Used vehicles and CO_2 emissions:

A quick scan of what we do and do not know about the effects of European export regulations on CO_2 emissions in Africa.

A short synopsis

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Summary

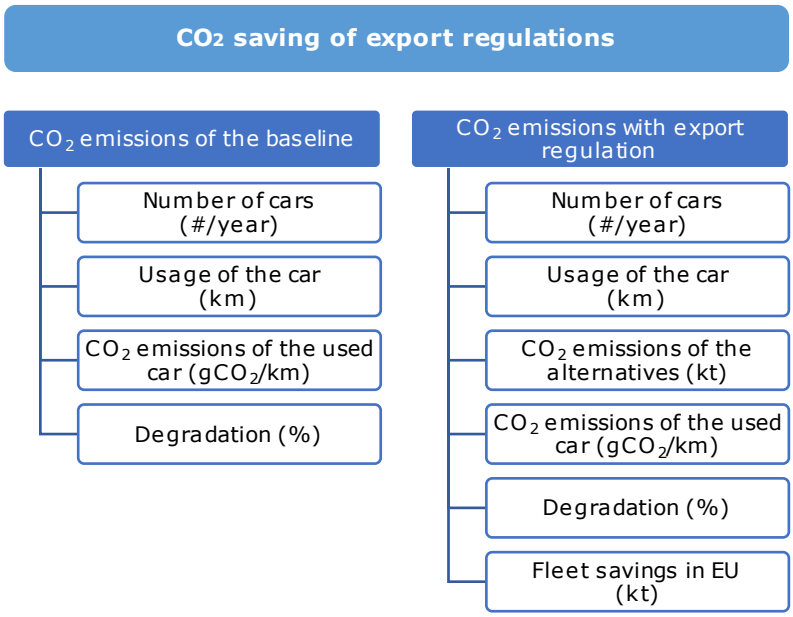
In 2020, around 335,000 used cars and other light duty vehicles were exported from Europe to Africa. Exported second-hand cars shipped from Dutch harbours are, on average, 18.2 years old and have a mileage of 226,000 km. As part of the revision of the European Commission's end-of-life directive, now is a good moment to consider the possible impacts of export regulations for used cars. Export regulations can prohibit the export of cars over a certain age (e.g. ten years), with a low Euro emission standard (e.g. at least Euro 4), over a certain mileage (e.g. 200,000 km), with high CO_2 emissions (e.g. above 150 gCO_2/km) or a combination of these aspects. In this exploratory study, we investigate what we do and do not know about the impact on CO_2 emissions of used cars exported from the Europe Union (EU) to Africa. Furthermore, we address whether the relevant knowledge gaps can be solved through further research. Air quality and safety are also relevant with respect to export regulations on second-hand cars, but they are beyond the scope of this exploratory study.

There are no export regulations in place for used cars, but we can learn from national import bans. Several case studies point out that, on a national level, import regulations contribute to a more fuel-efficient fleet. However, regulations may also increase the prices of and limit access to passenger cars. Some low- and middle-income countries have difficulties enforcing import bans on certain vehicles due to regulations not being harmonised combined with cross-border trade and a lack of expertise and funds. In addition, it can be argued that if one country or region adopts import regulations, the older and less fuel-efficient vehicles that do not comply with them are shipped to other countries and regions without regulations. This shows the importance of harmonised import regulations, and it may be a reason to adopt export regulations.

The CO_2 implications of export regulations depend on the variables given in Figure S1. The baseline is the current situation without export regulations. Even estimating baseline CO_2 emissions is difficult because we do not know how intensively and how long second-hand cars are used in Africa. In addition, data on the specific CO_2 emissions of exported used cars are not easily available. For the situation with export regulations, this becomes even more difficult. The number of cars that are not allowed to be exported with certain types of export bans is not easy to ascertain because data about what cars are exported and their characteristics is distributed across multiple databases, which have to be combined. In addition, the consequences of bans for the average CO_2 intensity of exported cars must be estimated. Moreover, the alternatives for second-hand vehicles from the EU in Africa are unknown. These alternatives can include motorcycles, mini vans, public transport, driving existing cars longer, new cars and purchasing second-hand cars from another region. These alternatives may emit less CO_2 but can also emit more CO_2 than a second-hand vehicle from Europe.

EU export regulations can limit the number of cars exported and their quality, for instance by setting a maximum age or minimum emission standards, or by limiting the specific CO_2 emissions of vehicles that can be exported. The regulations cannot influence the use of second-hand cars in Africa or the alternatives if fewer second-hand cars are available. As such, possible export regulations must be accompanied by initiatives that facilitate sustainable transport options in Africa.

Figure S1 **Conceptual model depicting factors that determine the CO_2 saving of export regulation**



Relying on a lot of assumptions about the CO_2 intensity of exported cars, the usage of the cars in Africa and the alternatives, we can estimate that the CO_2 savings are in the order of 2.6 Mt/year. Whether this is a large amount or not depends on perspective. On the one hand, the CO_2 reduction is less than a percent of the annual CO_2 emissions of all passenger cars in the EU. On the other hand, it is still 2.6 megatons of CO_2 each year. However, this rough estimate is very uncertain. With other assumptions, the CO_2 saving can become negative. As such, it is uncertain whether export regulations should be implemented in the European Union for CO_2 reduction reasons.

To provide better and more precise estimations of possible CO_2 savings of different types of export regulations, a lot of data has to be collected, which is not an easy task:

- Insights into the alternatives of second-hand cars from Europe;
- An overview of the actual specifications of European vehicles that are currently exported to Africa, including fuel efficiency;
- Statistics about car usage in Africa related to annual mileage and average scrapping ages.

It would be costly and time-consuming to collect this type of data. The overarching question is how relevant CO_2 implications are when considering export regulations of second-hand cars from the EU. It is possible that there are other reasons (e.g. enhancing road safety and improving air pollution in African countries) that export regulations for second-hand cars are justified, despite the uncertainty of realising significant CO_2 savings. In this case, intelligently formulating the export regulations could increase the probability that CO_2 would be saved compared to the baseline scenario without export regulations. For instance, it may be possible to set a threshold on specific CO_2 emissions. If this is impossible, a threshold related to age, for example, is more likely to lead to CO_2 savings than a threshold related to mileage because age is a relatively good indicator of CO_2 emissions per kilometre, while mileage indicates very little about the CO_2 intensity of the second-hand car.

Table of contents

1 Introduction

The European Union (EU) wants to reduce its greenhouse gas emissions by 55% by 2030 compared to 1990. To achieve this goal, various measures have been proposed as part of the fit-for-55 package, such as stricter emission requirements for passenger cars and vans by 2030 and a total ban on fossil-fuel based CO_2-emissions from new car engines by 2035. By limiting the CO_2 emissions of new vehicles, the European fleet will become more climate friendly.

Many used European cars are exported to African countries, such as Libya, Nigeria and Guinea. Poor quality used vehicles contribute to climate change, lead to additional safety risks and deteriorate air quality (UNEP, 2020). Several organisations, like the UNECE[1] and UNEP[2] are working on this issue. In addition, the end-of-life vehicle directive of the European Commission is under revision. This directive aims to prevent waste from vehicles, promote reuse and recycling, and improve the environmental performance of all economic operators in vehicle life cycles, especially those involved in the treatment of end-of-life vehicles. One of the identified issues with the current directive is the problem that it is difficult to distinguish between the legal export of used vehicles and illegal export of end-of-life vehicles (European Commission, 2021). Moreover, there are about four million unknown whereabouts annually. These are vehicles that are deregistered without a certificate of destruction or exported without a proper paper trail. Potentially, a substantial number of these vehicles are subject to illegal waste treatment or export to non-EU member states (European Commission, 2021; Kitazume et al., 2020).

Revising the end-of-life directive offers the opportunity to look critically at used cars that are currently legally exported to other continents, like Africa. Regulating exports could ensure that only good quality used vehicles are exported from Europe. Export regulations could, for example, ensure that second-hand cars have a valid road certificate or prohibit the export of cars over a certain age (e.g. ten years old), with a low Euro emission standard (e.g. lower than Euro 4), over a certain mileage (e.g. 200,000 km), with high specific CO_2 emissions (e.g. above 150 gCO_2/km) or a combination of these aspects. Export regulations can influence road safety and air quality as well as affecting CO_2 emissions. Note that, for CO_2 emissions, it does not matter where they are emitted; a tonne of CO_2 in Africa contributes as much to global warming as a tonne of CO_2 emitted in Europe. For fighting global warming, we not only have to reduce CO_2 emissions in Europe but also evaluate our behaviour that leads to CO_2 emissions elsewhere. In other words, does the export of used cars from the EU lead to additional CO_2 emissions in Africa, compared to a situation in which certain European cars are not exported?

