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SCRAP BONUS

EXTERNAL COSTS AND FAIR COMPETITION IN THE GLOBAL VALUE CHAINS OF STEELMAKING

ON BEHALF OF THE
GERMAN STEEL RECYCLING ASSOCIATION -
BUNDESVEREINIGUNG DEUTSCHER STAHLRECYCLING-
UND ENTSORGUNGSUNTERNEHMEN E.V. (BDSV)

BDSV
Bundesvereinigung Deutscher Stahlrecycling- und Entsorgungsunternehmen e. V.
German Steel Scrap Association

HALLE AN DER SAALE, FEBRUARY 17, 2020

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External Costs and Fair Competition in the Global Value Chains of Steelmaking

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Project No: 414123

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Status: 17.02.2020

We would like to thank the German Steel Recycling Association - Bundesvereinigung Deutscher Stahlrecycling- und Entsorgungsunternehmen e.V. (BDSV) for commissioning this project. Our thanks go to the members of the BDSV project management committee for their valuable feedback during the preparation of the study: Jörg Benn, Rainer Cosson, Daniela Entzian, Roland Mauss, Bernd Meyer, Gerhard Pariser, Michael Prahl, Olaf Pusch, Andreas Schwenter and Frank Wäckerle. The authors would also like to thank Birgit Brügmann and Michael Kraft for their support.

Executive Summary

Scrap is an essential raw material in steelmaking. The use of scrap reduces greenhouse gas emissions, decreases local environmental impacts and conserves natural resources. Thus, the use of scrap leads to a welfare gain: society benefits from avoided environmental burdens. This study introduces the indicator »scrap bonus« which denotes the social cost savings due to the environmental burdens avoided when using one ton of steel scrap.

Life cycle assessments from the literature are used to quantify the avoided environmental burdens. They calculate the emissions along the value chain of steel production, from mining to the steelwork's gate, and assess the emissions avoided by using scrap instead of virgin materials. The emissions are classified into environmental impact categories such as climate change. When using one ton of carbon steel scrap, greenhouse gas emissions are reduced by 1.67 t CO_2. This is equivalent to the emissions released when burning 705 liters of gasoline. The average German car could drive 9,000 km with this amount of gasoline. Additionally, scrap use reduces other environmental impacts such as summer smog. The use of one ton of stainless-steel scrap reduces emissions by 4.3 t CO_2. The larger emission reduction is due to the alloying elements, chromium and nickel. In 2018 steelworks in the EU used 93.8 million tons (Mt) of steel scrap. Assuming that these were solely carbon steel scrap, this quantity corresponds to a reduction of CO_2 emissions of about 157 million t. This is the equivalent of the emissions released by the automobile traffic in France, Great Britain and Belgium combined.

The scrap bonus is calculated by using studies that estimate the costs attributed to environmental impacts. These are employed to convert the avoided emissions into avoided social costs in euro. In the case of greenhouse gas emissions, three scenarios, based upon the literature, are used to reflect the complexity and uncertainty of the cost estimates. The lower bound of the social cost estimate is 30 euro per ton of CO_2. The upper reference is 110 euro per ton of CO_2. The medium reference social costs are assumed to be 70 euro per ton of CO_2. In the scenario where the social cost of carbon emissions is assumed low, our lower reference, the estimated scrap bonus is 79 euro per ton of carbon steel scrap. This means that social costs of environmental impacts of nearly 80 euro are saved with each ton of steel scrap. Assuming the upper reference costs of CO_2, the scrap bonus equals 213 euro per ton of carbon steel scrap. When using stainless steel scrap, the scrap bonus increases to values between 158 and 502 euro, depending on the scenario. In 2018, these results corresponded to environment cost reductions between 7.4 and 20.0 billion euro due to scrap use in Europe.

Currently, the reduction in environmental impacts due to using scrap is not adequately reflected in market prices. This is especially true if social cost of carbon lies above 30 euro per ton of CO_2. Thus, the use of steel scrap results in positive externalities: the positive environmental impacts are not adequately compensated. In the absence of a global CO_2 price, an integrated concept for the decarbonization of the European steel sector appears necessary. The European Emissions Trading Scheme (EU ETS) has already put a price on emitted greenhouse gasses. In addition, policy instruments should be implemented to secure the competitiveness of the steel industry. Measures should be considered that reflect the emissions embodied in intermediate inputs. Supporting research and development with a focus on small and medium-sized enterprises could strengthen steel recycling quantitatively and qualitatively. Numerous further measures can facilitate the work of the steel recycling industry. These measures range from more efficient approval processes to the improvement of rail infrastructure. These measures would not only help protect the environment but also strengthen the competitiveness of the steel and steel recycling industry.

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1
Introduction

In 2018, 93.8 million tons of scrap were melted in the European Union to produce steel. This is equivalent to about 56.0 % of the total steel production in the EU (BIR 2019). The German steel recycling industry, which procures, separates, and provides the logistics of steel scrap for the circular economy of steel, has supplied 26.8 million tons of scrap in 2018 to clients, both domestically and internationally.

The use of scrap as a raw material for the production of steel results in a positive environmental impact along the value chain. It reduces greenhouse gas emissions, lowers local environmental impacts and conserves natural resources (Broadbent 2015; Johnson et al. 2008). The firms of the steel recycling industry, that provide scrap as a raw material, and the steel producers that use them, produce positive externalities. They reduce environmental burdens and support the circular usage of finite resources (PWC 2019; Ellen MacArthur Foundation et al. 2015). Thus, they contribute to a decrease in costs associated with environmental burdens.

This study quantifies the social benefits resulting from the use of scrap as a raw material for the production of steel. For this purpose, the indicator »scrap bonus« is introduced and quantified. The scrap bonus is equivalent to the reduction in social costs from environmental impacts due to the use of scrap in steel production. In addition, this study suggests policy instruments that can internalize the scrap bonus in the pricing mechanism in the steel markets.

The scrap bonus is calculated in two steps. Firstly, the avoided environmental burdens attributed to the use of scrap in steel production are quantified. Life cycle assessments from literature are used to determine the emissions associated with the production of steel throughout the entirety of the production process, from the mine to the gate of the steelworks. Thereby, the emission reductions due to the use of scrap can be identified and condensed into categories of (avoided) environmental impacts. Examples include the mitigation of climate change or avoidance of summer smog. In this step, a differentiation is made between carbon steel scrap and scrap from stainless steel.

In the second step, avoided environmental impacts, measured in physical units such as tons of CO_2, are converted into monetary units. This step replies upon studies estimating the economic costs of damages to the environment. One can use the social cost of CO_2 emissions, also referred to as the social cost of carbon, as an example. These represent the welfare losses caused by climate change per ton of CO_2 emitted. Linking the avoided environmental burdens to their associated social costs allows us to quantify the scrap bonus. To reflect uncertainties associated with the estimation of the social cost of CO_2 emissions, the scrap bonus is calculated based on three scenarios. One represents a lower bound (»lower reference«) of the social costs of climate change, one an »upper reference« and lastly, the third lies in the middle (»medium reference«). The scrap bonus for carbon steel scrap and stainless-steel scrap differs because of differences in the avoided greenhouse gas emissions.

Recent studies (OECD 2018) suggest that the costs of climate change are not adequately reflected in market prices. Thus, the use of scrap in the production of steel results in a positive externality: it provides benefits for 3rd parties without being compensated for. In this study, several policy instruments will be discussed that can help internalize the positive externality. These range from pricing greenhouse gas emissions to the introduction of labels showing the proportion of recycled materials contained in a product. Measures are considered that will increase the demand for steel scrap as well as those that will increase the steel scrap supply.

This study is structured as follows. Chapter 2 illustrates the technical and economic fundamentals of steel as well as the raw materials used in its production. In addition, the term externality is introduced and illustrated. Chapter 3 defines and quantifies the indicator scrap bonus in two steps. Firstly, the emission reductions attributed to the use of steel scrap is estimated. Secondly, studies are used to determine the economic cost of environmental burdens in euro. Chapter 4 introduces and evaluates policy instruments that can be used to internalize the scrap bonus. Based on this, policy recommendations are made. Chapter 5 concludes.

2
Technical and Economic Fundamentals

2.1
Material: Steel

The norm DIN EN 10020 defines steel as a material »that contains a greater share of iron than any other element, whose carbon content is lower than 2 % and additionally contains other elements«. Steel exhibits several properties that have made it the most important metal in the world economy. It is hard, tough, corrosion resistant and thus, it is suitable for the manufacturing of durable products. Steel can be processed in a multitude of ways: it can be cold and hot-rolled, drawn, forged, cast or welded. Steel can be customized by altering the carbon content, by introducing alloying elements such as chromium, nickel or tungsten and by thermal or mechanical treatment. The material's diversity is documented by about 3,500 different grades of steel available today.

Stainless steels are an important group among these 3,500 grades. They are steel grades that contain at least 10.5 % chromium and at most 1.5 % of carbon (ISO 15510:2014). The addition of chromium causes a thin passive layer of only a few nanometers to form on the stainless steel that will prevent it from corroding. This means that stainless steel is more corrosion resistant than unalloyed steel. The introduction of nickel furthers the corrosion resistance of stainless steel. Furthermore, nickel changes the crystalline structure of the steel. Stainless steel with a nickel content of less than 8 % is known as ferritic stainless steel, whilst that with a nickel content of more than 8 % is known as austenitic stainless steel. Unlike carbon steel and ferritic stainless steel, austenitic stainless steel is not ferromagnetic.

2.2
Production and Use of Steel

Figure 1 shows the development of global crude steel production from 1950 to 2018. Crude steel production grew from about 190 million tons to more than 1,800 million tons in that time frame. An accelerated growth rate can be seen around the turn of the century. Between 2000 and 2018, global steel production more than doubled in volume. This can be primarily attributed to the output growth of Chinese production.

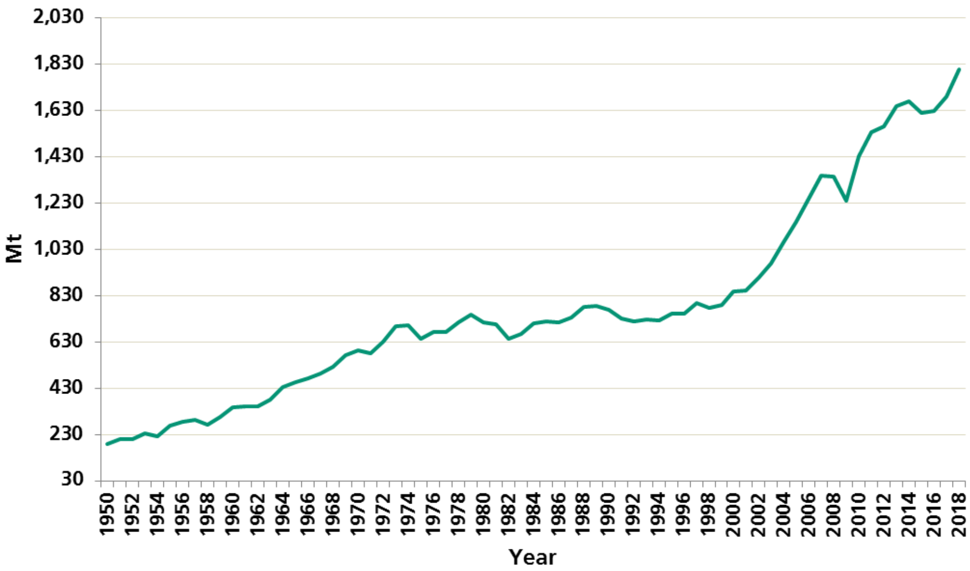

Figure 1: Global crude steel production from 1950 to 2018 in Mt.
Source: World Steel Association (2019b), own presentation

Figure 2 shows the evolution of the world's stainless-steel production between 1950 and 2018. In this time frame, stainless steel production has increased by a factor of fifty, from about 1 Mt in 1950 to about 50.7 Mt in 2018. Since the year 2000, the global production of stainless steel has grown by 162.7 %.

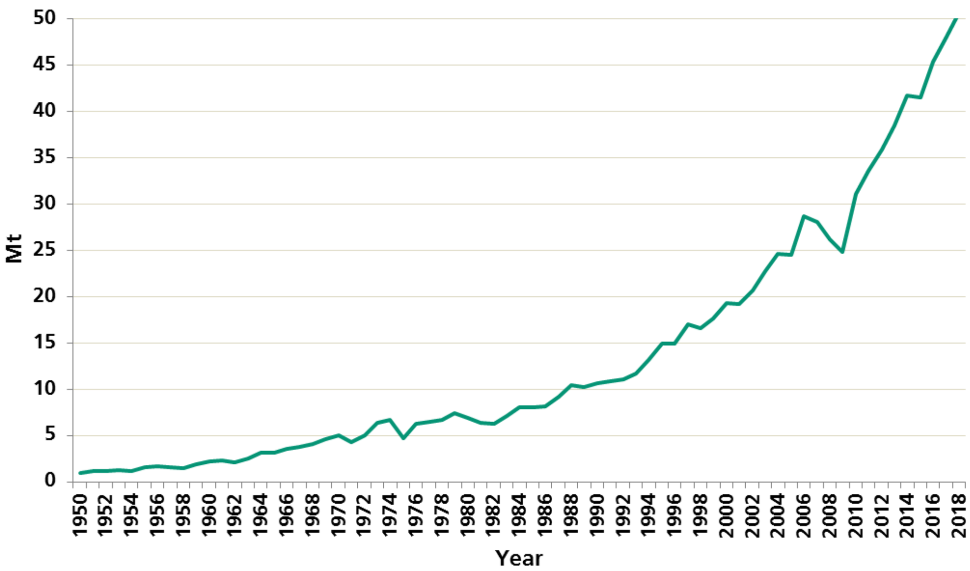

Figure 2: Global stainless steel production from 1950 to 2018 in Mt.
Source: ISSF (2019), own presentation

Figure 3 displays the regional structure of steel and stainless-steel production. It shows the shares of selected nations as well as those of the EU28 in the worldwide production of 2018 in per cent. Both the production of steel and stainless steel is dominated by China. In 2018, 51.3 % of the world's steel was produced in China and 52.6 % of the world's stainless-steel stems from the People's Republic.
The European Union supplied 9.3 % of the world's steel production. India, with a production share of 5.9 %, has risen to become the third most important supplier of steel. Japan produced 5.8 % of global steel and the USA 4.8 %. The global production of stainless steel in 2018 exhibited the same ordering of the most significant suppliers. 14.6 % of the global stainless-steel production took place in the European Union.

