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Roland Döhrn
Karoline Krättschell

Long Term Trends in Steel Consumption

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Universitätsstr. 150, 44801 Bochum, Germany

Technische Universität Dortmund, Department of Economic and Social Sciences
Vogelpothsweg 87, 44227 Dortmund, Germany

Universität Duisburg-Essen, Department of Economics
Universitätsstr. 12, 45117 Essen, Germany

Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI)
Hohenzollernstr. 1-3, 45128 Essen, Germany

Editors

Prof. Dr. Thomas K. Bauer
RUB, Department of Economics, Empirical Economics
Phone: +49 (0) 234/3 22 83 41, e-mail: thomas.bauer@rub.de

Prof. Dr. Wolfgang Leininger
Technische Universität Dortmund, Department of Economic and Social Sciences
Economics – Microeconomics
Phone: +49 (0) 231/7 55-3297, email: W.Leininger@wiso.uni-dortmund.de

Prof. Dr. Volker Clausen
University of Duisburg-Essen, Department of Economics
International Economics
Phone: +49 (0) 201/1 83-3655, e-mail: vclausen@vwl.uni-due.de

Prof. Dr. Christoph M. Schmidt
RWI, Phone: +49 (0) 201/81 49-227, e-mail: christoph.schmidt@rwi-essen.de

Editorial Office

Joachim Schmidt
RWI, Phone: +49 (0) 201/81 49-292, e-mail: joachim.schmidt@rwi-essen.de

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Roland Döhrn and Karoline Krättschell¹

Long Term Trends in Steel Consumption

Abstract

Since the iron and steel sector contributes considerably to industrial CO₂ emissions it is important to identify the underlying factors driving steel demand. Using a panel dataset this paper examines the interrelation of steel demand with GDP and its composition, in particular the investment share since investment goods can be expected to be particularly steel intensive. Our analysis confirms that there seems to be an increase of steel demand in an initial stage of economic development and a decline after economies have reached a certain level of per capita income. Moreover, we find some evidence that carbon leakage do not seem to play a role in the steel sector.

JEL Classification: L61, C33, Q53

Keywords: Steel consumption; intensity of use-hypothesis; carbon leakage

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¹ Roland Döhrn, RWI and University of Duisburg-Essen; Karoline Krättschell, RWI and Ruhr-Universität Bochum. – We thank Christoph M. Schmidt for valuable comments and suggestions. – All correspondence to Karoline Krättschell, RWI, Hohenzollernstr. 1/3, 45128 Essen, Germany, E-Mail: karoline.kraetschell@rwi-essen.de.

1. Introduction

The iron and steel sector contributes considerably to industrial CO₂ emissions. In Germany, e.g., its share in total emissions of the industry sector was approximately 10% in 2008 (RWI 2008: 16), which is about twice its share in industry turn over. Two major factors will determine future CO₂ emissions in the steel sector. The first is technological progress which could lead to more efficient production technologies. However, coke and coal which are the main source of CO₂ emissions, do not only serve as a fuel in the melting process and for casting and rolling the steel. Coke is furthermore needed for the reduction of iron ore, which makes it difficult to trim down its use beyond a certain level, even if substantial progress has been made in this direction. Nevertheless, advanced economies use coke more efficiently, as a rule, than emerging economies. Thus technological progress in steel making and the dissemination of technologies are one important factor that will drive the sector's future CO₂ emissions. The second major factor driving CO₂ emissions from the steel sector is future steel demand, which is in the focus of this paper.

Looking at the historical development of global steel production, we can distinguish three phases (Graph 1). The first phase, ending in the mid-1960s, was marked by post-war reconstruction which led to an increase in steel demand and production. In this period, the advanced economies were the main drivers of steel demand. It was the time when existing industries were reconstructed from war damages, new industries were established, and the infrastructure was developed. On the demand side, the increase of motorization was an additional driver. This period was followed by a phase of almost stagnation lasting until the late 1990s. The factors driving steel demand were still at work at this time, although less powerful, but the increase of demand for machines and cars was over-compensated by the reduction

of the amount of steel needed per unit of final product, which became possible through new techniques.