1.1 Goal and research question

The goal of this preliminary study is to assess what information is needed and available to assess the CO_2 implications for different kinds of export regulations on European second-hand cars. In addition, we provide an overview of the current relevant knowledge and data lacunes related to the CO_2 implications of different types of export bans. We also assess if these lacunes can be solved through further

[1] The United Nations Economic Commission for Europe (UNECE) is one of five regional commissions of the United Nations. Related to the theme of this synopsis, UN-ECE focuses on getting uniform inspection conditions for vehicles that are exported or imported. In addition, they aim to ensure that such inspections are also mutually recognised.
[2] The United Nations Environment Programme is the leading global authority on the environment. UNEP runs the Used Vehicles Programme, for instance, which supports the shift to cleaner and safer used vehicle flows through the introduction of minimum safety and environmental standards by both importing and exporting countries (https://www.unep.org/explore-topics/transport/what-we-do/regulating-used-vehicles).

research. Furthermore, to get an idea of whether it is worthwhile to further investigate the data and knowledge gaps to gain more insight into the CO_2 impacts of various export bans, we provide a rough estimation of the potential CO_2 savings resulting from limiting the flow of European cars to Africa. Overall, this preliminary study serves as a starting point to assess if further research into the CO_2 implications of different kinds of export regulations is needed and feasible.

This explanatory research can be summarised with the following main research question:

What do we know (and what are the relevant unknowns) about the effects of used cars imported from European Union to Africa on CO_2 emissions in Africa and the possible effect of different kinds of export regulations on these emissions?

This research question can be split into three sub-questions:

- *What do we know about the possible effects of certain import and export regulations?*
- *What determines the CO_2 impact of limiting the flow of used vehicles from the European Union into Africa?*
- *What kind of data and knowledge is missing that is necessary to estimate the impact on the CO_2 emissions of different types of export regulations?*

1.2 Scope

In this explanatory study, we look at the exports of used passenger cars from the European Union (EU) to Africa. We focus in this research on passenger cars, however sometimes passenger cars and vans are grouped together as light duty vehicles (LDVs). Used heavy duty vehicles (e.g. trucks and construction vehicles) are also exported from the EU to Africa. These HDVs are more diverse than passenger cars. As such, their impact on CO_2 emissions is very difficult to establish. Therefore, we only investigate passenger cars, although we believe that many insights also apply to HDVs.

In this preliminary study, we only investigated CO_2 emissions in the usage phase. For a complete overview of CO_2 impacts, emissions from shipping, scrapping and production should also be included. However, for energy intensive products, like cars, the usage phase causes most of the CO_2 emissions (Argonne National Laboratory, 2020).

We are aware that export restrictions on used vehicles can lead to all kinds of side effects, however, these are beyond the scope of this study. On the one hand, export restrictions may raise questions about equity, prosperity and wellbeing. For instance, banning certain types of cars causes scarcity and drives up the price of second-hand cars. This means that fewer people will have access to cars, which has consequences for prosperity and wellbeing (less access to employment, facilities and medical care). On the other hand, export regulations may enhance road safety and local air quality. Bad air quality causes many negative health effects and can even lead to premature deaths. In addition, limiting the flow of second-hand cars from the EU to Africa can also lead to opportunities to strengthen public transport and the African car production sector. In this preliminary study, we do not address the side effects of export regulations.

1.3 Method

We started this explanatory research by conducting a literature review. Three influential publications about exporting used vehicles have been written recently. The first is the Dutch report by the Human Environment and Transport Inspectorate (ILT, 2020); the second is the UNEP report and its update (UNEP, 2020; UNEP,

2021a; the third is a report from the University of California (Fulton et al., 2022). The focus of these reports is not on greenhouse gas emissions, but on the conditions of cars, the size of the flows, and regulations and motorisation management policies in different parts of Africa. Nevertheless, these reports provided a good starting point and helped us find other relevant references. They also provided insights into which countries receive the most used cars from Europe and the conditions of these cars (e.g. age, whether it was whole and whether emission devices functioned correctly).

Subsequently, we tried to find additional statistics, such as average mileage, vehicle age and fuel consumption. from the African countries that receive these cars from Europe. This proved to be very difficult. Accordingly, we contacted government representatives of several African countries. They indicated that much of this data is not collected. Besides requesting statistics, we used these contacts to gain a deeper understanding of the local situations.

We also conducted semi-structured interviews with people working in this field. In these interviews, we spoke about alternatives to used cars, the use of second-hand cars and potential consequences of different types of export regulations.

1.4 Reading guidelines

In Section 2, we explain the current situation regarding the export of used vehicles from the EU to Africa. Subsequently, in Section 3, the influence of national regulations in African countries on a more climate friendly fleet is discussed. This provides insight into the potential effects of certain types of exports bans. In Section 4, we clarify the variables we need to know to estimate the CO_2 effects of an export ban of certain types of cars. We then describe the current knowledge for each variable. Furthermore, we provide a very rough estimation of the first order of magnitude for possible CO_2 savings if export regulations are introduced. We end this explanatory study with a conclusion and an overview of relevant knowledge and data gaps.

1.5 Disclaimer

In this report, we often refer to all African nations as ‘Africa’ or use the term ‘African nations’ in a general sense. Similarly, we often use the term ‘African people’. We are aware that Africa consists of very diverse nations and people, each with their own culture, society and national identity. However, in order to make some general statements regarding the findings of this report, we often use these terms for clarity and conciseness.

2 Current situation

In this chapter, we describe the current situation regarding the export of used cars from the EU to Africa. This section is largely based on data from the UNEP reports, the RDW[3] and on the 2020 ILT report. The latter study combined desk research with field work conducted in the port of Amsterdam on cars that were going to be exported to Africa.

2.1 335,000 cars and other light duty vehicles exported from EU to Africa in 2020

Registrations show that around 335,000 used light duty vehicles were exported from the EU to Africa in 2020 (UNEP, 2021a). In the same year, roughly 900,000 cars were imported into Africa in total. In 2018, these numbers were significantly higher; slightly more than one million used light duty vehicles were exported from the EU to Africa out of a total of about 1.5 million that year. The reason for this large decrease between 2018 and 2020 is unclear.

In addition to legal registration, it is possible that some of the unknown remainder ends up in Africa either as usable vehicle or as waste. In 2017, there were about 3.8 million untraceable vehicles in the EU (European Commission, 2021).

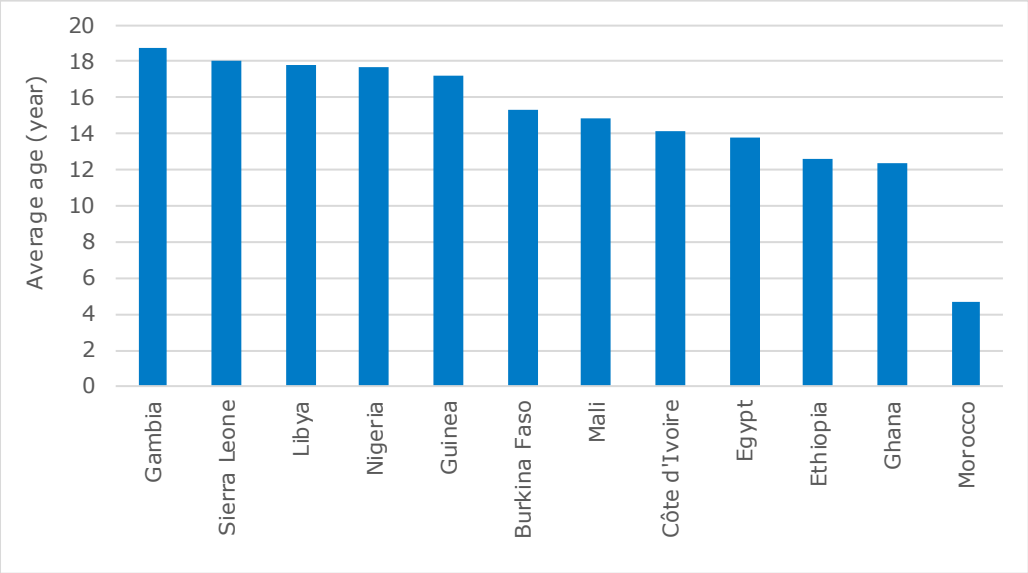
In 2022, approximately 37,000 cars from the EU were exported to Africa through Dutch ports. Half of those cars went to Libya. Other top destinations in 2022 included Guinea (11%), Benin (6%), Nigeria (6%) and Ghana (6%) (source: internal data provided by RDW). Some of these countries are gateways to other countries. For example, Libya seems to function as an important gateway for used vehicles, moving cars to other countries, like Sudan, Chad and Niger (UNEP, 2020). Benin also re-exports many used vehicles to Nigeria (Ezeoha et al., 2018).

2.2 Many cars are relatively old, ranging from 12 to 19 years old

Many cars exported to African countries are relatively old. Cars bound for Morocco are an exception, as they are 4.7 years old on average (see Figure 2.1). The average age of the cars bound for other African countries, however, is between 12 and 19 years old. In comparison, on average in the Netherlands cars are scrapped at 19.4 years old in 2021 (Kok et al., 2022). Passenger cars and vans exported to West African countries have similar characteristics to cars and vans scrapped in the Netherland with regard to age, Euro emission standard and mileage (ILT, 2020).

[3] RDW is the Dutch organisation charged with the registration of motorised vehicles and the distribution of driver's licenses.

