifications of the transformation of the car industry for workers by providing the first empirical estimates of the link between EV production and employment. Existing studies, mostly conducted by policy institutions, consulting firms and automotive industry associations, have generally followed two approaches. Using the bottom-up approach of counting the number of labor hours needed to produce each part of a vehicle and assemble them, Bauer et al. (2018) find that between 11 and 35 percent (23,000-97,000) fewer workers would be needed in 2030, depending on the share of EVs in yearly sales (25-80 percent). More optimistically, Küpper et al. (2020) find that EVs require about the same labor effort to produce as ICEVs, though labor-hours needed would be 7

[2] Our findings are robust to expanding the time horizon to include 2020. However, given the COVID-19 pandemic and the demand and supply shocks that were especially disruptive for the auto sector (see Boranova et al. 2022), our baseline specifications exclude the post-COVID-19 period.

percent lower if the production and assembly of battery cells is outsourced.[3] By contrast, various top-down approaches applied to select countries have estimated the effects of the EV transition on economic activity at the national level, which then affects firms' demand for workers. For the US, Barrett et al. (2021) propose scenarios for the sales of different types of vehicles and estimate 75,000 job losses over time if the US does not capture a greater share of global EV powertrains (electric motors and batteries).[4] Mönnig et al. (2019) analyze scenarios of vehicle sales in Germany and find that the EV transition ultimately leads to net job losses of 114,000 by 2035. Using an alternative model of economic activity, energy use and greenhouse gas emissions, European Climate Foundation (2017), on the other hand, predicts 145,000 more jobs in Germany by 2030 if new vehicle models are developed than in a scenario where old cars continue to be replaced by current, more fuel-efficient models, but new models are not developed, as gains from energy efficiency more than offsets higher costs of vehicle production.[5,6]

Our paper also contributes to the growing empirical literature on the effects of technological progress on labor market outcomes (see, for example, Graetz and Michaels, 2015, Gregory et al. 2016, Acemoglu and Restrepo, 2017, Autor and Salomons 2017, 2018, Edin et al. 2019, Grigoli, Kóczán, and Topalova, 2020). Relative to the existing studies, we focus on one particular sector, the automotive industry, which is not only macro-critical in many European countries but is also undergoing a major technology-enabled transformation. Finally, our study also adds to the growing literature on the real economic costs of the green transition and climate mitigation policies, and the potential employment shifts that these could imply (see, among others, IMF 2022a; IMF, 2022b; Bluedorn et al., 2022).[7]

The remainder of the paper is organized as follows. Section II documents key stylized facts about how the automotive sector is changing and the policy agenda that underpin this rapid transformation. Section III empirically estimates the potential labor market consequences of the transition by exploiting the heterogenous impact across sectors and across regions within Europe. Section IV focuses on the role of active labor market policies in this process. Section V examines the reallocation prospects of the workers at risk from the most-hit segments of the automotive sector, and Section VI concludes.

II. The Transition to EVs

The European automotive sector is in the midst of a historic transformation and its "future looks electric" (Delanote et al., 2022). Major automakers are phasing out ICE investments and announcing new targets for EV

[3] Other bottom-up studies include Spath et al. (2012), Bauer et al. (2020), NPM (2020), and Kuhlmann et al. (2021).

[4] Alternatively, job gains could reach 150,000 if the US captures the same market share as it has of ICEV powertrains (engine and auxiliary systems) and increases the share of domestically sold vehicles that are domestically produced from 50 to 60 percent.

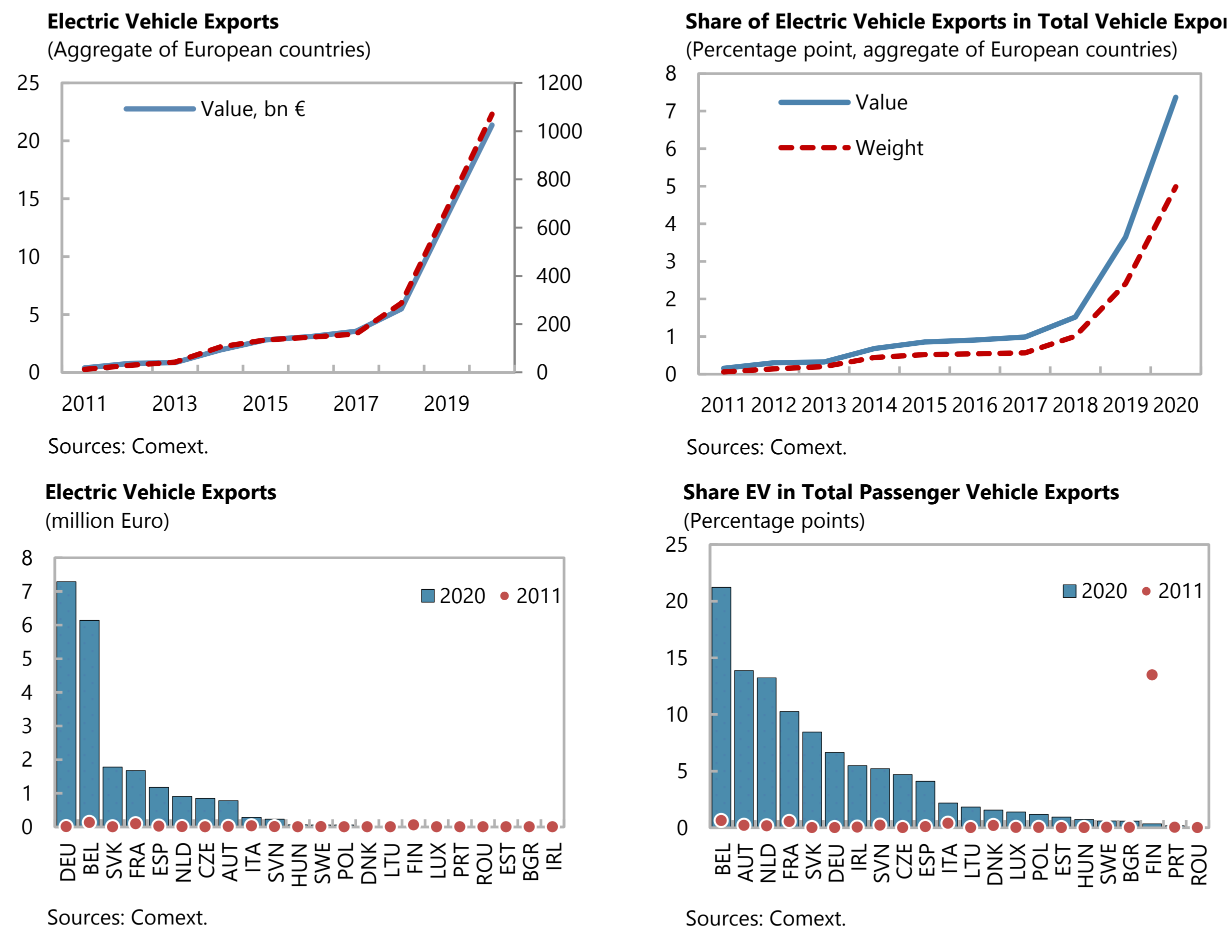
[5] Other top-down studies include von dem Bach et al (2020), Bernardt et al. (2022), Prandin et al. (2022), Mönnig et al. (2021), Schade et al. (2014), and TAB (2012).

[6] Other studies do not use economic models. CLEPA (2021) start from judgements about the likely development of production in different sectors and find that 275,000 jobs would be lost over time in Europe if tailpipe CO_2 emissions are 100 percent lower in 2035 and batteries are locally produced. Counting the jobs connected with ICEV technology, Falck et al. (2021) find that 613,000 jobs would be affected by the EV transition, though this number excludes jobs needed for EV production or infrastructure expansion.

[7] Academic studies of the auto industry have largely focused on estimating structural models of demand and supply and evaluating various trade policies (Feenstra, 1984, Feenstra 1988, Goldberg, 1995, Goldberg and Verboven, 2001). More recently, a growing literature examines the adoption of EVs by consumers and the effectiveness of incentives schemes (see, for example, Anghel, Auciello and Lacuesta, 2022, Azarafshar and Vermeulen, 2020, Clinton and Steinberg, 2019, Jenn et al., 2018, Mersky et al., 2016, Muehlegger and Rapson, 2022, Münzel et al., 2019, Wee et al., 2018).

production. Sales of EVs and hybrids exceeded 45 percent of automotive sales in 2022, from less than 2 percent in 2016, and production and exports of EVs have experienced unprecedented growth in recent years. European EV exports in 2020 more than quadrupled relative to 2015, amounting to 7 percent of total light-weight passenger car exports. In absolute value, Germany exported the most EVs among European countries in 2020. For countries like Belgium, Austria, and the Netherlands, EV contributed more than 10 percent of total car exports (Figure 1).