Germany, with an output of 42.4 Mt of crude steel in 2018, is the most important supplier of steel in Europe. Germany's global market share equates to about 2.3 %. This makes it the 7th largest global steel supplier in 2018. 433,000 tons of stainless steel were produced in Germany in 2018. This is about 0.9 % of the global output.

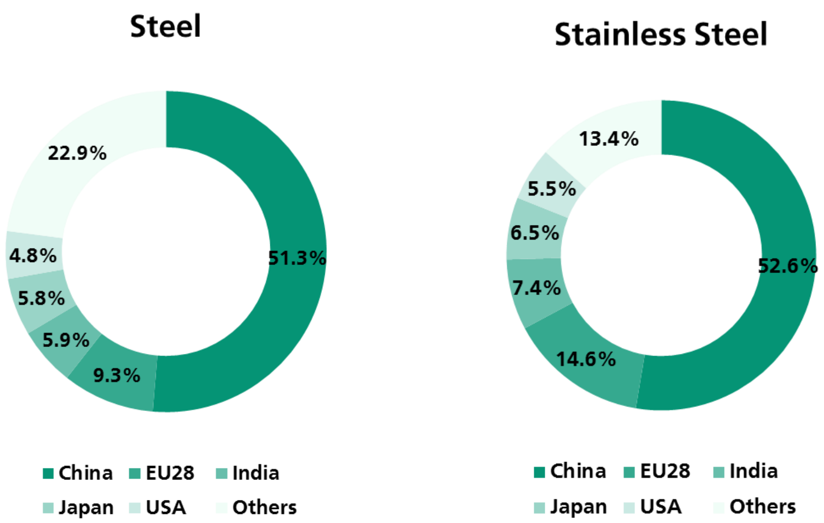

Figure 3: Market shares of selected regions in steel and stainless-steel output in 2018 in per cent. Source: World Steel Association (2019b), ISSF (2019), own presentation

Today, there are two main approaches used in the production of steel (production routes): the blast furnace route and the electric arc furnace route (Bartos et al. 2015). The blast furnace route produces steel in two steps. First, iron ore and coke are transformed into pig iron in the blast furnace. The economically significant iron ores consist of iron oxides. Coke is used as a reduction agent to extract the oxygen from the ores in an exothermic process. Pig iron is an intermediate product that exhibits a carbon content of about 4.0 % to 4.7 %. In the second step, pig iron is converted into crude steel. In basic oxygen converters, pure oxygen is pumped into the liquid pig iron. This step reduces the carbon content of the pig iron and, using additives such as lime, binds unwanted impurities (for example silicon and phosphorus) in the slag. It is an exothermic process that can reach temperatures of up to 3,000 °C. Steel scrap is added to regulate the temperatures in the converter. The amount of scrap can be altered within a technically feasible and economically profitable range. The shares of scrap in the converter lie between 10 % and about 30 %.

The electric arc furnace route uses electricity to produce steel. For this purpose, electric arc furnaces are used that reach temperatures of up to 3,500 °C (Bartos et al. 2015). Steel scrap is the main raw material used in this process. Direct Reduced Iron (DRI), i.e.

iron ores reduced without melting them, is also used in the electric arc furnace route. In stainless steel production, electric furnaces are also charged with ferroalloys, i.e. compounds of iron and alloying elements such as chromium and nickel.

In 2018, 70.8 % of global steel supply was produced using the blast furnace route, while 28.8 % was produced using the electric arc furnace route (World Steel Association 2019b). However, globally these shares differed considerably. 41.5 % of crude steel produced in the European Union used the electric arc furnace route, 29.9 % of German steel and the 68.0 % of steel produced in the USA using this route. On the other hand, in the People's Republic of China only 11.6 % of steel was produced using the electric arc furnace route. These variations reflect historical developments, the availability of scrap, but also differences in energy prices.

The production of stainless-steel exhibits regional differences in the production routes as well. Stainless steel is exclusively produced using the electric arc furnace route in Europe and North America. Asian countries additionally use the blast furnace route to produce stainless steel. A current example is the stainless-steel works in Morowali on the Indonesian island Sulawesi, opened in mid-2017 by the Chinese enterprise Tsingshan with a capacity of 3 Mt per year (Wood Mackenzie 2019). Quantitative information about the shares of the routes in stainless steel production is not available.

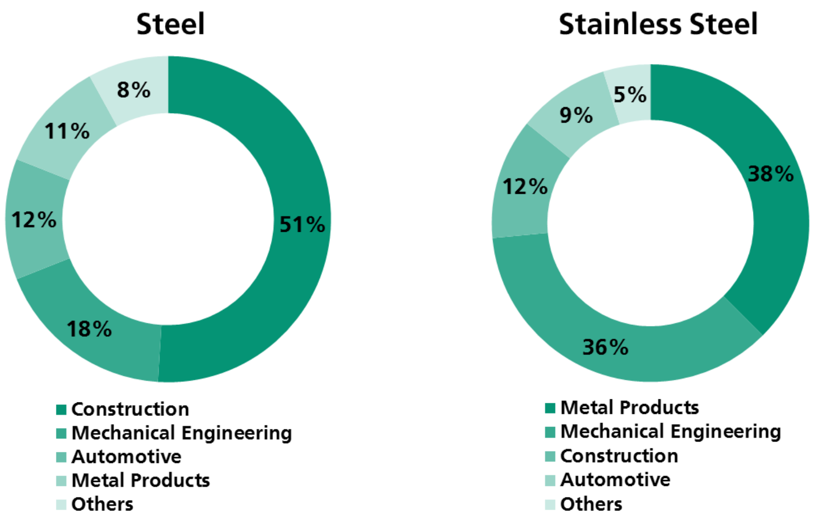

Figure 4: Sectoral shares in the use of steel and stainless steel in 2018 in per cent.
Source: World Steel Association, ISSF (2019), own presentation

Steel has a multitude of applications. Figure 4 illustrates the different applications for steel (left) and stainless steel (right). It shows the shares of different applications of (stainless) steel in per cent in 2018. The largest purchaser of steel is the construction sector. About half of global steel is used in buildings and infrastructure. A further 18 % is used in the manufacturing of machines, 12 % are required by the automobile industry. 11 % are used to make metal products such as heaters, pots, or tools. However, there are also regional differences in the use of steel: in 2017, only about 35 % of steel was used in the construction sector in Germany, but 26 % were used in the automotive sector (WV Stahl 2018).

With a share of 38 %, metal products are the most important field of application of stainless steel. Another 36 % is attributable to mechanical engineering, which also includes electrical machinery. Around 12 % are used in the construction sector, where stainless steel has both a functional and a decorative role. 9 % of global stainless-steel output is used in the automotive industry, for example in exhaust systems.

2.3
Raw Materials of the Steel Production Process

2.3.1
Ores and Coke

Steel is made from both ores and scrap. This section discusses iron, chromium and nickel, three important metals for the production of (stainless) steel, as well as coke, the most important reducing agent.

Iron is the 26th element of the periodic table and the main component of steel (DIN EN 10020). The economically important iron ores are iron-oxygen compounds such as magnetite (Fe_3O_4) and hematite (Fe_2O_3). The U.S. Geological Survey (USGS) estimates that in 2018, some 2.5 billion tons of iron ore with an iron content of 1.5 billion tons were mined worldwide. In Australia alone, ore with an iron content of 560 million tons or 36,2 % of world production was mined. Brazil accounted for 20.0 % and China for 13.6 % of global production. In Sweden, the most important iron ore producer in the European Union, 1.1 % was produced (U.S. Geological Survey 2019b).

Coke is a hard, brittle and porous carbon carrier. It is made from low-sulfur hard coal by heating it under exclusion of air, whereby the volatile components of the coal are separated. Coke is used as a reducing agent in blast furnaces. In 2017, 670 million tons of coke were produced worldwide, 449 million tons (67.0 %) of which in China. The EU produced 39 Mt or about 5.8 % of the global production (IEA 2019).

Chromium is the 24th element of the periodic table. Its main area of application is the production of stainless steel, which it protects from corrosion by forming a microscopic oxide layer. To produce stainless steel, chrome ore (chromite) is first processed into ferrochrome, a compound of chromium and iron. For this purpose, chromite is reduced in electric arc furnaces. In 2018, 35.1 million tons of chrome ore were mined worldwide, 45.6 % (16.0 million tons) thereof were mined in South Africa. Other important producing countries include India, Turkey and Kazakhstan (U.S. Geological Survey 2019a). One active chromite mine exists in Europe, located in Finland, with an annual production of roughly 2.4 million tons of chromium ore (U.S. Geological Survey 2018).

Nickel, the 28th element in the periodic table, is an alloying element in (austenitic) stainless steel. It enhances corrosion resistance in acidic environments, improves machinability and increases high temperature resistance. Stainless steel production is the most important application for nickel. 75 % of all nickel is used for this purpose (International Nickel Study Group 2018). In addition, it is used for nickel-based superalloys and in battery manufacturing. In 2018, about 2.3 million tons of nickel were mined. Indonesia accounted for 24.2 %, the Philippines for 14.7 %, and Russia as well as New Caledonia, a French special collectivity in the Pacific, each for 9.1 %. In Finland, 46 million tons or 2.0 % of the global supply of nickel was extracted. Nickel is primarily used in the form of ferronickel for the production of stainless steel. Outside of China, ferronickel is mostly made pyrometallurgically (Mistry et al. 2016). In Asia, a low-grade ferronickel called »nickel pig iron« (NPI) is also used. Its production is associated with significantly higher environmental pressures than that of ferronickel (Reuter et al. 2015).

2.3.2 Steel Scrap

Steel is primarily used in the production of durable goods. The steel used in machinery, vehicles or buildings can be considered as the in-use stock or a physical capital stock. Pauliuk et al. (2013) estimate an in-use stock of between 11 and 16 tons per capita in industrialized countries. In Germany, this value lies between 11.2 and 11.9 tons per capita. The global in-use stock of stainless totaled more than 400 million tons in 2015 (Team Stainless and Yale University 2019). If products made of steel are no longer used, they drop out of the in-use stock and can be reused as a raw material. For example, defective washing machines or empty tinplate cans are available for recycling. The steel recycling industry makes this source of raw materials accessible. Figure 5 outlines the material cycle of steel and the in-use stock as well as the role of the steel recycling industry as a part of this cycle.

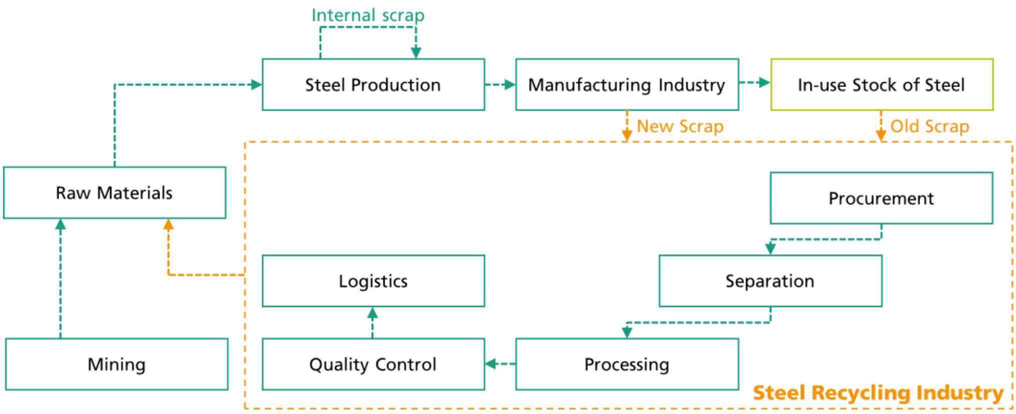

Figure 5: The in-use stock and the role of the steel recycling industry. Source: Own presentation.

Steel can be recycled an unlimited number of times without a loss of quality. When steel products reach the end of their life cycle, they are available as a potential source of raw materials. The steel recycling industry makes this source of raw materials accessible and thus reintroduces it into the material cycle of steel.

The steel recycling industry buys scrap, bundles the material flows and prepares them for usage. It ensures the quality of the scrap, both in terms of its mechanical properties (e.g. shape, diameter) and its chemical-metallurgical composition (e.g. proportions of alloying elements). The latter is particularly important for stainless steel scrap. To process the scrap, the steel recycling industry uses a variety of methods. These are summarized in table 1. The steel recycling industry is, furthermore, in charge of transporting the processed raw materials to its customers.

The steel recycling industry operates like reversed wholesale trade. It buys scrap in small quantities from a variety of suppliers, processes it into a high-quality raw material and sells it to customers in the steel sector and the foundry industry.

Scrap can be divided into three types based on its source (see Figure 5). Internal scrap is the scrap accruing in the production of steel. It is recycled directly in steelworks and foundries. New scrap is scrap arising from the processing of steel in manufacturing industries. The composition of new scrap is well known, it contains few impurities and the backward logistics to the steelworks is simple. Therefore, it is almost entirely recycled.

