International Transport Forum | CPB Corporate Partnership Board

New but Used

The Electric Vehicle Transition and the Global Second-hand Car Trade

Corporate Partnership Board Report

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The International Transport Forum

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Abbreviations and acronyms

BEV	Battery electric vehicle
BMS	Battery management systems
EV	Electric vehicle
FCEV	Fuel cell electric vehicle
HEV	Hybrid electric vehicle
ICEV	Internal combustion engine vehicle
SOH	State of health

Glossary

Vehicle stock	Also known as the "vehicle fleet", it refers to the total number of all vehicles that are currently registered and in operation within this country or a region. Vehicles are added to the national vehicle stock through new sales and used car imports, and vehicles leave the national stock through exports and car scrappage.
Stock outflows	Refers to the cars that leave a stock, either through export or scrappage. The total number of outflows is the sum of exports and scrapped cars.

Executive summary

Key messages

1. **Emerging economies need EVs:** They will depend on imported second-hand electric vehicles to decarbonise. Developed countries should not limit exports of EVs to emerging markets.
2. **Exporting countries are changing:** Exports of used cars from China are rising steeply. Used vehicle exports from China to emerging economies may overtake those of all OECD countries combined in the next ten years.
3. **Track the trade:** Used vehicle exports are underreported. Authorities must do more to track them to ensure environmental regulations can be enforced.

Main findings

Approximately one-quarter of the world's population lives in countries where at least half of the cars are imported used cars. Most of these are poorer countries that import second -hand vehicles from developed economies because they are cheap. Many of these imported vehicles are old and in poor condition, endangering humans and the environment.

Approximately a quarter of cars imported by emerging economies in 2023 will have low emissions standards (Euro 3 or lower). Restrictions on importing and exporting highly polluting vehicles could improve the quality of cars sent to emerging economies and bring significant benefits at minimal cost.

Historically, the major exporters of used vehicles to emerging economies have been Europe, Japan, Korea and North America. However, China is set to become a major exporter, too, following a 2019 government announcement to allow used car exports for the first time.

If China's used vehicle exports grow to a similar proportion as Japan and Korea, which export over one-third of deregistered vehicles, Chinese exports could reach 8 million vehicles per year. Even in a moderate scenario, Chinese used car exports to emerging economies would equal those of all OECD countries combined.

The transition to electric vehicles will dramatically affect the international trade in used vehicles. As developed economies switch to electric vehicles, unwanted combustion engine vehicles are being exported in ever-greater numbers to emerging economies, which could undercut their own shift to electric vehicles.

For the foreseeable future, exports of electric cars to emerging economies will remain marginal compared to those of petrol- and diesel-powered vehicles. The widespread availability of unwanted conventional cars in these countries, along with a lack of charging infrastructure, means demand for electric vehicles will take time to materialise. Additionally, exporter countries of electric vehicles will likely prefer to retain control of valuable end-of-use batteries for potential second-life applications or local recycling.

Unless developed economies help to accelerate the transition to electric vehicles beyond the developed world, vehicle electrification levels in emerging economies such as those in Sub-Saharan Africa will remain well below 40% of the vehicle fleet in 2050.

Top recommendations

Improve the traceability of internationally traded used cars

Used vehicle imports and exports are regularly underreported, exports in particular. Large discrepancies exist among the data from different sources, making it difficult to base decisions empirically. The ability to trace used vehicles is essential to enforce restrictions on their export or import and improve the quality of traded vehicles. Traceability helps to ensure the proper disposal of old vehicles via extended producer responsibility and monitor the treatment of end-of-life batteries and their high-value critical material components. The traceability of used car exports also helps choose the optimal locations for recycling and disposal services. Governments should improve reporting by tracking vehicle-related information in specialised databases. These should log the country vehicles are registered in, together with vehicle identification numbers and basic information on powertrain and emissions performance. Additionally, better enforcement is needed to track when vehicles are traded across borders.

Avoid hampering exports of used electric vehicles to emerging economies

Developed countries should not be overly restrictive on the export of used electric vehicles. They may be tempted to do so to develop a domestic second-hand market or to control the supply of critical materials used in batteries. But with few electric vehicles on their roads, emerging economies will struggle to develop charging infrastructure and decarbonise their own fleets, and an electrification gap between developed and emerging countries will result. Developed economies should help to ensure electric vehicles are properly disposed of at their end-of-life in emerging economies.

Ensure used cars for export meet clear roadworthiness criteria, including their emissions performance

Most countries do not impose significant restrictions on trading unroadworthy or highly polluting used vehicles. Both exporters and importers can help to restrict the sale of highly polluting conventional vehicles. These represent a relatively small share of total exports but produce disproportionately high air pollutant emissions. Governments should also link import restrictions to fuel standards to avoid degrading high-quality vehicles with poor-quality fuel. For second-hand electric vehicles, transparent reporting of battery health is crucial to avoid dumping hazardous waste vehicles and to develop market confidence.

Develop sustainable transport strategies in emerging economies to avoid their over-dependence on cars

The potential glut in the availability of cheap, unwanted combustion cars leaving developed economies may cause an uncontrolled expansion in car ownership there. Motorisation can help emerging economies meet citizen’s travel needs and create economic opportunities. Yet an over-dependence on cars at the expense of active and shared modes can cause urban sprawl and congestion and entrench high energy demand and air pollution. Instead, policies should bolster public transport systems and promote safe walking and cycling to reduce the reliance on private motor vehicles.

The global trade in used vehicles

The transition to electric vehicles (EVs) is gathering pace as a critical pillar for decarbonising the global passenger car stock. However, the speed of adoption of EVs varies significantly between countries. New vehicle technologies are typically adopted first in wealthier regions and only later elsewhere, often as exported second-hand cars.

Significant uncertainty remains about how quickly EVs will enter the passenger car stocks of emerging economies through second-hand exports and new sales. Emerging markets risk being flooded with unwanted conventional vehicles as they grow increasingly unpopular in developed economies. Equally, the export of EVs may face additional barriers, such as the desire to recycle or reuse batteries domestically and limited demand from importer countries, which could slow the adoption of EVs.

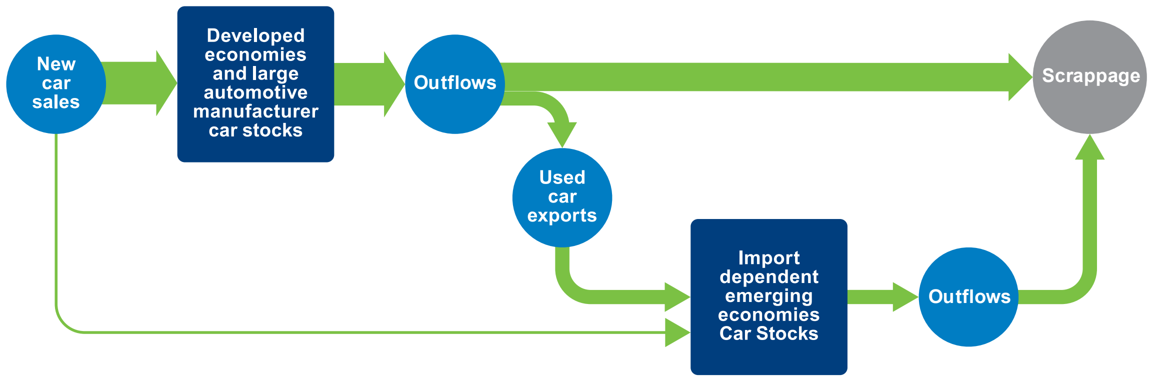
This report aims to shed light on the current global market for used passenger cars and understand how the arrival of EVs may change existing trade patterns. The analysis first explores the current flows of vehicles between countries and examines the age and quality of vehicles sent to emerging economies. It reviews existing policies that restrict the import of used vehicles and touches on forthcoming policy measures under discussion by both importer and exporter countries to improve the quality of used exports. The analysis also examines how the trade in used vehicles is closely intertwined with the industrial policies of some major automotive manufacturing countries and how recent policy announcements may shift the trade balance between regions. Finally, the analysis assesses the complexities of the transition to EVs. This includes how battery recycling, second-life applications and end-of-life treatment and disposal may impact the types of vehicles acquired by emerging economies.

Current flows of used vehicles

Countries differ in how they acquire vehicles. New cars initially enter the vehicle stocks of developed economies, as well as countries with significant automobile manufacturing, such as Argentina, Brazil, China and India. As vehicles age, they pass between multiple different domestic owners before potentially departing the national stock. Their fate typically falls into two categories: being scrapped (dismantled) or being traded to another region for a second life. Figure 1 graphically illustrates the lifecycle of vehicles and how they are traded between regions of the world.

Developed economies acquire most of their vehicles as new car sales to replenish their stocks. Conversely, many emerging economies heavily depend on used imports from richer nations. When vehicles in emerging economies reach the end of their life, they eventually leave the vehicle stock and are scrapped. This report analyses the intricate landscape of the global trade in used cars and focuses specifically on the flow of vehicles between developed and emerging economies.

Figure 1. Simplified flowchart of global vehicle flows



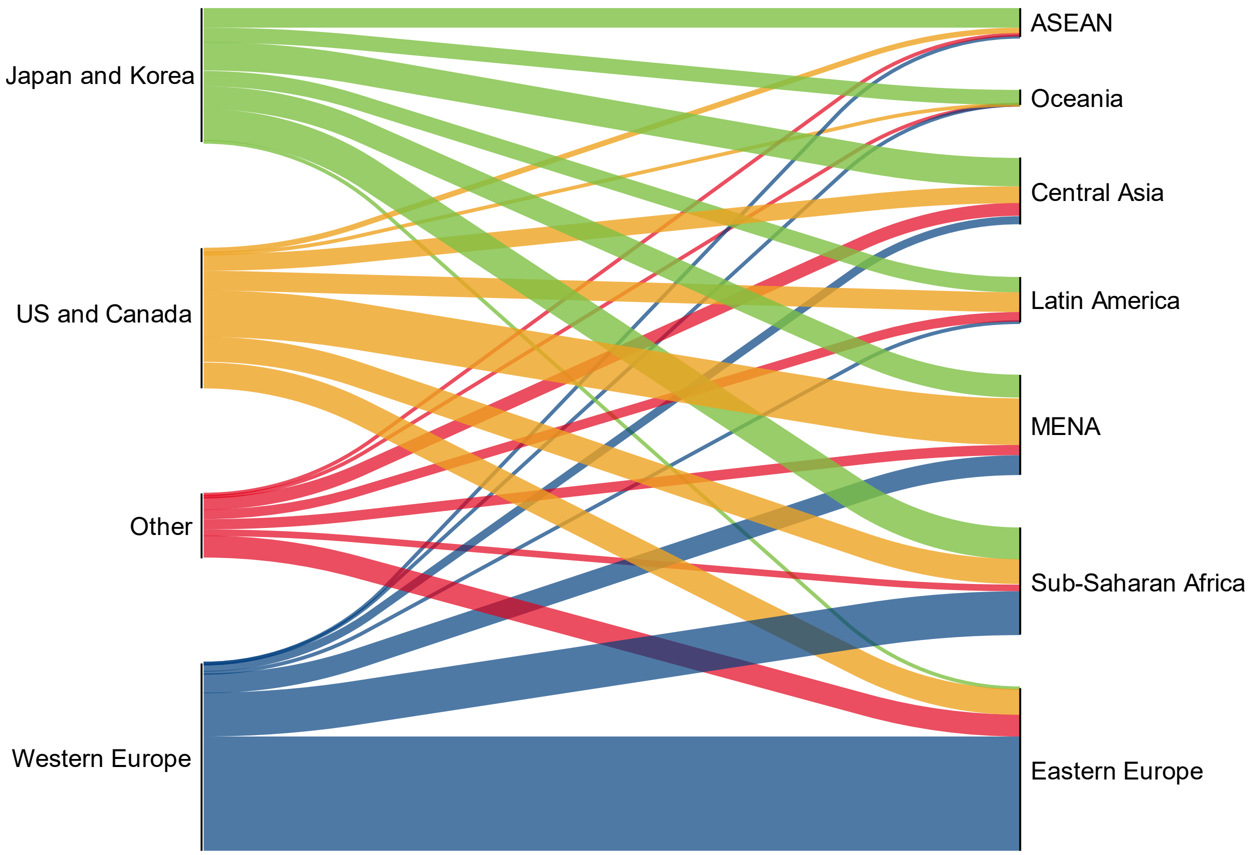
Note: The thickness of the arrows qualitatively depicts the volume of the vehicle flows. Used vehicle exports/imports within a region are not shown.

Consumers in low-income countries have favoured used vehicles for three main reasons: limited access to new vehicle options, significant price disparities between new and used imports and cost-effective repair services from lower labour costs in their regions. With a restricted availability of new vehicles, whether domestically produced or imported, consumers find purchasing imported used cars of their desired type easier. These used vehicles cost significantly less than new ones and, in some cases, may better meet the needs of households or businesses than new cars produced domestically or sourced from other markets. Also, vehicles depreciate faster in developed economies than in emerging economies. One reason is that labour expenses for repair and maintenance are lower in emerging economies. This means consumers in low-income economies may be more willing to pay for additional used vehicle maintenance requirements than equivalent consumers in developed economies (Coffin et al., 2016).

Used vehicles flow from developed economies with significant vehicle production, such as Europe, Japan, Korea and North America, to lower-income regions, as shown in Figure 2. Within Europe, there are many used vehicle flows between countries due to the relative ease of transport between markets and open borders. Vehicles typically move from wealthier Western European countries to lower-income Eastern European countries as they age. However, a significant number of vehicles are also exported, in particular to Sub-Saharan Africa. In the United States and Canada, used cars are likely traded between states, similar to used car flows between European countries. However, these flows are not shown in Figure 2 since they are domestic rather than international. The vehicle stock in Japan and Korea is approximately three times smaller than in the United States. Despite this, international car exports from both regions are similar in magnitude, partly due to national policies incentivising the export of used vehicles (explored later in this report).

Vehicles exported from Canada and the United States are sent to the Middle East and North Africa (MENA), Central America (in particular Mexico), and right-hand driving countries in Sub-Saharan Africa. Conversely, exports from Japan and the United Kingdom, where people drive on the left, are sent to left-hand driving South-Eastern Africa, including Kenya, Mozambique and South Africa. Japanese exports are also sent to Australia and New Zealand. Used vehicles often pass through an intermediate country, such as Chile, Libya, the United Arab Emirates and South Africa, on their way to their final destination in a neighbouring country.