Figure 1. Exports of Electric Vehicles



Alongside the sharp increase in supply, demand for EVs and hybrids rose significantly, supported by sizable tax incentives and subsidies.[8] In Germany, the share of EV and hybrid cars accounted for almost half of total new car registrations in 2022—five times higher than that in 2019. In 2022, more than 94 percent of new car registrations in Norway were for EVs and hybrid cars. Sweden, the Netherlands, Finland, Iceland and Denmark also had new EV and hybrid registrations shares above 55 percent in 2022. While the EU and other advanced European countries are leaders in the adoption of EVs and hybrid vehicles, demand is growing at a fast pace in many large markets, including China, Korea and the US (Figure 2).

[8] Existing studies show that EV subsidies significantly increase the uptake of EVs (see, for example, Münzel et al., 2018, for a review of the literature and Muehlegger and Rapson, 2022, for evidence from the US).

Figure 2. New Registrations and Sales of Electric Vehicles

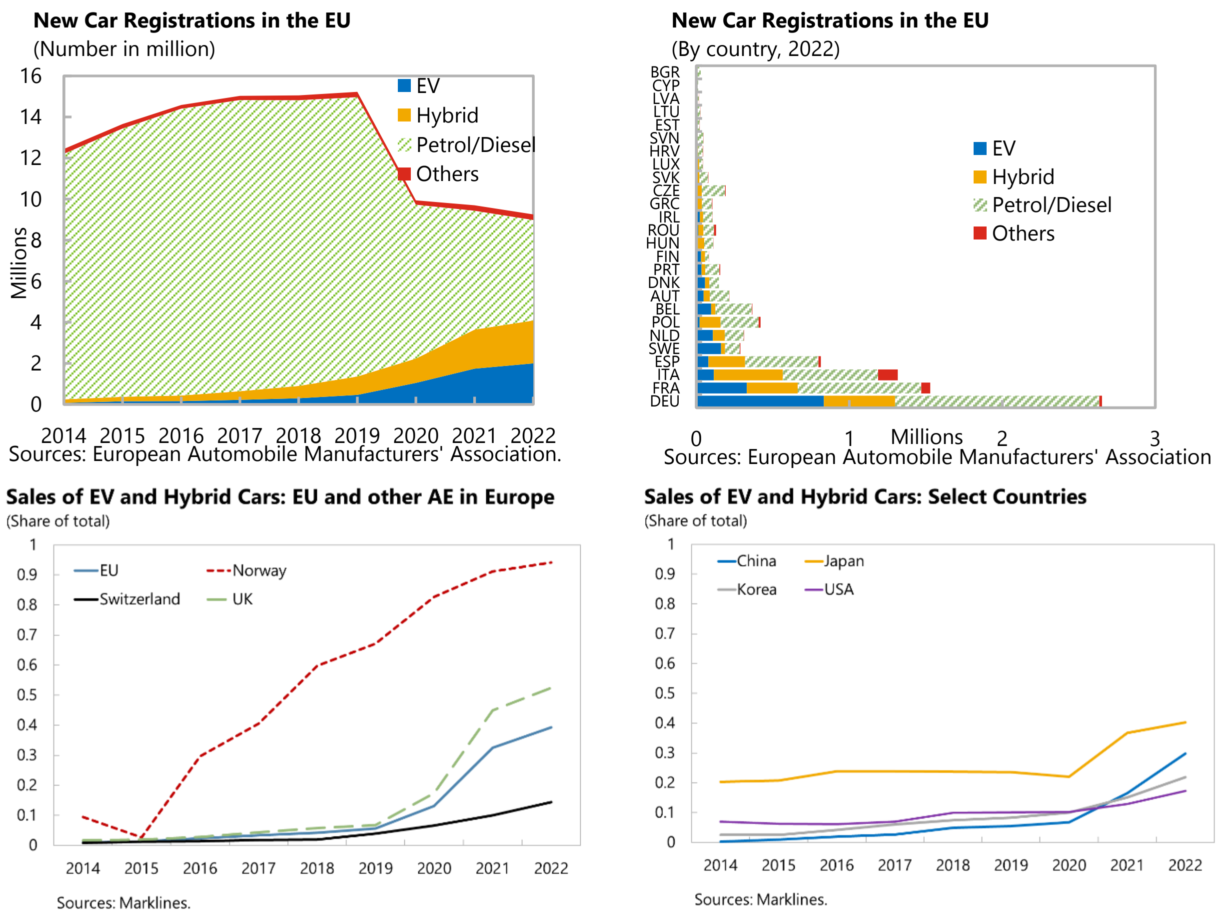
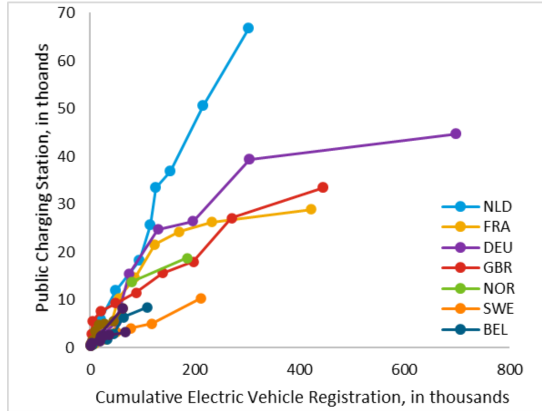


Figure 3. Electric Vehicle Charging Stations
(2012 to 2020)



Sources: European Alternative Fuels Observatory, European Environment Agency.

EV charging infrastructure is also growing at a fast pace in Europe. The expansion of charging stations outstripped the growth in EV registrations in 2010s, especially in the Netherlands, France, and Germany, though the pace has slowed in recent years. Countries also vary in the availability of chargers. The Netherlands has the highest charging station density, but most other countries are far behind (Figure 3).

The strong growth in electrification of the automotive sector in Europe was driven to a large extent by changes in the regulatory environment, as Europe has set out ambitious greenhouse gas (GHG) emissions reduction targets. Transport is an important sector for decarbonization. It accounts for one quarter of global (and EU) CO_2 emissions, with almost half of those coming from light duty vehicles.[9] The transition to battery-powered electric vehicles could play a major role in reducing emissions in the transport sector.[10] The full life-cycle GHG emissions of EVs are around half of those of ICEV, and the gap will likely widen with the increasing role of renewables in manufacturing and electricity generation. For examples, IEA (2022) estimates a further 25 percent potential reduction in GHG emissions from EVs with low-carbon electricity (IEA, 2022).

The EU currently aims for its fleet of cars to achieve 95 grams and light commercial vehicles ('vans') 147 grams of CO_2 per kilometer (EU Regulation 2019/631). These targets apply to the average tailpipe emissions of all cars and vans registered for the first time in the EU each year. To achieve these targets, binding requirements are set on each manufacturer according to the physical weight of their vehicles. Manufacturers of heavier vehicles, like BMW and Daimler, face lower requirements than the EU-wide target, and makers of lighter vehicles, like Fiat and Renault, face stricter requirements, such that the targets are achieved on average across all manufacturers.[11] If a manufacturer exceeds its emissions requirement in a given year, the manufacturer is liable to pay a fine for each gram per kilometer in excess of its requirement.[12] These EU targets are set to strengthen over time. By 2025, cars and vans should emit no more than 81 and 125 grams of CO_2 per kilometer, respectively, and by 2030, these targets drop further to 59 and 101 grams of CO_2 per kilometer.

[9] Studies also estimate that the combustion of fossil fuels in transport contributes to about 242,000 premature deaths each year worldwide (Chambliss et al., 2014).

[10] The difficulty of decarbonizing heavy trucks, shipping and airlines puts extra burden on decarbonizing light duty passenger vehicles.

[11] There are at least two material exemptions in the regulation that make it easier for manufacturers to comply with. First, different manufacturers can pool their emissions, effectively being regulated as one entity. Second, the regulation offers manufacturers additional incentives to sell zero- and low-emissions vehicles (those emitting 50 grams or less of carbon dioxide per kilometer). These incentives, available until 2022, allow manufacturers to count such vehicles more than once in the calculation of their emissions.