Name of process	Substances to remove / work to be done	Method or mechanism
Sorting and preparation, physical separation	Separation of metallic products from non-metallic products Miscellaneous adhesions Other valuable and recyclable materials	Manual separation through visual inspection of color, texture, density, etc. Portable optical emission spectrometer Technologies for computer image processing (color sorting), laser-induced plasma spectroscopy
Comminution	Shredding of large-sized scrap into smaller pieces for transport and feeding Increasing the density of the scrap before loading the furnace	Baling press: the scrap is compressed and compacted by hydraulic rams Briquetting: the scrap is compacted by two counter-rotating drums and heat Shearing: the scrap is cut into pieces by a hydraulic guillotine
Shredding / fragmentation	Conversion of larger objects into matching pieces (motor vehicles and white goods) Produced: ferrous metal and shredder residues (SR) (light fraction and heavy fraction)	Crushing of objects by hammer mill (force, air separation, magnetic properties and manual sorting)
Magnetic separation	Separates ferrous from non-ferrous scrap	Belt or drum permanent magnets or electromagnets are used (magnetic properties of ferrous metals and, if required, manual sorting)
Eddy current separators	Removes non-ferrous metals from waste and SR	Inclined ramp separator with a series of magnets with non-magnetic sliding surface (magnetism for magnetic products and electrical conductivity for non-magnetic products)
Separation of heavy media	Recovers non-ferrous metals from SR	Uses finely ground magnetite or ferrosilicon with water (specific gravity, relative density and viscosity)
Spark, magnetic, chemical and spectroscopic testing	Separation and classification of different steel alloys	By magnets, acids, grinding (for alloys) and X-rays (ferromagnetism, acid reaction, color and spark length, emitted light spectra)
Coating removal techniques	Removal of zinc, tin, fuels, oils, greases, paints, lubricants and adhesives, etc.	Use of thermal methods such as evaporators and incinerators (temperature differences and abrasion)

Table 1: Methods of scrap sorting and processing.
Source: Hiebel and Nühlen (2016) on the basis of Yellishetty et al. (2011), own translation

Old scrap is made up of products at the end of their life cycle. Even for old scrap, high recycling rates are reached. For example, about 88 % of all steel parts in the construction sector are recycled and another 11 % are reused (Helmus and Randel 2015). Even tinplate packaging made of electrolytically tinned sheets of steel can achieve recycling rates of more than 90 % (GVM 2017). For stainless steel products, Reck et al. (2010) list recycling rates between 92 % (in industrial machinery) and 60 % (for metal products)[1]. These recycling rates can be considered as conservative estimates.

Old and new scrap can be split into different grades that have been defined on a voluntary basis by both the steel recycling industry and the steel industry. For carbon steel scrap, a distinction is made between 16 scrap grades (BDSV 2010).[2]

Figure 6 shows the use of scrap in steel production in selected countries, based on data from the Bureau of International Recycling (BIR). The columns correspond to the use in millions of tons (left axis). The points represent the scrap input rate, i.e. the ratio of scrap input to crude steel produced in per cent (right axis). At 187.8 million tons, China had the largest absolute steel scrap input in 2018. This corresponded to a scrap use rate of 20.2 %. The scrap input in China has grown significantly in recent years. In 2017, it was 147.9 million t and in 2016 it was only 90.1 million t. The scrap utilization rate in Germany was 43.9 %, throughout the EU it was 55.9 %. The differences in scrap utilization rates reflect, among other things, historical developments in the steel sector of individual countries as well as energy prices and the availability of scrap.

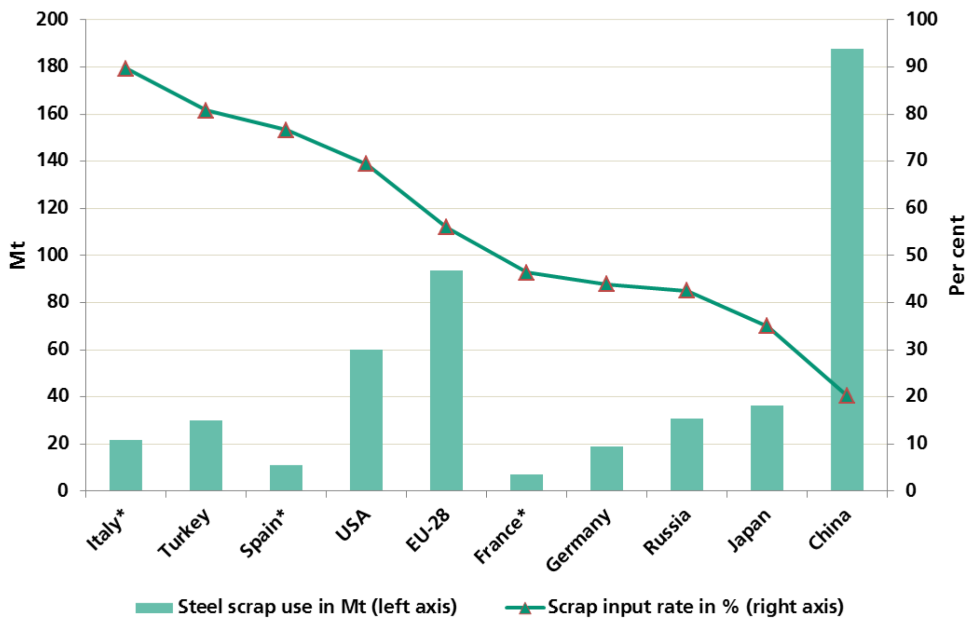

Figure 6: Scrap use in steel production by country. All figures for 2018 unless indicated by a star, then for 2017.
Source: BIR (2019), own presentation.

[1] A portion of the stainless-steel scrap is used for the production of carbon steel. This especially true for ferritic stainless-steel scrap (Team Stainless and Yale University 2019). Ferritic stainless steel, just like carbon steel, is ferromagnetic. This means they cannot be separated magnetically from each other.
[2] An overview can be found online at: https://www.bdsv.org/die-branche/stahlschrottsorten/

Figure 7 shows the average prices for selected grades of steel scrap[3] in Germany from January 2009 to July 2019. These are to be understood as ex-warehouse sales prices. The prices differ significantly between the grades of steel scrap. For example, grade 4 scrap (shredder steel scrap, free of scrap steel sourced from waste incineration or separation) had an average price of € 240.76 per ton. The average price of grade 5 scrap (steel shavings) only had a price of around € 187.92 per ton.

In addition, Figure 7 shows significant price fluctuations between 2009 and 2019. For grade 4 scrap, for example, the price ranged from €125.30 per ton in March 2009 to € 355.70 per ton in January 2011. The prices of the individual steel scrap grades are highly correlated. The correlation coefficients are at least at 0.97. Additionally, there is a close correlation with iron ore prices.

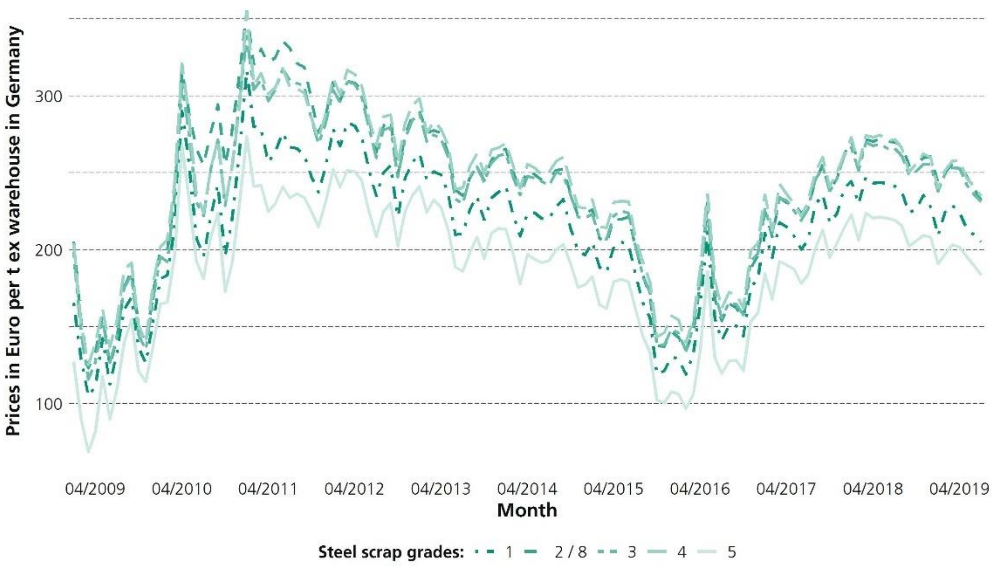

Figure 7: Ex-warehouse prices for selected steel scrap grades in Germany. Source: BDSV, own presentation

Stainless steel scrap is priced using the steel grade numbers that define the composition of steels. The pricing is based on the prices of the alloying elements contained in the scrap. The price of nickel in austenitic stainless-steel scrap, for example, is linked to the price of nickel at the London Metal Exchange (Lüning 2019, Mauss 2019).

Steel scrap is an internationally traded raw material. Between the 2000 and 2018, an average of 8.5 million tons of steel scrap were exported per year from Germany. 86.7 % thereof were exported to EU28 member states. In the same period, 5.1 million tons of steel scrap were imported annually, of which 88.6 % came from the EU. From 2000 to

[3] Grade 1: Steel scrap, at least 4 mm thick, maximum dimensions: 1.50 x 0.50 x 0.50 m; Grade 2: New steel scrap, at least 3 mm thick, maximum dimensions: 1.50 x 0.50 x 0.50 m; Grade 3: Heavy steel scrap, at least 4 mm thick, maximum dimensions: 1.50 x 0.50 x 0.50 m; Grade 4: Shredded steel scrap, free of steel scrap sourced from waste incineration or waste separation, bulk weight (i.tr.): min. 1,1 t/m³ Fe-content metallic: min. 92 %; Grade 5: steel shavings, free of cast iron and machine steel chips; Grade 8: New steel scrap, less than 3 mm thick, maximum dimensions: 1.50 x 0.50 x 0.50 m (BDSV 2010)

2018, an average of 836,000 tons of stainless-steel scrap were exported annually (94.6 % of which went to the EU), and 318,000 tons were imported (73.8 % sourced from the EU). For stainless steel, there was a significant increase in net exports, from 294,000 t in 2000 to 860,000 t in 2018 (Eurostat 2019a). This can be attributed to a decline in the production of stainless steel in Germany.

Set against a background of an increasingly global steel scrap market, the European Union's trade flows of steel and stainless-steel scrap are shown below. Figure 8 shows the exports and imports of steel scrap in million tons (excluding stainless steel scrap) for the EU 28 from 2000 to 2018. Only trade with third party countries, i.e. non-members of the EU, is considered.

Steel scrap imports into the EU increased from 3.6 million tons in 2000 to 6.3 million tons in 2004. Following this, they once again fell and have, since 2009, averaged 2.6 million t. The main countries of origin of imported steel scrap in 2018 were Switzerland (28.2 %), Russia (18.4 %), Norway (18.0 %) and the USA (6.7 %).
Exports of steel scrap from Europe have more than doubled between 2000 and 2018, from 9.2 million tons to 21.3 million tons. Important importers of steel scrap are, with the exception of Egypt (7.4 % of all exports), mainly located in Asia. Turkey alone imported around 56.2 % of European steel scrap exports. Another 7.4 % went to Pakistan and 7.1 % to India. Only 0.6 % of steel scrap exports were shipped to China.

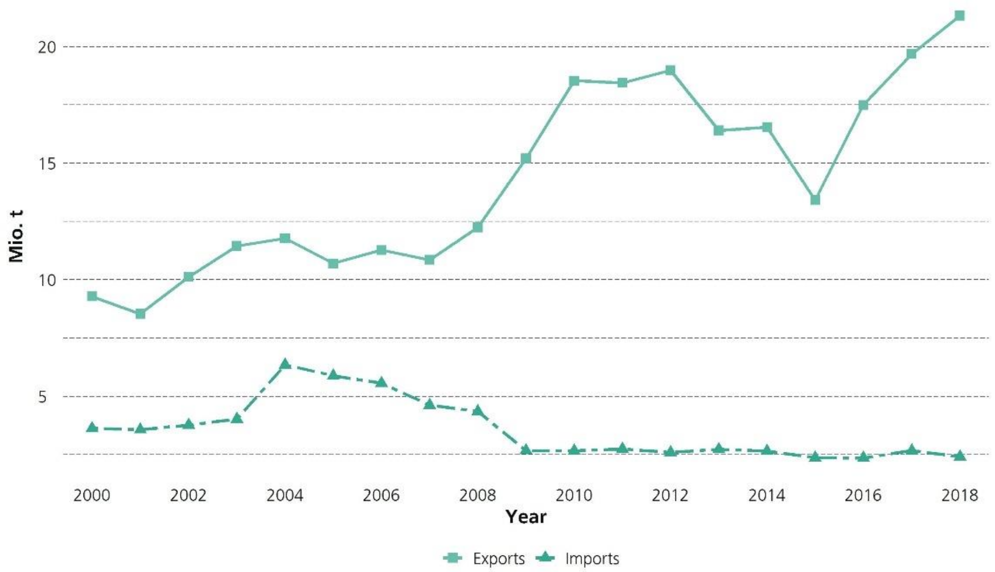

Figure 8: Imports and exports of steel scrap (excluding stainless steel scrap)[4]
Source: Own presentation based on Eurostat (2019a)

[4] Steel scrap is listed in the Harmonized System (HS) of the World Customs Organization (WCO), on which the foreign trade statistics in Germany and Europe are based, under the code 7204. Stainless steel scrap is designated with the code 720421. In Figure 8, trade in stainless steel scrap (720421) was excluded from the steel scrap (7204).

Figure 9 shows the European Union's imports and exports of stainless-steel scrap to third party countries from 2000 to 2018 in 1000 tons. It reveals a very different picture than Figure 8 does. Until 2006, the EU was a net importer. Between 2000 and 2006, net imports averaged 459,000 t per year. After that, imports of stainless-steel scrap and thus net imports declined. From 2007 to 2018, the European Union exhibited an average net export of 61,000 tons per year. Imports and exports are, thus, largely balanced.