Figure 2. Flows of used vehicles from exporter regions to importer regions in 2019

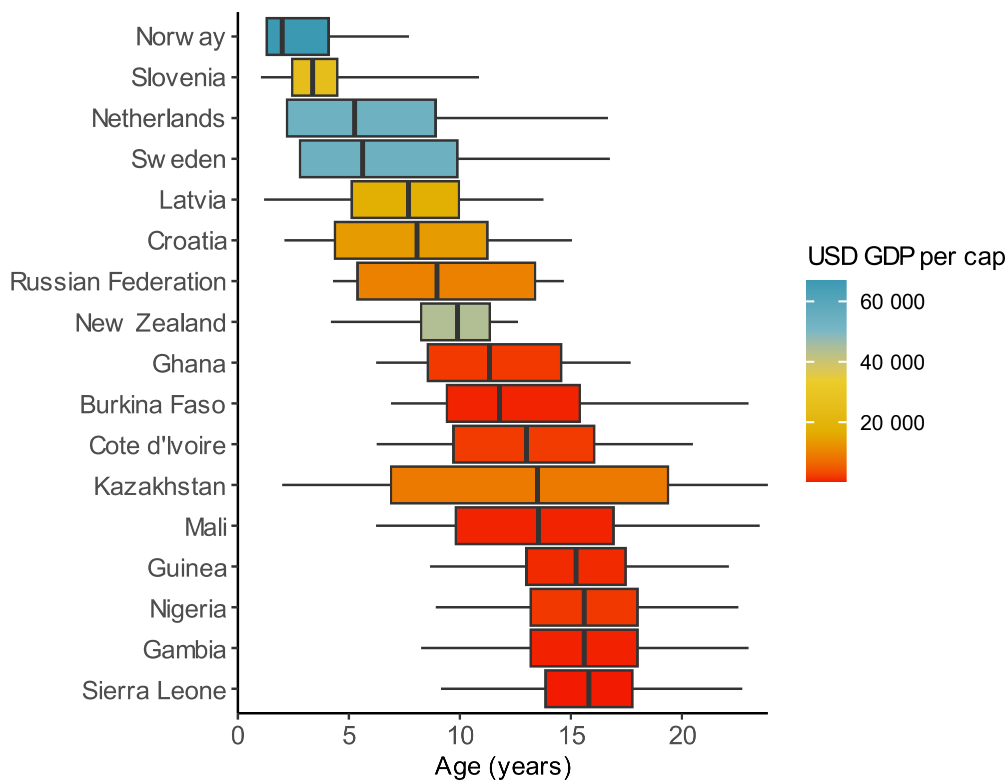


Source: Trade data from international statistics or national statistics offices compiled by ITF. Full details of the data sources used are shown in the methodology section.

The quality of used vehicle exports

The vehicles imported into emerging economies are typically older than those traded between developed economies. Figure 3 shows the age distributions of vehicles imported into selected countries. Used vehicles imported into the Netherlands, Norway, Slovenia and Sweden are typically relatively new and do not account for significant shares of total new annual registrations. Used vehicles imported into Croatia, Latvia and other Eastern European countries are already considerably older (median age ~7-8 years) and account for a greater share of total vehicles entering the national vehicle stock. African countries import even older used vehicles, many with a median age of over 15 years.

Figure 3. Age of vehicle imports for selected countries

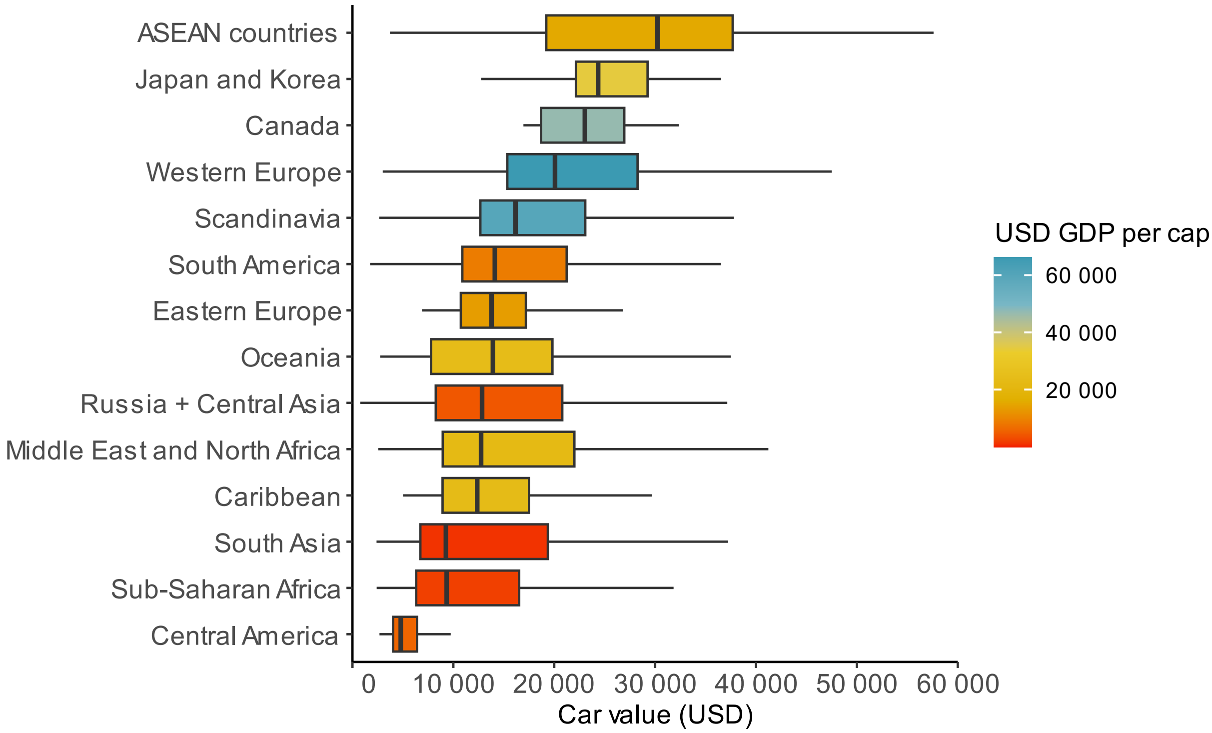


Source: Age distributions from OECD countries are sourced from ITF collection of national statistics. Data from African countries are sourced from (Ministry of Infrastructure and Water Management, 2020). The vertical black line in each boxplot denotes the median age, box edges denote the 25th and 75th percentiles and horizontal black lines are 5th and 95th percentiles of the age distribution.

In parallel with being older, used car exports to many emerging markets are often of poor quality. Figure 4 shows the distributions of the unit value of used car exports from the United States to the largest markets by volume of cars. The average value of a car exported to Central America is around USD 4 800, whereas cars exported to ASEAN countries value more than USD 31 000.

A recent investigation by the Netherlands Human Environment and Transport Inspectorate found that the quality of vehicles being exported to African countries from Dutch ports was similar to those sent for dismantling at end-of-life, considered junk and worthy of scrappage (Ministry of Infrastructure and Water Management, 2020). Exported vehicles were found to have similarly high mileage and age as vehicles sent for dismantling, with only a minority having valid roadworthiness tests. The investigation also found evidence of stolen vehicles being exported and illicit activities such as the removal of catalytic converters, faulty diesel particulate filters and modified odometers. Vehicles that are no longer driveable and classified as waste were also being exported illegally.

Figure 4. The value of exported cars from the United States (2008-2021) to selected markets



Source: Value distributions are sourced from United States national statistics (see Table 1). The vertical black line in each boxplot denotes the median car value, box edges denote the 25th and 75th percentiles and horizontal black lines are 5th and 95th percentiles from the variation between the years 2008-2021.

The poor quality of vehicles exported to emerging markets raises a number of safety and environmental pollution concerns. Inspections of vehicles being exported to Africa found numerous vehicles to be unsafe, often having been involved in accidents or with severe structural damage. In addition, old vehicles produce significantly more air pollutant emissions, particularly if they are not well maintained with high-quality components. Many after-treatment systems containing precious metals as catalysts are often removed before the vehicle reaches the final consumer in emerging economies. This causes even more air pollution emissions, leading to severe health impacts. Furthermore, when vehicles reach their end of life in emerging economies, they must be dismantled and disposed of properly, avoiding environmental damage from materials and liquids in the vehicle. The importance of safe disposal will only increase with the shift towards EVs with even more hazardous materials. Currently, many emerging economies do not have appropriate regular roadworthiness testing procedures to ensure that faulty, dangerous or highly polluting vehicles are properly maintained. A stronger legal framework with better-defined responsibilities, oversight and enforcement is needed (CITA, 2020).

Used vehicle trade: The current policy context

Effective governance and harmonised regional regulations are essential to regulating used vehicle imports. Regulations can control the quality of used vehicle imports, avoiding unsafe or highly polluting cars, but their effectiveness hinges on enforcement. Governance plays a pivotal role in upholding regulations. Notably, both fuel quality and vehicle import quality must be regulated to attain benefits in reducing air pollutants.

Import restrictions

Many countries worldwide have already implemented import restrictions on used vehicles. The United Nations Environment Program (UNEP) reviewed the policies of 146 countries and found that approximately 60% of countries have some form of import restrictions, albeit varying in stringency and enforcement levels (UNEP, 2020). Nations with domestic vehicle manufacturing industries, such as Argentina, Brazil, India, China, Thailand, and Vietnam, often impose stringent import restrictions as protective measures. Many African countries have also implemented import restrictions to avoid unsafe and highly polluting vehicles entering the market. Ensuring such regulations include quality standards is vital to prevent the import of unsafe vehicles. This includes vehicles that have been involved in accidents and have severe structural damage. Many governments also have little incentive to impose stringent import bans because vehicle import taxes can generate significant government revenue (Ayetor, Mbonigaba et al., 2021).

Recent efforts have been made to harmonise fuel and vehicle standards in the West African region. In September 2020, the Economic Community of West African States (ECOWAS) Council of Ministers adopted regionally harmonised fuel quality standards. It introduced Euro 4 minimum vehicle emission standards for both new and used vehicles. Additionally, they imposed age restrictions on imports of used vehicles, allowing only vehicles under five years for LDVs and ten years for HDVs, with a ten-year implementation period. In East Africa, the East Africa Community Council of Ministers adopted harmonised Euro 4 standards and in-use vehicle emission limits for used vehicle imports in May 2022. Euro 4 vehicles date from between 2006 and 2010, so they are already at least 13 years old.

The World Forum on the Harmonization of Vehicle Regulations (Working Party 29, WP.29) is the UN body responsible for international vehicle regulations. WP.29 has established the Informal Working Group (IWG) on Safer and Cleaner Used and New Vehicles (SCUNV) to develop regulations and standards in the areas of safety and environmental protection for both new and used vehicles (UNECE 2022). The IWG aims to develop minimum environmental and safety requirements and test procedures to qualify used vehicles as suitable to be exported/imported.

While emerging economies are increasingly aiming to control the quality of used vehicles entering their countries using import restrictions, a number of countries have included specific exemptions for EVs. Egypt and Bhutan, for example, permit the import of used EVs provided they are relatively young (less than three years) and of low mileage (with odometer reading less than 30 000 km) (UNEP, 2020).

Fuel quality regulations

In addition to restrictions on the import of used vehicles, many countries face a parallel challenge of regulating fuel quality. A mismatch between the fuel and air pollutant emission standards can significantly affect emission control systems in vehicles. Vehicle emissions standards are closely linked with fuel standards (UNECE, 2023). For example, low pollutant emissions in recent emission standards (e.g. Euro 6) rely on modern exhaust gas after-treatment systems (e.g. NO_x catalytic converter), which are highly sensitive to poor fuel quality. Catalytic converters are subject to degradation mechanisms, such as catalyst poisoning through trace chemicals such as sulfur (Wise, 1991, Kumar et al., 2017). Therefore, the Euro 6 standard has a recommended fuel standard with a sulfur content of less than 10 ppm. Some importing countries like Morocco have an import ban on vehicles older than five years and require Euro 6 as an emission standard. However, they only have fuel quality standards equivalent to those required in Euro 4, which have a sulfur threshold of <50 ppm. Egypt or Nigeria require emission standards equivalent to Euro 6 but have fuel standards less than required for Euro 1 vehicles (sulfur content <2000 ppm) (Ayetor, Mbonigaba et al., 2021). Such high levels of sulphur and impurities in the fuel lead to catalyst deactivation and degradation of exhaust gas after-treatment systems, significantly increasing local air pollutant emissions.

Age restrictions, which indirectly influence a vehicle's emission standard without corresponding fuel quality standards, can be detrimental to emission reduction efforts. To effectively address these issues, a comprehensive approach to regulation, enforcement, and harmonisation is essential for both vehicles and fuels.

Export restrictions

Many importing countries have not yet put in place import restrictions to avoid unsafe and highly polluting vehicles. Even when they are in place, challenges in local governance can reduce their effectiveness. For these reasons, there are growing calls for enhancing vehicle export restrictions and rules around the disposal of end-of-life vehicles. The European Union (EU) is playing a leading role and, in 2022, put forth a proposal during the United Nations Environment Assembly. It advocated for a global strengthening of regulations concerning the trade in used vehicles. In parallel, the European Commission has initiated an examination of the used vehicles market as part of a broader review of the Directive on end-of-life vehicles (ELV Directive)(2000/53/EC) and published proposals in July 2023 (European Commission, 2023b).

The proposals include measures to make vehicle producers financially responsible for the vehicles they produce when they reach the end of their lives. These measures, known as "Extended Producer Responsibility", could dramatically change automotive manufacturers' incentives to design vehicles for recyclability and recovery. Under the proposals, manufacturers would be required to participate in collecting vehicles in EU member states, ensuring high-quality end-of-life treatment and covering the associated costs. The Commission's impact assessment suggests the cost to manufacturers would be approximately EUR 39 per vehicle (European Commission, 2023a), which would be passed on to consumers. The proposal outlines that member states are responsible for overseeing the effectiveness of the regulations. The proposal outlines that end-of-life vehicles in Europe can be exported and treated outside the European Union, but only in compliance with EU regulations. An exporter of an end-of-life vehicle must provide evidence that the vehicle was disposed of "in conditions that are broadly equivalent to the requirements laid down in this Regulation [EC No. 1013/2006]". Such non-specific language inspires little confidence in proper enforcement. In addition, there are no provisions to ensure that a used vehicle (not yet at its end of life) exported to a non-EU country is properly disposed of when it eventually reaches its end of life. This raises the possibility that used vehicles could be exported to emerging economies just before their end of life to avoid having to provide evidence of proper disposal.

Ensuring traceability of vehicles using digitally accessible data is essential for enforcement of used vehicle restrictions to understand the quantity, quality and destination of exported used cars, as well as the illegal trade in stolen or unreported vehicles. The European Commission aims to record specific details about each vehicle in a "vehicle passport" to be included in custom declarations through a centralised digital portal known as MOVE-HUB. Additionally, the Commission aims to introduce mandatory roadworthiness tests for all exported used vehicles, ensuring they possess a validity period spanning several months. This is part of an effort to establish clear and binding criteria to differentiate between vehicles classified as "used" and those designated as "end-of-life", which should be disposed of (European Commission, 2023a).

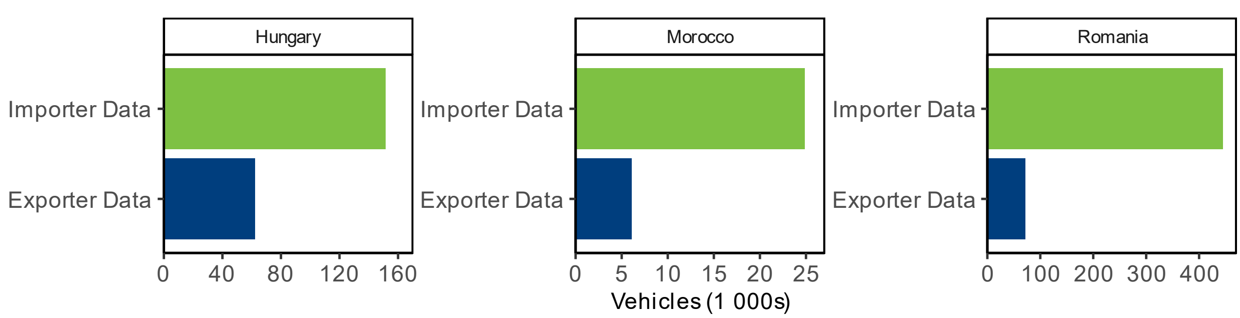
The effects of restrictions on the used vehicle trade

An increasing number of countries now have import restrictions on used vehicles to completely ban imports or limit the import of unsafe or highly polluting vehicles. However, regulations are only as effective as their enforcement. Additionally, their introduction may have unintended side effects, such as limiting access to advanced vehicle technologies.