[12] Currently, the fine is set at €95 for each gram per kilometer more than the requirement. For example, if the emissions of a vehicle exceed its target by 10 grams per kilometer, and 100,000 vehicles of the manufacturer were registered in the EU that year, the manufacturer must pay a penalty of €95 million. As of 2021, the emissions requirements are based on the worldwide harmonized light vehicles test procedure (WLTP). To prevent cheating on emissions tests, the regulations require further collection of emissions data from vehicles' on-board monitoring systems, in real time or during vehicle servicing.

Under the European Green Deal, the EU has committed to reduce emissions by 55 percent of 1990 levels by 2030, and 100 percent by 2050. Towards achieving these goals, the proposed Fit for 55 package of revisions to EU's climate, energy and transport-related legislation envisages that all new cars and vans sold in the EU from 2035 onward should be zero-emission vehicles. The Fit for 55 proposals also require member states to install publicly accessible infrastructure for the recharging and refueling of low-emissions vehicles.[13] Individual countries are also setting their own deadlines for banning the sale or registration of new ICE vehicles, with European countries extending the ban to plug-in hybrids (Figure 4).

Figure 4. Countries in Europe with Official Targets for a 100 Percent Phase Out of ICE Vehicle Sales

(Announced phase-out year and country)

	Austria		
	Denmark*		
	Greece		
	Iceland*		
	Netherlands*		France
Norway	Slovenia	United Kingdom	Spain
2025	2030	2035	2040

Sources: International Council on Clean Transportation (ICCT).
Note: Includes countries that have set targets to only allow the sale or registration of new battery EVs or fuel cell vehicles (FCEVs) through February 2023. Vehicles considered are passenger cars and vans/light trucks. * indicates that only passenger cars are covered in the country's targets.

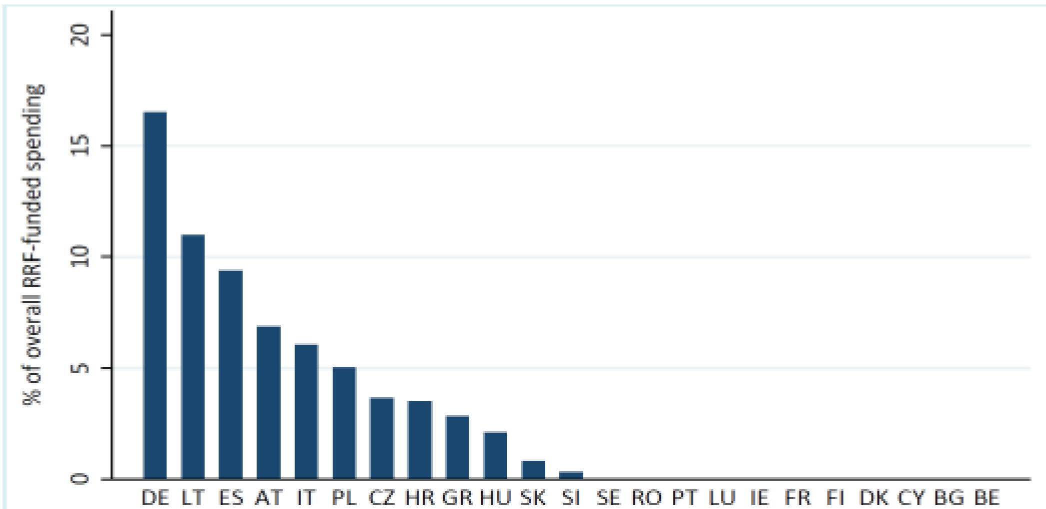
In addition to regulations, the electrification of the European automotive sector is also supported by public investment. Many EU governments are committing to purchasing only zero-emissions public vehicles by specific target dates in the future. This could make a significant contribution to decarbonizing transport, since the public sector manages large vehicle fleets.[14] The Recovery and Resilience Facility (RRF), the €700 bn centerpiece of EU's pandemic recovery plan, also provided an important opportunity to accelerate green investment, including towards sustainable mobility. EU countries have allocated about €71bn under the RRF to sustainable mobility related expenditures including zero- and low-emission vehicles, alternative refueling and recharging stations, and green public transport.[15] The automotive sector is a sizable beneficiary of RRF spending in several countries, where it accounts for a significant share of manufacturing, such as Spain, Austria, Italy and Germany (Figure 6).

[13] The proposals specify that electric recharging infrastructures for light-duty vehicles should be no more than 60 km apart, while for heavy-duty vehicles they should be no more than 60 km apart along the most important routes of the Trans-European Transport Network, and no more than 100 km apart along other routes.

[14] Annual purchase of vehicles by public authorities has been estimated to be in the order of 110,000 passenger cars, 110,000 light-duty vehicles, 35,000 lorries and 17,000 buses for the EU-25. At COP26, 15 countries, including 5 in the EU (Austria, Denmark, Finland, Luxembourg, the Netherlands), agreed to purchase only zero-emission buses by 2040. Denmark and the Netherlands are aiming to achieve this by 2025, and Austria by 2032.

[15] The expenditures include tax incentives for the purchase of new vehicles (6 countries), or tax exemptions on registration (Germany) or charging (Denmark). Thirteen countries plan to use RRPs to finance the purchase of zero-emission buses. Seventeen countries' RRPs include plans to invest in charging and refueling infrastructure for alternative fuels, including electricity, hydrogen and natural gas. Other initiatives in RRPs include research and development of hydrogen (France, Italy), the production of fuel-cell components (Germany), and the construction of sites to recycle electric car batteries (Greece).

Figure 5. RRF-Funded Spending Dedicated to the Automotive Sector
(Percent of overall RRF spending)



Sources: Delanote et al (2022), based on Eurostat, National Recovery and Resilience Plans, and EIB.
Note: Includes spending on electric vehicle purchase incentives and charging stations. Excludes spending on roads.

In response to these regulatory requirements, all major traditional automakers are accelerating the shift towards electrification, with many announcing new investments and explicit time schedules for the EV transition. As discussed by Delanote et al. (2022), according to company announcements, 50% of BMW vehicles and 40% of Ford vehicles will be fully electric by 2030. Renault targets to have 30% of its vehicle be electric by 2025. Moreover, automakers' electrification targets are significantly more ambitious for the European car market, compared to the rest of the world.[16] While these electrification goals are difficult to compare – some automakers consider both battery EVs as well as plug-in hybrids and fuel cell vehicles, others only battery EVs – they have become an important part of automakers' marketing strategies and investment plans.[17]

III. Evidence on Employment Effects

To shed light on the employment effects of the shift towards EVs, we take advantage of the rapid expansion of EV production since 2015 and the cross-country heterogeneity in the speed of the expansion across EU countries in two simple and complementary difference-in-difference exercises. First, using sectoral employment data, we examine whether employment in sectors heavily exposed to ICE grew significantly slower than in other sectors in EU countries where the share of EV exports in total car exports grew relatively faster over the 2015-19 period. While this first piece of evidence is suggestive of the potential effect the switch to EV production might have on employment in the ICE-related sectors, it does not speak to the overall labor market consequences of the automotive sector's transformation. If workers that might have been employed in the

[16] For example, Nissan and PSA-Stellantis target 70% of European car sales to be electric, but only 40% of US car sales by 2030. By 2030 Volkswagen targets 70% of electric car sales in Europe, but 50% for China and USA (Delanote et al., 2022).

[17] For example, Toyota announced investments worth USD 35 billion, while Volkswagen, Stellantis, Ford and BMW announced investments worth USD 30 billion each (Delanote et al. 2022).

automotive sector – were it not for the switch to EV production – could easily find jobs in other sectors (for example, in the expanding industries that provide EV use infrastructure), then overall employment might not be adversely affected. Our second empirical exercise aims to overcome this shortcoming. Using sub-regional employment data across EU countries, we examine whether regions within a country that were more exposed to ICEV activity through their employment mix prior to the EV take-off experienced relative employment losses (or smaller employment gains) in countries where EV exports grew relatively faster. The data used in the analysis is described in Annex I.