In 2018, three supplier countries accounted for 5 % or more of EU imports: Russia (22.9 %), Turkey (19.5 %) and Switzerland (13.5 %). Stainless steel scrap was exported mainly to Asia. The main destinations were India (52.2 %), Taiwan (10.0 %), Bangladesh (9.6 %), Pakistan (6.7 %), Indonesia (6.5 %) and the USA (6.5 %). 3.0 % of stainless-steel scrap exports went to China.

The firms in the steel recycling industry also take over the logistics of steel scrap. The procurement of scrap by the steel recycling industry is usually carried out by trucks on the road. The delivery to steelworks and foundries is often carried out by freight trains and (inland) ships. For example, DB Cargo indicates that it transported about 8.1 million tons of scrap in 2016 (DB Cargo 2017).

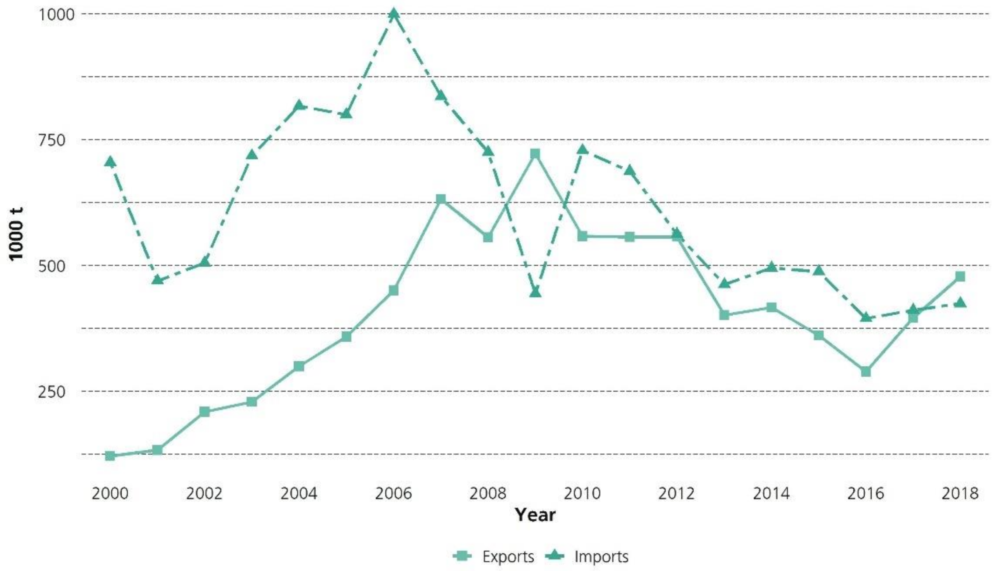

Figure 9: Imports and exports of stainless steel from the EU28 to third party countries
Source: Own presentation based on Eurostat (2019a)

2.4 Externalities and Steel Scrap

As with all materials, steel production is associated with environmental pollution. The extent depends on the technology used. The steel industry in Germany, for instance, reduced its primary energy consumption in crude steel production by 13.8 % from 1990 to 2016 (WV Stahl 2017). The use of scrap as a raw material can reduce pollution in the value chain of steel production substantially (see subsection 3.2).

The ecological effects of steel production – and their reduction through the use of scrap – have an economic dimension. They give rise to externalities. In economics, the term external effect or externality denotes effects of an economic activity on uninvolved third parties that are not compensated. As a result, the polluters do not have to include the external effects in their production or consumption decisions. Thus, private and social benefits of an economic activity diverge if externalities occur.

There are negative and positive externalities. Examples of negative externalities include the emissions of CO_2 or local air pollutants. These cause economic costs that are not accounted for in the production decisions of the emitters. Positive externalities occur, for instance, when avoiding pollution, when recycling or when conducting research and development. Such activities have positive effects on the economy. However, the producer is not fully compensated for undertaking them. In both cases, externalities lead to a misallocation of resources and distortions in the market.

In the value chains of steelmaking, negative external effects such as greenhouse gas emissions and local air pollution arise. The use of steel scrap avoids emissions and thus generates positive externalities. Abstracting from the effects induced by externalities, the structure of the scrap market can be illustrated schematically as shown Figure 10. The horizontal axis denotes the scrap price, the vertical displays the quantity.

The scrap supply (**S**) responds moderately to changes in price. An increase in the scrap price leads to an increase in the amount of scrap offered, in particular of old scrap (Damuth 2011). It should be noted that the supply of steel scrap is influenced by factors other than price. The availability of new scrap, for example, depends on the production of the steel processing industry. The demolition of old infrastructure or the expectations of market participants can influence the supply as well. To highlight the logic of externalities, Figure 10 abstracts these factors.

The demand curve (**D**) also responds to changes in the scrap price. For instance, the quantity of scrap used in converters can be varied within technical limits and the production levels of the electric arc furnaces can be adjusted. Thus, the demanded scrap quantity falls moderately in price. It should be noted that the interaction between scrap and ore prices is not shown in Figure 10.

The market equilibrium lies at the intersection of the supply and demand curve. In equilibrium, a quantity q_M is traded at a price p_M. This market equilibrium does not correspond to the economic optimum. Market participants do not benefit from the social benefits (positive externalities) of scrap input such as the avoidance of greenhouse gas emissions. Therefore, production decisions are distorted.

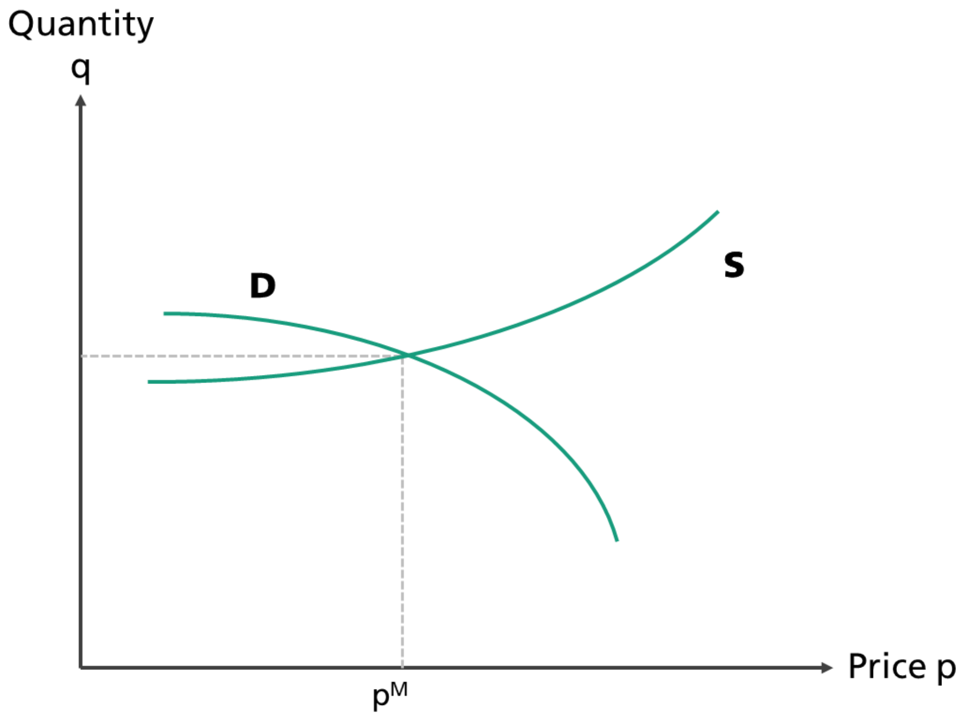

Figure 10: Schematic illustration of the scrap market.
Source: Own presentation

Figure 11 illustrates this market failure. The starting point is the market equilibrium shown in Figure 10 with the price p_M and the quantity q_M. In the market equilibrium, too little scrap is used. The economically optimal scrap demand can be represented by the right-shifted demand curve (**D***), which considers the positive externalities resulting from the use of scrap. In this demand curve, the positive effects of scrap use are part of the price mechanism. In the socially optimal equilibrium, a larger amount of scrap q* is used at a higher price p*.

The area shaded in red represents the welfare loss caused by market failure – the market equilibrium does not correspond to the social optimum. Welfare loss includes too much use of ores and too little use of scrap. In addition, climate change causes welfare losses.

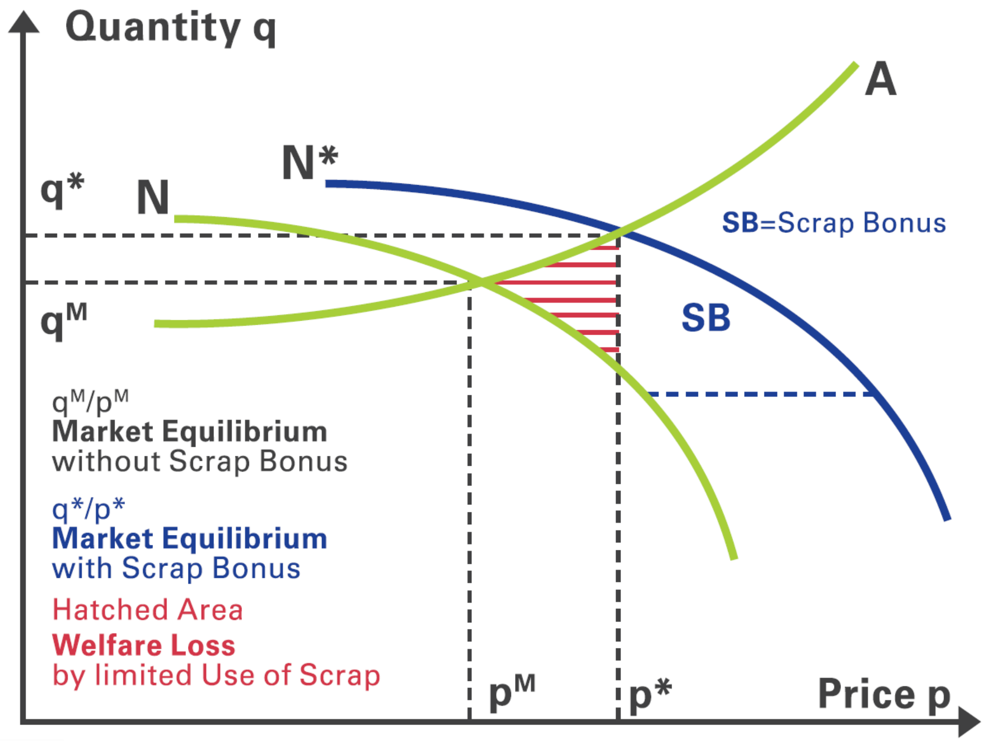

Figure 11: Schematic presentation of the internalization of externalities associated with scrap inputs
Source: Own presentation

The scrap bonus (**SB**) designates the welfare gains generated by recycling along the value chain of steel production. As shown in Figure 11, the scrap bonus reflects the difference between the demand for scrap at social optimum and the unregulated market demand. Thus, it corresponds to the environmental impact avoided per ton of scrap used, measured in euro.

Figure 11 shows that non-internalized external effects create misallocations, i.e. distorted production decisions, and thus welfare losses. It appears economically advisable to counteract these misallocations. Instruments that can be employed to integrate the avoided environmental impacts due steel scrap inputs into the price mechanism are discussed in Chapter 4.

3
Scrap Bonus: Concept and Quantification

3.1
Definition

The use of scrap as a raw material in steel production avoids emissions and conserves natural resources. Reduced environmental impacts create economic welfare gains because external effects are avoided. Thus, the reduced burdens are associated with monetary cost savings. The indicator scrap bonus quantifies the environmental costs that are avoided by using a ton of scrap as a raw material of steel production.

The scrap bonus is calculated in two steps. The first step is to quantify the environmental impacts avoided when using a ton of scrap in steel production. The avoided impacts differ depending on whether carbon steel scrap or stainless-steel scrap is used. In the second step, economic estimates are used to convert the avoided environmental impacts into euro. In other words: the (avoided) impacts are assigned a price.

3.2
Avoided Environmental Impacts

3.2.1
Fundamentals

To fully calculate the emissions associated with the production of steel, the entire value chain must be considered. Life cycle assessments (LCAs), are designed for this purpose (Guinée 2002). They model the value chain of a product from the extraction of raw materials through to its manufacture, use and disposal or recycling. Life cycle assessments of materials are usually considered as far as the manufacturer's gate, because the materials can be used in a variety of products. The raw materials used and the emissions released along the value chain are recorded in an inventory. The individual emissions can then be aggregated into impact categories, i.e. types of impact on the environment.[5] One example of an impact category is climate change. Individual greenhouse gases such as CO_2 or methane are evaluated according to their global warming potential, converted into CO_2 equivalents and thus made comparable.

Figure 12 outlines the methodological guidelines of the World Steel Association for life cycle assessments of steel. These require that all processes necessary for steelmaking and the related ancillary services are considered. The starting point is the extraction of raw materials used in steel production and their transportation. The processing of raw materials, such as manufacturing coke from coal, must be considered. Raw materials and energy carriers used in the production of steel, including their associated ancillary processes (e.g. water treatment), need to be accounted for. These steps summarized as »gate-to-gate« in Figure 12. Even in steelmaking itself, scrap can contribute to avoiding emissions. In particular, the use of high-quality scrap saves energy and thus emissions (Haupt et al. 2017). Credits are given for by-products, such as slags that can be used in road construction (World Steel Association 2017a).

[5] These are known as midpoint indicators in the literature.

The functional unit of a life cycle assessment of steel is one kilogram or one ton of semi-finished steel. Semi-finished steel includes cast products such as slabs, flat products such as cold and hot rolled sheets and long products such as wires or rails. The use of these semi-finished products in manufacturing industries is not considered.