The third phase in global steel demand began in the late 1990s when production started to grow markedly again. Driving force now were the emerging markets, which entered a stage of economic development which resembled very much the stage the advanced economies were in during the 1950s and 1960s. Most important in this context is China where apparent steel consumption in 2009 was four times as high as 1999. In recent years, almost every second ton of crude steel produced in the world came out of a Chinese steel mill (table 1). But other countries contributed to the surge of steel production, too. In India, e.g., steel consumption per capita increased by 60 %, even if starting from a level which was much lower than in China. However, due to the country's size and growing population its share in global steel production approached 5% recently. In the meantime, India takes the fifth position among the world's most important steel producing countries.

This paper tries to identify driving factors of global steel production. The analysis will be based on a comparison of the variation of steel consumption per capita between countries and over time. In the second section some theoretical consideration on the relation between steel use and income are presented. Furthermore, the problems associated with calculating steel-intensity of GDP are discussed. In the third section, the estimations for the entire sample are displayed. In the fourth section, differences between advanced economies and developing countries are elaborated. In the final part the results are summarized.

2. Steel consumption and income levels

The amount of steel consumed in an economy is mainly linked to two factors: On the one hand, the importance of the industry sector and its structure, on the other hand the income of its population and its demand for steel intensive products such as cars. To some extent, these factors are unique to each country, and as far as this

is concerned, neither history nor international comparisons will provide many insights into the future of global steel demand. In the subsequent analyses they will be treated as country-specific effects. However, there are also strong similarities among countries and over time that may give some guidance for global future trends.

These similarities originate mainly from “economic laws”. Firstly Engel’s law may apply in this context. It describes the observation that the income share of the expenditure for food declines with rising income. This creates opportunities to increase spending on more sophisticated products, which in turn gives rise to a more capital intensive production and a more developed infrastructure. As a consequence, steel demand can be expected to increase with rising income. However, this increase will be limited if not reverted by another “law” the empirical relevance of which is also well documented. Already in the 1930s Fisher (1935) and Clark (1940) discovered that the demand for tertiary products will increase relative to total expenditure after incomes having reached a certain level, whereas the demand for secondary (manufacturing) products will decline relatively.

Taking both ideas together, it can be assumed that the relation between income and the demand for steel is hump shaped. In a first stage, steel demand will increase relative to economic activity with rising living standards, but it will decline when income surpasses a level at which consumer’s preferences shift towards services. Relating steel demand to GDP, this pattern is addressed in the literature as “intensity of use-hypothesis” (Crompton 1999, 2000; Wårrel, Olsson 2009).

Wårrel and Olsson (2009) tested the intensity of use-hypothesis for a panel of 61 countries over a period of 35 years. They could confirm the assumed hump-shaped relation between steel use and per-capita income only after having introduced a time trend or a set of time dummies as additional variables, which they consider to be a measure of technological progress which shifts the ratio downward over time. This interpretation suggests that the cross section dimension of the panel can help

to identify the steel/GDP relation at a given time, whereas the time dimension helps to isolate a technological factor.

However, the approach they are using has two important problems. Firstly, their definition of intensity of steel use is difficult to interpret. Generally, steel intensity is defined as steel consumption per unit of GDP. Yet, the actual measurement is not straightforward. Whereas its numerator is a technical entity, the denominator is a statistical construct which is influenced by many factors. To adjust it for inflation, it must be measured in constant prices, and to make it comparable between countries, it is often converted into a single currency. Therefore, steel consumption per unit of GDP depends heavily on the base year chosen for the price adjustment and on the exchange rate used. When GDP at constant prices and exchange rates are used, as e.g. Wårrel and Olsson (2009) did in their analysis, the transformation is neither neutral to the changes over time nor to the cross sectional dimension. These considerations cast some doubts on the validity of their estimates: Since pooled regressions try to exploit information contained in differences between countries as well as in differences over time. If these differences depend on the choice of the denominator the results of the analyses may be misleading.

Secondly, GDP is not only the denominator of steel intensity but also used as a right hand side variable in the regression, inducing potential endogeneity problems. In particular, changes in the base year for calculating real rates influence income levels and steel intensity in opposite direction, which also may spoil the regression results. Therefore a different approach will be used here, which is admittedly less elegant, but burdened with considerably less methodological problems: The analyses will focus on steel consumption per capita, which is comparable between countries as well as over time.