Figure 2.1 **Average age of cars exported to various West-African countries (ILT, 2020)**



2.3 Many exported cars bound for Africa are in bad shape

As stated, many cars bound for African nations from the Netherlands are in a condition in which they would usually be scrapped. The ILT did fieldwork testing on 160 vehicles in the port of Amsterdam and found the average mileage of all tested vehicles was 226,000 kilometres. Often, the vehicles lacked valid periodic roadworthiness certificates (Periodical Technical Inspection (PTI)). 20% of the 122 tested petrol vehicles failed the tests for emission requirements and 86% of the tested 38 diesel vehicles did not have particulate filters due to their age (five tested diesel vehicles had one, but only one functioned properly). In several cases, the catalyst had been removed. 85% of all tested cars were Euro 3 or below; only 15% were Euro 4 or above. However, since several of the filtering devices did not work properly or had been removed, the cars may not have been as clean in terms of air pollutants as the Euro emission standard would suggest. Due to this, a Euro 4 car might even emit as much or even more air pollutants or particulates as a Euro 3 car.

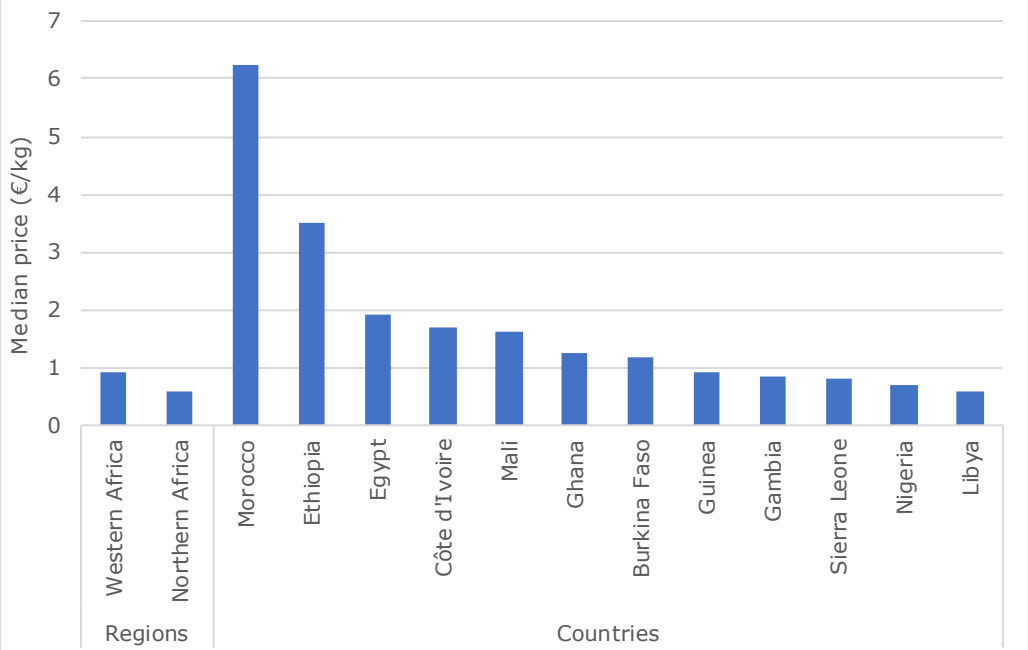
Although PTI, missing particulate filter and catalyst removal do not say anything much about CO_2 emissions, it shows that many cars exported to Africa are in bad shape and not considered roadworthy in Europe. Furthermore, it shows that enforcing export regulations on Euro emission standards may have less effect on air quality in practice than on paper.

2.4 Many exported cars are low in value

Although the actual value of an exported car is dependent on age, mileage, condition and brand, the average price can be expressed in price per kilo. In Figure 2.2, the median price of cars exported from the Netherlands to different regions and countries in Africa is given. Most used cars that are exported to Northern and Western African countries have a price per kilo lower than 1 EUR per kg; commonly between 0.40 and 0.70 EUR (ILT, 2020).[4] This means that an average car, weighing 1,300 kg[5] will yield between 520 and 910 EUR when exported to Africa. To put this figure into perspective, an average second-hand car in the Netherlands costs around 23,500 EUR (RTL, 2022).

[4] For reference, the price of scrap iron is around 15 eurocents per kilo (Geelhoed, 2023).
[5] Based on an average of 9 vehicles referenced in ILT (2020).

Figure 2.2 **Median price of cars exported from the Netherlands to different regions and countries in Africa (ILT, 2020)**



Bron: ILT (2020)

2.5 Many African countries depend on imported second-hand vehicles

In 2020, around 900,000 used light duty vehicles were imported to Africa. The main origins of these vehicles were EU (37%), Japan (25%), the United States and South Korea (together 37%). On average, more than 60% of the annual growth of the African car fleet comes from imported used vehicles (UNEP, 2020). In Nigeria, 85% of the cars added to the fleet every year are imported second-hand vehicles; in Uganda and Rwanda this is more than 90%, and in Kenya it is more than 95% (UNEP, 2020; GFEI, 2020; Twagirimana, 2022; Forster and Nakyambadde, 2022). In South Africa on the other hand, the percentage is zero, because of an import ban on second-hand vehicles.

2.6 The African car fleet will continue to grow

In the coming decades, over one billion cars will be added to the world's car fleet, almost doubling it in size. Most of this growth will take place in the Global South[6], which the African continent is part of. The growth of the African fleet will consist of imported cars from the Global North and newly sold cars (de Jong, 2023). In 2020, there were approximately 72 million passenger cars in Africa, compared to 237 million in the EU (Ayetor et al., 2021a). In 2014, only 2% of the sub-Saharan population owned a car, compared to 50% in Europe and 70% in the United States (IEA, 2014). The International Energy Agency (IEA) expects the number of vehicles in Sub-Saharan African countries to triple by 2040 (IEA, 2014), see Figure 2.3 and Figure 2.4.

[6] The Global South mainly refers to Africa, Middle America (including Mexico), South America and large parts of Asia (excluding Japan and South-Korea). The Global North refers to Europe, the U.S. and Canada, Australia, Japan and South Korea (Braff and Nelson, 2022).

Figure 2.3 **Growth of the African passenger car fleet by 2040, compared to 2012. West, Central, East and Southern refer to groups of African countries. Our study focusses on West Africa, which includes Nigeria, Ghana and Benin (IEA, 2014).**

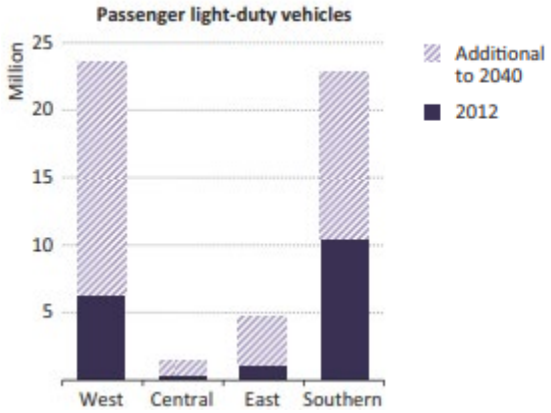
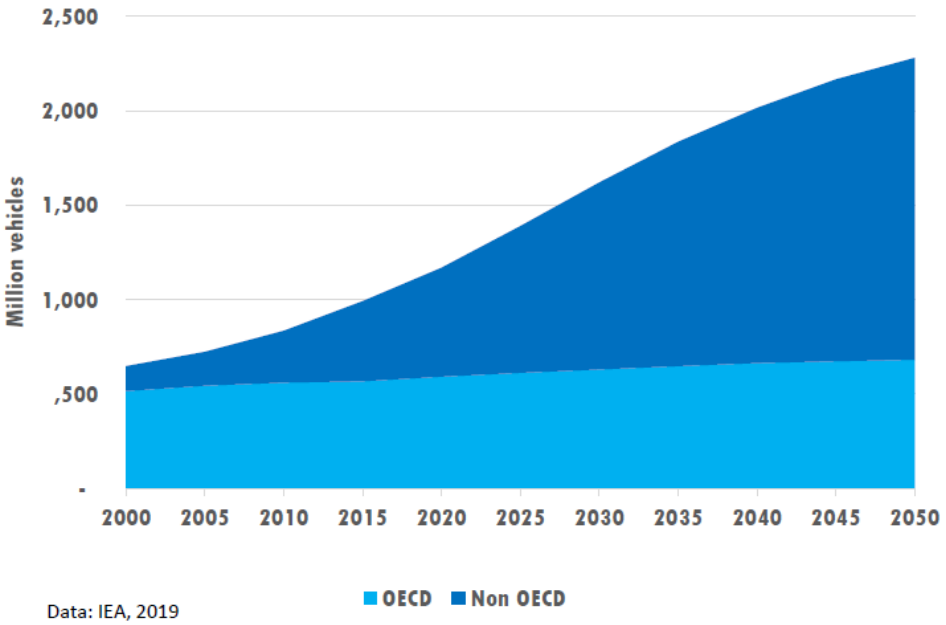


Figure 2.4 **Growth of the world's passenger car fleet in the coming decades. African countries fall under 'Non-OECD' (de Jong, 2023).**



Textbox 1: CO_2 emissions and Euro emission standards

The European emission standards are vehicle standards for pollution and set maximum amounts of NOx, particulate matter and total hydrocarbons that a vehicle may emit (amongst other emissions). Each new land surface vehicle sold in the European Union must meet these standards. The first standard for passenger cars, Euro 1, was introduced in 1992. Currently, passenger cars have to meet Euro 6.