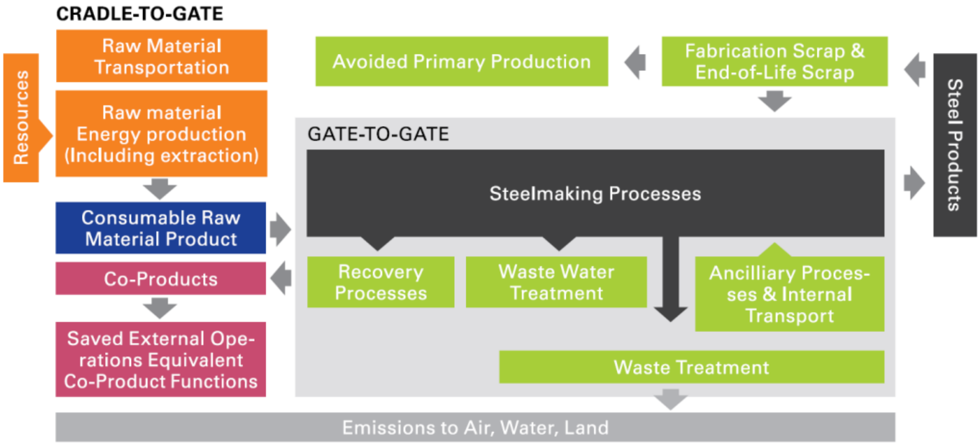

Figure 12: Methodological approach of life cycle assessments of steel. Source: Own diagram based on World Steel Association (2017b)

The scrap bonus reflects the environmental costs avoided through the use of scrap as a raw material in the production of steel. The entire value chain of steelmaking is considered in its quantification. This approach is associated with three implicit assumptions that are discussed below.

The first assumption is that recycling takes place in a closed cycle (»closed-loop recycling«). This means that steel scrap is recycled into steel and does not end up in the production of other materials. This assumption is appropriate for the well-developed recycling processes in the steel sector. This also applies to stainless steel scrap, from which predominantly new stainless steel is produced.

The second assumption concerns the question of the extent to which ores or coke are replaced by scrap. The scrap bonus implicitly applies the »avoided burden method« (Guinée 2002). It means that the use of a ton of steel scrap replaces the corresponding amount of ore, coke and energy. The interaction between supply and demand on scrap markets is ignored (Zink et al. 2016). When considering the marginal ton of steel scrap, this assumption seems unproblematic.

The third assumption concerns the allocation of the avoided environmental burdens along the life cycle (or life cycles) of steel. The scrap bonus is allocated to the input side of steel production. It is disregarded whether the product which is made of steel is recycled itself. For the LCA of a product, this approach would not be optimal. It does not create an incentive for manufacturers to optimize the recyclability of their products. However, no individual products are being investigated when quantifying the scrap bonus. Thus, this implication is less of a disadvantage in the context of this study.

The World Steel Association proposes an alternative way of allocating emission savings due to the use of scrap (World Steel Association 2017a). In this methodology, emissions embodied in the scrap are added while credits are given for the recycling of the product. Therefore, credits are given for a net gain in recycling. When calculating a products' LCA, this method has the advantage that it creates incentives for a recycling-friendly product design.

Another option for allocating emission savings is the multi-recycling approach (Neugebauer et al. 2013, Mengarelli et al. 2017). It looks at a material over several life cycles. The emissions of the initial production from ores as well as the multiple recycling cycles are distributed uniformly over all life cycles.

3.2.2 Carbon Steel

This subsection presents the emission avoidance associated with the use of scrap in the production of carbon steel. The figures are based on the Scrap LCI (scrap life cycle inventory) provided by the World Steel Association. In this approach, a hypothetical steel production process is modeled in which no scrap is used and compared to a production process using 100 % scrap. In addition, a correction is made for the yield loss of the process, which reflects that more than one ton of scrap must be melted to manufacture one ton of steel. By comparing the two production processes, emission savings due to the use of scrap can be quantified.

The World Steel Association's Scrap LCI contains global averages of emission avoidance. Since steel, products made from it and steel scrap are all traded internationally, the use of global averages appears to be a reasonable assumption.

The study uses the most recent scrap LCI, with 2018 as its base year[6], for its calculations (World Steel Association 2019a). In 2018, the use of one ton of carbon steel scrap in steel production avoided greenhouse gas emissions equivalent to 1.67 tons of CO_2.

The CO_2 emissions avoided by the use of scrap can roughly be estimated by comparing the emissions of the blast furnace route to the electric arc furnace route. Since scrap is used in the blast furnace route (more precisely in the converter) whilst the electric arc furnace route can use DRI, this comparison is imprecise. Nevertheless, the results of such a comparison can be contrasted with the results of the Scrap LCI.

Figure 13 shows the CO_2 emission in kg per ton of steel by country and production process. The required data is sourced from a series of studies.[7] It covers China (CN), Germany (DE), the European Union (EU), the United States (US) and Mexico (MX). Generally, the reference year for the studies is 2010.

The emissions resulting from the blast furnace route average 2.11 t CO_2 per ton of steel. Arens et al. (2017) find that the combination of DRI and the electric arc furnace (EAF) route yields emissions of 1.49 t CO_2 per ton of steel. For the electric arc furnace route, average emissions are 0.88 t CO_2 or 0.63 t CO_2 when excluding China. The emissions of more than 1.5 t of CO_2 arising from the EAF route in China can be attributed to the high a proportion of direct reduced iron used as a raw material and the CO_2-intensive power generation in the People's Republic (Hasanbeigi et al. 2016).

[6] The life cycle inventory of the World Steel Association is updated regularly. The next update is scheduled for the end of 2019.

[7] A similar diagram can be found in Hiebel and Nühlen (2016).

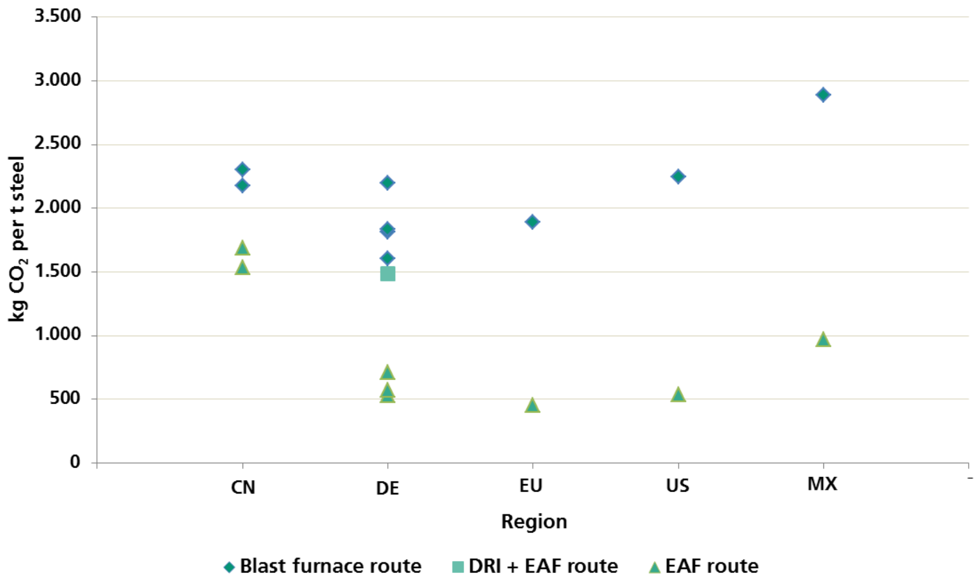

Figure 13: CO_2 emissions per ton of steel in China (CN), Germany (DE), the EU, the US and Mexico (MX) by process route.
Source: Own presentation on the basis of Arens et al. (2017); BCG and VDEh (2013); Chen et al. (2014); (Hu et al. 2006); Neugebauer and Finkbeiner (2012); Hasanbeigi et al. (2016); Rojas-Cardenas et al. (2017)

Comparing the process routes yields an average difference between the blast furnace route and the electric arc furnace route of 1.52 t CO_2 per ton of steel (excluding China). This number is below the 1.67 t from the scrap LCI. The difference can be explained by two factors. On the one hand, the Scrap LCI considers other greenhouse gases besides CO_2. These account for around 7 % of total greenhouse gas emissions in the steelmaking process (World Steel Association 2017b). On the other hand, it does not take into account that scrap is also used in the blast furnace route. Therefore, it seems plausible that the avoided emissions calculated based on the comparison of the process routes are lower.

In addition to greenhouse gas emission abatement, the Scrap LCI captures the effects of scrap use on three other impact categories: The acidification potential, measured in SO_2 equivalents, indicates a decrease in the pH values of soils and waters by pollutants such as sulfur dioxide. Acidification damages plant and marine life. Eutrophication denotes an excessive nutrient input into soils and waters. It is caused primarily by over-fertilization, but also by the release of nitrogen and phosphorus into the air. Photochemical oxidation is related to the emergence of summer smog, which damages the respiratory organs of humans and animals. In all three impact categories, the use of scrap reduces environmental burdens.

3.2.3 Stainless Steel

The emission reductions due to the use of stainless-steel scrap in the production of new stainless steel can also be quantified on the basis of scientific life cycle assessments. Johnson et al. (2008) investigate the use of energy and the associated CO_2 emissions in the production of stainless steel with a chromium content of 18 % and a nickel content of 8 %. These contents correspond to the most commonly produced grade of stainless steel, designated as 1.4301 or AISI 304. The study by Johnson et al. (2008) reflects the

technological state of the early 2000s. Therefore, nickel pig iron is not considered as an input in the production of stainless steel.
Johnson et al. (2008) calculate emissions from stainless steel production, depending on whether primary raw materials or scrap were used as raw materials. They calculate CO_2 emissions of 5.3 tons per ton of stainless steel when ore is used in the production process and 1.6 tons when scrap is used. This would correspond to an emission reduction of 3.7 t CO_2. Although nickel accounts for the smallest mass fraction (8 %) of the three main constituents of the stainless steel considered, the production of (ferro-) nickel accounts for the largest share of energy consumption and emissions.

For comparison, Hiebel and Nühlen (2016) find CO_2 emission reductions of approximately 4.5 t of CO_2 per ton of stainless-steel scrap used. A study by Fraunhofer UMSICHT identifies avoided emissions of about 4.7 t of CO_2 per ton of austenitic stainless-steel scrap used (Hiebel et al. 2010). In further unpublished studies, similar magnitudes of emission reductions are found, depending on the composition of the considered stainless steel grade (Hiebel 2019).

The CO_2 emission reductions due to the use of a ton of stainless-steel scrap lie within a range of approximately 3.7 t to 4.7 t CO_2. The exact values depend on the alloying elements contained in the scrap. Therefore, a reduction of 4.3 t CO_2 per ton of stainless-steel scrap is assumed when computing the scrap bonus.

No data is available in the evaluated studies concerning the other impact categories (acidification, eutrophication, photochemical oxidant formation). However, it can be assumed that the use of stainless-steel scrap reduces local environmental pollution. Therefore, we assume that it avoids the same amount of local pollutants as the use of carbon steel scrap. Since the production of ferroalloys is energy intensive, it can be assumed that the actual levels of avoided pollutants is even greater.

3.2.4 Comparisons

The analyses in sections 3.2.2 and 3.2.3 show that the use of one ton of carbon steel scrap saves about 1.67 tons of CO_2. For austenitic stainless-steel scrap, the savings are about 4.3 t CO_2 per t of scrap. In comparison, burning one liter of gasoline releases about 2.37 kg of CO_2. Thus, the use of one ton of steel scrap would result in reductions of as much CO_2 emissions as are emitted by incinerating 705 liters of gasoline. The use of stainless-steel scrap saves the same as 1,814 liters of gasoline would have emitted upon incineration. Assuming that the average fuel consumption by gasoline-fueled cars in Germany lies at 7.8 liters per 100 km (BMVI 2019), the use of one ton of steel scrap avoids emissions equivalent to about 9,000 km driven, a route from Berlin to Beijing. The use of one ton of stainless-steel scrap would be equivalent to a distance of almost 23,300 km.

In 2018, steel producers in the European Union used 93.8 million tons of scrap. Making the conservative assumption that this was only carbon steel scrap, this amount would correspond to an emission reduction of about 157 million t CO_2. This is roughly equivalent to the greenhouse gas emissions of automobile traffic in France, the United Kingdom and Belgium combined (Eurostat 2019b).

Further significant savings can be achieved by shifting scrap transport from road to rail and inland waterway vessels: every ton-kilometer, i.e. every ton of goods transported over one kilometer, in trucks (starting at 3.5 t) is associated with CO_2 emissions of 103 g. In contrast, rail freight releases only 19 g of CO_2 per t/kg and inland waterways release 32 g per t/kg (UBA 2018).

A falling CO_2 intensity of power generation also increases the emission reductions from the use of scrap in steelmaking, especially in the electric arc furnace route. In Germany, CO_2 emissions per kWh of electricity fell from 764 g to 474 g between 1990 and 2018 (UBA 2019a).

3.3 Social Costs and Environmental Impacts

3.3.1 Fundamentals

The emissions avoided when using scrap in steel production can roughly be separated into two categories. On the one hand into the emission of greenhouse gases, in particular CO_2, and on the other hand into other emissions. The key difference between these groups is that greenhouse gases are global pollutants. The effects of a ton of CO_2 on the global climate are independent of where it was emitted. Impact categories such as the eutrophication of soils and waters have more localized effects.

The different regional dimensions of the impact categories are reflected in different methods to monetize them. These are presented in the following subsections. The next section is concerned with monetizing the emissions of greenhouse gases, i.e. convert these from tons to euro. The monetization of the other impact categories is discussed in section 3.3.3.