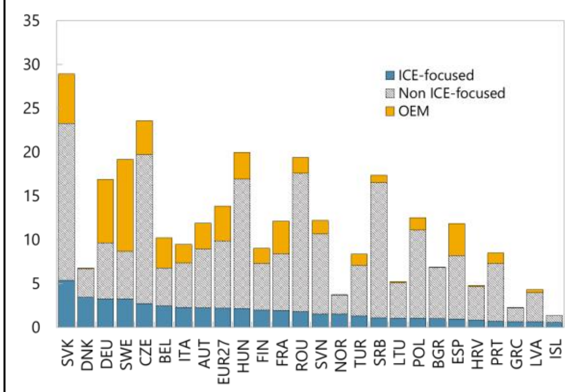
Evidence Based on Different Sectoral Exposures to the Automotive Sector Electrification

To examine empirically whether there is a link between employment and the transition towards EV production, we exploit variation in the sectoral exposure to EV expansion. Automobiles are complex products that require thousands of components coming from different sectors, from simple items such as brake pads, and windshields, to sophisticated compounds such as engines. The electrification of cars will not affect the production of some car parts; others would become obsolete. For example, sectors that produce components used in both ICE and EV—such as manufacturing of bodies for motor vehicles, rubber tires and tubes—would be less affected by a switch to EV production. Those that focus exclusively on ICE-related components—such as manufacturing of pumps and compressors, manufacturing of bearings, gears, gearing and driving elements—could face severe reduction in demand with EV replacing ICE. Meanwhile, original equipment manufacturers (OEMs), which mainly assemble vehicles, could retrain workers from assembling ICE to assembling EV. Therefore, the share of employees in these sectors could shed some light on the size of sectors at-risk from the EV expansion (Figure 7). According to Eurostat's Structural Business Statistics Database, the Slovak Republic, Denmark, and Germany are among the top three across European countries where ICE-focused sectors constitute about 3 percent of total manufacturing employees.[18] The large share of workers employed by OEMs—about 7 percent of total manufacturing employees—also suggests potentially high retraining needs to help workers adapt to the new EV assembling lines.

[18] Falck et al. (2021) estimate that 7 percent of the total employment in Germany would be directly affected by the EV transition, including both those who will be positively affected (e.g., electronic components manufacturing) and those adversely affected (e.g., devices for combustion engine) sectors.

Figure 6. Employment of Automotive-Related Sectors

(Percent of total manufacturing employment, 2019)



Sources: Eurostat European Structural Business Statistics.
Note: For BEL, ISL, ITA, PRT, and SWE, data comes from 2018, For FRA and TUR, data comes from 2017 and 2014, respecively.

We use this variation in sectoral exposures to EV penetration, along with the heterogeneity in countries' shift towards EV production, to estimate the association between sectoral employment and the transition from ICE to EV. With diminishing demand for ICE, we would expect employment growth in ICE-focused sectors to lag behind employment growth in other sectors within automotive production, namely OEM or non-ICE-focused sectors, and more so in countries, which shifted more rapidly towards EV production. To exploit this idea, we use detailed data on sectoral employment from a panel of 26 European countries.[19] We classify the 13 auto-production related sectors into ICE-focused, non-ICE focused and OEM, based on their products and functionality in the automotive production network, following Kuhlmann et al. (2021). We combine this sectoral data with the share of a country's car exports accounted for by EVs.[20] We focus on a relatively short time period, 2015 to 2019, around the take-off of EV exports.

Specifically, we estimate the following equation:

$$\ln L_{sct} = \lambda \ln L_{sct-1} + \beta \times (Share\_EV\_exports_{ct} \times D_s) + \gamma \ln Q_{ct} + \alpha_{sc} + \epsilon_{sct} \quad (1)$$

where the dependent variable is the logarithm of number of employees in sector *s*, country *c*, at year *t,* denoted by L_{sct}. The key variable is EV exposure— which is equal to the share of EV exports in total light weight passenger car exports by country *c* at time *t* $(Share\_EV\_exports_{ct})$ times a dummy variable (D_s) indicating whether the sector is ICE-focused or not. Total light weight passenger car exports (Q_{ct}) is included to capture aggregate trend in the automotive industry at the country level. Given the lack of data on sectoral characteristics at such a disaggregate level, we adopt a dynamic panel setting by including the lagged value of number of employees $(\ln L_{sct-1})$ as a control variable. α_{sc} denotes country-sector fixed effects. To avoid the bias in fixed effects estimator for dynamic panel, we use the half-panel jackknife estimators based on Chudik, Pesaran, and Yang (2018).

The regression estimates suggest that employment in ICE-focused sectors is negatively related to expansion of EV exports in the sample of European economies. A one percentage point increase in the EV's share in total car exports is associated with a 1.4 percent decline in employment in ICE-focused sectors relative to other sectors in the short term ($\hat{\beta} = -0.014$ in Table 1, column 1) and a 6.3 percent relative decline in the long term ($\hat{\beta}/(1 - \hat{\lambda}) = -0.064$). This is an economically significant impact. Across the countries in our sample, the median employment growth in ICE-focused sectors was 2.8 percent in 2015. Based on the median increase in EV's share in total car exports from 2015 to 2019, the median country experienced 0.3 percent reduction in the employment growth of ICE-focused sectors. The 75th percentile increase in EV's share would drag growth rate

[19] Countries included are AUT, BEL, BGR, CZE, DEU, DNK, ESP, EST, FIN, FRA, GBR, GRC, HRV, HUN, IRL, ITA, LTU, LUX, LVA, NLD, POL, PRT, ROU, SVK, SVN, SWE. Sectors included are C2211, C2312, C2620, C2711, C2720, C2740, C2813, C2815, C2825, C2910, C2920, C2931, C2932, in NACE Rev 2 classification.

[20] Exports of ICE and EV cars are used as a proxy for production since production of car by fuel type is not readily available for all European countries in our sample.

down by 0.9 percent. With higher EV exposure from the top of the distribution, employment growth could turn negative for ICE-focused sectors. For OEM sector, who could mitigate the impact from the switch from ICE to EV by reskilling the workers on the assembling line, their employment growth is not significantly hampered by EV expansion (Table 1, column 2).

The finding of a large employment impact, and the sign and statistical significance of the coefficients of interest (β and λ), are robust to various additional checks. As we rely on lagged variables to control for sector-dependent dynamics in employment, we first allow additional lags of employment and our measure of EV exposure to affect employment (column 3 and 4). Second, we allow the relationship between ICE-focused sectors and total car exports to be different from the other sectors (column 5). Lastly, we restrict the sample to include only advanced economies (column 6), where data quality might be better, and we remove outliers by trimming the top and bottom 1 percentile of employment growth (column 7).

Table 1. Labor Market Outcomes and Exposure to Electrification: Sectoral Evidence

	Baseline	EV exposure for OEM	lag	2-yr lags	sector-specific relationship with car	only AE	trim 1%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
EV exposure for ICE focused sector	-0.014*	-0.017*	-0.016*	-0.031*	-0.029*	-0.024*	-0.008*
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	0.000
ln(employee) $_{t-1}$	0.780**	0.779**	0.779**	0.887**	0.778**	0.670**	0.838***
	(0.250)	(0.250)	(0.250)	(0.280)	(0.250)	(0.210)	(0.080)
ln(car exports)	0.103*	0.104*	0.104*	0.150*	0.111	0.143**	0.072**
	(0.050)	(0.050)	(0.050)	(0.060)	(0.060)	(0.050)	(0.030)
EV exposure for ICE focused sector $_{t-1}$		-0.014	-0.013	0.003	-0.023	-0.028	
		(0.020)	(0.020)	(0.020)	(0.030)	(0.030)	
EV exposure for OEM		-0.13					
		(0.110)					
EV exposure for OEM $_{t-1}$		-0.074					
		(0.230)					
ln(employee) $_{t-2}$				-0.179			
				(0.120)			
EV exposure for ICE focused sector $_{t-2}$				0.018			
				(0.020)			
ln(car exports)*ICE focused sector					-0.024		
					(0.070)		
N	1112	1112	1112	1032	1112	916	1090