The effectiveness of import restrictions

A statistical analysis by Coffin et al., (2016) showed that restrictions on used vehicle imports have broadly been highly effective at their desired effect of restricting vehicle flows, leading to an average drop of 76% in imported cars. Similarly, other policies setting restrictions on the quality of vehicle imports were found to have reduced imports by 38% on average. Despite these regulations, there are still loopholes in enforcement and monitoring.

Figure 5. Under-reporting of used vehicle trade: Differences between importer and exporter data



Note: Used export flows of passenger cars for the year 2019. See Table 1 in the appendix for sources. Importer data is the declared total number of used cars imported into each respective country. Exporter data is the total number of used cars declared in exporter country databases as being sent to each country.

Exports of used vehicles are often under-reported from exporter countries. Figure 5 shows the differences between the total numbers of used vehicles entering selected countries based on national statistics from importer countries and exporter countries. Statistics on total used imports collected from importer countries are often significantly higher than the total numbers of exports from the exporting countries, suggesting significant levels of underreporting. Additional differences between data sources are included in the appendix (Figure 17).

In addition to uncertainty regarding the precise numbers of vehicles exported, there are also uncertainties about the final destinations of vehicles. There are two ways of exporting vehicles: direct export and re-export. In the case of direct exports, the car remains in the importing country. Re-export means the importing country is only a transit hub, and the vehicle usually remains in a free trade zone of this country. For example, the major hubs for re-exports of Japanese cars are Chile, the United Arab Emirates (UAE) and South Africa. For land-locked countries and countries with high import tariffs, some importers reportedly choose to bring in used vehicles through ports in countries with lower tariffs and less strict regulations and then transport the vehicles to their final destinations (Brooks, 2012; FIA, 2020). Additionally, counterfeit documentation (FIA, 2020) and corruption of officials at borders (Brooks, 2012) means tracking the final destination of vehicles, obtaining accurate importation data and enforcing import restrictions remains challenging.

For instance, the 1975 ECOWAS agreement permits the temporary transit of used vehicles in partner countries for up to 90 days before legal registration. This allows used vehicles to enter relatively easily and requires stringent enforcement to ensure vehicles are then registered. Drivers are incentivised to avoid registration if they can avoid paying import taxes; this means vehicles may go undeclared. It can also mean that if neighbouring countries do not have a unified approach to used vehicle imports, both on the standards of vehicles permitted and enforcement, then highly polluting or unsafe vehicles may be able to travel in neighbouring countries, reducing the effectiveness of local restrictions.

An investigation by the Netherlands Human Environment and Transport Inspectorate (Ministry of Infrastructure and Water Management, 2020) found evidence of poor-quality vehicles being exported to countries even though they would not comply with local import restrictions. However, import restrictions did influence the age and Euro emissions standard of vehicles sent for export.

An essential measure to improve the effectiveness of restrictions on the trade in used vehicles is to improve traceability and data collection. One promising approach is that of the European Car and Driving Licence Information System, EUCARIS (European Commission, 2022). EUCARIS is a collaborative initiative involving multiple European countries governed by a multilateral treaty. Its primary purpose is to enable data exchange to track vehicles between participating countries better to avoid illegal trade of vehicles (e.g. stolen vehicles). Notably, EUCARIS operates without a central European database, with each participating country maintaining its own vehicle and driving license records, thereby reducing the cost and administrative burden. However, the system is not currently available for non-EU used vehicle importer countries.

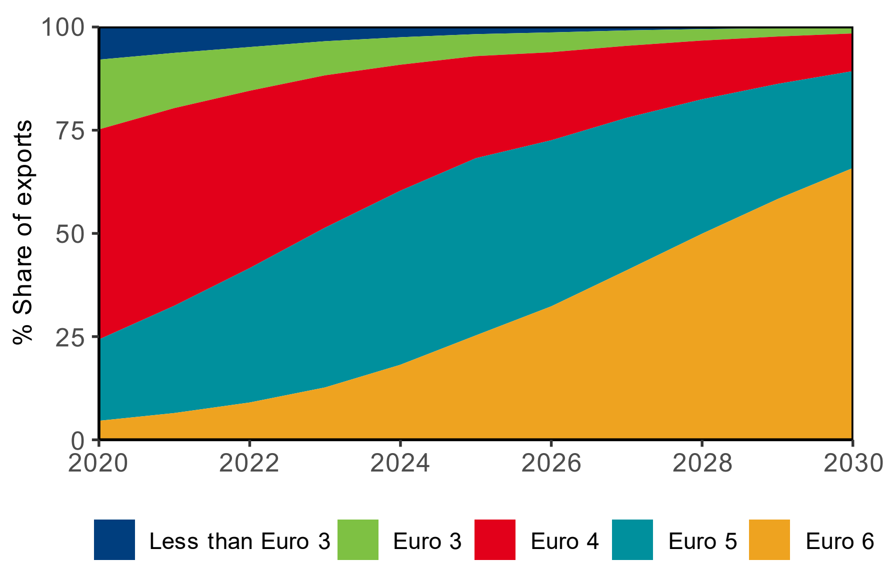
Systemic effects of restrictions on used vehicle flows

In addition to ensuring that import and export restrictions are strictly adhered to and enforced, it is also important to assess the wider systemic impacts of imposing restrictions on the trade in used vehicles. Restricting the flows of used vehicles to emerging economies may have several unintended consequences that need to be evaluated beforehand.

Import restrictions can effectively improve the average quality of vehicles entering a country (for example, by avoiding importing Euro 1-3 vehicles). However, they can also reduce the number and limit the availability of vehicles entering a country. These factors could lead to consumers postponing the decision to upgrade their vehicle, causing them to drive an older, more polluting vehicle for longer. It is important to ensure that the benefits of limiting the import of low-quality vehicles are not offset by additional mileage in older vehicles already on the road in importing countries, which usually have even lower emission standards and higher fuel consumption. In addition, export restrictions in one region may shift vehicle flows of high-polluting vehicles to other countries without import restrictions or with poor regulation and enforcement. However, a study from Nigeria (ICCT, 2019) found that the societal benefits (e.g. resulting from reduced air pollution) of limiting imports to a minimum Euro 4 standard outweighed the additional costs of the vehicles by a factor of ten.

Conversely, import restrictions may help boost domestic manufacturing in importing countries or stimulate vehicles from developed economies to be exported at a younger age by reducing the demand for older vehicles. Figure 6 shows ITF estimates of the share of global vehicle exports between regions by Euro standard equivalents and how these may change over time (full methods described in appendix). Figure 6 highlights that in 2020, approximately 30% of used vehicle exports (mostly from developed to emerging economies) were of a lower standard than Euro 4. An export ban on vehicles with a rating of Euro 3 or less, as advocated for by leading organisations such as UNEP, would help to prevent the most polluting vehicles from being exported. These are not an unsubstantial share of exports today, which could significantly reduce the global pool of available vehicles for export. However, their prevalence will decrease over time and banning their export will likely have a positive impact on reducing air pollution.

Figure 6. Global used vehicle exports by Euro standard equivalent



Note: Euro standards are mapped based on vehicles' year of first sale: vehicles sold before 1993 are Euro 0, between 1993 and 1996 are Euro 1, 1997-2000 are Euro 2, 2001-2005 are Euro 3, 2006-2010 are Euro 4, 2011-2015 are Euro 5 and 2015 onwards are Euro 6. Exports from North America and other regions that do not use Euro standards are given an equivalent rating based on the year of first sale.

Emerging economies still have relatively low levels of motorisation (vehicles per capita), although travel demand is expanding rapidly (ITF, 2023). A large availability of cheap imported vehicles can help meet consumers' travel demands and provide a government revenue source from vehicle and fuel taxation. However, it may also risk entrenching an over-dependence on private passenger cars, causing congestion, urban sprawl and air pollution. Import restrictions, in combination with adequate provision of alternative transport modes and fuel taxation, can help to avoid excessive motorisation in emerging economies. An important long-term way to reduce the dependence on poor-quality used imported cars is to promote motorisation management practices, avoiding past mistakes made by many developed economies (Boateng and Klopp, 2022). A promising avenue to reducing the dependence on the import of used cars and accelerating electric mobility is promoting the use of smaller, lighter EVs such as two and three-wheelers and microcar options (ITF, 2023). Embracing the opportunity of electrification to shift towards new mobility solutions can prove to be both an affordable and sustainable way of reducing the dependence on imported used cars.

The industrial policy of used vehicle exports

Exporting significant volumes of used vehicles can keep the vehicle stocks of exporting countries relatively young. It can also help to stimulate automotive production and new sales of vehicles domestically, thereby boosting industrial capacity. Similarly, limiting imports of used vehicles can help to boost the domestic production of vehicles and associated industries within importing countries. Many major automotive manufacturing countries, such as Argentina, Brazil, China and India, have introduced regulations restricting used vehicle imports to develop domestic automotive industries successfully.

Figure 7 shows the new sales in selected major automotive manufacturing countries and an estimated volume of outflows of vehicles leaving the domestic market. Outflows include vehicles intended for export and vehicles sent to be destroyed in local scrap yards. Outflows from vehicle stocks tend to be of similar magnitude to new vehicle sales but with a lag of approximately 15 years, which is the typical lifetime of a vehicle in developed markets. Just as vehicle sales have progressively grown over time, so too have outflows from vehicle stocks.

Figure 7 also includes the number of used vehicle exports from each country/region. To compare regions, we focus on the share of used exports in the total vehicles flowing out from the stock:

$$\text{Share of exports} = \frac{\text{Used exports}}{\text{Used exports} + \text{Scrapped vehicles}}$$

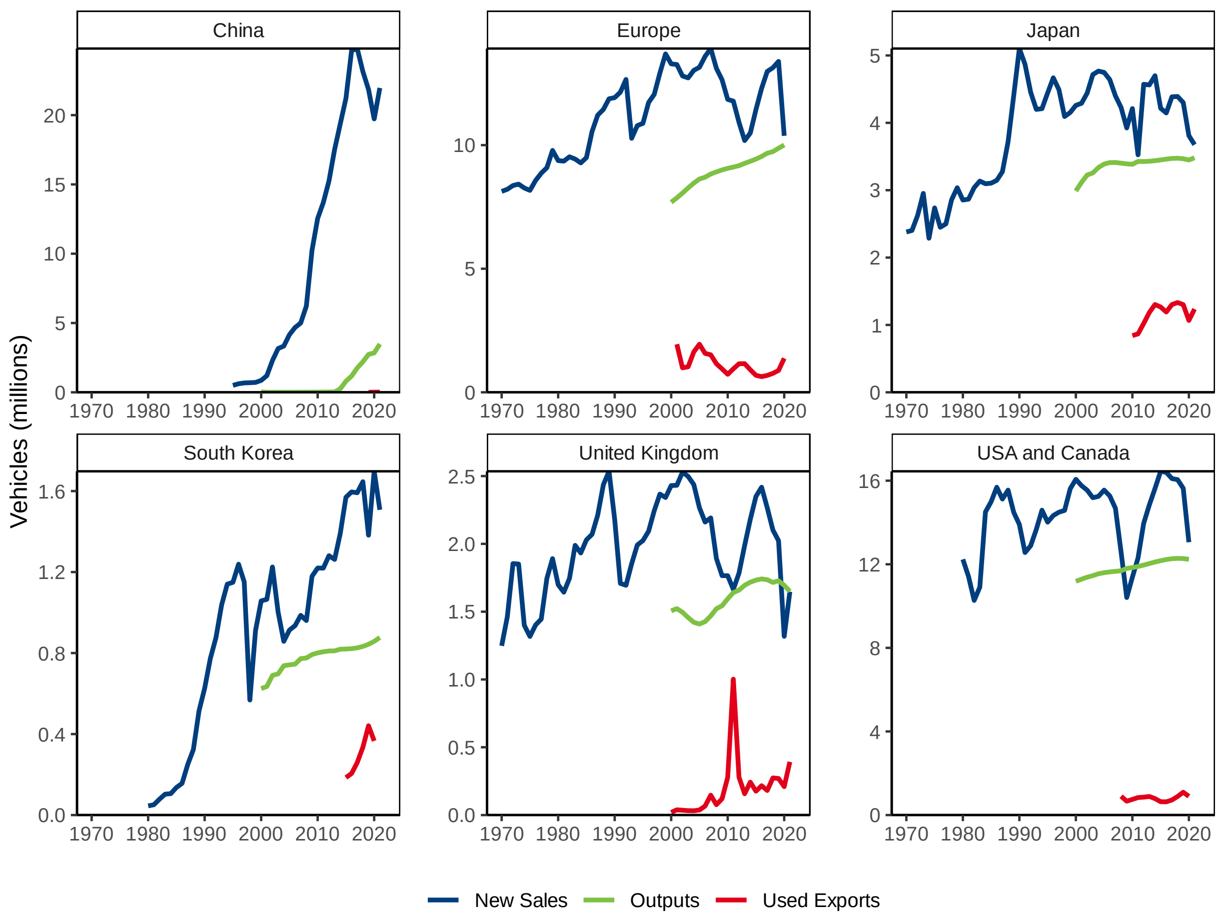
On average, between 2015 and 2020, Japan and Korea both exported 36% of vehicle outflows. The remaining vehicles may have been scrapped domestically. Conversely, the United Kingdom exported approximately 13% of outflows, and right-hand-driving European countries exported 7% of vehicles no longer in use outside of Europe. This share is lower because a significant share of used exports are traded within Europe to Eastern European countries where they are used until their end of life and are therefore not exported outside Europe. Looking only at Western right-hand driving European countries, the share of exports is approximately 12% of outflows, similar to the United Kingdom. The United States and Canada exported approximately 7% of vehicles no longer in use.

On the other hand, China exported an insignificant share of vehicles reaching their end of life. These estimates are based on data collected from government statistics. However, it is well known that some flows are under-reported (see Figure 5), particularly over land borders, meaning the share of exports in Europe and North America may be higher.

The effects of the United Kingdom's 2009-2010 vehicle scrappage scheme can be seen in the number of used vehicle exports in 2011. During this time, the British government gave financial incentives to trade in an old vehicle for a new one. The policy aimed to improve the environmental performance of the domestic vehicle stock. It also stimulated new vehicle purchases and the domestic manufacturing industry after the 2008 financial crisis (Klößner and Pfeifer, 2015). The policy led to a large increase in the number of vehicles exported overseas in 2011, with 218 678 vehicles sent to Zimbabwe, 169 270 to Kenya, 140 400 to Zambia and 128 938 to Namibia. This was more than ten times higher than historical levels. Several OECD countries introduced scrappage schemes after the 2008 crisis, which have been shown to be a relatively expensive way to reduce carbon emissions but relatively effective in boosting domestic automotive manufacturing (ITF, 2011).