3.3.2 Greenhouse Gas Emissions

The economic effects of greenhouse gas emissions are referred to as »social cost of carbon«. Following Nordhaus (2017), we define the social cost of carbon as the discounted welfare loss caused by an additional ton of CO_2-equivalent emissions.

This definition requires further explanation. Welfare loss is usually understood as a reduction of consumption when calculating the social cost of carbon. The damage caused by climate change leads to production losses. Agricultural production, for instance, is likely to be negatively affected by climate change. With the losses in production, consumption options are lost. Effects of climate change on aspects of quality of life beyond the consumption of goods and services are generally not considered because they can hardly be reliably quantified. For better comparability, the welfare losses are discounted. Thus, they are expressed as present values. The definition also indicates that greenhouse gas emissions other than carbon dioxide are taken into account by expressing these as CO_2 equivalents.

The social cost of carbon is estimated primarily by means of »integrated assessment models« (Nordhaus 2014). These long-term models simulate the world’s climate and economy simultaneously. Integrated assessment models thus combine the climate science dimension with the economic dimension of climate change. Using feedback loops between emissions, climate change and production, they estimate welfare losses caused by the release of greenhouse gases.

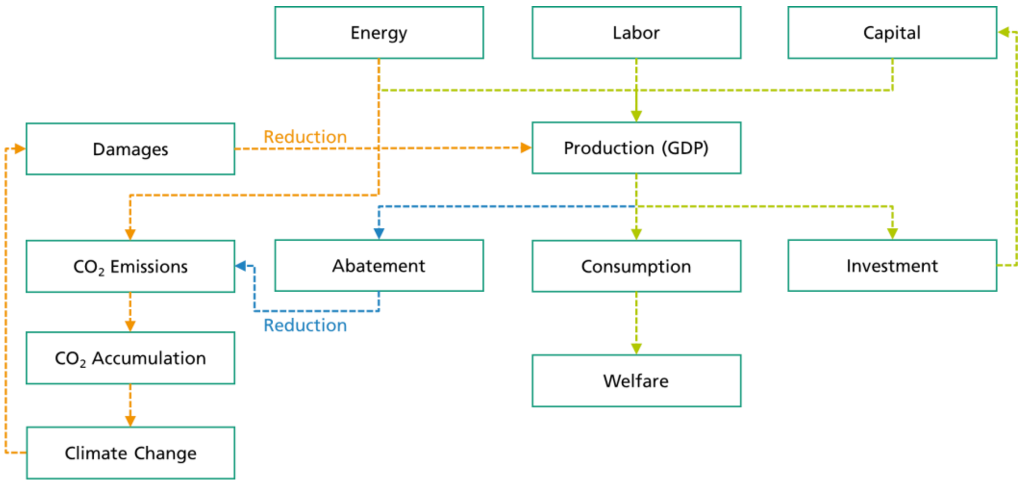

Figure 14: Schematic presentation of an Integrated Assessment Model based on the DICE model (Dynamic Integrated model of Climate and the Economy). Source: Own presentation based on Wieners (2018)

Figure 14 shows the structure of an integrated assessment model schematically. The starting point is the production factors labor, capital and energy. The production factors are used to manufacture goods and added value (gross domestic product, GDP). The goods can be used for three purposes: firstly, they can be consumed to generate welfare. Secondly, the goods can be used for investment purposes and thus are added to the capital stock. Thirdly, they can be used to reduce the CO_2 emissions associated with the use of (fossil) energy sources (abatement).

The climate science module begins with the emission of CO_2. The greenhouse gases accumulate in the atmosphere and contribute to global warming. A damage function translates global warming into economic effects. The quantification of the damage function poses a great challenge due to the multitude of possible cause-and-effect relationships. For instance, agricultural yields are diminished by droughts, which are likely to occur more frequently due to climate change. At the same time, CO_2 acts as a fertilizer in the air. Higher temperatures increase the energy requirements for cooling and reduce the energy requirements for heating.

Three conclusions with respect to the damage function can be drawn from the literature on the economic consequences of climate change. First, strong temperature increases have clear negative economic consequences, while minimal increases may even have positive effects. It should be noted, however, that the greenhouse gas emissions necessary for small temperature increases have already been released. Second, the estimates are associated with significant uncertainties. An underestimation of the economic impact of climate change is much more likely than an overestimation of the same magnitude. Third, poorer and warmer regions are more affected by climate change than developed economies in Europe and North America (Tol 2009, 2018)

The damage function affects productivity. It determines how strongly climate change hinders the production of goods from the factors labor, capital and energy. This creates a feedback loop between the economy and the climate. On the basis of long-term simulations, it is estimated how additional CO_2 emissions affect welfare. Thus, the social cost of carbon can be quantified.

Estimating the social cost of carbon is fraught with uncertainty. Three factors underlying the uncertainty are addressed. First, the damage function, the relationship between climate change and economic productivity, itself is estimated under uncertainty.

Secondly, the assumptions about technical progress have an important impact on the estimation results. On the one hand, technical progress triggers economic growth and thus additional energy consumption. On the other hand, it can reduce the CO_2 intensity of production. In addition, technical progress can facilitate adaptation to climate change, thereby reducing the damages caused by climatic change.

Thirdly, the »pure rate of time preference« is of great importance for the social cost of carbon. The term rate of pure rate of time preference refers to the rate at which welfare losses in the future are discounted to a present value. It quantifies how the well-being of future generations is weighted against the well-being of today’s generation. A pure rate of time preference of 0 % expresses that the well-being of future generations is valued in the same way as that of the present generation. A pure rate of time preference of more than 0 % means that welfare will be less heavily weighted in the future than today. The higher the pure rate of time preference, the more weight today’s welfare is given. It thus acts much like an interest rate.

Tol (2018) derives a probability distribution of the social cost of carbon from the literature. Figure 15 displays this distribution as a function of the assumed rate of time preference. It shows how probable certain social cost of carbon are. It distinguishes between all observations and studies assuming rates of time preference of 1 % and 0 %.

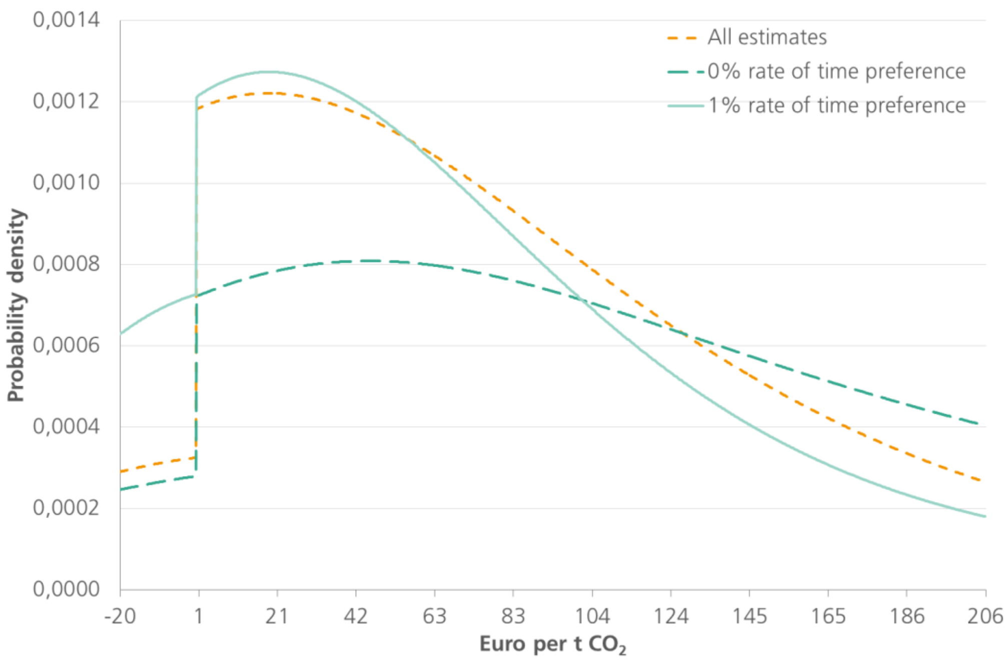

Figure 15: Distribution of social cost of carbon depending on the pure rate of time preference in euro per ton of CO_2
Source: Tol (2018), own presentation

Figure 15 illustrates the influence of the pure rate of time preference on the social cost of carbon. Assuming a pure rate of time preference of 1 %, low costs of 20 to 30 euro per ton of CO_2 seems much more likely than costs of more than 100 euro. In fact, the median is 53.80 euro per ton of CO_2. This means that social cost of carbon of more than € 53.80 are as likely as those below € 53.80. The mean, however, is € 74.00 per ton of CO_2. This implies that the welfare losses associated with climate change can be very high.

When assuming a rate of time preference of 0 %, the distribution becomes flatter. Low social cost of carbon is less likely, costs exceeding 100 euro per ton of CO_2 are more likely. Accordingly, the median increases to 111.00 euro per ton of CO_2 and the average to 139.20 euro per ton of CO_2.

In July 2019, the prices of EU ETS emission certificates at the European Energy Exchange (EEX) in Leipzig rose to values between 28 and 30 euro per ton of CO_2[8], the highest price level since the introduction of the EU ETS. The OECD uses a value of 30 euro per ton of CO_2 as a lower reference value when assessing effective carbon prices in a large number of countries (OECD 2018). Nordhaus (2017) estimates social cost of carbon at 27 and 33 euro per ton of CO_2 in 2015 and 2020, respectively. The UBA (2019b) recommends the use of significantly higher social cost of carbon of 180 per ton of CO_2 at a pure rate of time preference of 1 %.

The social cost of carbon is crucial to quantify the scrap bonus, i.e. the externalities avoided by using scrap in steel production. High values imply that the reduction of greenhouse gas emissions dominates the scrap bonus. Simultaneously, Figure 15 shows that determining the social cost of carbon is associated with great uncertainty. For this reason, the scrap bonus is quantified based on three scenarios. In the »lower reference« scenario, social cost of carbon of 30 euro per ton of CO_2 are assumed. The »medium reference« scenario uses social cost of carbon of 70 euro per ton of CO_2. The »upper reference« scenario assumes social cost of carbon of 110 euro per ton.

3.3.3
Local Environmental Impacts

The use of scrap in steelmaking does not only reduce greenhouse gas emissions but also avoids other environmental impacts. It decreases the acidification of waters, reduces the excessive input of fertilizers (eutrophication) and avoids summer smog. These effects can also be monetized, i.e. converted into monetary units. For this purpose, approaches from the life cycle assessment literature can be used (Pizzol et al. 2015).

Approaches to monetize these environmental effects differ methodically from the estimation of the social cost of carbon. This is because these effects have more local and direct impacts on humans and ecosystems while climate change has long-term and global implications. Nonetheless, the approaches from the life cycle assessment literature also consider climate change as an impact category.[9]

A variety of methods can be used to convert (avoided) environmental impacts into euro. These include the use of market prices (if goods traded on markets are damaged), the evaluation of household behavior and various survey methods (Ahlroth 2014). In contrast to calculating the social cost of carbon, which typically quantify the impact of greenhouse gas emissions on consumption, other aspects of welfare are considered.

Pizzol et al. (2015) investigate and compare a variety of approaches to monetize LCA results. Some of these approaches differ drastically in their results. For example, the highest estimate for the social costs of the impact category photochemical oxidant formation (summer smog) is 100 times higher than the lowest.

[8] https://www.eex.com/de/marktdaten/umweltprodukte/spotmarkt/european-emission-allowances

[9] The impacts of climate change are partially quantified using the literature on the social cost of carbon (e.g. Ahlroth and Finnveden 2011).

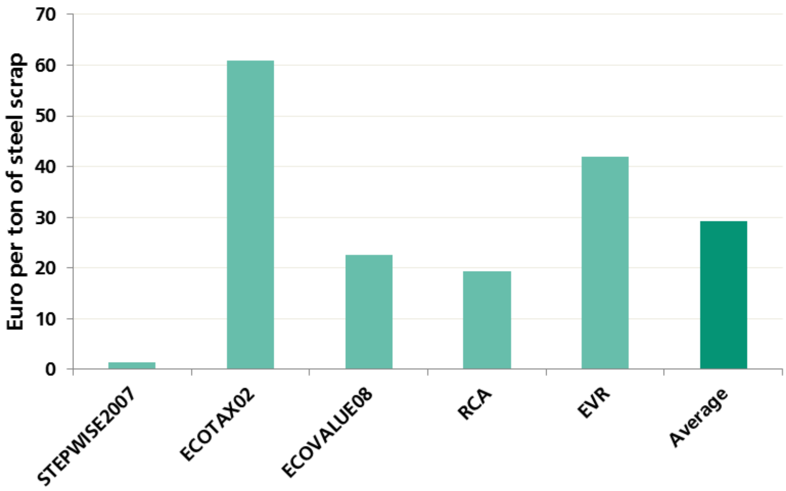

Figure 16: Avoided costs of local environmental impacts due to the use of one ton of carbon steel scrap by monetization method.
Source: Own calculation based on data from World Steel Association (2019a), Pizzol et al. (2015)

Figure 16 illustrates the social costs of local environmental burdens avoided by using one ton of carbon steel scrap in steelmaking. It shows the results based on the five approaches examined by Pizzol et al. (2015) that provide cost estimates for all relevant impact categories. In addition, Figure 16 shows the average of the approaches. To compare these, all figures were converted to 2017 euro. The cost estimates range from 1.40 euro to 61 euro per ton of scrap. The average value is around 29 euro. Henceforth, this average is used to calculate the scrap bonus. Since it is assumed that the use of stainless-steel scrap leads to the same avoidance of local environmental pollution, the corresponding avoided environmental costs are also estimated at about 29 euro.