3. Estimation results

Nevertheless, the problem of scaling GDP cannot be avoided entirely in our regressions since the variable also appears on the right hand side of our regressions. Subsequently, we will mostly use GDP in current Purchasing Power Parities (PPP). By doing so, the comparison between countries will not be influenced by the fact whether a country's currency is over- or under-valued. Thus it forms in our view the ideal representation of GDP. However, to evaluate the sensitivity of our results with respect to different GDP measures, we will in an initial step also use two other variants of GDP. Therefore, we also run the regression for GDP per capita in current US-Dollars and for GDP in US-Dollars at 2000 prices and exchange rates.

Besides income, additional factors can be expected to be at work. It can be assumed that the structure of aggregate demand will matter, too. Since investment in structures and equipment is more steel-intensive than consumption, the investment quota – defined as the share of investment in GDP – may be a good representative to reflect this factor. As the investment quota varies considerably over the business cycle, this variable furthermore provides some adjustment for differences in the position in the business cycle the countries may be in.

Data on steel consumption per capita were taken from the statistics of the International Iron and Steel Institute. The use of steel is measured as steel deliveries (or production) plus steel imports and minus steel exports. However, this measure does not take into account indirect trade in steel which is embodied in products such as cars, machines etc. (Molajoni and Szewczyk, 2012). Therefore, it is labeled as apparent steel use, in contrast to true steel use, which also considers indirect trade in steel. True steel use would be a better measure of a country's actual steel consumption. However, no data are provided on it.

Per capita income in internationally comparable prices and in current US-Dollars per person where taken from the IMF World Economic Outlook Database, GDP per capita in US-Dollars at 2000 prices and exchange rates from Feri. Data on invest-

ment as a percentage of GDP were obtained from Worldbank sources. The period under inspection is 1980 to 2009. The panel covers 44 countries. As data for some years are missing for some countries, the analyses are based on an unbalanced panel which contains 1245 observations.

Since it can be assumed that steel intensity increases initially with rising income and will decline after a certain income level is reached, per capita income will enter the regressions linear and additionally in a quadratic transformation. In the regression with our GDP variable of interest, GDP per capita in current PPP, we also control for country and time specific fixed effects.

Table 2 shows that the estimated coefficients are significant at a 99%-level for all explanatory variables. The investment quota is positively correlated with steel consumption. Furthermore, for the three different GDP per capita measures all coefficients show the expected sign: Per capita income has a positive impact, squared per capita income a negative, generating a hump shaped relation between income and steel consumption. However, depending on the GDP per capita measure we obtain different income levels at which steel consumption per capita reaches its maximum other things being equal². For GDP per capita in US-Dollars at 2000 prices and exchange rates this is the case at an income of 24.800 US-Dollars, for GDP per capita in current US-Dollars at an income of 36.100 US-Dollars. The difference of more than 11,000 US-Dollars makes evident that the results depend heavily on the base year chosen. Furthermore, using per capita income at market exchange rates could be misleading because currencies may be under- or over-valuated during some years of the period under scrutiny. Since income in current international dollars is not influenced by these factors we will use these data in our further investigations.

² The coefficients of per capita income and per capita income squared determine at which income level steel consumption reaches its maximum.

In a next step we introduce country as well as time specific effects into our regressions. As can be seen from table 3, the estimated turning point where steel consumption per capita reaches its maximum is only slightly influenced by the fact whether these fixed effects are included or not. When country and time fixed effects are included in the regression the turning points are somewhat higher than in the version without these effect. The maximum is at 28.700 \$ using time fixed effects, at 29.000 \$ when including country fixed effects and at 31.800 \$ when country and time fixed effects are considered. The coefficient of the investment quota becomes smaller when including time fixed effects which underpins that this variable also covers some cyclical effects that are in part time-specific. Furthermore, the time fixed effects in equation (2) and (4) show a downward trend (graph 2). Interpreting the time fixed effects as a measure of technological progress this result supports the idea that technological progress reduces steel consumption per capita over time.