In Japan, car ownership costs increase for older and more polluting vehicles to help promote new, more efficient cars. For example, road tax varies with engine displacement and age, meaning vehicles older than 13 years become approximately 15% more expensive to use (OIST, 2023). The fee for the Shaken test, which is the technical roadworthiness car inspection in Japan, becomes 20% more expensive once the car's age exceeds 13 years (Japanese Nostalgic Car, 2023). These policies help to stimulate domestic demand for new cars and increase the vehicles available for export.

Figure 7. New vehicle sales, used exports and outflows of passenger cars in selected vehicle manufacturing countries



Note: Outputs (outflows) refer to vehicles leaving the national vehicle stock to be either exported or destroyed in domestic scrap yards. They are statistically estimated using a scrappage curve (see appendix for methodology). Estimated outflows for the year 2011 in the United Kingdom do not include the effects of the scrappage scheme causing a jump in used exports. Trade data from international statistics or national statistic offices compiled by ITF. Full details of the data sources used are shown in the methodology section.

Japan has been exporting vehicles since the 1960s and peaked in 2010 with 1.327 million units exported. In the first years of exports, vehicles were reportedly highly inconsistent in quality, leading to complaints from importers and even diplomatic problems (Chinese Ministry of Commerce, 2021). In response, Japan introduced compulsory inspection standards in 1971, which were more stringent than technical standards for local car inspection, including strict requirements for tyres and batteries. These standards were gradually relaxed until they were removed entirely in 1996 (Chinese Ministry of Commerce, 2021).

Expectations for China's rapid ascent in global second-hand exports

In recent years, China has risen impressively as a global automotive power. In 2009, China bypassed the United States to become the largest market globally for new vehicle sales. In addition, the country's exports of new vehicles have been growing consistently in the last few years. In the first quarter of 2023, China overtook Japan as the global leader in the export of new cars, with a total of 1.07 million vehicles exported, of which nearly 40% were electric (Zachariah, 2023).

China's rise is now expanding to the used car market. Until 2019, the export of used vehicles in China was prohibited. The primary reason for this restriction was to ensure the domestic availability of used vehicles to meet constantly growing domestic demand. The rapid expansion in domestic car sales in the past decades will result in a huge number of used vehicles leaving the domestic stock in the coming years. These cars will either be exported or scrapped domestically.

Additionally, the demand for new internal combustion engine vehicles (ICEVs) is decreasing due to increasing rates of electrification, both domestically and in developed countries. This has led to unused manufacturing capacities of ICEVs in China, capable of producing up to 15 million ICEVs per year, which are no longer needed, neither for the domestic nor international market. According to an article in the New York Times, a former chief executive of Chrysler China said that China's car industry has to start exporting to avoid shutting down factories (Bradsher, 2023). However, this oversupply of new ICEVs will likely speed up fleet internal fleet turnover, resulting in even more relatively young used vehicles and thus contributing to the oversupply of used vehicles.

To tackle the coming wave of vehicles leaving the domestic stock (see Figure 7), the Chinese government allowed vehicle exports in 2019 and reimagined their long-term strategy on used car exports, echoed in the official release of the 2021 "Guide to China's Export of Used Cars" (Chinese Ministry of Commerce, 2021). Since then, the Chinese Ministry of Commerce has pursued an active strategy to promote the export of used vehicles. The guide aims to support businesses and individuals interested in China's second-hand car export business. The guide identifies 23 countries from the Middle East, Eastern Europe and Africa. It covers various aspects of China's second-hand car export business, such as detailed market analysis of potential importing countries, policy interpretation and risk prevention for Chinese export businesses. The ministry actively supported 30 domestic regions to develop and optimise their car export business as a pilot test, including Beijing and Shanghai (Chinese Ministry of Commerce, 2021). Since then, the Chinese export industry has improved, including used car export management systems, facilitation of the allocation of export licenses and vehicle registration cancellation.

The analysis in the guide also includes the experience of used car exporters in developed countries, such as Japan and Korea. In the case of Korea, their car exports increased significantly with the international recognition of vehicle quality, and once the domestic car market was going to be saturated. Given increasing technological prowess and recently increasing recognition of Chinese cars, China is preparing to push the export of used vehicles. The export of high-quality is favoured to push upfront acceptance in targeted countries. Guidelines and export quality standards have been introduced in the recent report to ensure the high quality of used car exports. Improved quality inspection standards have been issued in later policy updates of the guide. China's Automobile Dealers Association aims to develop the used car business in tandem with the export of new cars to ensure that sufficient after-sales service platforms and spare parts are available in the respective markets. Chinese dealers of used vehicles aim for vehicles "in the range of 30 000 km" on the odometer with "no distinct scratches" (Nan, 2022) to obtain good international recognition. The guide indicates that no vehicles shall be exported where the technical roadworthy certificate will expire within one year.

The country's efforts to facilitate the trade of used vehicles appear to be yielding positive results. Since the start of vehicle exports from China in 2019, the volume has experienced more than a tenfold increase (~3 000 units in 2019 and more than 40 000 units in 2022), and the average value of an exported car has tripled (USD 4900 in 2019 to more than USD 15 000 in 2021) (Keju, 2023; Nan, 2022). The top five destinations of used exports in 2021 were Angola, Benin, Djibouti, Nigeria and Mongolia, with a total of 6 864 units, accounting for nearly 50% of the total exports in this year. The share of new energy vehicles (Fuel Cell EVs [FCEV] Plug-in Hybrid EVs [PHEV] and fully battery electric vehicles [BEV]) from the first half of this year was more than 43%, where FCEVs only represent a negligible share. For now, new energy vehicles are preferably exported by rail and road to inner-Asian countries since some shipping companies refuse to transport used EVs (Keju, 2023). The "Guide to China's Export of Used Vehicles" states that the first wave of domestic EVs is entering the replacement period; thus, EV exports are expected to grow (Chinese Ministry of Commerce, 2021).

Recent export numbers on quantity, type and quality of the used car exports and the Chinese strategy strongly indicate that exports will increase in the coming years. Recent reports state that a shortage of vessels able to ship cars (roll-on-roll-off ships) around the globe is the current bottleneck to vehicle exports from China (Mianqiang, 2022), both for new and used cars. According to VesselValue, a British shipping data firm, the daily rate to charter a ship suitable for transporting cars has increased from USD 16 000 to USD 100 000 within two years (Dixon, 2022). The Chinese car manufacturer BYD has spent a total of USD 600 million for the six biggest vehicle transport ships ever built. Nearly all current worldwide pending orders of 170 ocean-going car-transporting vessels belong to Chinese car manufacturers, such as BYD and Chery, or European and Singaporean shipping lines (Bradsher, 2023). While many of these assets will be used to transport new vehicles, the increase in capacity is expected to lead to greater used vehicle exports as well.

Allowing and promoting used vehicle exports supports the aspirations of the Chinese government to become a major supplier of used vehicles, especially to emerging economies. Since the qualitative requirements for export are high and are enforced in China, the exported vehicles may be in better condition in the future than those from the other major exporting nations. Used cars are likely to be affordable to the consumer since prices for used cars will be relatively low due to the increasing speed of domestic fleet electrification. If Chinese exports to emerging economies are rapidly expanded and transport barriers for new energy vehicles are overcome, it may allow for vehicles to be on the road for several years. This will positively impact the fair transition to sustainable transportation. In the coming years, China will likely continue its journey to dominate used vehicle exports globally.

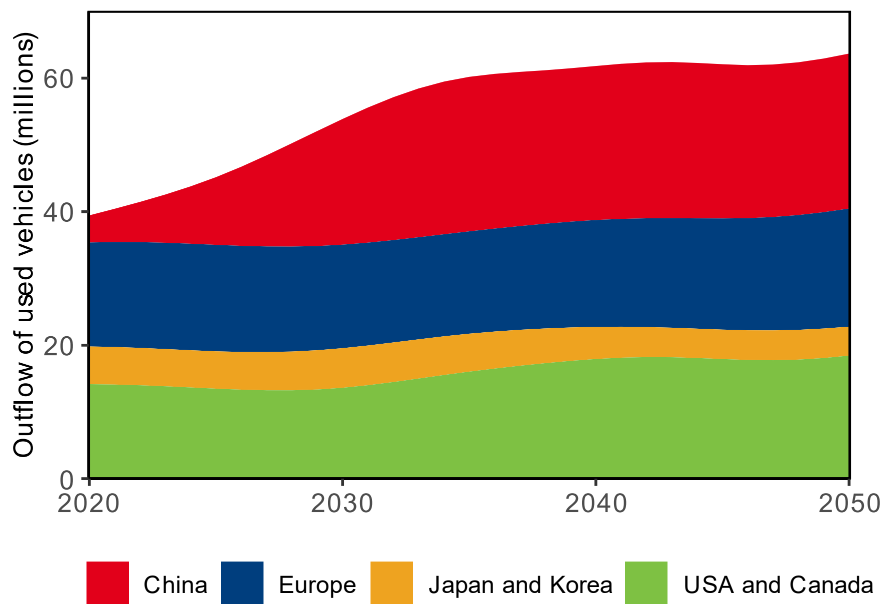
Modelling future changes in the origin of used vehicles

The used vehicle export market is set to change dramatically due to the growing relevance of Chinese vehicle exports and a growing momentum to further regulate the sale of used vehicles by both importing and exporting countries. To investigate the impact of these rapidly changing developments, we examine a possible future scenario for the used vehicle trade (detailed assumptions are included in the appendix).

OECD countries have historically exported a significant share of vehicles rather than disposing of them domestically (see Figure 7). The revision of Chinese export restrictions and their policy ambitions to develop a market for the export of vehicles means they are expected to follow suit and develop significant export capacity.

Figure 8 shows the number of vehicles expected to reach the end-of-life in the stock (stock outflows) of traditional exporter regions and China. It should be noted that these numbers do not represent vehicle exports. Future travel demand by passenger cars in traditional export markets (Europe, Japan and Korea, North America) is likely to be broadly saturated (ITF, 2023). Population growth in these regions is expected to be weak, and in some cases, such as Japan and Korea, populations are expected to fall by 16% in 2050 relative to 2019 (UN, 2022). Similarly, vehicle ownership rates have also plateaued over the past decade. This means future volumes of exported used vehicles from traditional markets are expected to be relatively constant over time.

Figure 8. Global forecast of vehicle stock outflows by region of origin



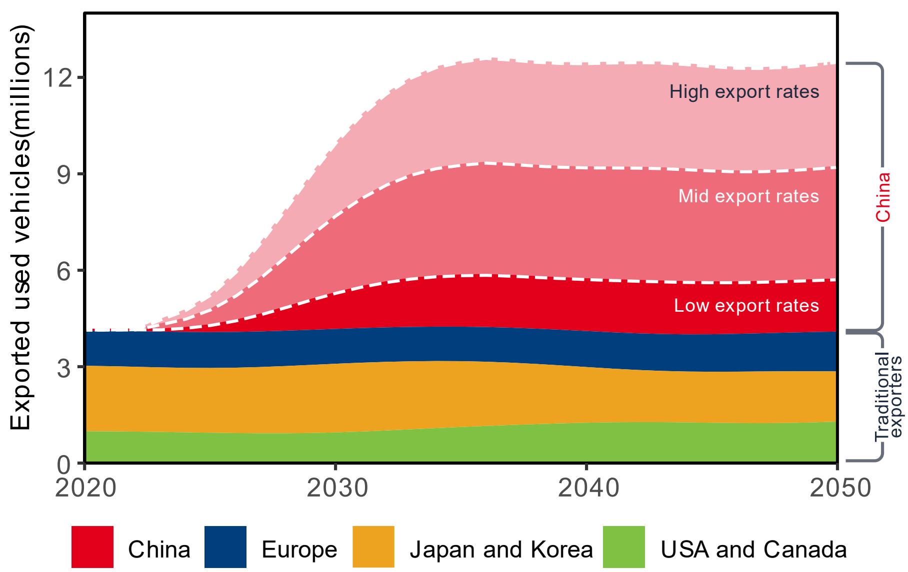
Note: The methodology to estimate the stock outflows can be found in the appendix.

Conversely, Chinese vehicle sales grew rapidly between 2010 and 2020, culminating in 2017 with 24.8 million units sold. This resulted in a rapidly expanding and relatively new vehicle stock (see Figure 7). The average estimated lifetime of a vehicle in China is 17 years until it leaves the domestic fleet. These vehicles will either be dismantled domestically (scrapped) or exported. However, used car exports usually have a younger stock outflow share, whereas older cars are more likely to be scrapped (Chinese Ministry of Commerce, 2021). Following the rapid increase in vehicle sales in the last decade, the number of vehicle outflows from the Chinese stock is set to increase rapidly this decade.

Figure 9 shows an estimate of future used vehicle exports from traditional exporters and China, assuming the share of used exports to the total number of vehicle outflows remains constant in traditional exporters (36% in Japan and Korea, 7% in Europe and 7% in North America). It also includes several scenarios for the scale-up in exports in China, assuming a linear increase from 1% in 2022 to between 7% (equivalent to Europe and North America), 36% (equivalent to Japan and Korea) and a middle estimate of 22% by 2035.

The increasing volume of vehicles coming to their end of use in China (outflows) and the growing share of vehicles now being exported means that Chinese used vehicle exports are expected to change the composition of global used vehicle flows dramatically. The volume of expected Chinese used vehicle exports alone could be similar in magnitude to all other traditional exporters combined.

Figure 9. Modelled export of used vehicles by region of origins

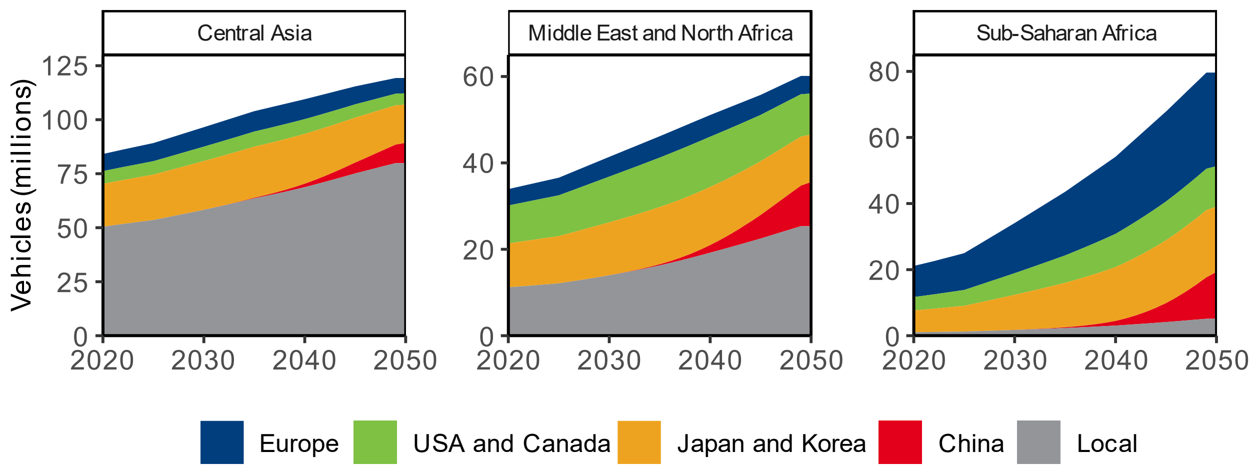


Note: The methodology can be found in the appendix. The figure shows scenarios for the scale-up of Chinese used car exports, assuming a linear increase from 1% in 2022 to between 7% (equivalent to export rates in Europe and North America) and 36% (equivalent to export rates in Japan and Korea, respectively) and a middle estimate of 22% by 2035.