3.4 Scrap Bonus: Quantification

The indicator scrap bonus represents the welfare gains from avoided environmental pollution associated with the use of one ton of scrap in steel production. It is calculated by converting the environmental impacts avoided as described in sub-chapter 3.2 into monetary units. The conversion is based on estimates of the social cost of carbon and estimates of the other relevant impact categories. To account for the uncertainty in determining the social cost of carbon, the scrap bonus is calculated based on three scenarios. In the »lower reference« scenario, every ton of carbon dioxide is valued at 30 euro. The »medium reference« scenario assumes social cost of carbon of 70 euro per ton of CO_2-equivalent greenhouse gas emissions and the »upper reference« scenario assumes social costs of 110 euro per ton of CO_2. The avoided social costs of local environmental impacts are included in the scrap bonus as well.

Figure 17 shows the scrap bonus for carbon steel scrap in euro per ton. In the »lower reference« scenario, it equals 79 euro. 29 euro thereof are attributable to local environmental pollution. By using a ton of scrap in carbon steel production, environmental costs of almost 80 euro are avoided.

The scrap bonus for carbon steel scrap is calculated as follows. By using one ton of scrap, greenhouse gases amounting to 1.67 tons of CO_2 are avoided. If these are multiplied by the social cost of carbon of 30 euro per ton of CO_2, as in the »lower reference« scenario, climate costs of about 50 euro are avoided. By reducing local environmental impact, a further 29 euro in social costs are avoided. In total this results in a scrap bonus of 79 euro per ton of carbon steel scrap.

Assuming social cost of carbon are 70 euro, the scrap bonus increases to 146 euro. In the »upper reference« scenario, which assumes social cost of carbon of 110 euro per ton, the scrap bonus for carbon steel scrap reaches a value of 213 euro. In comparison, steel scrap of grade 1 (steel scrap, at least 4 mm thick, maximum dimensions: 1.50 x 0.50 x 0.50 m) had an average price of 237 euro per ton in 2018.

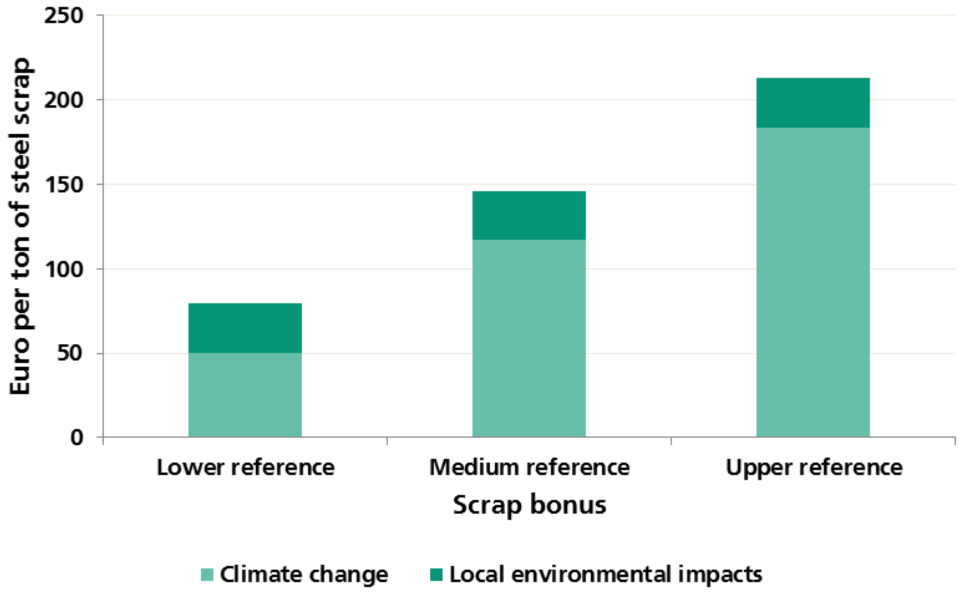

Figure 17: Scrap bonus in euro per ton of carbon steel scrap in the three scenarios. Source: Own calculation

The use of one ton of stainless-steel scrap in the production of new stainless-steel saves approximately 4.3 tons of CO_2. As a result, the scrap bonus for (austenitic) stainless steel scrap amounts to 158 euro per ton in the »lower reference« scenario, 330 euro per ton in the »medium reference« scenario and 502 euro per ton in the »upper reference« scenario.

A number of factors that could affect the level of the scrap bonus are not considered due to a lack of data. These include the use of land and water but also social aspects such as working conditions in mines.

In 2018, the steel industry in the European Union used about 93.8 million tons of scrap. Assuming that this only constitutes carbon steel scrap, the cumulative scrap bonus of the European steel industry amounts to 7.4 billion euro in the »lower reference« scenario. In the »medium reference« scenario, it amounts to 13.7 billion euro and in the »upper reference« scenario to 20.0 billion euro.

4
Options for the Internalization of the Scrap Bonus

4.1
Fundamentals

Externalities represent a form of market failure, as socially and privately optimal production volumes diverge. This has already been described in detail in subsection 2.4. The results in subsection 3.3 indicate that the reduction in environmental impacts due to steel scrap inputs is dominated by climate change abatement. Furthermore, climate policy represents the main challenge of global environmental policy. Therefore, this chapter focuses on climate policy. Other environmental burdens, especially at the local level, are not explicitly discussed. The same applies to ecological and social issues that cannot be quantitatively assessed due to a lack of data. These include, for example, the use of land or working conditions in mining. Nevertheless, the conclusions drawn in this chapter are, at least in part, transferable to other environmental impacts.

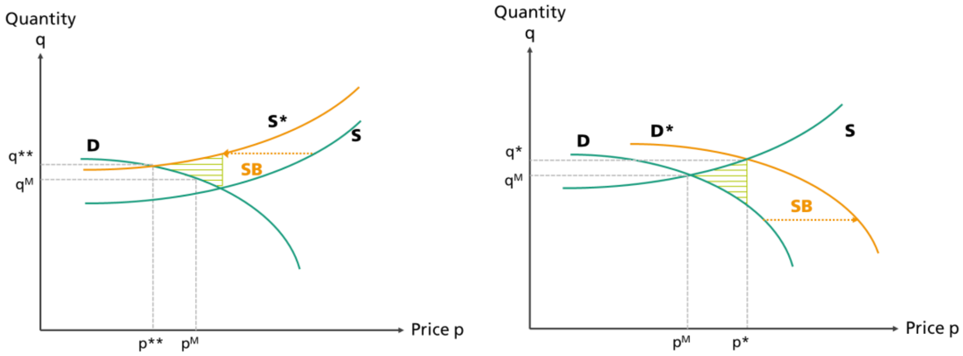

Figure 18: Internalization of the scrap bonus on the supply (left) and demand (right) side. Source: Own presentation

The internalization of externalities, i.e. their integration into the price mechanism, can ensure achieving socially optimal decisions and thus generate a welfare gain (Held 2018, p. 44f). The externalities avoided by using scrap in steel production can be integrated into the price mechanism in two ways. Either measures are taken which have a direct impact on the steel recycling sector or instruments are used that have an indirect effect on the steel recycling industry by strengthening incentives for scrap use. In both cases, the relative prices change in favor of scrap and to the detriment of virgin raw materials. Figure 18 illustrates both ways.

The direct approach to the internalization of the scrap bonus is shown in the left panel of Figure 18. There, an instrument is illustrated that reduces the costs of scrap supply and thus shifts the supply curve from **S** to **S***. At each market price p, a larger amount of scrap q is offered. The supply curve is shifted by the scrap bonus, so that the socially optimal amount q** is reached. As the supply of scrap is increased, the market price reaches p**, which is below the one obtained by the indirect approach (p*)[10]. The welfare gain achieved by the internalization of the scrap bonus corresponds to the green-shaded area.

The indirect approach is shown in the right panel of Figure 18 and is the inverse of Figure 11 (page 21). If, for example, the use of ore and coke becomes more expensive, the relative price of scrap decreases. This shifts the demand curve from **D** to **D***. In the right panel of Figure 18, the demand curve is shifted exactly by the scrap bonus (**SB**). Thus, the economically optimal scrap quantity q* is used at the price p*. The green-shaded area corresponds to the welfare gain achieved by internalizing the scrap bonus. It should be noted that additional demand from final customers for products made of recycled materials also shifts the demand curve for scrap to the right.

Figure 18 is a substantially simplified illustration of the approaches to internalize the scrap bonus. The determinants of scrap supply and demand, as already discussed in subsection 2.4, are only roughly illustrated. In addition, the scrap market is considered in isolation. If the indirect approach is accompanied by an increase in costs for the steel sector, it will put a strain on its competitiveness. If the scrap supply is supported by public funds, these must be financed by taxes, which in turn burden households and companies. These effects are not shown in Figure 18, but are considered below.

It should also be noted that parts of the scrap bonus are already internalized by existing climate and environmental policy instruments. However, the OECD's study on effective CO_2 prices indicates that this internalization is incomplete, especially if high social cost of carbon is assumed (OECD 2018). This applies in particular to developing and emerging market economies.

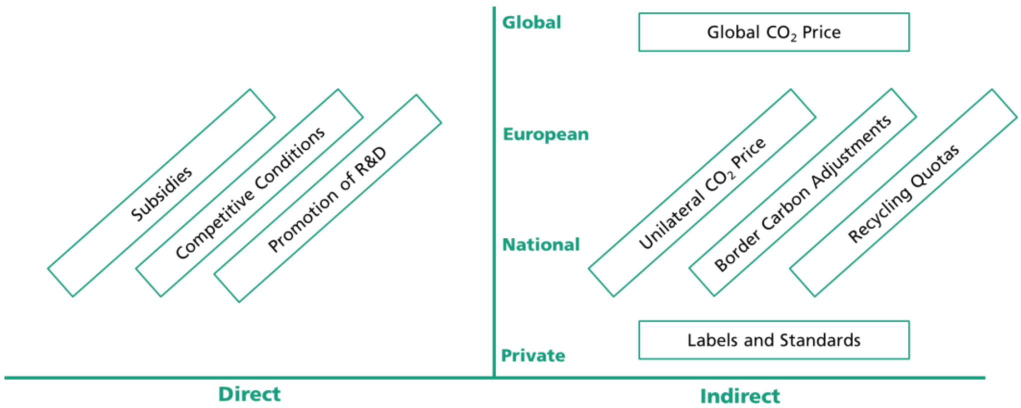

Figure 19: Instruments for the internalization of the scrap bonus.
Source: Own presentation

[10] From the suppliers' point of view, the prices could be higher if the scrap bonus were adequately compensated.

Options for the Internalization of the Scrap Bonus

Various instruments can be used to internalize the scrap bonus. Figure 19 shows eight of them. They are divided into instruments that affect the steel recycling industry directly or indirectly. The institutional level to which they can be assigned to is also shown. These eight options do not, however, represent an exhaustive list of all possible instruments. The selected instruments are discussed below. Their advantages and disadvantages are presented.

4.2 Instruments

4.2.1 Global CO_2 Price

The first instrument is a worldwide price on the emission of greenhouse gases such as CO_2. Prices on greenhouse gases can be introduced, on the one hand, as quantitative solutions via emissions trading systems or as price solutions via the taxation of CO_2 emissions. Some scientists see clear advantages of the price solution over the quantity solution, among other things because the revenues from it are easily predictable and controllable for individual nations. The revenues will be available to boost economic growth and thereby bring developing countries on board (Cooper 2017). In addition, global quantity restrictions are associated with a number of problems, such as the negotiation of a global emission limit and the distribution of permissible emissions among nations. Therefore, they have not yet fulfilled the hopes placed in them (Cramton et al. 2017). MacKay et al. (2017) point out that in a global price solution, taxes on CO_2 equivalents would not necessarily have to be globally uniform but could take differences between countries into account. In this case, however, the authors advocate for a globally fixed minimum price.

Advantages

Global greenhouse gas pricing appears to be the most efficient option for internalizing the social costs of greenhouse gas emissions within the framework of global climate policy (cf. MacKay et al. 2017). Comprehensive pricing of CO_2 would make it possible to internalize the social costs of emissions and thus also reflect the positive externalities of using steel scrap, as discussed in Chapter 2.4, via the price mechanism. At the same time, all steps of the value chain are covered by global greenhouse gas pricing.

Disadvantages

At the moment, there is no global solution for pricing greenhouse gases in sight. In the short and medium term, policy makers will have to rely on other (unilateral) measures to internalize the positive effects of the use of steel scrap.

4.2.2 Unilateral CO_2 Price

CO_2 pricing at the national or European level is another way of internalizing the external effects of greenhouse gas emissions. Here, the market mechanisms work analogously to global climate policy: relative prices of carbon-intensive raw materials and production processes rise while relative prices of less carbon-intensive materials and processes fall.

Unilateral climate policy can be organized both at the European and national level. The European Emissions Trading Scheme (EU ETS) is the EU's central climate policy instrument. It comprises more than 11,000 installations in the European Union, Iceland, Liechtenstein and Norway as well as air traffic within and between these countries. It is a cap-and-trade system: The amount of emissions is limited and the price is determined by trading emission certificates on a market. Alternatively, CO_2 emissions can be taxed. This instrument is already in use in Great Britain and Sweden, for example. The German Federal Government's Council of Economic Experts recommends pricing greenhouse gas emissions that are not covered by the EU ETS without committing to one of these instruments (SVR 2019).

Unilateral climate policy shifts the demand curve for steel scrap to the right, consumers (i.e. the steel industry) use more scrap. Thus, unilateral greenhouse gas pricing has an indirect effect on the internalization of the scrap bonus.

Advantages

As the examples show, a unilateral CO_2 price can be implemented at both the national and the European level. It can effectively and efficiently achieve its goal of reducing domestic emissions.