European emission standard	Year enforced
Euro 1	1992
Euro 2	1996
Euro 3	2000
Euro 4	2005
Euro 5	2009
Euro 6	2014
Euro 7	Probably 2025

The emission standards do not have criteria for CO_2 emissions. However, the standards refer to the age of a vehicle. Age is a very good predictor for specific CO_2 emissions (also see Textbox 2). Accordingly, export regulations related to emission standards will also affect the average specific CO_2 emissions of exported cars.

3 The influence of national regulations on the CO_2 emissions of imported cars

Several African countries have regulations banning the import of certain second-hand cars. Some countries have a total ban, while others apply an age limit or minimum emissions standards. The reasons for import bans are environment (more specifically air quality) and safety, as well as the protection of the domestic car manufacturing industry (UNEP, 2020; UNEP, 2021a).

In this chapter, we take a closer look at the effects of certain types of import bans because these can be predictors of the effects of specific export bans. These can prohibit the export of cars that do not meet an age limit or minimum emission standard. Both emissions standards and age affect cars' CO_2 emissions, as is described in Textbox 1 and Textbox 2, respectively.

3.1 National regulations seem to help to create a more fuel-efficient fleet

Based on two different case studies, local regulations seem to help achieve a more fuel-efficient fleet.

UNEP conducted research on the vehicles imported into three East African countries, namely Kenya, Uganda and Rwanda (UNEP, 2020). These countries all depend mainly on used cars from Japan imported through the harbour of Mombasa in Kenya. In this sense, the countries are comparable. Table 3.1 summarises the situation in Kenya, Uganda and Rwanda. It can be seen that the used cars entering Kenya are significantly younger than the cars entering Uganda and Rwanda. Kenya has an age restriction of eight years, while the age restrictions in Uganda are less strict (15 years) and were implemented more recently. Rwanda has only allowed used cars with Euro 4 emission standards since 2019. Although Euro emission standards do not enforce maximum specific CO_2 emissions, it says something about the production year of a car, and year is a good proxy for CO_2 emissions (see Textbox 1). It can be concluded from Table 3.1 that used cars that enter Kenya are younger and have lower CO_2 emissions than those that enter Rwanda and Uganda.

Table 3.1 Specifications of the imported used cars into Kenya, Rwanda and Uganda (UNEP, 2020)

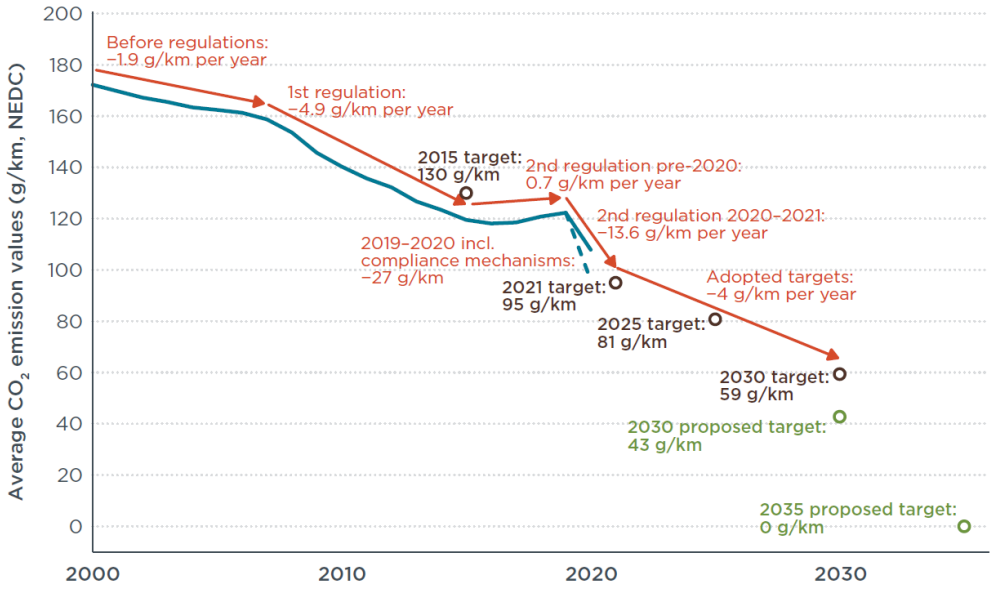
	Restrictions	**Average age (years)**	**Fuel economy (l/100 km)**	**CO_2 emissions (g CO_2/km)**
Kenya (2018 data)	Eight-year age limit	7.2	7.4	177
Rwanda (2018 data)	Min. Euro 4 emission standard (since 2019)	> 15	9.2	220
Uganda (2018 data)	15-year age limit (since 2019)	15.4	9.5	314

Textbox 2: Relation between manufacture year and CO_2 emissions

Over time, the CO_2 emissions of newly sold cars in Europe have largely decreased thanks to various CO_2 emission standards. Therefore, an age limit on exported or imported cars will affect the CO_2 emissions of the fleet in the country receiving the second-hand vehicles.

The historical CO_2 emission values of passenger cars and the CO_2 emission targets are given in Figure T1. In Figure T1, it is clear that, after the first CO_2 emission target was announced in 2008, the CO_2 emissions decreased at a faster rate than before the target was set (4.9 gCO_2/year compared to 1.9 gCO_2/year). The target of 2015 was 130 gCO_2/km, and this target was adequately achieved with an average CO_2 intensity of newly sold cars of 120 gCO_2/km. After the 2015 targets were met, and in the absence of targets before 2020, average CO_2 emissions increased by 0.7 g/km per year. In 2020, a new target was set: 81 gCO_2/km in 2025. This led to a significant reduction in the average CO_2 emissions of passenger cars.

Figure T1: Historical average NEDC CO_2 emission values, targets and annual reduction rates of new passenger cars (ICCT, 2021)



Note that the CO_2 emissions and corresponding targets are based on NEDC test cycle, which lead to an underestimation of the actual CO_2 emissions.

A similar trend can be seen in a case study conducted in Colombia, Peru and the Dominican Republic, see Table 3.2 (Fulton et al., 2022; Kendall, 2023). Colombia has an import ban on used vehicles and, on average, cars there have better fuel economy and lower CO_2 emissions than the other two countries. However, the difference in specific CO_2 emissions of cars between Peru and Colombia is relatively small. Peru requires all cars are at least of Euro 4 emission standards and are five years old at most. The Dominican Republic also has a five-year age limit in place, although many imported vehicles are older than five year old. This, together with a preference for large engine sizes, results in relatively high specific CO_2 emissions. Although this case study does not concern Africa directly, it confirms that national regulations, like import bans, contribute to creating more fuel-efficient fleets.

Table 3.2 **Specifications of light duty vehicles in Colombia, Peru and Dominican Republic (Fulton et al., 2022; Kendall, 2023)**

	Restrictions	Average age (year)	Fuel economy (l/100 km)	CO_2 emissions (g CO_2/km)
Colombia (2016 data)	Ban on used vehicles	New vehicles only	7.0	163
Peru (2015 data)	Euro 4 emission class and five-year age limit	N/A	7.6	178
Dominican Republic (2015 data)	Five-year age limit[1]	5.1	9.8	229

1. In May 2021, a law was proposed that would increase the age limit from five to seven years old.

3.2 Import regulations can increase the prices of vehicles

Local import regulations may increase vehicle prices, and they can even lead to shortages (Ayetor et al., 2021b). For instance, in 2020, the import tax in Ethiopia for second-hand vehicles was raised to 100% of the value of the car if the car was four years old, to 200% for cars of seven years old and to 500% for cars older than seven years with an engines larger than 1,800 cc (Sahlu, 2019). This led to significantly higher prices for cars than in neighbouring countries with lower taxes (Dandessa, 2022). In Ethiopia, a large part of the middle class cannot afford cars (Dandessa, 2022). In addition, this led to shortages for some popular second-hand models (Fulton et al., 2022).

Since a large part of the middle class could not afford cars, the Dominican Republic recently decided to increase the age limit of imported used vehicles from five to seven years old (Dominican Today, 2021). Although these are anecdotical examples, they show that regulations may lead to higher prices and to less access to cars.

What kind of alternatives people use if no affordable second-hand vehicles are available is unclear. We will return to this issue in Section 4.

3.3 More regulations are anticipated in West African countries

The Economic Community of West African States (ECOWAS) adopted a vehicle directive for both new and used vehicles in 2020 (UNEP, 2021a). The directive requires all imported petrol and diesel vehicles, both new and used, to comply with at least Euro 4 or equivalent emissions standards. Used light duty vehicles more than five years old are also prohibited from being imported. ECOWAS members have a period of ten years to implement the age restrictions; the emission standard came into force on 1 January 2021 (UNEP, 2021a). While ECOWAS imposes deadlines on member states regarding directives being implemented, it is unclear what the consequences are if a deadline is not met or if a directive is not implemented at all. As many second-hand cars from Europe currently go to West-African countries, the ECOWAS directive may have significant implications for the export of European second-hand cars in the future.