Some of the regions with the highest shares of used vehicle imports include Central Asia, the Middle East and North Africa (MENA) and Sub-Saharan Africa (countries included in each grouping are listed in the appendix). Vehicle stocks in these regions currently have large shares of cars originating from traditional exporter regions (Europe and North America and Japan and Korea). This is likely to continue in future due to the long timescales needed to replace vehicle stocks in these regions and the continuing addition of used imports from traditional exporter regions. However, the expected increases in used imports from China will likely lead to emerging economies using a growing share of vehicles first sold and used in China. This is particularly the case for Sub-Saharan Africa, which has the highest reliance of all regions on used vehicle imports. By 2050, 15-20% of vehicles in Africa may have first been used in China.

The analysis in this chapter highlights that the future trade of used vehicles is expected to change significantly. Regions importing significant shares of used vehicles will likely source an increasing share of vehicles from China rather than traditional exporters. However, this is not the only significant change awaiting the trade in used vehicles. The accelerating transition to EVs adds additional complexity to predicting the future trade in used vehicles and is explored in the following section.

Figure 10. Estimated passenger car stock for selected regions with significant used imports by region of origin



Note: Figure shows the total regional passenger car stock, coloured by the region in which the vehicles were first sold. “Local” refers to vehicles in the stock that were newly sold within this region. Countries included in each region are listed in the appendix. The relative shares of used imports originating from each region are kept constant for traditional exporter regions but scaled downwards to account for the increasing share of exports from China, assumed to be 22% of the vehicle outflows, as shown in Figure 9.

Exploring possible future scenarios of electric vehicle adoption in emerging economies

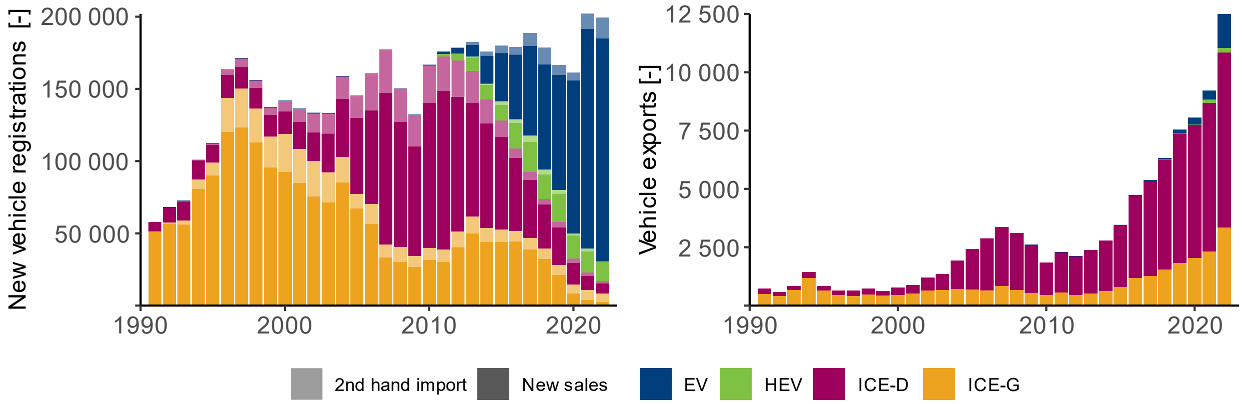
Developed economies are set to adopt an increasing share of EVs within their new vehicle sales, progressively leading to the stock's electrification over the next two decades. As EVs reach their end of use in developed economies, they may be increasingly exported to emerging economies for a second life. As EVs become more popular and gain market share in developed countries, the popularity and residual value of ICEVs will drop as consumers rush to not be the last to use fossil fuel infrastructure. This will increase the incentive to sell used ICEVs to secondary markets, such as Eastern Europe, and subsequently to emerging economies once they become unwanted in the secondary market.

Since fleets in emerging economies heavily rely on the import of used vehicles, their fleets will electrify through imported EVs rather than new sales. That requires that developed economies export their vehicles and that emerging economies have an appropriate demand for EVs and import them. This section explores a number of scenarios to better understand the potential uptake of EVs in emerging economies via the trade in used vehicles. It highlights some of the governing parameters determining the final destination of an EV.

The impact of electrification on used vehicle exports: A case study of Norway

Norway is generally considered one of the frontrunners in electromobility, with the highest share of EVs in new car sales of any country globally. Exploring Norway's transition to EVs and the impact is has had on used vehicle exports can serve as an indication of future market trends in other developed economies. Figure 11 (left) shows the vehicle registrations, consisting of new sales and used imports and exports of used vehicles by powertrain type (right) in Norway between 1990 and 2022.

Figure 11. Vehicle imports and exports by powertrain in Norway from 1990-2022



Source: Data from Norway National Statistics.

Note: EV = electric vehicle, including both battery electric vehicle (BEV) and plug-in hybrid electric vehicle (PHEV), HEV = hybrid electric vehicle, ICE-D = diesel internal combustion engine vehicle, ICE-G = gasoline internal combustion engine vehicle.

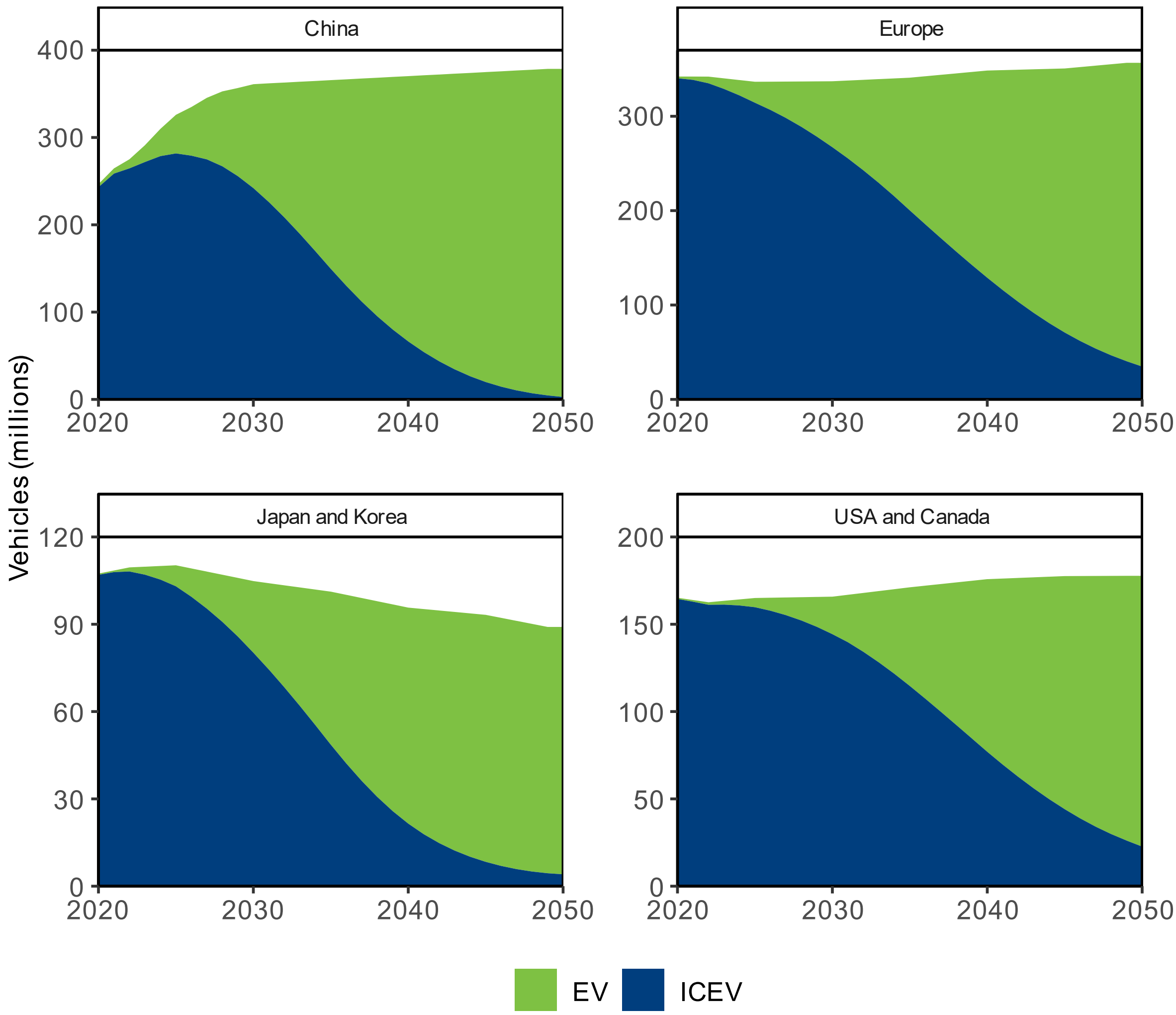
Starting in 2010, when e-mobility took off in Norway, new registrations (new sales and used imports) have been increasingly electric, up to a new registration share of 94.8% in 2022 (EV and HEV), at the expense of new diesel vehicles. The exports from Norway (Figure 11, right) have been consistently increasing since 2010, with an increasing share being diesel vehicles. In recent years, some EVs have started to be exported from Norway.

The example of Norway shows that existing ICE vehicles are exported at increasing shares, with increasing electrification of the vehicle sales. EVs account for nearly all newly registered vehicles, so the vehicle stock will eventually fully electrify at the speed of the vehicle turnover rate. With an average lifetime of a passenger car in the fleet of 10-15 years, fleet electrification will be reached in 15 years. Until then, the remaining conventional combustion vehicles will leave the stock as they reach their end of use in Norway (Figure 11). As the stock of conventional vehicles drains and EVs age, an increasing number of EVs will reach their end of life and be exported.

The transition to electric vehicles in developed economies

Vehicle fleets in developed economies and regions, where new sales are mostly responsible for fleet turnover, are likely electrifying with the increasing penetration of EVs in new sales, driven by national policy announcements. It should be noted that all national policies have targets for new electric sales rather than targets for stock electrification. Figure 12 shows the composition of passenger car stocks in the main used vehicle exporting regions (China, Europe, Japan and South Korea and the United States and Canada), accounting for current trends in EV new sales shares and assuming that EVs reach 100% of sales around 2035 in each region.

Figure 12. Estimated passenger car stock for selected vehicle exporting regions by powertrain

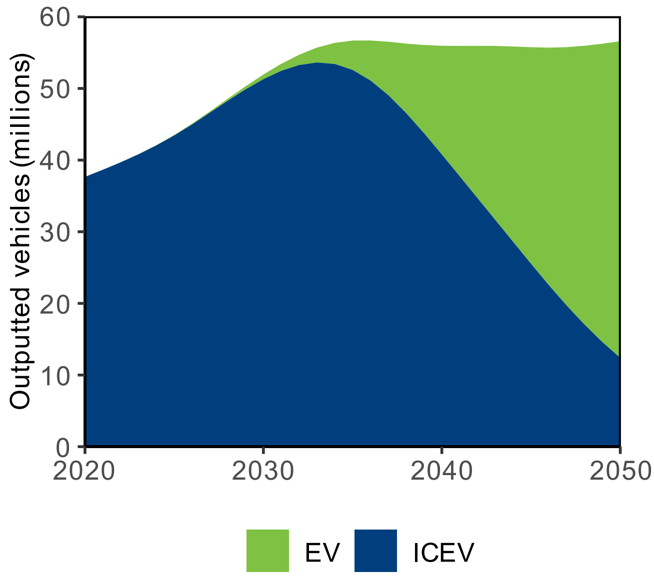


Note: EV = electric vehicle, ICEV = internal combustion engine vehicle.

Such a rapid transition to EVs in developed economies will lead to a significant number of EVs reaching their end-of-use after 2035 if historical trends in trade continue. Figure 13 shows the total number of vehicle stock outflows from major exporting regions. However, this would assume that an EV and a conventional ICE vehicle of similar age have a similar probability of export.

There are a number of reasons to believe this is optimistic. There is considerable uncertainty about how electric vehicle adoption will impact the trade of used vehicles and whether historical trade flows will remain the same. One of the main reasons for this uncertainty is the vehicle's battery, which has the potential for secondary applications, such as energy storage or can be recycled, which may make the export of a vehicle (with a battery) less likely. The following sections examine some of the governing parameters likely to impact the flow of used EVs and their batteries.

Figure 13. Estimated stock outflow cumulated from all major exporting regions by powertrain type



Note: Figure shows vehicles outputted from the stocks of major exporting regions (China, Europe, Japan and Korea and the United States and Canada). Full assumptions and methods are included in the appendix. ICEV = internal combustion engine vehicle, EV = electric vehicle.

What will happen to old electric cars?

A number of decisions dictate the final destination of an EV and its battery. Figure 14 illustrates a flowchart showing potential routes for EVs and their batteries as they age and reach their end of life. When the final owner of an EV in a developed economy chooses to part ways with it, the vehicle could be sent to various destinations. If the vehicle is no longer fit for road use, for example, if the battery can no longer meet the owner's range requirements due to ageing, it may be retired locally. Alternatively, the final owner may choose to sell the vehicle abroad, where the vehicle could enjoy a second life in emerging economies. The value of the vehicle in a foreign export market depends on the willingness of prospective buyers in emerging markets to buy an EV based on its perceived value and factors such as the prevalence of local charging infrastructure.

If the value of the battery is higher than the car's perceived value, for example, if it has been involved in an accident or is no longer roadworthy, then it may not be exported for a second life, and the battery could be separated from the vehicle locally. If the battery is reusable and can be refurbished, it may be used in a secondary application, such as for stationary storage. Conversely, if it is not possible to reuse the battery, it may be recycled or disposed of locally.

Battery recycling can recover valuable raw materials used in the battery, which can be reused to produce new batteries. If recycling is cost-competitive or if policy measures such as the EU Battery Regulation and ELV Directive make recycling mandatory, the battery will be recycled.