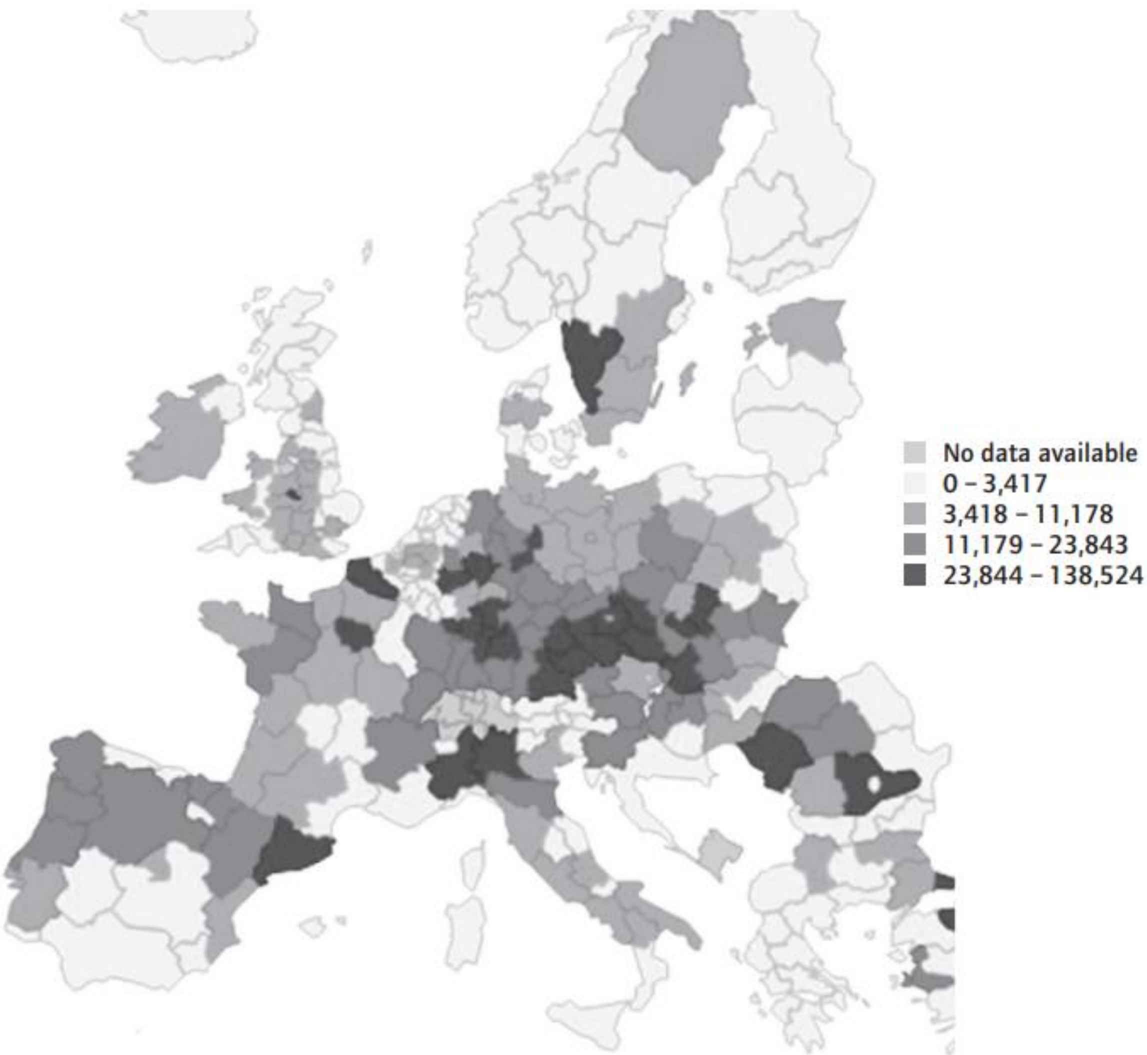
Note: All regressions include country-sector fixed effects. Standard errors are clustered at the country level. EV exposure for ICE focused sector is the interaction of the share of EV exports in a country's total car exports and an indicator equal to 1 for ICE focused sectors. Regressions are estimated using the half-panel jackknife estimators based on Chudik, Pesaran, and Yang (2018).* p<0.10, ** p<0.05, *** p<0.01.

The sectoral analysis focuses on the employment implications from the switch to EV for the ICE-focused sectors. Given our difference-in-difference strategy, it is unable to shed light on whether EV-focused sectors in the economy experienced an absolute employment boost, or whether workers that might have been employed in ICE-focused sectors – were it not for transition to EV production – found employment in other sectors. Therefore, the overall impact could be smaller or larger than the estimates presented here. Moreover, as vehicle production networks often extend beyond country borders, there could be spillovers from other countries' EV expansion.

Evidence Based on Different Regional Exposures to the Automotive Sector Electrification

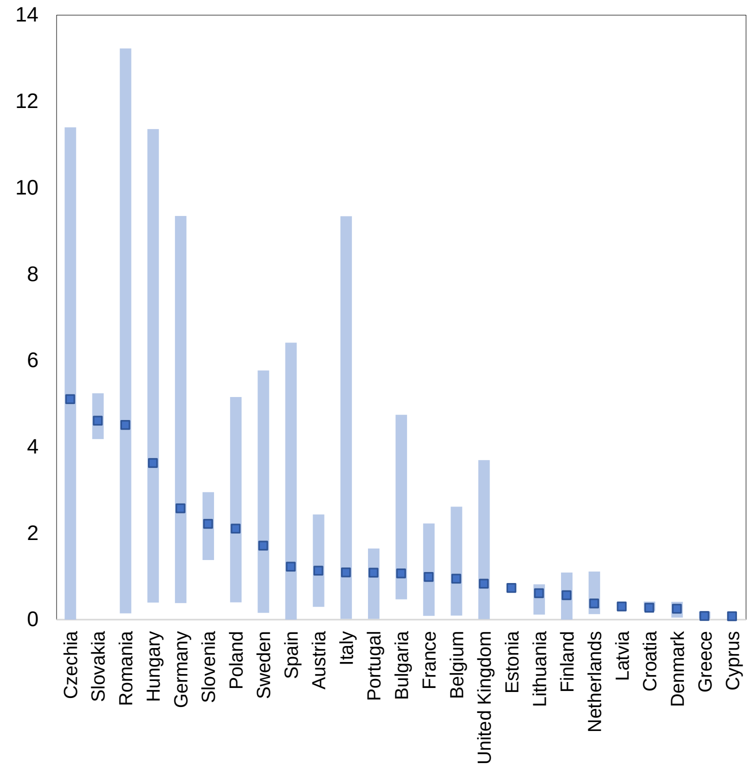
To examine whether there is a link between the switch to electric vehicle production and employment outcomes at the local labor market level, we exploit the fact that the European automotive employment is highly concentrated geographically. Car production tends to be concentrated in certain regions within countries, which generates substantial variation in its importance in local labor markets both within and across countries (see Figures 8 and 9). The interaction between the importance of the automotive industry as an employer in a particular region prior to the arrival of EV production and the increase in the share of EV exports during the 2015-2020 period provides a measure of a region's exposure to the EV shift through its employment mix. We can then examine whether changes in employment and unemployment rates at the regional level are correlated with the region's exposure to the EV transition.

Figure 7. Number of Automotive Employees (FTE) by Region, 2015



Sources: Lefeuvre and Guga (2019), based on DG Growth Cluster mapping tool.

Figure 8. Employment in the Automotive Sector in European Regions, 2015
(Percent of Total Employment)



Source: Eurostat Structural Business Statistics Database and IMF staff estimates.
Note: The figure plots the regional average percent of workers employed in the automotive sector (dark blue square) and the range across NUTS2 regions in the country.

More specifically, we estimate the following regression:

$$L_{rct} = \alpha_{rc} + \alpha_{ct} + \beta \times (Share\_EV\_exports_{ct} \times Share\_Auto\_employment_{rc,2015}) + controls_{rct} + \epsilon_{rct} \quad (2)$$

Where L_{rct} is the employment (or unemployment) rate in region r in country *c* in year *t*, $Share\_EV\_exports_{ct}$ is the share of EV exports in total car exports[21] by country *c* in year *t*, and $Share\_Auto\_employment_{r,c,2015}$ is the share of workers in the automotive industry in total employment in region *r*, in country *c*, in 2015. α_{rc} are regional fixed effects which absorb all time invariant differences across regions, while α_{ct} are country-year fixed effects which control for all factors that vary at the country-year level (such as economic growth and labor demand, inflation, productivity changes). The set of controls includes standard determinants of employment rates, such as the region's population, male-to-female ratio, level of education (proxied by the share of 25-64 years old with secondary and/or tertiary education), and industrial structure (captured by the employment shares in each of 4 broad sectors: agriculture, manufacturing, services and mining). The regressions are weighted by regional population, given the vast heterogeneity in the size of regions across Europe, while standard errors are clustered at the regional level.

[21] As in the sectoral analysis, car exports are used as a proxy for car production since consistent and comparable data on production of vehicles by country and type (namely, ICE vs electric) are not available.