Currently, countries are still in the process of implementing the ECOWAS directive in their national regulations, although the implementation date has passed. For instance, the ECOWAS regulation in Nigeria has not been integrated into national

regulations yet, and it is not being enforced (personal communication with NADDC). This means the impact of the ECOWAS directive on the quantity and quality of used vehicles imported into Africa is still unclear.

3.4 Import versus export bans

It is important to stress that some low- and middle-income countries have difficulties when enforcing regulations related to the import of used vehicles (UNEP, 2020; Twagirimana, 2022; Fulton et al., 2022). For instance, several countries lack the expertise and the funds to check emission standards of imported vehicles. To perform a proper check on the actual emissions standard of a used vehicle, the presence and correct functioning of vehicle emission equipment has to be checked (UNEP, 2020). Accordingly, regulations regarding age may be easier to implement. However, even this may be difficult to enforce because many countries import cars and immediately re-export again. For instance, it is estimated that about 90% of second-hand cars that enter Benin via the Cotonou Port are destinated for Nigeria, 5% for Niger and only 5% end up on the domestic market (Ezeoha et al., 2018). Importing vehicles via Benin is attractive for Nigerian people because it saves on import tax duties and rules on age restrictions can be circumvented. Note that the trade in second-hand vehicles between Benin and Nigeria is mostly illegal, informal and not well-documented (Ezeoha et al., 2018). This example shows that unharmonised regulations, combined with cross-border trade, makes import checks challenging (UNEP, 2020). UNEP's safer and cleaner used vehicle project helps countries to instate harmonised regulations, standards and processes to ensure that African countries only receive good quality second-hand vehicles (UNEP, 2021b).

It can also be argued that as a result of one country or region adopting import regulations, older vehicles that do not comply with them will be shipped to other countries and regions without regulations. This shows the importance of harmonised import regulations, but it also may be a reason to adopt export regulations too.

4 Determining CO_2 reduction as result of an export ban on certain cars

4.1 A conceptual model to determine CO_2 emission reductions

We use the following formula to determine the amount of CO_2 that could be reduced by export restrictions:

CO_2 savings = CO_2 emissions with export regulations – CO_2 emissions of baseline

The baseline scenario is the current situation where annually about 335,000 cars and other LDVs are exported from Europe to Africa (UNEP, 2021a). In a situation with export regulations, it is likely that fewer cars would be shipped to Africa, and they will be destroyed in Europe. Shipping and destruction emissions are relatively small compared to usage emissions, and these are therefore ignored here.

The CO_2 emission of the baseline and in a scenario with export regulations can be calculated as follows:

*CO_2 emissions of baseline = N_{bas} * CO_{2_bas} * U_{car_bas} * (1-FED_{bas})*

CO_2 emissions with export regulations = N_{ex} CO_{2_ex}* U_{car_ex}* (1-FED_{ex}) + CO_{2_alt} – FS_{EU}*

where:

N_i number of vehicles exported to Africa in the baseline (bas) or in the export regulations scenario (ex)

CO_{2_i} average CO_2 emissions of exported cars in the baseline (bas) or in the export regulations scenario (ex) (gCO_2/km)

U_{car_i} the total mileage driven in Africa with the second-hand car in the baseline (bas) or in the export regulations scenario (ex) (km)

FED_i fuel efficiency degradation in the baseline (bas) or in the export regulations scenario (ex) (%)[7]

CO_{2_alt} CO_2 emissions of the alternatives that are used instead of a second-hand car (tCO_2). This depends on the number of cars that are less exported (N_{bas} – N_{ex}) and on the alternatives that are used.

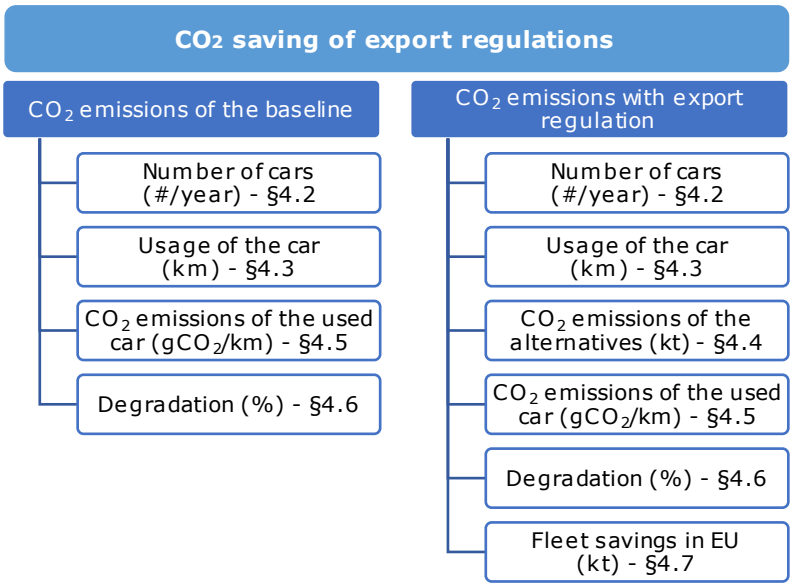
FS_{EU} Fleet savings in Europe (tCO_2)

The conceptual model depicting all these factors is given in Figure 4.1. Each of these variables is treated separately in this chapter; see Figure 4.1 for an overview.

It is important to note that through export regulations, the EU could influence the number of exported cars and the specifications of the exported cars in terms of emissions (for instance), either directly or indirectly. Regulations have no or very little influence on the use of second-hand cars in Africa, nor on degradation or the alternatives that would be used if fewer cars were exported to Africa. Possible export regulations should therefore be accompanied by initiatives that facilitate sustainable transport options in Africa.

[7] With fuel efficiency degradation, we mean that the efficiency of cars decreases over time due to ageing and/or poor maintenance.

Figure 4.1 Conceptual model depicting factors that determine the CO_2 saving of a certain export ban



4.2 Estimating the number of cars with and without export regulations

In 2020, 335,000 cars and other LDVs were exported from the EU to Africa (UNEP, 2021a). How this number would be affected by export bans is unknown. In principle, it should be possible to determine how many cars would currently meet certain export criteria in terms of age, mileage, specific CO_2 emissions or Euro emission standard, for instance.

On a European level, the Eurostat COMEXT website contains data about LDV export at a disaggregated level. It contains data about vehicle type, the number of seats, engine, cylinder capacity and vehicle weight (Fulton et al., 2022). However, data about specific vehicle model, age, Euro emission standard, CO_2 emissions per kilometre, fuel efficiency and mileage are missing.

For Dutch second-hand vehicles, it is possible to link customs data with vehicle registration data from the RDW by using the license plate number and vehicle identification number (VIN). Custom data gives information about goods, like their value, the country of destination and country of recipient. RDW vehicle data includes data about the vehicle type, fuel type, vehicle brand, emission standard and mileage. However, linking these data sources is not easy. ITL (2020) managed to do this, and their report provides an extensive description of the problems they encountered.

For second-hand cars from other European countries, what kind of custom data available per country should be checked and if this can be linked with country-specific vehicle data.

4.3 The use of second-hand cars in Africa is hard to determine

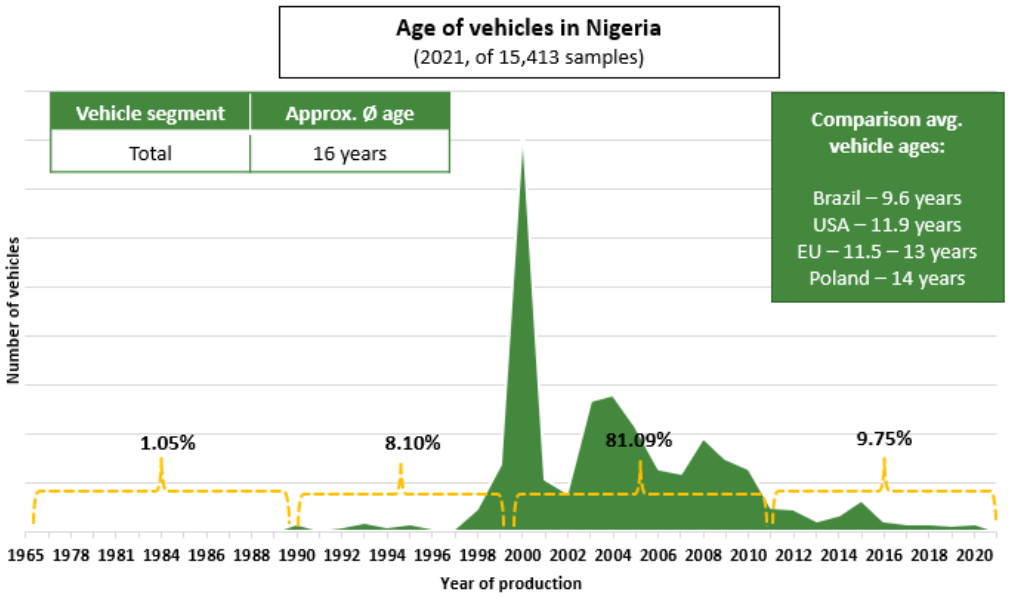
The use of second-hand cars in Africa, expressed in the number of kilometres cars can drive, depends on how many years the car is in use and the annual mileage. This proved difficult to determine.