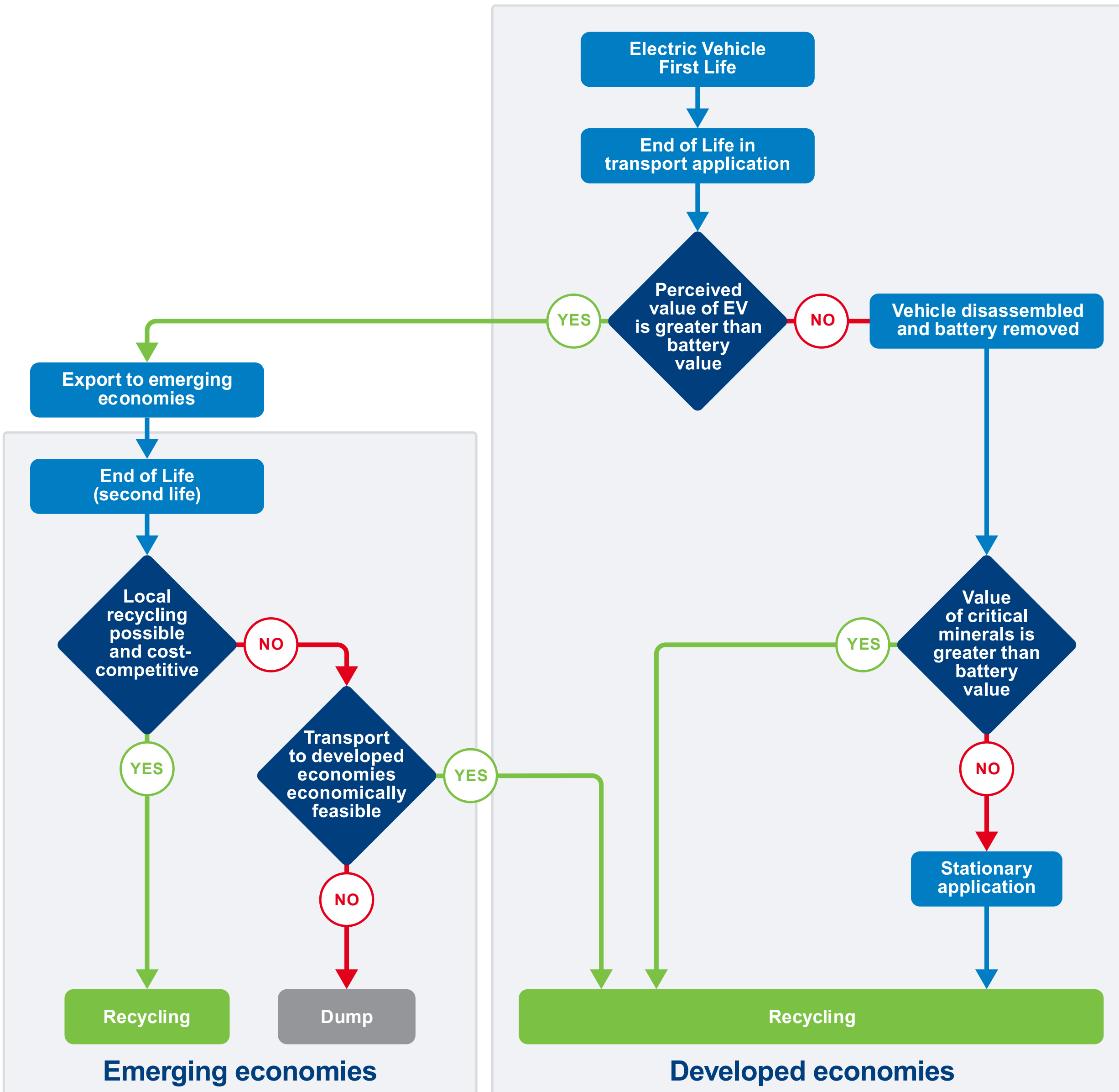
The cost competitiveness of battery recycling depends on sufficient availability and volumes of batteries to recycle and on transportation and processing costs. Currently, the primary source of recycled batteries is defective production scrap, a situation expected to persist until 2030 (ICCT, 2023). Consequently, current recycling plants are typically situated near existing or planned battery factories. However, in remote destinations with small numbers of EVs reaching their end of life, it may not be practical to recycle locally, meaning batteries may entail significant transportation costs, accounting for up to 40% of the variable costs in recycling (Slattery et al. 2021).

After the vehicle has had a second life in emerging economies, it could be recycled locally if the infrastructure is available and economically more viable than transporting and recycling materials in developed economies. However, this is highly uncertain, given the lack of information availability of the battery chemistry and the safety requirements to the recycling process. If none of these conditions are met, the vehicle may be discarded as a landfill, posing a significant risk to health and the environment. It is illegal to dispose of batteries and other non-inert waste in landfills in Europe (European Commission, 2023b). However, not all regions have such restrictions, meaning vehicles may end up being discarded or improperly disposed of.

The feasibility of using a battery in a secondary application depends on a trade-off between the costs associated with refurbishing the battery (and the subsequent economic benefits of its use) compared with the potential revenue from recycling the battery. If used batteries are still in an acceptable state of health at the end of a vehicle’s life, it may be possible to use them for stationary storage systems to provide electricity grid flexibility services (by charging and discharging at appropriate times to help the grid manage voltage and frequency levels) (Harper et al., 2019). Several pilot projects using old vehicle batteries to provide grid services have been rolled out during the last decade (Zhu et al., 2021). However, repurposing batteries for stationary applications presents challenges from both a liability and technical perspective. The repurposing entity will be held responsible for the battery during its entire second life. From a technical perspective, batteries are designed to operate in vehicles, and battery management systems (BMSs) are highly specialised to individual batteries, requiring severe modifications (see next chapter). A retired battery could also be used for energy storage applications for private, residential purposes (“behind-the-meter” application). However, given the perceived risk to the customer of an old battery and the lowering costs for different battery chemistries used for stationary applications, battery refurbishment for stationary energy storage applications will likely be deprived to industrial users. Projections suggest that the global market for second-life stationary applications could become saturated by 2035, given the upcoming wave of retired EV batteries. Once this saturation occurs, batteries will either be recycled or disposed of. Batteries may also be stored until recycling becomes cost-competitive.

The final destination of retired EVs is, therefore, a complex trade-off between various pricing dynamics which are closely interconnected. However, the potential to reuse batteries for secondary applications in developed countries and profit from recouping critical materials from recycling means that they will have a lower probability of being exported than conventional vehicles.

Figure 14. Flow diagram of the whereabouts of electric vehicles/batteries that have reached their end of life in developed economies



Note: The "first life” in developed economies refers to an entire region and may include domestic second use or trade within the region. SOH = state-of-health; EoL = end of life; EE = emerging economies; DE = developed economies.

Reuse, replace, recycle: What’s next?

The value of the battery plays a decisive role in the value of the entire vehicle. The battery’s value varies with the state of health (SOH), which is the amount of energy that the battery can still hold compared to its initial value. The SOH decreases over time due to battery degradation.

Battery degradation

EV lithium-ion batteries are complex electrochemical systems that degrade over time and decrease in performance. In battery degradation, a distinction is usually made between calendar and cyclic ageing, which can overlap and occur simultaneously. If the battery is handled properly, calendar ageing is independent of the battery's use and happens at all times, as well as when the battery is at rest condition. However, battery health remains sensitive towards state-of-charge and ambient conditions, such as temperature or humidity. Conversely, cyclic ageing comprises all degradation mechanisms during charging/discharging cycles.

Battery degradation is not linear over time. It declines quickly at the beginning and end of a battery's life, with a long plateau of minor degradation for most of the battery's life in the time between. At the end of a battery's life, the degradation process is self-reinforcing due to the increasing inner resistance of the battery, which results in more heat generation that speeds up the degradation process. While these trends and timescales are well-known from laboratory experiments (Stroe et al., 2018), only limited information is available under real-world operation from widespread use. The lifetime of a lithium-ion battery, based on calendar ageing since production, is around 15-20 years, around three times longer than the 5-7 years for conventional lead-acid batteries (Turcheniuk et al., 2018). Cyclic ageing highly depends on the charging conditions, such as charging power and external factors, such as ambient temperature.

Some estimates suggest battery cells in EVs are expected to last for 1.6 million kilometres (Harlow et al., 2019). However, the early stage of market deployment of EVs means only a relatively small number of vehicles have reached their end of life.

Battery information inferred from telematic data from thousands of EV vehicles on the road indicates that EV batteries degrade on average around 1.8% per year (Argue, 2023; Geotab, 2021), but varies between brands and models, with the handling of the vehicle and the conditions it is operated in. However, since recent telematic data include older models and battery chemistries, it is expected to be lower. The main factors influencing battery health are: (i) battery age, (ii) high ambient temperatures, (iii) operation at high (>80%) and low (<20%) stages of charge, (iv) fast charging, rather than high usage (high mileage and thus frequent charging at normal charging, if handled properly). For example, batteries of vehicles operated in hot climates (a temperature of 27°C and over for more than three days a month) and with an elevated share of high-power charging (more than three times per month) degrade a lot faster (up to 5.6% per year) (Geotab, 2021).

Over the last years, EV manufacturers have tended to build EVs with increasing battery sizes to limit consumers' range anxiety. While this is far from ideal on a systemic level for using scarce materials, one positive side effect is that large batteries age at a slower rate than small batteries (Canals Casals et al., 2022). Also, the vehicles now reaching their end of life often have old battery chemistries with lower lifetime expectancy than recently developed battery chemistries sold today. This implies that future batteries will degrade less, resulting in longer lifetimes and better battery health at the end of life (Canals Casals et al., 2022).

The state of health of a battery

The state of health (SoH) of a battery indicates the amount of energy it can still hold compared to its initial value. Once the battery SoH drops below a certain value, it may no longer be appropriate for transport applications if range requirements are no longer met. The typical benchmark for the EoL of a battery in transport applications is 80% SoH (Canals Casals et al., 2022; Wood et al., 2011). However, it's important to note that the EoL of a battery is not a physical restriction but rather an indicator below which the battery pack in an EV should be replaced. This definition dates back to 1996 and was first introduced by the United States Advanced Battery Consortium in the "Electric Vehicle Battery Test Procedure Manual" (USABC, 1996). However, given constantly increasing battery sizes and efficiency improvements, this threshold should likely be reconsidered as an indicator for battery EoL since an EV with a battery SoH of, for example, 60% may still satisfy daily range requirements (Canals Casals et al., 2022).

The reliability of technology in EVs, especially the battery (degradation or failure, maintenance costs, etc.), is a significant worry for prospective buyers. Providing reliable and transparent information regarding battery SoH and battery warranty requirements is important to alleviate these concerns. Some recent policy announcements now set requirements for battery warranties. For instance, the California Advanced Clean Cars II regulation mandates that dealerships display the battery SoH of used zero-emissions vehicles (ZEVs) clearly and understandably for potential buyers. Manufacturers must ensure a minimum SoH of >70% over 8 years or 100 000 miles (~160 000 km), whichever comes first for model years 2026-2030 and >75% over 8 years or 100 000 miles for any vehicles sold after 2031. These warranty requirements encompass PHEVs and BEVs.

Similarly, the United Nations Economic Commission for Europe (UNECE), which establishes legally binding technical regulations concerning vehicle design and construction for the European and Japanese car market, has included similar warranty requirements. These requirements stipulate that the battery must retain >80% of its "rated usable energy" after 5 years or 100 000 km and >70% after 8 years or 160 000 km, whichever comes first.

Another vital component of these regulations is the battery passport, which links to a digital platform where manufacturers disclose battery data, making it easier for repair and assessment. While these legislations will undoubtedly lead to an increase in the quality of vehicles and batteries and help alleviate the concerns and uncertainties of potential used car buyers in the US and European used car markets, these measures must also be supported and enforced in developing countries. This encompasses accessing SoH battery data for incoming used ZEVs, ensuring transparency and reliability across global markets. For potential repairability, this may include appropriate training for the local workforce for safe and effective battery and vehicle maintenance.

Battery replacement

If a vehicle has reached its EoL due to battery degradation, it is possible to replace the battery. However, battery replacement strategies for used EVs face significant challenges. Spare parts of conventional vehicles are often small, inexpensive, common between different vehicle models or brands, and can be easily transported across the globe. Conversely, a battery is a highly specialised core part of an EV, with a battery management system taking over vital tasks in monitoring and controlling the battery pack, including thermal management of the battery, which is crucial to its safe operation (Liu et al., 2022). Since the EV market is still relatively young, the aftermarket is poorly developed, especially for critical components such as the battery. That makes it less likely for replacement batteries to be available for various models, particularly in emerging economies.

A battery pack consists of multiple modules, each comprising multiple cells, which fail at different rates. Ideally, individual cells should be replaced instead of replacing the entire battery. However, batteries are currently not designed to be repaired. Some manufacturers even design batteries with barriers to repairability as they do not use common platforms in battery management systems (BMS) or onboard diagnostics systems (Slattery et al., 2021), as is the case for conventional vehicles. This could allow the diagnostics of the battery on a module or cell level. Battery replacements will pose significant challenges for emerging economies, where vehicle repair and maintenance largely rely on unofficial workshops.

A potential second life for a battery

The rapid uptake of EVs will result in a growing number of retired batteries from EVs in the future, which, though no longer suitable for their original purpose, may still be used in secondary applications where the performance requirements of the battery are lower. For example, they could be disassembled and used in micromobility applications, local storage (i.e., residential or industrial purposes), grid flexibility services or as a larger buffer in high-power charging applications to avoid costly grid updates.

Repurposing a battery involves disassembling the battery to a cell level, evaluating each cell's performance and safety, and adding a new BMS adapted for its new application. The new BMS would have to adapt to different battery chemistries, reduced energy and power capabilities, as well as large inconsistencies between different battery cells (Zhu et al., 2021). After repurposing, the refurbishing entity must guarantee its safe operation in a stationary application for the ~10 years of expected service. This transfer of responsibility remains a significant impediment to battery repurposing, especially in residential applications, where consumers may have reservations given the high perceived risk.

The costs of repurposing are mainly driven by the high manual effort of the disassembly (Zhu et al., 2021). However, this could be kept as low as USD 20/kWh, according to the battery-refurbishment cost calculator from the National Renewable Energy Laboratory (NREL). Much research is underway for fully automated battery disassembly and inspection (Meng et al., 2022) and screening and sorting (Lai et al., 2019; Yang et al., 2023). Trends in market dynamics on the future price of second-life EV batteries indicate that in the long term, the price will only be governed by the supply of EoL batteries rather than the refurbishing costs or the price of new batteries (Sun et al., 2018). Therefore, once sufficient transport-related EoL batteries are available, it can be assumed that the costs of second-life batteries will be low. However, it is widely accepted that the supply of EoL batteries will by far exceed the need for second-life applications as a consequence of the strong uptake of EVs (Canals Casals et al., 2022; Harper et al., 2019; McKinsey, 2019; Sun et al., 2018; Zhu et al., 2021). It is also conceivable that old batteries in developed economies are used in applications where they have only a marginal benefit towards decarbonisation and could instead be used to achieve greater emissions-saving benefits in emerging economies.

Battery recycling

Battery recycling is a process that involves collecting, disassembling, and reprocessing used or end-of-life EV batteries to recover valuable materials in the battery. According to Reuters, at least 80 companies globally are involved in battery recycling (Carey et al., 2023). Common battery recycling approaches include material separation after battery disassembly (e.g. by the American Battery Technology Company), shredding into black mass[1] (e.g. by the company Li-Cycle), or remanufacturing the cathodes (e.g. by the company Ascend Elements) (Spector, 2022). Battery recycling minimises the environmental impact of disposing of batteries in landfills or incineration and improves resource efficiency. Different techniques allow raw material recovery rates up to 95% (EVBox, 2023).

Recycling is a main pillar in transport decarbonisation and is highly likely to improve resilience to potential supply chain shortages in critical minerals. In 2022, there was approximately 1.6 TWh of battery manufacturing capacity worldwide (IEA, 2023). However, global battery recycling capacities amounted to just 0.01% of this, meaning just ~0.117 GWh can currently be recycled (Baum et al., 2022). China not only

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[1] Black mass describes the type of waste which results from shredding lithium-ion batteries. The black mass contains all precious metals, such as lithium, cobalt, nickel, manganese or graphite, dependnig on the battery chemistry.

globally leads the entire upstream value chain of lithium-ion batteries used in EVs (75% of global battery supply, >70% of anode and cathodes production and about 50% of refining capacities of critical minerals are located in China [IEA, 2022]), but also the recycling process. More than two-thirds of the global recycling capacities for EV batteries are located in China (Baum et al., 2022). China is buying used EV batteries (Bloomberg, 2021) or importing shredded black mass (Carey et al., 2023) from overseas, which is of increasing concern to local recycling companies.