The analysis relies on data from a relatively short time period (2015-2020) surrounding the time when EV exports from Europe took off (as discussed in Section II). To minimize the potentially confounding effect of the global pandemic, which inflicted a massive supply and demand shock on the car sector in Europe, we perform the analysis with or without the year 2020 to ensure the robustness of the findings. Throughout the analysis we focus on male workers. The reasons for this are two-fold. First, female employment in the car industry is relatively low. Women comprise only between one-fifth and one-quarter of all automotive workers, though with some variation across countries (ILO, 2020). Second, there are significant differences in the drivers of male and female employment and labor force participation rates that would be hard to control for in the regional level analysis. For example, female employment has been shown to be highly responsive to the availability of childcare, which would typically vary at the subnational regional level and over time (see, among others, Jaumotte, 2003, Cipollone et al., 2013, Thévenon, 2013, Grigoli, Kóczán and Topalova, 2018).

Table 2 reports the results from estimating our baseline specification, presenting the estimated coefficient on the interaction between the share of EV exports in total car exports and the share of employment in the automotive sector at the regional level in 2015 (i.e., the coefficient β in equation (2)). Columns (1)-(4) use the employment rate, while columns (5)-(8) use the unemployment rate, as the outcome of interest. Across all specifications, we find that the switch the electric vehicles is associated with relatively worse labor market outcomes, namely smaller increases in the employment rate (and conversely, lower declines in the unemployment rate) in regions with a greater concentration of vehicle production. Columns (1) and (5) are based on the 2015-2020 period. In columns (2) and (6), we exclude data for 2020 to minimize the potentially confounding effect of the COVID-19 pandemic. In columns (3) and (7), we focus on long differences, by including only the pre-EV (2015) and post-EV (2019) year. Columns (4) and (8) report the result for our preferred specification, which relies on the 2015-2019 sample and includes controls at the regional level.

Table 2. Labor Market Outcomes and Exposure to EV Production: Regional Evidence

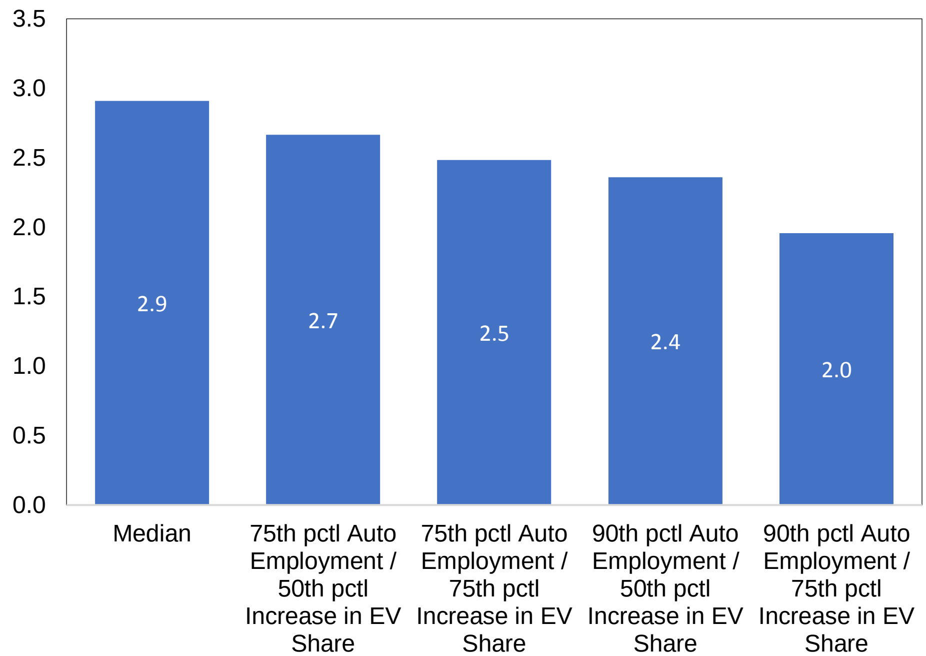
	Male Employment Rate				Male Unemployment Rate			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EV exposure	-0.023***	-0.046***	-0.056**	-0.057***	0.028***	0.045***	0.056**	0.055***
	(0.008)	(0.016)	(0.022)	(0.016)	(0.009)	(0.016)	(0.022)	(0.016)
Time period	2015-2020	2015-2019	2015, 2019	2015-2019, controls	2015-2020	2015-2019	2015, 2019	2015-2019, controls
N	1,435	1,230	492	769	1,391	1,207	478	767

Note: All regressions include country-region and country-year fixed effects. Regressions are weighted by regional population. Standard errors are clustered at the regional level. EV exposure is the interaction of the share of EV exports in a country's total car exports and the share of workers in the automotive industry in total employment in the region in 2015. Columns (4) and (8) control for region's population, level of education (proxied by the share of 25-64 years old with secondary and/or tertiary education), male-to-female ratio, and industrial structure.* p<0.10, ** p<0.05, *** p<0.01.

The economic magnitude of the relationship is nontrivial (Figure 8). The estimates suggest that a region at the upper quartile in terms of employment in the automotive sector (i.e., a region with 2 percent of its workers employed in the automotive sector in 2015) located in a country with the median increase in the share of electric vehicles in its car exports (an increase of 2 percentage points) experienced 0.2 percentage point smaller rise in employment rate than the median increase in employment at the regional level over this time period (i.e., 2.7 percent per year, as opposed to 2.9 percent per year, the second versus the first bar in Figure 10). A region at the 90th percentile in terms of employment in the automotive sector (i.e., a region where 4 percent of workers are employed by the automotive sector) saw 0.5 percentage points lower gain in employment rate. To put this in perspective, between 2015 and 2019, the employment rate increased by 2.9 percentage points for the median region in Europe.

Figure 9. Change in Employment Rate, 2015-19

(Percentage Points)



Source: IMF staff estimates based on regression estimates in Table 2, column 4.

Another way to interpret the estimates is to examine what they imply about the aggregate number of workers expected to be affected by the transition to EVs. Assuming that the average region's share in auto employment is 1.5 percent and using the elasticity of $\hat{\beta} = -0.057$ estimated in Table 2 column 4, the model in equation (2) suggests that the growth in EV production that occurred between 2015 and 2019 (from 0 to 7 percent of vehicle exports) already reduced the employment rate by 0.3 percentage points over this period. This means that the employment rate grew slower than it otherwise would have. This reduction represents about 600,000 fewer jobs out of a total of 189,700,000 jobs in the EU (Table 3, column 1).

We can also extrapolate these estimates to see what they imply about the future effects of the EV transition. If EV production expands so that EVs account for 50 percent of vehicle exports, the estimates of model (2) based on evidence from 2015 to 2019 ($\hat{\beta} = -0.057$) and the average region's share in auto employment (1.5 percent) together suggest that employment rates would be about 2 percentage points lower, which translates into about 3.8 million fewer jobs in the EU (Table 3, column 1). This point could be reached around 2027/2028, according to projections of EV sales from the European Automobile Manufacturers' Association.[22] However, these estimates are highly uncertain because they are based on extrapolating the share out to 50 percent using data

[22] According to the report entitled "Electrification trends worldwide," published by the European Automobile Manufacturers' Association on November 25, 2022. Available at https://www.acea.auto/news/electrification-trends-worldwide/.

only up to 7 percent. For instance, the estimation uncertainty alone places the estimate of 3.8 million within a 95 percent confidence interval of between 1.7 and 5.9 million jobs.

Table 3. Scenarios of the numbers of EU workers affected by the EV transition

	EV share of exports goes from:	
Effect on the:	0 to 7 percent	7 to 50 percent
Employment rate (ppts)	-0.3	-2.0
Implied no. of workers (millions	0.6	3.8
Upper 95% C.I. (millions)	1.0	5.9
Lower 95% C.I. (millions)	0.3	1.7

Note: The change in the EV share of exports from 0 to 7 percent is in-sample, while the changes from 7 to 50 and from 7 to 100 are out-of-sample extrapolations. The implied number of affected workers is based on 189.7 million employed workers in the EU in 2021. C.I. denotes confidence interval.

The effect of the electrification of the automotive sector is uneven across workers. First, workers' education matters. The association between change in employment rates and exposure to EV exports is most pronounced for workers with secondary education (Table 4). The point estimate on the exposure to EV exports is almost 5 times larger in magnitude for workers with secondary education compared to workers with tertiary education, and 3 times larger than workers with primary education or below. This finding is consistent with the idea that technological advances may lead to hollowing-out of the middle of the income/skill distribution. One possible interpretation is that shifting production to EVs requires capital investment, which gives manufacturers the opportunity to automate their processes, and research has shown that middle-skill jobs are more exposed to automation (Autor and Dorn, 2013).