For annual mileage, we only found the average mileage for South Africa in 2012, which was 21,000 km (Posada, 2018). Other mileages we considered were based on personal communications and showed large ranges, making them less representative.

We know the average age at which used cars are exported to Africa, although this varies per country (see Figure 2.1). To estimate the number of years that used cars are still used, we need to know how old cars are when they are destroyed in Africa. However, outflows and destruction age are not registered in African countries. In addition, the average age of fleets is unknown for many African countries. Nigeria is an exception with respect to this. Recently, a consultancy firm determined the age distribution of vehicles in Nigeria through a counting exercise in major urban cities. This exercise's results are shown in Figure 4.2. You would expect some flattening of the curve at the left side of the graph, which would give an indication of the demolishing age; however, this is not visible. This suggests that demolition rates are currently low, and cars are repaired repeatedly rather than replaced. Most cars exported to Africa in the past decades are still driving (personal communication UNEP). Since there is hardly any outflow, the average age of the African car fleet continues to rise (for now, that is; this growth will inevitably stop at some point). This makes it difficult to determine the useful life of exported vehicles, as there are not many cases to base the average lifespan on.

An alternative approach would be to look at the average mileage of African cars when they are scrapped and subtract the average mileage when they are exported (around 220,000 kilometres) from the EU, however, no data like this was found either.

Figure 4.2 Age distribution of vehicles in Nigeria in 2021 (Wandimi, 2021)



4.4 No clear alternative for second-hand cars imported from Europe

Demand for cars has been growing amongst African people (see Section 2.6), and with this, the demand for imported used cars has been growing too. Currently, it is not entirely clear what alternatives would be used if that demand cannot be satisfied by second-hand cars from Europe. Ayetor et al., (2021b) showed that national policies that have reduced the flow of imported used vehicles into the country have not led to higher sales of new vehicles. This suggests that other alternatives are chosen instead. Possible alternatives include not replacing your car, buying a second-hand car from elsewhere and car-pooling. Furthermore, alternatives to cars can also be used, like motorcycles, three-wheeled vehicles, mini-vans and public transport.

One alternative to buying a second-hand car from Europe is sourcing a second-hand car from another region. Currently, Japan and the United States also export significant numbers of used cars to Africa (UNEP, 2020). However, these countries do not have an infinite supply of them either. It is expected that China, which has the largest fleet in the world, will become a large exporter of second-hand vehicles in the future (Minter, 2019). As such, it is important that not only Europe, but also other regions adopt export regulations for second-hand vehicles.

Another possible alternative to sourcing a second-hand car from the EU is buying a new car, either manufactured in or imported into Africa. The UNEP contact expects that at least some of the demand will be filled with new cars although this is not an affordable alternative for most of the population. Locally produced new cars, however, may not necessarily be a desirable alternative either. Quite a lot of used vehicles have superior fuel economy margins compared to new produced vehicles sold on the continent (Vanherle and Vergeer, 2016 in Ayetor et al., 2021b). Hence, new cars could emit more CO_2 per kilometre than some of the older imported cars from Europe (personal communication with UNEP). In addition, new vehicles equipped with obsolete technology are sold in Africa; these could lead to higher harmful emissions than good quality second-hand vehicles (Ayetor et al., 2021b). Also, four of the 39 investigated new cars sold in Africa scored poorly on safety (AA Research, 2022). These cars were not equipped with air bags, anti-lock brake systems (ABS)[8] or electronic stability controls (ESC)[9]. Therefore, a potential export ban should only cover the export of older and lower quality cars, because good second-hand cars with proper functioning emission and safety devices have better fuel efficiency, lower specific CO_2 emissions and higher safety scores than some newer cars.

4.5 CO_2 emissions of cars exported to Africa

In Figure 4.1, a conceptual model to determine the effect of a ban on certain types of exported cars is provided. The CO_2 emissions of a used car currently exported to Africa can be determined at the ports in Europe or Africa. For CO_2 emissions after export regulations are in place, we should look to the specifications of cars leaving Europe. In Section 4.5.1, we discuss what we know about the cars entering Africa and, in Section 4.5.2, we look to the specifications of second-hand cars leaving the EU.

4.5.1 *CO_2 emissions of used cars are only known for a few countries and vary strongly*

For several African countries, the average emissions of imported second-hand vehicles are known and based on measurements in the ports. Most of these countries (e.g. Rwanda, Uganda and Kenya) are beyond the scope of this project. However, they do not receive a lot of vehicles from the EU (GFEI, 2014). Eastern and Southern African countries (e.g. Rwanda, Uganda and Kenya) receive a large number of cars from Japan because they drive on the left side of the road. Whether a country drives on the left or the right side of the road is an important factor in average fleet emissions, as this determines where a country imports from (the U.S. and Europe or Japan). The country of origin determines the emissions. For instance, cars from the US emit more CO_2 per kilometre on average than cars from Europe. Compared to European cars, cars from Japan are relatively new (UNEP, 2021a) and thus often relatively fuel-efficient when they are exported. This is due to a very rigorous and expensive biyearly inspection in Japan for cars more than three years old (*Shaken*), which causes owners to sell their cars after five or seven years. These newer cars are then exported to Africa, amongst other countries (UNEP, 2021a).

[8] ABS has been mandatory for new cars sold in the European Union since 2004.
[9] ESC is the most significant introduction in vehicle safety since the seat belt and is mandatory in new cars sold in the European Union since 2014 (AA Research, 2022).

Data on average CO_2 emissions of imported vehicles vary significantly between countries. On average, second-hand vehicles imported into Nigeria emit 297 gCO_2/km (GFEI, 2019); for Ghana, this is 162 gCO_2/km (GFEI, 2018), see Table 4.1. This means the effects of a ban on the exports of certain types of used cars could vary quite significantly per country, and specific data is needed for each country.

Table 4.1 **Specifications of the imported used cars into Nigeria and Ghana (UNEP, 2020; GFEI, 2018, 2019)**

	Restrictions	**Average age (year)**	**Fuel economy (l/100 km)**	**CO_2 emissions (g CO_2/km)**
Nigeria (2017 data)	Age limit of 15 years, Euro 3 standard	10.8	9.1	297
Ghana (2016 data)	Graduated tax that restricts vehicles over 10 years and Euro 2 standard (since 2019)	N/A	7.2	162

4.5.2 *CO_2 emissions data on exported cars are not easy to acquire*

An alternative approach to determine the CO_2 emissions of the imported cars is to investigate the cars exported to Africa. Similarly, as described in Section 4.2, the specifications of the exported cars could be determined. Note that if data about vehicle model and age are known, specific CO_2 emissions can be cross referenced with either manufacturer's specifications (although these are often overly optimistic), emissions from NEDC or WLTP test cycles, or websites that let users log fuel economy for their car (like www.autoweek.nl/verbruiksmonitor).

Alternatively, average CO_2 emissions of cars could be used as proxy based on for instance year of manufacture. In Figure T1 (in Textbox 2), we saw that the average CO_2 emissions of a vehicle produced in 2015 for the European market would emit 120 gCO_2/km. However, this emissions profile is based on a NEDC test cycle. The NEDC leads to lower emissions than the currently used WLTP, which produces more realistic CO_2 emission estimates. The difference between the WLTP and NEDC is, on average, a factor 1.21 (ICCT, 2021). As an example, a vehicle produced in 2015 for the European market would emit about (120 * 1.21) = 145 gCO_2/km in practice if the car was new.

4.6 Fuel efficiency degradation might have a small influence

While the emissions of air pollutants like NO_x and CO generally increases as a car ages, there is little evidence that this is the case for CO_2 emissions too (Borken-Kleefeld & Chen, 2014). From personal communication with the UNEP, however, it became apparent that research into this topic is generally done in the Global North. However, a considerable share of cars in Africa are not maintained according to the same standards as in the Global North. For example, oil changes are much less frequent or completely lacking. Wear and tear due to poor maintenance and overloading lead to higher fuel consumption in old cars than one would estimate based on the year of manufacture (personal communication with UNEP). These effects are signified by many vehicles belching out smoke (which is unburned fuel).

Due to this higher fuel consumption, the amount of CO_2 emitted is also higher. There is little data on this, making it hard to quantify this effect.

Fulton et al. (2022) slightly nuances the remarks about the poor quality of the maintenance, stating that, at least in Nigeria, Egypt and Kenya, various periodical inspections are mandatory and enforced. These inspections may have a positive influence on the frequency and quality of the maintenance, and they may limit or even lead to no degradation in fuel efficiency.

4.7 The influence of export regulations on the European fleet composition is likely to be small

Export regulations could lead to changes in the fleet composition of European countries. For instance, if second-hand cars are replaced by new (electric) cars at a higher pace, this may accelerate the development of a more climate friendly fleet in Europe and lead to higher CO_2 savings compared to a situation in which there are no export regulations. Whether this will happen depends, amongst other things, on the value of the second-hand car and the price of new or second-hand cars.