However, legislative approaches in the United States and the EU will majorly impact global battery recycling. In the United States, the Inflation Reduction Act, which offers a federal tax credit of USD 7500 for a new EV, requires that 80% of the critical minerals be mined or processed in the United States or countries with which it has a free trade agreement (US Congress, 2022). It also meets eligibility criteria if the battery materials are recycled in North America, regardless of where the battery was manufactured (ICCT, 2023).

The recently passed EU Battery Regulation (7/20232) also introduces significant changes to boost battery repairability and recycling. The directive mandates repairability at the battery-cell level. Under this directive, batteries must be made available as spare parts for five years after the last unit of a specific model is placed on the market. The regulation also sets minimum standards for the use of recycled material (e.g. cobalt 16%, lead 85% and 6% for lithium and nickel) (European Parliament, 2022; Right to Repair Europe, 2022). However, the part of the regulation concerning repairability will not come into force until at least 2026, meaning that all batteries in use before then will not be subject to the provisions outlined in the directive and will face challenges to being repaired (Right to Repair Europe, 2022).

If batteries cannot be recycled, they must be disposed of safely. In Europe, it is illegal to dispose of batteries and other non-inert waste in landfills (European Commission, 2023b). However, if EVs reach their EoL in emerging economies, there is a significant risk of improper disposal. This can include illegal landfilling or informal processing, such as deliberately burning batteries, which severely contaminates soil, water and air. Stockpiled or buried batteries can catch fire even months or years after they have been discarded (Mrozik et al., 2021). Improper disposal or abandoned EVs have been reported in emerging economies (UNEP, 2020), and lax environmental legislation in these countries will potentially lead to an increase in this disposal pathway once more EVs reach their EoL in emerging economies (Kwade and Diekmann, 2018). These concerns highlight the importance of supporting stringent local waste management practices.

Will electric vehicles make their way to emerging economies?

The transition to EVs will significantly impact historical patterns of the used vehicle trade. To better understand the impacts of these additional complexities, the following analysis explores different used EV trade scenarios in emerging economies based on the dynamics introduced in the previous sections. In particular, the modelling examines the probability of EV export compared with historical patterns.

If EVs and conventional ICEVs of equal age have a similar probability of export, then EVs will be adopted steadily in emerging economies as they become unwanted in developed economies, in line with historical patterns of trade. In this scenario, emerging economies will continue to receive old vehicles, except an increasing share will be electric. We refer to this scenario as EVs having 100% of the probability of export as ICEVs.

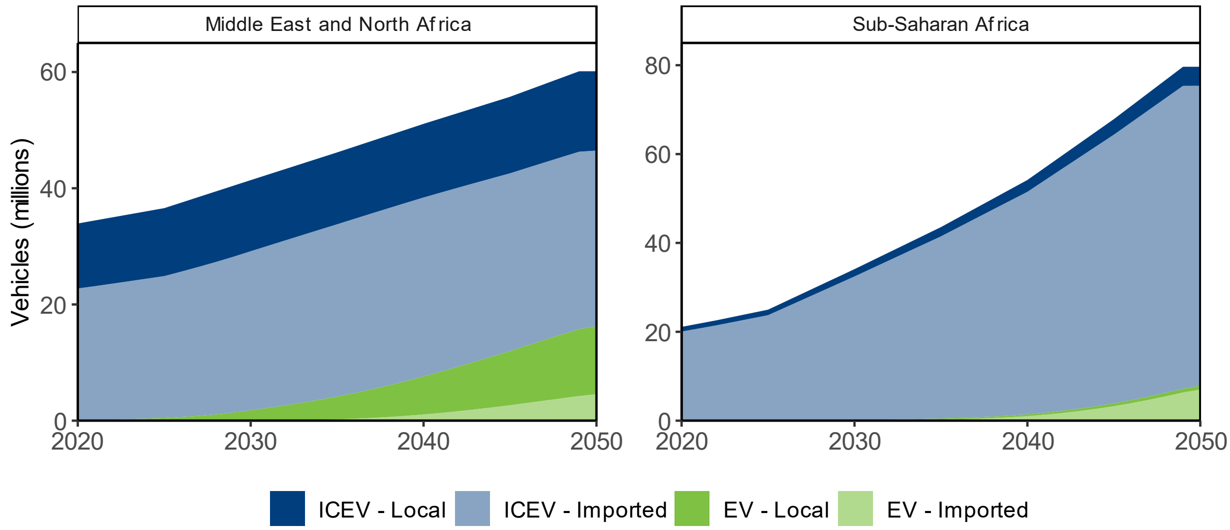
However, several factors are likely to reduce the probability of the export of EVs compared with ICEVs. These include:

- Potential restrictions on the export of used EVs, either from desires to retain control of critical materials or out of concern about the EoL treatment of batteries in emerging economies. These may lead to EVs being dismantled and scrapped in developed countries.
- The residual value of EV batteries, either for second-life applications in stationary storage or as recycled materials, which may lead to a reduction in the exports of EVs.
- The lack of charging infrastructure or even electricity access in many emerging economies may also reduce demand for EVs with respect to ICEVs. Many emerging economies are unlikely to have the government funding available to provide similar levels of subsidies for public charging infrastructure as developed economies to overcome initial market risks when demand for charging is low. While this may change if governments decide to electrify, e.g. public transportation, it is unlikely that the related grid updates will also enable a widespread network of public charging infrastructure.
- Electric two- and three-wheelers may be the first to decarbonise and thus reduce the demand for electric passenger vehicles. They are cheaper, don’t require extensive public charging infrastructure, and are already produced locally, which may make them preferable over an EV-type passenger car.
- If EVs have longer lifetimes and lower maintenance requirements, they may last longer in developed economies before being exported, which would postpone exports relative to ICEVs.
- As vehicle stocks electrify in developed economies, conventional ICEVs will likely become less desirable. This could lead to an oversupply of used ICEV exports in the short- to medium-term (as seen in Norway), meaning EVs could account for a lower share of exports, particularly if the residual value of unwanted ICEVs is substantially lower than that of used EVs.

It is unclear exactly how these factors will influence the probability of EVs being exported relative to ICEVs. However, to provide some indication of the potential impacts, we explore several different probabilities. A probability of 20% represents a scenario in which EVs reaching the end of their use in developed economies are five times less likely to be exported than ICEVs of comparable age and condition.

Figure 15 shows how the vehicle stock in the MENA and Sub-Saharan Africa regions could be influenced by the types of vehicles imported, assuming EVs only have a 20% probability of being exported as ICEVs. These regions are highly dependent on used vehicle imports but would only receive a small share of EVs after they had first been used in developed economies. If EVs are less likely to be exported to these regions, they will likely remain dependent on old ICEVs.

Figure 15. Modelled passenger car stock by powertrain and origin for the Middle East and North Africa (MENA) and Sub-Saharan Africa



Note: This figure shows a scenario in which EVs are assumed to be five times less likely to be exported than comparable ICEVs. ICEV = internal combustion engine vehicle; BEV = battery electric vehicle.

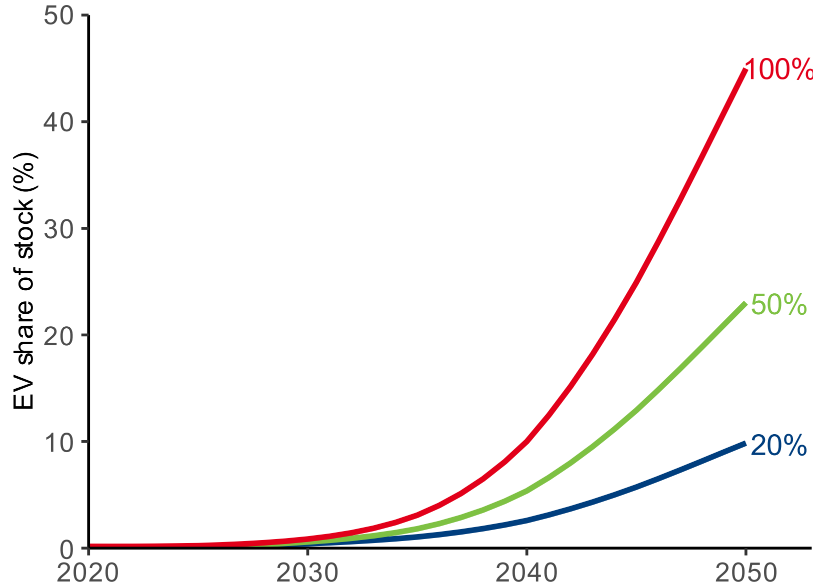
However, with concerted policy action, there is the potential for a greater share of good-quality EVs to make their way to emerging markets. For electromobility to take off in emerging markets, private investment in charging infrastructure, stimulated by public policies, will be needed to deploy charging infrastructure networks.

Irrespective of the actual numbers of received EVs, developed economies should help to manage EoL vehicles to avoid environmental damages from unproperly disposed vehicles or batteries. Additionally, if concerns about the availability of critical materials turn out to be overblown, and developed economies avoid excessive restrictions on used exports while ensuring roadworthy vehicles and batteries are in a good state of health, EV exports could be significantly higher.

Recent ambitions expressed by the Chinese government to export EVs and roadworthy vehicles of adequate quality suggest this is possible. Figure 16 shows the share of EVs in the passenger car stock of Sub-Saharan Africa under different scenarios of the probability of EVs being exported compared to ICEVs of similar age and condition.

If EVs have the same chance of being exported as ICEVs (100%), then it is theoretically possible that almost 40% of the Sub-Saharan African stock could be electrified through the used vehicle trade from developed economies. This is likely to represent an optimistic “upper-bound”, but there is the potential for a significant share of the stock to be electrified even with lower probabilities of export.

Figure 16. Electric vehicle share in the passenger car stock in Sub-Saharan Africa under different probabilities of export



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Appendix: Methodology

Used vehicle flow data sources

Table 1 lists all the datasets sourced by ITF, including descriptions of which were used in the core analysis of this report.

It is challenging to find publicly available and accurate data on the number and type of vehicles imported into emerging economies. For this reason, this analysis relies primarily on data from exporter countries. This analysis groups countries into global regions and investigates used vehicle flows between them (rather than within them) to overcome some of the challenges of cross-border flows of vehicles between countries. Therefore, we hypothesise that a vehicle imported into a region will likely remain within it, even though its final destination country may differ from the country it is imported into.

Having collected data from multiple different sources we found considerable differences between them. Figures 17 and 18 show the differences in total imports and exports of used vehicles between national sources and the Eurostat database. These figures highlight the large inconsistencies between different databases. However, the differences are not limited to the Eurostat database. Comparing the flows of used vehicles between countries where national databases are available (and disaggregated by origin/destination country) again suggests significant inconsistencies.

Many of the national data sources available do not disaggregate used imports or exports by origin/destination. For this reason we use a consolidated data set for the main analysis comprising the data from Brazil, China, Canada, Eurostat, Korea, Japan, United Kingdom and USA. Other predominantly European national datasets are not used for the main analysis since the flows are already included in the Eurostat database (although differing slightly in magnitude). Selected national datasets were used for specific figures as outlined in Table 1.

Table 1. Data sources of used vehicle imports/exports

Country	Source	Used in the analysis?
Albania	Personal communication with Institute of Statistics	No
Armenia	Personal communication with Statistical committee	Only for Figure 18
Austria	Personal communication with statistics Austria	Only for Figure 17
Brazil	https://www.gov.br/mdic/pt-br/assuntos/comercio-exterior/estatisticas/base-de-dados-bruta	Yes

Country	Source	Used in the analysis?
Canada	https://www150.statcan.gc.ca/n1/pub/71-607-x/71-607-x2021004-eng.htm	Yes
China	Chinese Ministry of Commerce, Department of Foreign Trade (2021), *China's Used Car Export Country Guide*	Yes
Croatia	Personal communication with Ministry of Interior	Only for Figure 18
Czech Republic	http://portal.sda-cia.cz/stat.php?o#str=oje	No
Estonia	http://andmebaas.stat.ee/?lang=en#	No
Korea	Personal communication with UNEP	Yes
Europe	https://ec.europa.eu/eurostat/databrowser/product/view/ds-045409?lang=en	Yes
Finland	https://trafi2.stat.fi/PXWeb/pxweb/en/TraFi/	No
Germany	Personal communication with Destatis (Statistisches Bundesamt)	Only for Figure 17
Hungary	www.ksh.hu/docs/eng/xstadat/xstadat_annual/i_ode007.html	Only for Figure 6
Ireland	https://data.cso.ie/	Only for Figure 18
Italy	www.anfia.it/it/automobile-in-cifre/statistiche-italia/trade-automotive	Only for Figure 17
Japan	Personal communication with Ministry of Land, Infrastructure, Transport and Tourism	Yes
Latvia	Personal communication with Satiksmes ministrijas	Only for Figure 18
Moldova	Personal communication with National Bureau of Statistics	Only for Figure 18
Mongolia	www.mdpi.com/2071-1050/14/21/14582	No
Morocco	Personal communication with Ministère du transport et de la logistique	Only for Figure 6
Netherlands	Personal communication with Centraal Bureau voor de Statistiek	Only for Figure 17
New Zealand	www.transport.govt.nz/statistics-and-insights/stock-statistics/2019-annual-stock-statistics/	No
Norway	Personal communication with Statistics Norway	Only for Figure 11 and Figure 17
Portugal	Personal communication with Statistics Portugal	Only for Figure 17
Romania	http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table	Only for Figure 6
Slovakia	Personal communication with Ministry of Interior	No
Slovenia	https://podatki.gov.si/dataset/evidenca-registriranih-vozil-presek-stanja#	No
Sweden	Personal communication with Trafik Analys	No
Switzerland	Personal communication with Swiss Federal Office for Customs and Border Security	Only for Figure 18
United Kingdom	Personal communication with Department for Transport	Yes
United States	https://www.trade.gov/data-visualization/used-vehicle-trade-data-visualization	Yes