Table 4. Unemployment Rate and Exposure to EV Production: The Role of Workers' Education

		By Education		
	All	Primary Education or Below	Secondary Education	Tertiary Education
	(1)	(2)	(3)	(4)
EV exposure	0.055***	0.032	0.066***	0.014
	(0.016)	(0.046)	(0.018)	(0.015)
N	767	674	755	576

Note: All regressions include country-region and country-year fixed effects. Regressions are weighted by regional population. Standard errors are clustered at the regional level. EV exposure is the interaction of the share of EV exports in a country's total car exports and the share of workers in the automotive industry in total employment in the region in 2015. All columns control for region's population, level of education (proxied by the share of 25-64 years old with secondary and/or tertiary education), male-to-female ratio, and industrial structure.* p<0.10, ** p<0.05, *** p<0.01.

Second, there are also large differences in the estimated coefficients across workers in different age groups (Table 5). Younger workers (25-34 year-old) appear to be particularly vulnerable to the shift towards EV production: the point estimate on the exposure to EV for this age group is 3 times larger than the point estimate for the average worker. Many reasons may underpin the seeming vulnerability of this age-group. One reason could be their relative lack of tenure on the job (or in the industry) compared to older workers, which may be associated with lower accumulated job-specific human capital, lower likelihood of being in a unionized job, and/or lower likelihood of having a permanent contract..

Table 5. Unemployment Rate and Exposure to EV Production: The Role of Workers' Age

		By Age				
	All	15-24 year old	25-34 year old	35-44 year old	45-54 year old	55-64 year old
	(1)	(2)	(3)	(4)	(5)	(6)
EV exposure	0.055***	0.013	0.146***	0.041	0.052	0.086
	(0.016)	(0.061)	(0.032)	(0.040)	(0.040)	(0.068)
N	767	695	633	534	542	485

Note: All regressions include country-region and country-year fixed effects. Regressions are weighted by regional population. Standard errors are clustered at the regional level. EV exposure is the interaction of the share of EV exports in a country's total car exports and the share of workers in the automotive industry in total employment in the region in 2015. All columns control for region's population, level of education (proxied by the share of 25-64 years old with secondary and/or tertiary education), male-to-female ratio, and industrial structure.* p<0.10, ** p<0.05, *** p<0.01.

IV. The Role of Policies

Taken together, the results in the previous section suggest that the transformation of the automotive sector may have adverse employment consequences for workers in vehicle manufacturing and ICEV related sectors. At least in the short run, workers that would have been employed in the automotive sector, were it not for the EV transition, cannot seamlessly transition to expanding sectors as suggested by the region level analysis. The finding that labor-saving technological progress may lead to employment losses in directly affected sectors is in line with existing studies. But there is evidence from Europe that even such transitory adjustment costs of technology in terms of employment losses could erode the supply of labor, causing more long-lasting harm to the economy's potential output. For example, Grigoli, Kóczán, and Topalova (2020) find both micro- and macro-evidence that the automation of tasks where labor is easily substitutable by capital reduces the labor force participation of prime-age workers. More broadly, detachment from the labor force during an individual's peak productive time is associated with lower happiness and life satisfaction for men (Winkelmann and Winkelmann, 1995; Knabe and R¨atzel, 2011; Lucas et al., 2004; Krueger, 2017), poorer health and higher mortality (Eliason and Storrie, 2009; Gerdtham and Johannesson, 2003; Sullivan and Von Wachter, 2009), and depressed employment prospects (Arulampalam et al., 2000; Arulampalam et al., 2001).

We thus examine whether policies can help mitigate the potentially adverse employment effects of the shift to EVs by speeding up the reallocation of workers to other sectors, thus minimizing the associated personal economic and psychological costs for directly affected workers and the possibility of long-lasting economic damage. It has long been argued that training and lifelong learning would be key to minimize the dislocation of workers and associated adjustment costs brought on by technological innovation by helping ease their transition to expanding sectors of the economy. We analyze whether countries that had higher spending on training were able to attenuate the link between electrification in the automotive sector and slower gains in employment rates in the labor markets where the auto industry is concentrated. More specifically, we augment our baseline specification (equation (2)) to include an interaction of exposure to EV and country-level spending on training as a share of GDP; or percent of the workforce participating in training.

$$L_{rct} = \alpha_{rc} + \alpha_{ct} + \beta \times \left(Share_{EV_{exports_{ct}}} \times Share_{Auto_{employment_{rc,2015}}}\right) + \gamma \times \left(Share_{EV_{exports_{ct}}} \times Share_{Auto_{employment_{rc,2015}}}\right) \times Training_{ct} + controls_{rct} + \epsilon_{rct} \tag{3}$$

The analysis suggests that training indeed can play an important role in minimizing the short run adverse labor market consequences of switching from ICE to EV production (Table 6). The coefficient (γ) on the interaction of the exposure to EV with both spending on training (columns 2) and the share of workforce participating in training (columns 3) are positive and statistically significant, suggesting that stronger training policies can mitigate the negative association between EV exposure and regional employment rates. Together with the findings on the role of education in the previous section, these results imply that further investment in education, and training, could potentially make the automotive workforce more resilient to the transformations the industry is set to undergo.

Table 6. Labor Market Outcomes and Exposure to EV Production: The Role of Policies

	Employment Rate			Unemployment Rate		
	(1)	(2)	(3)	(4)	(5)	(6)
EV exposure	-0.057***	-0.129***	-0.185***	0.055***	0.129***	0.185***
	(0.016)	(0.041)	(0.070)	(0.016)	(0.040)	(0.066)
EV exposure*Training Spending		0.312**			-0.314**	
		(0.129)			(0.125)	
EV exposure*Training Participation			0.072**			-0.073**
			(0.032)			(0.031)
N	769	552	546	767	552	546

Note: All regressions include country-region and country-year fixed effects. Regressions are weighted by regional population. Standard errors are clustered at the regional level. EV exposure is the interaction of the share of EV exports in a country's total car exports and the share of workers in the automotive industry in total employment in the region in 2015. Training spending is measured as a country's public spending on training labor market policies as a share of GDP. Training participation is the stock of workers that participate in training programs as a share of the labor force. Both measures are from the OECD database on labor market policies. All columns control for region's population, level of education (proxied by the share of 25-64 years old with secondary and/or tertiary education), male-to-female ratio, and industrial structure..* p<0.10, ** p<0.05, *** p<0.01.

V. Reallocation Prospects of the Adversely Affected Sectors

As shown in the previous section, the shift from ICEVs to EVs could potentially trigger labor outflows from the ICE-focused sectors. A key question is whether these workers can quickly find jobs in other sectors/occupations and remain in the labor force. To gauge the reallocation prospects of the adversely affected workers, we need two pieces of information: first, how easily these workers can switch to other sectors; second, whether the destination sectors have the capacity to absorb the workers in the context of the green transition.

One way to measure the likelihood for workers switching jobs is “skill relatedness,” as proposed by Neffke et al., (2017). Based on the German Employee History database, Neffke et al. (2017) calculate the skill relatedness between sectors based on the historical transition of workers between sectors. In particular, the skill relatedness of sector *i* to *j* is measured as the ratio of the number of workers moving from *i* to *j* and the expected number of workers moving from *i* to *j*, where the latter is calculated as total worker outflows from *i* multiplied by the total inflow of workers to *j* as a share of the total number of workers that switch sectors. The intuition behind this measure is that if the skill match between sector *i* and all other sectors are the same, then the expected number of workers transitioning from sector *i* to *j* would be proportional to the size of inflows to *j* as a share of total job switchers.[23] In this case, the skill relatedness of *i* to *j* would be equal to one. If sector *i* is not a good match for *j* at all—i.e., no workers move from *i* to *j*, then skill relatedness would be zero. On the other hand, if sector *i* is a perfect match for *j*—i.e., all outflows from *i* move to *j*, then skill relatedness could be potentially very large. The final index of skill relatedness is rescaled from $[0, +\infty)$ to $[-1, 1)$, with larger values indicating higher skill relatedness.

Following IMF (2022a), the share of green jobs within a sector is used to gauge whether the sector is likely to grow during the green transition. For each sector, the share of green jobs is computed based on the distribution of occupations in the sector and the classification of green occupation by O*NET Center (2021).[24] The O*NET’s taxonomy of green occupations categorizes each occupation’s underlying bundle of tasks into green or non-green tasks. Green tasks are those identified as directly related to improving environmental sustainability and reducing GHG emissions. For example, the occupation “roofer” involves a task summarized as “installing vapor barriers or layers of insulation on the roof decks of flat roofs and sealing the seams,” which is considered green as it aims to improve energy efficiency. Examples of high green-job intensity sectors include collection/treatment of waste and recovery of sorted materials. Manufacturing of footwear and apparel are among the lowest green-job intensity sectors.