Currently, the average value of second-hand cars exported to Africa is relatively low compared to second-hand cars in the Netherlands, namely 520–910 EUR in comparison to 23,500 EUR (see Section 2.4). Due to this very large price difference, it is not likely to be a motivator for buying a new or second-hand car in the Netherlands. This is probably also true of other Western European countries. In other parts of Europe (like Eastern and South Europe) the difference between buying a second-hand car and the value of an exported car might be smaller. This means that in those countries the price of an exported car could be a small driver for purchasing a new or second-hand car.

If there are export regulations in place, residual values of used cars will probably increase due to higher demand. However, if this is enough to be a significant driver for Western European consumers to buy a new (or a newer second-hand) car is questionable given the large difference between the typical price of exported vehicles to Africa and new and second-hand vehicles.

In addition, the number of exported vehicles from Europe to Africa is relatively small compared to the total numbers of cars driving in the European Union. Currently, the European Union's fleet consists of 242.7 million passenger cars (ACEA, 2021), making the influence of exporting yearly 335,000 LDVs to Africa very small.

4.8 Additional CO_2 emissions due to imported used vehicles in Mexico

We found an article that estimated CO_2 emissions resulting from the export of second-hand vehicles from the United States (U.S.) and Canada to Mexico between 2005 and 2008.[10] Davis and Kahn (2010) estimated that this caused between 47 Mt and 84 Mt CO_2 emissions in total. They calculated this range by investigating the numbers of cars that were exported (2.5 million) and their fuel efficiency. They also considered the reduction in CO_2 emissions of the American fleet due to there being fewer overall and more fuel-efficient cars. Similar to this explanatory study, Davis and Kahn did not have the data about the second-hand vehicles' annual mileage, their lifetime and the alternatives to second-hand vehicles. As such, Davis and Kahn (2010) made assumptions for these variables. For instance, they assume that if there were no second-hand cars, people would use transport that did not cause CO_2 emissions (i.e. either walking or using high-occupancy public transport) or they

[10] In this period, the import restrictions of used vehicles from the United States and Canada were relaxed in Mexico.

would drive vans with eight occupants.[11] Due to the large numbers of assumptions, the additional CO_2 emission estimates must be interpreted with caution.

4.9 A rough estimation of the order of magnitude of possible CO_2 savings

In the above, we have outlined what is necessary to calculate the CO_2 reduction of certain export bans and the difficulties to acquire this data. However, with some simplified assumptions we can calculate the order of magnitude of possible CO_2 savings of a certain export ban.

Currently, around 335,000 cars and other LDVs are annually exported from Europe to Africa (see Section 2.1).[12] We assume an export ban, based on age for instance, would reduce the export flow by about 50%. This would mean that around 167,500 fewer cars would be exported from Europe to Africa in the new situation.

Exported cars are typically 12–19 years old. In 2007, the average emissions of new cars sold in the EU was about 160 gCO_2/km based on the NEDC test cycle (see Figure T1). This relates to actual CO_2 emissions of almost 200 gCO_2/km, which is assumed as the average CO_2 emissions of used cars without export regulations. With export regulations, the cars are assumed to be built after 2015, leading to average emissions of around 145 gCO_2/km (see Section 4.5.2).

Subsequently, we assume exported cars drive 100,000 km on average over their lifetime.[13] For now, we assume that the CO_2 savings resulting from creating a more fuel-efficient or more electrified fleet in European countries would be negligible (also see Section 4.7). We also ignore any deterioration of fuel efficiency (also see Section 4.6). The alternatives used in Africa will also emit CO_2. For now, we assume actual savings of around 50% compared to second-hand vehicles[14], but this is very uncertain.

With these assumptions, CO_2 emissions would be reduced by approximately 2.6 Mt per year (see Appendix A for the full calculation). To put this estimate of 2.6 Mt/year into perspective, it can be compared to the annual CO_2 emissions from passenger cars in the EU. In 2019, the total of greenhouse gasses emitted in the EU by passenger cars was 485 $MtCO_2e$[15] (EEA, 2022). This means that the impact of the export ban as described above would be less than 1%. Whether this reduction is significant is a matter of perspective. On the one hand, this CO_2 reduction is less than 1% of the annual CO_2eq-emissions of all passenger cars in the EU. On the other hand, it is still 2.6 megatons of CO_2 every year.

The calculation of this CO_2 reduction is only meant to give an order of magnitude. It is important to stress that this rough estimate depends on many assumptions, like the amount of cars being exported as a result of an export ban, the use of cars in Africa and the CO_2 emissions of the alternatives. Especially assumptions about this last two variables could lead to very different outcomes. If we assume that everybody uses public and active modes of transport instead of buying a second-hand car, then this would double the CO_2 reduction. However, if we assume that

[11] Another possible alternative would be buying a new vehicle or buying a second-hand car from another country. The latter option was impossible because there is only a trade agreement for cars from Canada and United States. In addition, Davis and Kahn found no evidence that new vehicle sales in Mexico were influenced after vehicles were imported from the U.S. and Canada. Therefore, they only used a no CO_2 emission and a minibus scenario.
[12] For this calculation, we assume that this are only passenger cars and not vans.
[13] We do not have any information on this variable, so this is a very rough assumption.
[14] Davis and Kahn used a 60 – 100% saving in the Mexico situation. However, they concluded that cars were not an alternative for a second-hand car from the U.S. and Canada because new car sales did not drop, and no other countries were allowed to export used cars to Mexico.
[15] Keep in mind that this figure refers to the total of greenhouse gasses and not just CO_2. In the transport sector, however, most of the GHGs are CO_2, so we assume this to be roughly the same.

everybody uses another vehicle, then this could also lead to no or even a negative CO_2 reduction.

In future phases, it would be good to further examine the estimation of the CO_2 saving and perform full sensitivity analyses. However, before this can be done, more data is needed about the alternatives, the use of second-hand cars in Africa and the CO_2 emissions of the exported cars in the baseline as well as in the export regulations scenario, as these are the key assumptions that determine largely the outcome.

5 Conclusion

In this preliminary study, we tried to answer the following research question: *What do we know (and what are the relevant unknowns) about the effects of used cars imported from European Union to Africa on CO_2 emissions in Africa and the possible effect of different kinds of export regulations on these emissions?* To finalise, we answer the three sub-questions and then the main question. Subsequently, we end this chapter with an overview of the knowledge gaps and a discussion on the benefits of further research.

What do we know about the possible effects of certain import and export regulations?
There are currently no export regulations in place for used cars, but we can learn from national import bans. Several countries have import regulations in place for second-hand cars related to age and/or emissions standards. No examples were found of import regulations related to the maximum mileage or specific CO_2 emissions. Countries that have import regulations in place have a more fuel-efficient fleet than those without import regulations. However, regulations may also increase the prices of and limit access to passenger cars.

Note that some low- and middle-income countries have difficulty enforcing import bans due to unharmonised regulations combined with cross-border trade and a lack of expertise and funds. In addition, it can be argued that because one country or one region adopts import regulations, the older and less fuel-efficient vehicles that do not comply with them will be shipped to other countries without regulations. As such, export regulations in Europe could complement import bans in African countries.

What determines the CO_2 impacts of limiting the flow of used vehicles from the European Union into Africa?
CO_2 impacts can be determined by looking at the difference between a baseline scenario and scenarios with export regulations. The CO_2 emissions in both scenarios depend on many variables. An overview of these variables is provided in Figure 5.1.

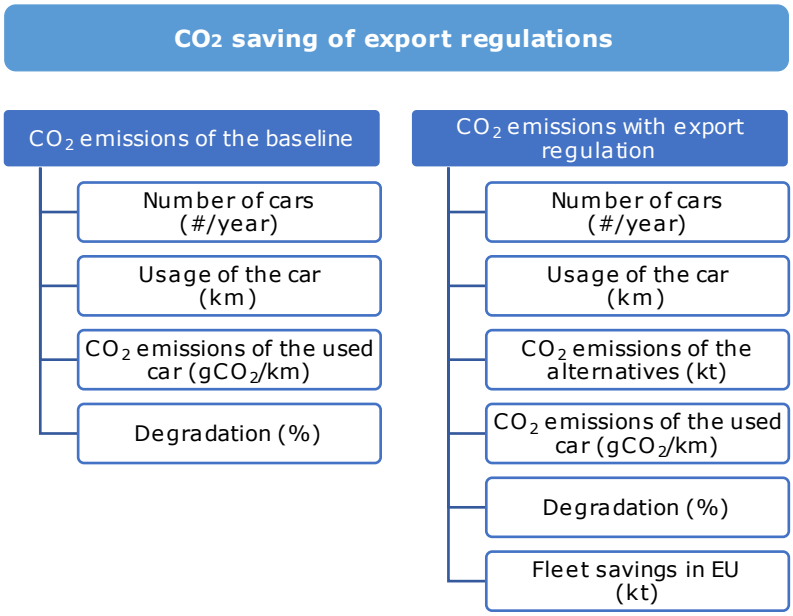
In general, the use of cars, the CO_2 emissions of the used car, the number of cars for the baseline and the export regulations scenario are the most important variables. The CO_2 emissions of the alternatives is a key variable.