Disadvantages

Internalizing the scrap bonus via unilateral CO_2 pricing is associated with two main disadvantages compared to a global solution: Firstly, only domestic emissions are covered. Greenhouse gases released in the production of imported products are not considered. This applies, for example, to the extraction of ores or the production of ferroalloys, which take place predominantly outside of Europe. Secondly, unilateral climate policy leads to additional costs for domestic industry, which negatively impacts firms in international competition. This poses the risk that the domestic steel industry will be threatened and ultimately displaced by (non-regulated) foreign competitors. Thus, the unequal cost burden would lead to production relocations (Held 2018, p. 26). This effect is referred to in the literature as »carbon leakage«.

4.2.3 Border Carbon Adjustments

Border carbon adjustments are an instrument designed to offset the disadvantages of unilateral climate policy. They are intended to avoid carbon leakage by reducing energy-intensive, trade-exposed sectors' cost disadvantages due to unilateral climate policy. To this end, the greenhouse gases released during the production of imported goods would be taxed at the border. Domestically paid CO_2 prices would be refunded if goods were exported. This should at least partially offset the additional cost burden on domestic industry and contribute to fair competition (»level playing field«).

In economic research, border carbon adjustments are investigated both theoretically and quantitatively, often in comparison to the free allocation of emission allowances as another instrument to avoid carbon leakage (Böhringer et al. 2016; Böhringer et al. 2012; Monjon and Quirion 2011).

The effects of border carbon adjustments on the scrap bonus are indirect. CO_2-intensively produced primary raw materials become more expensive, which increases the demand for scrap. As a trade policy instrument, border carbon adjustments would be established at the European level.

Advantages

Border carbon adjustments are able to compensate, at least in part, for the disadvantages of unilateral climate policy. On the one hand, emissions contained in imported intermediate inputs are priced. On the other hand, an excessive burden on energy-intensive companies in international competition is avoided.

Disadvantages

Border carbon adjustments function like an (emission-dependent) tariff. Their practical applicability is politically controversial, as they provide a pretext for strategic trade policy and could thus restrict the international exchange in goods. Moreover, it has not been conclusively decided whether they are in compliance with WTO regulations.

The exact design of border carbon adjustments is complex. For example, one challenge is to precisely quantify the emissions contained in an imported product. For this reason, simplified calculation methods would have to be used in practice, the incentives of which would have to be investigated and discussed (Kuik and Hofkes 2010). Further research seems necessary to develop concepts for the design of border carbon adjustments and to assess their advantages.

4.2.4 Labels and Standards

Labels that document the proportion of recycled materials in a product indicate that the manufacturer uses raw materials circularly. Appropriate standards ensure that these percentages are calculated in a transparent and appropriate manner. Customers with a preference for goods made from recycled materials can thus be targeted. Manufacturers of final products can commit themselves to using minimum proportions of recycled materials in their products. This gives both private customers and consumer goods manufacturers the opportunity to set incentives for the circular use of raw materials. The use of recycled raw materials can also be considered as a criterion in public tenders. Here, too, widely accepted labels and standards are helpful.

Labels and standards could increase the demand for recycled materials and thus the demand for scrap. They constitute indirect instruments for encouraging the use of scrap. Labels and standards can be developed as well as implemented by private firms and associations.

Advantages

With increasing environmental awareness, both in private households and in the public sector, consumers may be willing to pay higher prices for circular economy products. By using labels, this additional willingness to pay can be accessed. Consumers would thus voluntarily internalize at least part of the positive external effects of using scrap.

Disadvantages

The use of labels and standards for minimum proportions of recycled materials reflects customers' willingness to pay for sustainably produced goods. These customers thus voluntarily incentivize CO_2 savings. However, there is no internalization of the scrap bonus independent of the preferences of the final customers.

4.2.5
Recycling Quotas

Recycling quotas are an instrument that can increase the demand for scrap. A recycling quota is defined here as a (politically defined) minimum proportion of recycled materials in a product[11]. In steel production, a recycling quota implies a minimum proportion of scrap in the raw material mix.

The design of a recycling quota can take many different forms. A rigid quota for all steel producers would not be economically recommendable since scrap is not allocated to the firms who derive the greatest utility from using it. Alternatively, a system with tradable recycling certificates could be developed. The obligation to provide evidence of the recycling content could be imposed both on steel producers or on the steel-processing industry. A model for the latter option are the »Packaging Recovery Notes« with which companies in Great Britain demonstrate that a sufficient quantity of packaging materials has been recycled in order to achieve the prescribed recycling quota. The Packaging Recovery Notes are tradable and are also required for imported products and packaging materials (see Söderholm and Ekvall 2019).

If the recycling quota would be set at a level above that achieved without it, it would lead to an increase in scrap demand. It therefore has an indirect effect on the internalization of the scrap bonus. It could be organized at the European or the national level.

Advantages

A recycling quota for steel would lead to an increase in scrap demand and thus an increase in scrap prices. This would contribute to the internalization of the scrap bonus.

Disadvantages

The main disadvantage of a recycling quota is that it does not target the pollutants released during steel production. As an instrument of climate policy, recycling quotas discriminate in favor of scrap use compared to other processes with which the steel sector can reduce its greenhouse gas emissions. This leads to inefficiencies in greenhouse gas abatement.

The challenges of designing a recycling quota would be similar to those of unilateral climate policy. Equal treatment of domestic and imported steel would have to be ensured through the design of the instrument.

4.2.6
Subsidies

Subsidies are unilateral, usually conditional, transfers of money or payments in kind from governments to enterprises without a corresponding market transaction. Subsidies could be paid to internalize the scrap bonus. Their amount would have to correspond to the scrap bonus minus the externalities already internalized elsewhere, e.g. by the EU ETS.

[11] In other contexts, the recycling rate is understood as the proportion of recycled materials in the mass of waste. Such a definition is used, for example, in the European Union's End-of-Life Vehicles Directive (see UBA and BMU 2019).

Alternatively, EU ETS certificates could also be issued, the quantity of which corresponds to the greenhouse gas emissions saved outside Europe by using scrap. This would correspond to a payment in kind, which would also act as a subsidy. Such an approach would be similar to the Clean Development Mechanism (CDM), through which emission reduction projects in developing countries were incentivized by issuing emission allowances.

A subsidy in the form of payments or monetary benefits would lower the market price of scrap. The supply curve on the scrap market would shift and the scrap bonus would be internalized directly. Such a subsidy could be introduced at the European or the national level.

Advantages

A subsidy could internalize the scrap bonus. This applies regardless of whether it is in the form of a payment or a payment in kind.

Disadvantages

Subsidizing the use of scrap favors it over other options for avoiding emissions in steel production. Such a distortion would lead to inefficiencies in the decarbonization of steel production.

A subsidy in the form of cash payments implies that taxes would have to be levied to finance them. Additional taxation would burden companies and households, causing welfare losses. A subsidy in the form of payments in kind would have other side effects. Crediting EU ETS certificates would, for example, reduce the effectiveness of emissions trading, as additional certificates would enter the market. In addition, it would be questionable to what extent subsidies on the use of scrap could be legally implemented.

4.2.7 Promotion of Research and Development

The attractiveness of using steel scrap compared to primary raw materials could be increased by improved technology for the collection, sorting and processing of scrap. Efficient technologies could increase the supply of scrap. Increasing scrap supply would cause scrap prices to fall, as shown on the left-hand side of Figure 18.

Research and development in the steel recycling industry has further positive externalities, beyond the avoidance of greenhouse gases, in the form of knowledge generation. Since knowledge does not remain permanently within the company that generated it, it can also be used by other market participants. This is a classic case of a positive externality which should be internalized as well. Without this internalization, individual investment in research and development would be below the social optimum.[12]

Research and development programs or tax incentives for these efforts could be conceivable as instruments of support. When designing research and development programs, care must be taken to ensure that small and medium-sized enterprises, which are the hallmarks of the steel recycling industry, can participate in them.

[12] Licht and Schnell (1997) already analyzed the necessity of supporting research and development in detail in their article in 1997.

Advantages

Improved processes for sorting and processing of scrap can increase its supply. Reducing prices, this would increase the amount of scrap used.

Disadvantages

The promotion of research and development in the steel recycling industry strengthens the supply of scrap both qualitatively and quantitatively. It compensates for positive externalities associated with research and development but does not internalize the scrap bonus in a targeted manner.

4.2.8 Improvements in the Steel Recycling Industry's Competitive Conditions

Another option for increasing the supply of scrap is to improve the working conditions of the steel recycling industry. This option does not constitute one instrument but a variety of measures simplifying the collection, processing and transport of scrap. Examples include improving transport infrastructure, especially rail infrastructure, or simplifying approval processes.

Such measures reduce the costs of scrap supply. Scrap as a raw material for steel production becomes cheaper, leading to a shift in the supply curve. Measures to improve the competitive conditions of the steel recycling industry can be taken at various levels, from the European Union to individual towns and cities.

Advantages

The instruments for improving the competitive conditions in the steel recycling sector are often »no-regret measures«. Irrespective of their effects on the climate and the environment, they lead to positive economic outcomes.

Disadvantages

Measures to improve competitive conditions in the steel recycling industry increase the supply of scrap, but do not directly contribute to the internalization of the scrap bonus.

4.3
Summary

A globally coordinated CO_2 price should be aspired as the most efficient instrument to internalize the external effects of greenhouse gas emissions. Since it cannot be achieved in the short and medium term, a combination of measures appears recommendable to internalize the scrap bonus. These should be part of a European strategy to decarbonize steel production. Individual measures do not seem suitable to solve the problem in its entirety.

A unilateral (European) CO_2 price can effectively reduce greenhouse gas emissions within its scope. In addition, it is efficient, i.e. it achieves its reduction targets at the lowest cost. In the case of unilateral climate policy, however, two challenges arise. Firstly, emissions resulting from the production of imported intermediate inputs are not taken into account. Secondly, energy-intensive, trade-exposed sectors of the economy, including the steel industry, suffer competitive disadvantages. Supplementary measures, such as border carbon adjustments, could offset these disadvantages. However, further analyses are necessary in order to develop the design of such compensation measures. In addition, it should be examined whether their benefits exceed the risks associated with their introduction. These analyses could build on existing economic research (Böhringer et al. 2012; Böhringer et al. 2016; Keen and Kotsogiannis 2014).

Subsidizing the use of steel scrap is not economically recommendable. It favors scrap use over other approaches to avoid greenhouse gas emissions and leads to misallocations in the decarbonization of steel production. For similar reasons, recycling quotas do not appear to be a suitable instrument for internalizing the scrap bonus.

The promotion of research and development is a central component of climate policy. It should be designed in such a way that it encourages the circular use of steel. To this end, funding programs should be designed to be technology-open and especially accessible to small and medium-sized enterprises.

In addition, firms can become active themselves, for example by introducing recycling labels and standards. Taking into consideration the increasing importance of the circular economy, such an instrument appears to be suitable to access environmentally conscious consumers' willingness to pay more.

Overall, a European decarbonization strategy for the steel sector appears necessary. A well-designed decarbonization strategy would largely internalize the scrap bonus, accelerate technical progress and safeguard the competitiveness of the steel as well as the steel recycling industry.

5
Conclusion

In this study the indicator »scrap bonus« is introduced and quantified. It denotes the climate and environmental costs which are avoided when using one ton of scrap as the raw material of steel production. In addition, instruments for integrating the scrap bonus into the price mechanism are analyzed. The results of the study can be summarized in five key messages.

The steel recycling industry provides high-quality and environmentally friendly raw materials

For every ton of scrap used in the production of carbon steel, the steel industry saves an average of 1.67 tons of CO_2 compared to production from ores. For austenitic stainless-steel scrap, this figure rises to 4.3 t CO_2 per ton of scrap. This increase is mainly due to the alloying elements chromium and nickel. In 2018, the European steel industry used around 93.8 million tons of scrap. Assuming that these only constituted carbon steel scrap, 157 million tons of CO_2 were saved. This corresponds roughly to the combined greenhouse gas emissions of automobile traffic in France, Great Britain and Belgium. The steel recycling industry buys and processes scrap, ensures its quality and handles its logistics, and thus, closes the material cycle of steel. Therefore, it acts as an enabler of these savings.

The use of scrap in steelmaking brings about welfare gains

The scrap bonus quantifies the environmental costs avoided by using one ton of scrap. It takes into account the entire value chain of steel production, from the mine to the steel mill's gate. Depending on the assumption about the economic costs of climate change, the scrap bonus is between 79 and 213 euro per ton of carbon steel scrap and between 158 and 502 euro per ton of stainless-steel scrap. The use of 93.8 million tons of scrap in Europe saved environmental costs of between 7.4 and 20.0 billion euro in 2018.

The scrap bonus should be part of the price mechanism

Currently, the beneficial environmental impacts of using scrap in steel production are reflected insufficiently in market prices. This is particularly true in developing and emerging market economies. As a result, firms and consumers make inefficient decisions that result in welfare losses. For this reason, it seems economically recommendable to integrate the scrap bonus into the price mechanism.

The internalization of the scrap bonus should be part of a European decarbonization strategy

The European Emissions Trading Scheme (EU ETS) is an instrument that already reduces greenhouse gas emissions effectively and efficiently. However, it seems recommendable to supplement the EU ETS with further measures as part of a European decarbonization strategy for the steel sector. For example, accompanying measures could take into account the emissions resulting from the production of imported inputs and compensate for the competitive disadvantages of the European steel industry. Further analyses are needed to develop such measures. In addition, support for research and development could strengthen the supply of scrap. Within the framework of a European decarbonization strategy, the positive ecological effects of the use of scrap would be compensated for.

The competitive conditions of the steel recycling industry should be improved

Even in the absence of a European decarbonization strategy for the steel sector, the competitive conditions of the steel recycling industry can be improved. For example, improving the rail infrastructure could make the transport of scrap easier and more environmentally friendly. Streamlining administrative and approval processes could reduce the costs of the steel recycling industry and thus the price of steel scrap. Thereby, greenhouse gas emissions could be reduced, circular economy concepts could be strengthened and employment could be secured.

6
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