Workers from ICE-focused sectors could have a fair chance of switching to a green job, compared to workers in other manufacturing sectors. As depicted in Figure 9, the skills of workers in ICE-focused sectors are more related to the types of skills needed in green sectors compared to the skills of the average manufacturing worker. Across all destination sectors, workers from ICE-focused sectors are competitive for medium green-job intensive sectors (the blue circles are on average higher than the red circles in Figure 11, panel 1, suggesting that the skills of ICE-focused workers would be a better match than the skills of workers in other manufacturing sectors for destination sectors, with share of green jobs between 20 to 50 percent). Some of the sectors that have the highest skill relatedness with the ICE-focused sector are manufacturing of industrial gases, manufacturing of electric motors, and manufacturing of electrical equipment for vehicles. These are also relatively green-job intensive sectors. One possible explanation is that the high content of engineering skills

[23] Neffke and Henning (2013) show evidence from surveys that their index measures mostly skills, rather than other factors such as preferences or information that might affect labor flows between sectors.

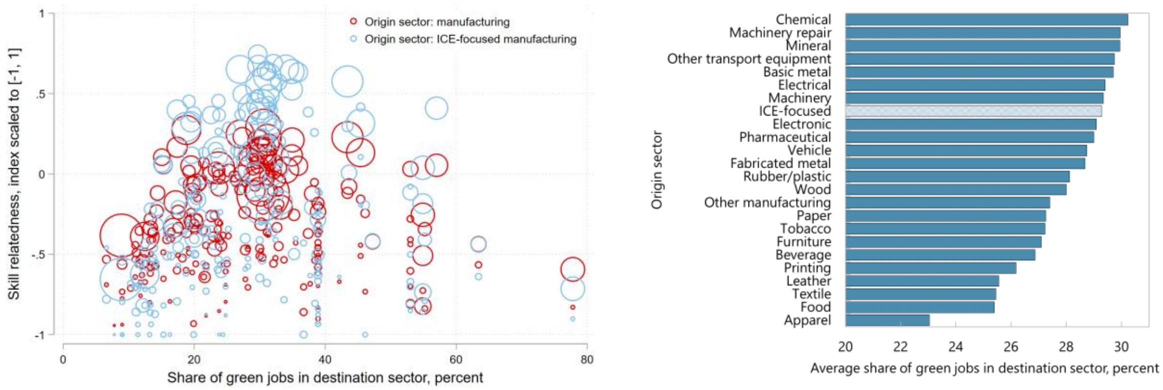
[24] The sectoral occupation distribution at detailed occupation level is only available for the U.S., so the sectoral share of green jobs calculated here is based on the U.S. data from BLS.

grants a higher leverage for workers in the ICE-focused sectors in switching to a green job, compared with relatively low-skill manufacturing workers such as those in food, textile, etc. (Figure 11, panel 2).

However, the reallocation of workers in ICE-focused sectors could still be challenging. The green transition will affect a broad range of economic sectors, raising the competition for green jobs. For instance, the likely downsizing of brown energy sectors, such as coal-mining, oil and the like, would force more workers to seek alternative employment opportunities. At the same time, further technological progress – such as robotization, digitalization and automation – may depress the demand for workers, including in green occupations.

Figure 10. Prospects of Switching to a Green Job: Germany

Likelihood of switching to a green job, by origin sector | Share of green jobs in destination sector and skill relatedness



Sources: BLS, Eurostat, Neffke et al. (2017), O*NET, IMF staff calculations.
Note: Share of green jobs in destination sectors is based on industry-occupation matrix from BLS, where green jobs are identified by O*NET green occupations. The likelihood of switching to a green job is the average of share of green jobs in destination sectors, weighted by skill relatedness. The skill relatedness of a worker moving from sector i to sector j is measured by the ratio between the actual number of workers moving from i to j and the expected number of workers moving from i to j, where the latter is calculated as total worker outflow from i times total inflow to j as share of total number of workers that switch sectors. Skill relatedness is calculated using the German Employee History database by Neffke et al. (2017). In the chart on the left, each circle represents a destination sector at four-digit NACE level, and the size of the circle indicates the number of workers.

VI. Conclusion

The transition to electric vehicles represents a historic transformation of vehicle manufacturing activity, on which about 7 percent of the workforce in Europe depends for its livelihood. The literature has estimated the number of jobs that will be affected by this transformation based on the likely evolution of aggregate labor demand (the so-called top-down approach) and based on detailed comparisons of the production processes of EVs and ICEVs (the bottom-up approach). In this paper, we provide new evidence from recently observed labor market developments in Europe, by comparing outcomes in different economic sectors and subnational regions, of the impacts on employment and the policies that have helped to ease the transition.

We find that the expansion of EV production between 2015 and 2020 led to smaller increases in employment in ICE-supplying sectors than in other sectors, and to smaller increases in employment in vehicle-producing locations than in other locations. Both findings confirm that workers are already being affected by the transition to EVs.

Furthermore, the estimated impacts are economically significant. A one percentage point increase in the share of EVs in total car exports is associated with a one percent relative decline in employment in ICE-focused sectors. This suggests that the country with the median expansion of the share of EVs in total car exports saw employment grow by 0.3 percentage points a year less in ICE-focused sectors than in other sectors. (For reference, the median increase in employment in ICE-focused sectors in our sample was 2.8 percent in 2015.) Similarly, in the country with the median expansion of the share of EVs in total car exports, the employment rate grew by 2.9 percentage points between 2015 and 2019, but only 2.7 percentage points in an auto-focused region (a region with 2 percent of its workers employed in the automotive industry).

Our estimates suggest that by 2035, in the absence of any policies nor technological advances, if all vehicles produced in Europe are EV, a large share of workers will either have to switch jobs, change tasks in the same job, or exit the labor market through retirement, emigration or unemployment. One silver lining of Europe's aging societies is that some of the affected workers will contribute to the needed transformation by retiring at normal retirement ages (Falck et al., 2021).

Fortunately, our evidence suggests that the skills of workers in sectors that supply products for ICE vehicles are not too dissimilar from the skills that will be in demand in the green transition. On average, workers in the auto sectors would have a similar chance to reallocate to "green" sectors as the average worker in manufacturing. Moreover, we find evidence that training can ease the needed reallocation and minimize the adjustment costs associated with the sector's transformation. In addition to training, other active labor market policies like job search assistance could make it easier for workers to move. Active labor market policies are part of Europe's broader labor market reform needs, including reforms to employment protection legislation, unemployment insurance, labor taxation, minimum wages and collective bargaining (Ando et al, 2022; Aiyar et al, 2019).

It is important to bear in mind the caveats to the estimates presented here. For example, the EV transition requires substantial investments in charging infrastructure, which will have important job implications that are not captured here. Furthermore, European production of batteries for EVs is set to increase in future, which will add jobs and capture more of the global value chain within Europe. Other key challenges for future empirical work will be to distinguish between the changes due to the transition to EVs and those due to the shift from manual to automatic gearboxes, the shift away from diesel engines, and the automation of manufacturing and driving, which arguably would have happened even in the absence of the transition to EVs.

Annex I. Data Sources and Variable Construction

Several databases are used in the analysis of this paper.

- The key variable—exports of total cars and EVs—is from Comext. Prior to 2016 January, EVs were registered under CN code 87039010, and they have been registered under CN code 870380 afterwards.
- Employment at sectoral level and employment/unemployment rates at regional level are obtained from the Eurostat European Structural Business Statistics dataset.
- Regional controls, such as total population, population by education categories, gender and workers by broad industrial structure are from OECD Regional Business Demography dataset.
- Country-level measures of labor market policies are from the OECD labor market policy database. We use spending on training programs as a share of GDP, and the stock of participants in training programs as percent of the labor force.
- EV exposure at the sectoral level is based on categorizing into ICE-focused, non-ICE focused, and OEM, following Kuhlmann et al. (2021).
- EV exposure at the regional level is constructed as the share of EV exports in total car exports at the country level, and the share of automotive workers as a share of total employment in the region in 2015. Share of workers in the automotive sector is proxied by employment in NACE code 29 as a share of the total workers.

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