What kind of data and knowledge is missing that is necessary to estimate the impact on the CO_2 emissions of different types of export regulations?
The CO_2 emissions in the baseline scenario are not easy to determine as we do not know how intensively and how long cars are used in Africa. In addition, data on the average CO_2 emissions of exported used cars are not readily available. Also, the effect of degradation is unknown, but it is expected that this factor is less relevant compared to the other unknown variables.

For the scenario with export regulations, the CO_2 emission calculation becomes even more difficult. For instance, it is relatively unclear how many used cars will still be exported after certain types of export regulations are introduced. Moreover, we do not know what kind of alternatives African people will use if fewer cars are exported from the EU into Africa. Possible alternatives for second-hand cars from Europe include driving existing cars longer, buying new cars, importing second-hand cars from other regions, and switching to motorcycles or public transport. Some of these

alternatives will emit less CO_2, but others will emit more. This makes it very hard to determine the CO_2 savings of different types of export bans.

Figure 5.1 Conceptual model depicting factors that determine the CO_2 saving of export regulation



What do we know (and what are the relevant unknowns) about the effects of used cars imported from the Europe Union to Africa on CO_2 emissions and the possible effect of different kinds of export regulations on these emissions?

In 2020, around 335,000 used cars and other LDVs were exported from Europe to Africa. On average, exported second-hand cars shipped from Dutch harbours are 18.2 years old and have a mileage of 226,000 km. However, the specific CO_2 emissions and the uses of these cars are unknown. This makes it difficult to indicate how much CO_2 is emitted by cars exported from the EU to Africa over their lifetimes.

Export regulations could take different forms. For instance, they could be related to age, Euro emission standard, mileage, specific CO_2 emissions or a combination of these. However, it is unclear how many cars would still be exported if export regulations were in place. Another important variable in determining the CO_2 impacts of export regulations is the alternatives that African people will use if fewer cars are exported from Europe to Africa. These alternatives may create more or less CO_2 than the second-hand cars that are currently exported. Insight into this is key for estimating CO_2 impacts, but it is very difficult to acquire.

Note that EU export regulations can limit the number of cars exported and the quality of these vehicles, for instance by setting minimum emissions standards. Regulations have no or very little effect on the alternatives that African people will choose if not enough second-hand cars are available, how the second-hand cars are used in Africa and the degradation. So, possible export regulations must go hand in hand with initiatives that facilitate sustainable transport options in Africa.

To give an initial idea of the order of magnitude of CO_2 savings of export regulations related to used cars, we assume that any export ban would limit the flow of European second-hand vehicles to Africa to 50%. In addition, we assume that the alternatives used emit, on average, 50% less CO_2 compared to a second-hand vehicle, but this assumption is very uncertain. Furthermore, we must make

assumptions about the CO_2 intensity before and after implementing export regulations (200 and 145 gCO_2/km) and the uses of second-hand vehicles (assumed to be 100,000 km over the lifetime of the car). This rough estimate results in a CO_2 saving of 2.6 Mt/year. This CO_2 saving would be less than 1% of the annual CO_2eq emissions of all passenger cars in the EU. However, these amounts are very uncertain. With different assumptions, about the total mileage, for instance, the CO_2 reduction could easily double. In addition, assumptions about the alternatives to second-hand vehicles could lead to no or even negative CO_2 savings. Given the significant uncertainties surrounding CO_2 savings, it is uncertain whether export regulations should be implemented in the European Union for CO_2 reduction reasons.

5.1 Knowledge gaps and the benefits of further research

Additional data is needed to estimate the consequences of different types of export bans for CO_2 emission in a more precise way. However, collecting this type of data would be costly and time-consuming. In this section, we provide an overview of the most important data and knowledge gaps and some preliminary ideas about how to tackle these gaps.

- One of the most important factors to determine the potential CO_2 reduction of export regulations is to gain **insights into the alternatives** that will be used if an export ban on specific types of cars is implemented. These alternatives could be new cars, cars from other regions, two-wheelers or minibuses. In addition, it could also result in fewer trips being made overall. Assumptions about the alternatives can easily double or cancel potential CO_2 savings. This knowledge gap can be tackled by surveying people in Africa that buy second-hand vehicles about what they would have done if these vehicles ceased to be available. It would also be useful if a worldwide model is made of the car market along with alternatives to cars. This model should integrate supply and demand of used and new vehicles. Important variables to consider include the economic development of and population growth in different countries, import and export regulations of vehicles, regulations that influence the car fleet, like taxation, and CO_2 norms. With a model like this, the following questions could be answered: What kind of price increase is expected in Africa after an export ban of older cars in Europe? Would the price increase reduce the demand for cars and increase the demand of alternatives, such as two-wheelers? Would a price increase attract a larger supply of younger, more fuel-efficient vehicles from Europe and lead to a cleaner fleet in Europe? Or would exports of second-hand cars from other regions (like the U.S. or Asia) grow?
- **Export data about used vehicles** is uncomplete, fragmented and unharmonised. To investigate the CO_2 implications of different export bans, data is needed about the specifications (e.g. related to age, Euro emission standard and mileage) of all the vehicles that are currently exported. The available data has been challenging to acquire because it is fragmented. Collection and harmonising this data on a European – or ideally global – level would be helpful to provide better estimates of the CO_2 savings of different types of export bans.
- **Statistics about car use** in West-Africa related to yearly mileage and average scrapping age or scrapping mileage are missing, and they are necessary to calculate the magnitude of potential CO_2 savings. These statistics should ideally be collected locally by such parties as governments, agencies and universities.

None of our questions are easy to answer and, as a result, they all require specific expertise and extensive investigation. The overarching question is how relevant the CO_2 implications are when considering export regulations of second-hand cars from the EU. It is possible that other reasons (e.g. enhancing road safety and improving air pollution) justify export regulations for second-hand cars despite the uncertainty

of achieving significant CO_2 savings. In this case, intelligently formulating the export regulations could increase the probability that CO_2 would be saved compared to the baseline scenario in which there were no export regulations. A threshold on specific CO_2 emissions has the largest chance to achieve CO_2 savings. If this is impossible, a threshold related to age is more likely to lead to CO_2 savings than a threshold related to mileage because age is a relatively good indicator of CO_2 emissions per kilometre, while mileage says very little about the CO_2 intensity of second-hand cars (also see Figure T1 on page 15).

Used vehicles and CO_2 emissions: A quick scan of what we do and do not know about the effects of European export regulations on CO_2 emissions in Africa.

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Appendix A: CO_2 saving calculation

In order to determine the amount of CO_2 that potentially can be reduced by restrictions on export, we use the following formula:

CO_2 savings = CO_2 emissions with export regulations – CO_2 emissions of baseline

*CO_2 emissions of baseline = N_{bas} * CO_{2_bas} * U_{car_bas} * (1-FED_{bas})*

CO_2 emissions with export regulations = N_{ex} CO_{2_ex} * U_{car_ex} * (1-FED_{ex}) + CO_{2_alt} - FS_{EU}*

CO_{2_alt} = (N_{bas} – N_{ex}) * *red%* * CO_{2_bas} * U_{car_bas}

where:

N_i number of vehicles exported to Africa in the baseline (bas) or in the export regulations scenario (ex)

CO_{2_i} average CO_2 emissions of exported cars in the baseline (bas) or in the export regulations scenario (ex) (gCO_2/km)

U_{car_i} the total mileage driven in Africa with the second-hand car in the baseline (bas) or in the export regulations scenario (ex) (km)

FED_i fuel efficiency degradation in the baseline (bas) or in the export regulations scenario (ex) (%)

CO_{2_alt} CO_2 emissions of the alternatives that are used instead of a second-hand car (tCO_2). This depends on the number of cars that are less exported (N_{bas} - N_{ex}) and on the CO_2 emissions of the alternatives that are used.

FS_{EU} Fleet savings in Europe (tCO_2)

Red% Reduction percentage of CO_2 emissions of the alternatives compared to the CO_2 emissions of second-hand cars in the baseline scenario.

In the main text, we described the assumption, which leads to the values of the variables as given in Table A2.

Table A2 **Input for the calculation**

Variable	Value	Variable	Value
N_{bas}	335,000	N_{ex}	167,500
CO_{2_bas}	200	CO_{2_ex}	145
U_{car_bas}	100,000	U_{car_ex}	100,000
FED_{bas}	0%	FED_{ex}	0%
Red%	50%	FS_{EU}	0

CO_2 savings = CO_2 emissions with export regulations – CO_2 emissions of baseline

CO_2 savings =(N_{ex}*CO_{2_ex}*U_{car_ex}*(1-FED_{ex}) +CO_{2_alt}–FS_{EU}) - (N_{bas}*CO_{2_bas}*U_{car_bas}* (1-FED_{bas}))

CO_2 savings =(N_{ex}*CO_{2_ex}*U_{car_ex}*(1-FED_{ex}) +(N_{bas}–N_{ex}) *Red%* CO_{2_bas}*U_{car_bas} – FS_{EU}) - (N_{bas}*CO_{2_bas}*U_{car_bas}* (1-FED_{bas}))

CO_2 savings = (167,500 * 145 * 100,000 * (1-0) + (335,000-167,500) * 50% * 200 * 100,000 – 0) - (335,000 * 200 * 100,000 * (1-0) = 6.7 Mt – 4.1 Mt = 2.6 Mt

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