Dataset comparison

Figure 17. Used vehicle exports: comparison of Eurostat and national sources

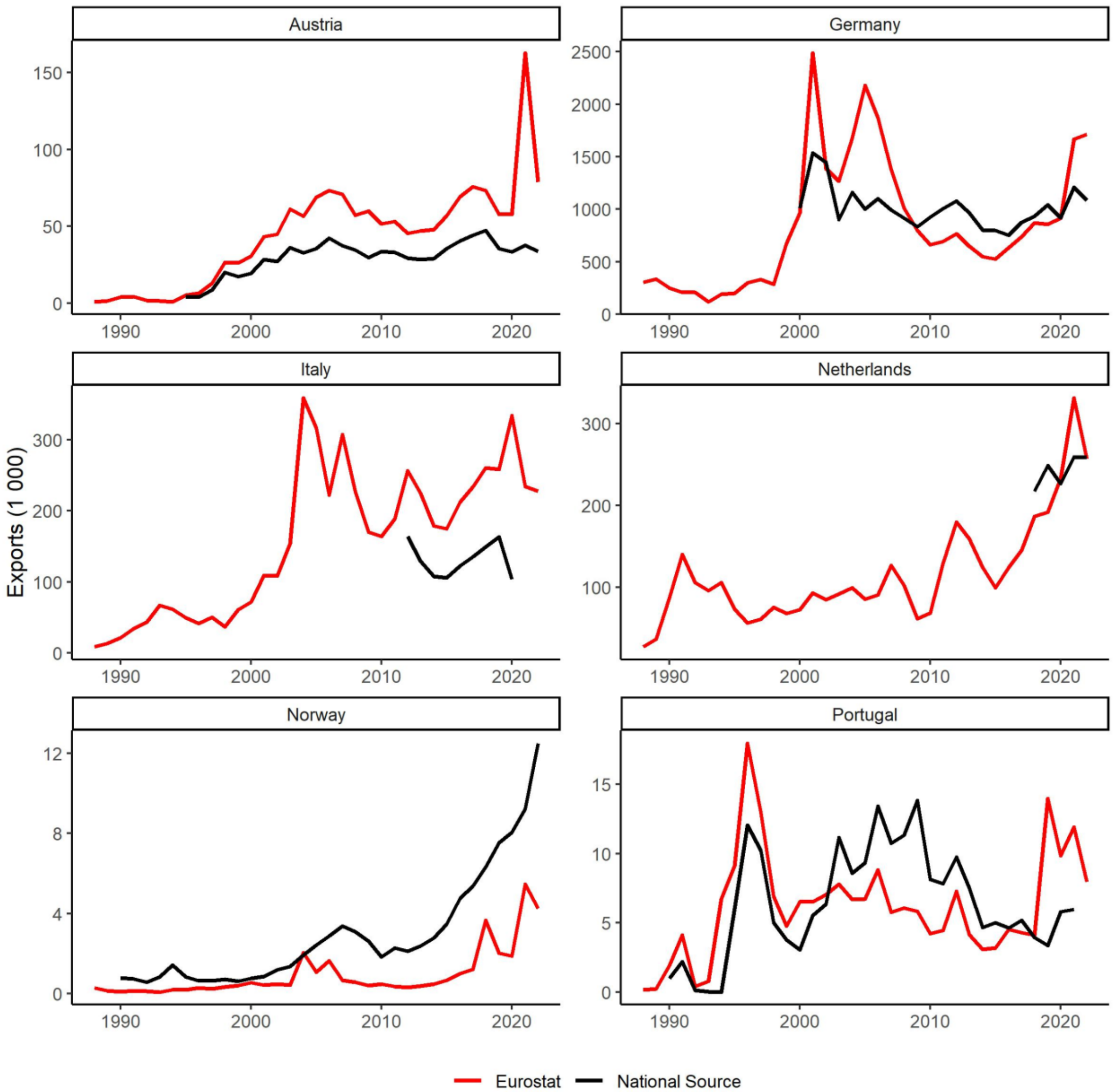
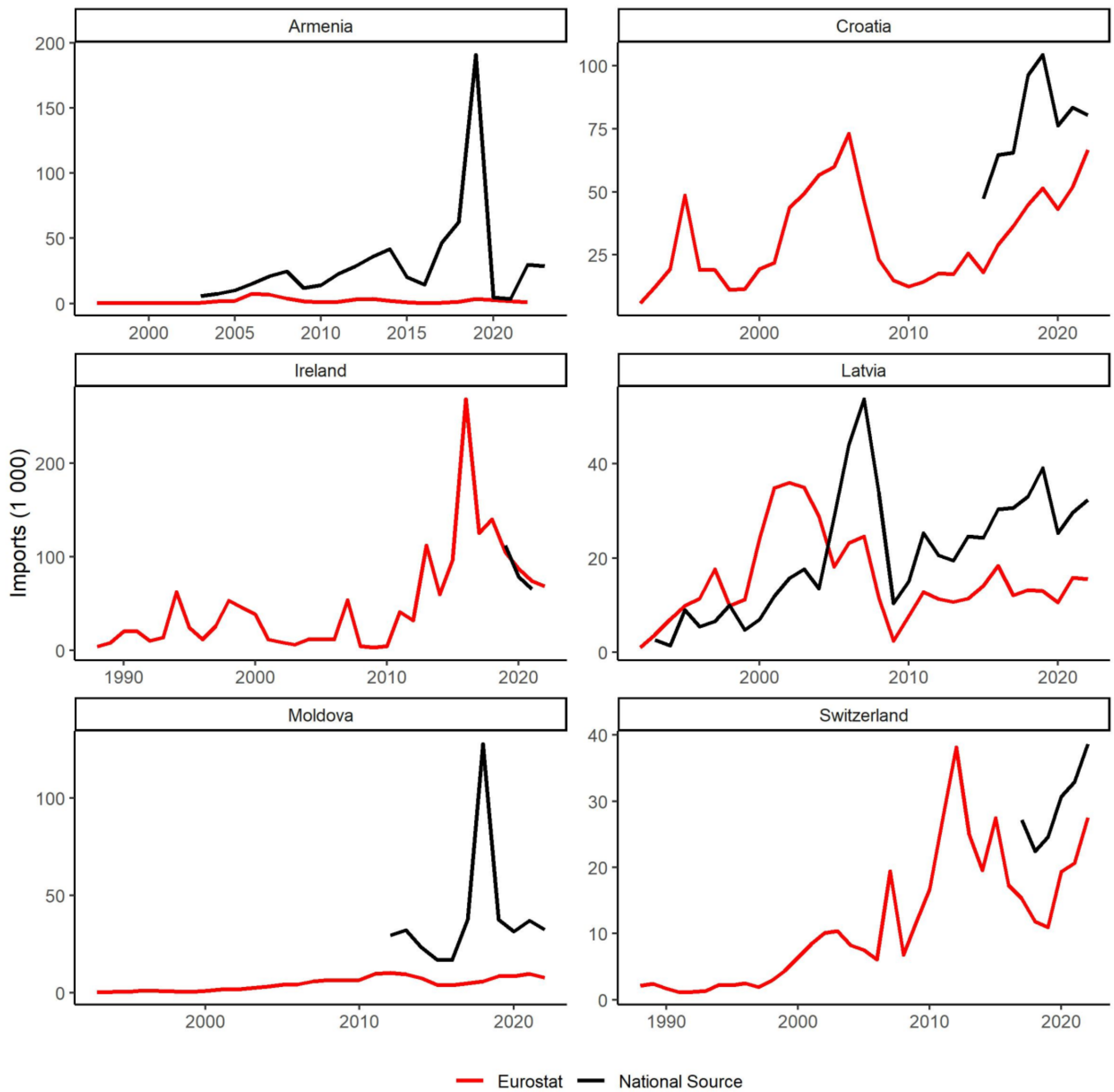


Figure 18. Used vehicle imports: comparison of Eurostat and national sources



Forecasting vehicle stocks

The quantitative analysis of this report builds on the ITF vehicle stock model. This section describes novel additions developed to the stock model for the analysis of this report and the methodology used for specific figures of this report. For a more general description of the ITF stock model and its interactions with other ITF demand models, the reader is referred to the documentation available on the ITF website (ITF, 2023).

Passenger car stocks change over time in line with travel demand projections from the Current Ambition scenario of the ITF Outlook 2023 by region. The model estimates survival curves for each vehicle type in each region and year based on historical time series of vehicle sales (the sum of used imports and new sales) and national stock data. An optimisation module fits parameters b and T_c to select an optimum probability of vehicle survival ϕ, given by the following Weibull distribution equation:

$$\phi_a = e^{-\left(\frac{a+b}{T_c}\right)^b}$$

Where a is the age of the vehicle in years (new vehicle age=0), b is the failure steepness, and T_c is the characteristic lifetime. The optimum Weibull curve is one that minimises the error between historical vehicle sales (inputs into the stock) with data on the national stock in a particular year:

$$\text{Error} = \text{Stock} - \sum \text{Sales}_a \times \phi_a$$

Outflows from the vehicle stock from a region in a given year are estimated using the following equation:

$$\text{Outflows} = \text{Sales}_a \times \phi_a \times (1 - \phi_a/\phi_{a-1})$$

These curves are used to estimate the lifetime of different vehicles over time. When a vehicle is scrapped, it must be replaced by a new vehicle. Similarly, if transport demand using a specific vehicle increases over time, additional new vehicles must be added to the stock to satisfy demand. These factors govern the size of vehicle stocks and their demographics over time. The probability of survival of vehicles in each region and for all powertrains is assumed to remain constant in future.

Modelling the quantity of used vehicles imported/exported

New vehicles must be added to regional car stocks to replace outflowing vehicles from regional stocks and meet additional travel demand. These new vehicles can be either brand new vehicles or used imports. The share of used vehicle imports in total new annual additional vehicles is assumed to remain constant in all regions over time in line with historical shares. To estimate this, we combined used vehicle imports data (see Table 1) with new sales data (from ITF data collection activities and IEA Mobility Model). Europe, China, North America, Japan and Korea are all assumed to continue with ~1% used imports from outside their respective regions (this does not include used vehicle flows within each region). Central Asia is assumed to import 40% of vehicles entering the stock each year, Middle East and North Africa (MENA) 67% and Sub-Saharan Africa (95%).

The median age of used vehicle imports by region is assumed to be similar to historical values and kept constant over time. Informed by the age distributions presented in Figure 3, we assume the age distribution of used vehicle imports into Europe, China, North America, Japan and Korea are normally distributed with a mean of 4 years and a standard deviation of 1.5 years. We assume normally distributed age of imports for Central Asia, MENA and Sub-Saharan Africa have a mean of 12 years, 12 years and 16 years, respectively, with a standard deviation of 3 years, 3 years and 5 years, respectively.

Modelling the origin of used imports

The share of vehicle exports to outflows from traditional exporters is assumed to remain constant at historical values. This assumes Japan and Korea will continue to export 36% of vehicles leaving their domestic stocks (with the remainder being dismantled domestically). Europe and North America are assumed to export 7% of outflows. We assume Chinese used vehicle exports scale up from 1% of stock outflows today to 22% by 2035.

The relative shares of vehicle imports from different regions remain constant over time but are modified to account for the increasing importance of Chinese exports. For example, Sub-Saharan Africa has traditionally received 47% of vehicles from Europe, 20% from North America and 33% from Japan and Korea. We assume these relative shares between traditional exporting regions remain constant, but the total shares decrease with the growing importance of Chinese exports. For example, the origin of imports to Sub-Saharan Africa in 2050 is assumed to be: 45% from China, 26% from Europe, 18% from Japan and Korea and 11% from North America.

Used vehicle exports are only modelled from traditional exporting regions (Europe, North America, Japan and Korea) and China. Potential future used exports from other regions such as India and South East Asia are not explored.

New sales shares of EVs and internal combustion engine vehicles in each region are sourced from the Current Ambition scenario of the ITF Outlook 2023. Passenger car stocks in each region are firstly split by powertrain type based on the origin of the vehicle (whether it was first sold locally or imported from a specific region) and the year of first sale. For example, vehicles first sold in 2030 in Sub-Saharan Africa and still present in the stock in 2040 are split by the new sales share in Sub-Saharan Africa in 2030 (e.g. 10% EVs, 90% ICEVs). Vehicles first sold in 2030 in Europe but present in the stock of Sub-Saharan Africa in 2040 are split by the new sales share in Europe in 2030 (e.g. 60% EVs, 40% ICEVs).

However, this assumes that a used ICEV and BEV have the same probability of export. In a second step, these shares are modified to account for the possibility that BEVs are less likely to be exported to emerging economies than used ICEVs of similar age. To do this, we reduce the sales shares of EVs in used imports by a factor ranging from 20% to 80% and replace the remaining vehicles with used ICEVs of similar vintage.

Regional groupings

Several regional groupings of countries are used to simply the visual representation of trends in this report. They include:

- MENA (Middle East and North Africa): Morocco, Algeria, Tunisia, Egypt, Saudi Arabia, Oman, Yemen, Iraq, Lebanon, Syria, Israel, Palestine etc.
- ASEAN: Indonesia, Malaysia, Philippines, Singapore, Thailand.
- Central Asia: Mongolia, Kazakhstan, Uzbekistan, Russia, etc.
- Sub-Saharan Africa: All African nations not included in MENA.
- Europe: All EEA nations + the United Kingdom + Ukraine etc.
- Latin America: All nations in the continents of North and South America, excluding the United States and Canada.

Workshop attendance list

Onsite /Online	Title	Name	Company
Online	Mr	Aditya Rai	Amazon
Online	Mr	Mohamed Ali Saafi	Aramco Americas
Online	Mrs	Emma McCarthy	UK Department for Energy Security and Net Zero
Online	Mr	Andries Petrus Van Tonder	Chairperson of the IWG on SCUNV
Online	Mr	Lewis W	Columbia SIPA Center on Global Energy Policy
Online	Mr	Jack Queenan	UK Department for Energy Security and Net Zero
Online	Mr	Eduardo Barrientos	ExxonMobil
Online	Mrs	Sheila Watson	FIA Foundation
Online	Mr	Enno Christan	Human Environment and Transport Inspectorate, NL
Online	Mrs	Marietta Harjono	Human Environment and Transport Inspectorate, NL
Online	Mr	Renato Ferreira Formigari	Iberdrola
Online	Mrs	Isabel Gomez	Iberdrola
Online	Mr	Alexander Tankou	International Council for Clean Transportation
Online	Mr	Jacob Teter	International Energy Agency
Online	Mrs	Elisabeth Windisch	International Transport Forum
Online	Ms	Lauren Chester	International Transport Forum
Online	Mr	Matteo Craglia	International Transport Forum
Online	Mrs	Sharon Masterson	International Transport Forum
Online	Mrs	Célie Denez	International Transport Forum
Online	Mr	Andreas Kopf	International Transport Forum
Online	Mr	Godwin Ayetor	Kwame Nkrumah University of Science and Technology
Online	Mr	Rob De Jong	UNEP
Online	Mr	Vahid Aryanpur	University College Cork
Online	Mrs	Alissa Kendall	University of California, Davis
Online	Mr	Lewis Fulton	University of California, Davis
Online	Mr	Roger Gorham	World Bank
Onsite	Mr	Victor Gordillo	Aramco Overseas Company BV
Onsite	Mr	Pierpaolo Cazzola	Columbia University, University of California
Onsite	Mrs	Victoria Delicado Montoya	ENEL
Onsite	Mr	Alexis Roca	ExxonMobil
Onsite	Ms.	Asuka Ito	Fédération Internationale de l'Automobile
Onsite	Ms	Olivia Wessendorff	International Transport Forum
Onsite	Mr	Matteo Craglia	International Transport Forum
Onsite	Ms	Sharon Masterson	International Transport Forum
Onsite	Mr	Soichiro Minami	Ministry of Land, Infrastructure and Tourism Japan
Onsite	Mr	Teruki Yamada	Ministry of Land, Infrastructure and Tourism Japan
Onsite	Mr	Valentin Bouzigues	Mott MacDonald
Onsite	Mr	Mike Conroy	TotalEnergies
Onsite	Mr	Takayuki Kusajima	Toyota Motor Co.

International Transport Forum

New but Used
The Electric Vehicle Transition and the Global Second-hand Car Trade

This report analyses the global trade in used cars and how the transition to electric vehicles may impact it. The analysis explores the quality and age of used vehicles traded globally and maps out how they are traded from developed economies to emerging markets. The report reviews recent importer and exporter policy announcements and uses quantitative analysis, for the first time, to understand how policies may impact the flows of used vehicles between countries. It evaluates potential scenarios of electric vehicle adoption in emerging economies through used vehicle imports.

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