The advanced economies with the highest incomes (USA, Switzerland, and Norway) have surpassed the income level at which steel consumption per capita reaches its maximum (30.000 \$) in the late 1990s. Other advanced economies, among which are Germany, Japan and France, reached it some years later. None of the emerging economies in the sample except Taiwan has entered already the region in which steel consumption per head can be expected to decline. They are still on the upward branch of the consumption curve and steel consumption per capita will therefore continue to rise.

4. Differences between advanced and developing economies

As mentioned in the introduction and indicated by the decreasing time fixed effects, technological progress can be a factor that will reduce future steel consumption. Thus, for future trends in steel consumption (and therefore also for the CO₂ emissions caused by the steel industry) it may be decisive how fast developing countries will adapt technologies which are already at hand in the advanced economies. To get some indication about the previous experience, two subgroups are

analyzed in the following. The first group, which is labeled as advanced economies, contains all countries having reached income levels at which steel consumption per capita is projected to decline (30.000 international dollars). The countries which are still on the upward branch of the steel consumption/income-curve are labeled here as developing economies, although many European countries with relatively low income can be found in this group as well.

To assess whether steel consumption is generally smaller in developing countries, a dummy variable is included in the following regressions that is 1, if a country is a “developing” economy in this sense, and is 0 in all other cases. Such country specific dummy variables must be used carefully in panel analyses, as they might be correlated with country-specific effects. Therefore, only time fixed effects are considered in the subsequent regressions. Furthermore, the investment quota is additionally interacted with the “developing” dummy variable to examine whether investment is more or less steel intensive in developing countries. The results are shown in table 4.

The intercept dummy in equation (5) in table 4 is negative and significant. It implies that steel consumption per capita in developing countries is – other factors being equal – on average 84.8 kg per head lower compared to advanced economies. Including this dummy has only a small impact on the coefficient of per capita income. Moreover, the coefficient of the interaction term in equation (6) is negative, which could be an indication that investment is less steel intensive in developing countries. However, this interpretation does not necessarily make sense. It must be considered rather that we are looking at apparent steel consumption. As developing countries import a high share of the investment goods, the steel embodied in these products influences apparent steel consumption only in the exporter’s country and has no impact on the steel balance of the importer’s country. This fact also may explain the negative intercept dummy for developing countries in equation (5).

5. Conclusions

This paper presents some new estimates of the relation between apparent steel consumption per head and income levels. It confirms that there seems to be an increase of steel intensity in an initial stage of economic development, and a decline after economies have reached certain level of per capita income. This level seems to be reached at GDP per capita of about 30 000 Dollars on a purchasing power basis. A second factor influencing steel consumption is the share of investment in GDP, which, however, seems to impact steel consumption differently in advanced and in developing economies. Whereas it drives steel consumption strongly in the first group, its influence is considerably lower in the second group. This can be explained by the fact that most developing countries are importers of investment goods which are quite often steel intensive. Imports of finished goods, however, do not influence apparent steel consumption.

A similar measurement problem arises when calculating a country's carbon emissions. The United Nations Framework Convention on Climate Change (UNFCCC) measures a country's carbon emissions according to the production in this country and not according to domestic absorption (consumption and investment). Thus, the measure does not account for the emissions contained in imported goods. Associated with this measurement problem another environmental related problem has gained much attention in the public debate and in the empirical literature (see e.g. Aichele and Felbermayr, 2012) which is often referred to as "carbon leakage", "race to the bottom" or "pollution haven hypothesis". It occurs if companies in particularly emission and pollution intensive sectors, such as the chemical industry, relocate their production from countries with high environmental standards to countries with less stringent environmental policy regimes to avoid the cost associated with pollution or emission abatement policies in their home country. The goods produced in these countries would then be imported by the advanced countries, but the emissions caused by the production would not be attributed to the advanced countries. However, in the empirical literature there is no consensus whether or not

carbon leakage really exists. In contrast to Aichele and Felbermayr (2012), several other empirical studies find no or only weak evidence for carbon leakage, e.g. Eskeland and Harrison (2003) and Manderson and Kneller (2012).

From our analysis one can conclude that carbon leakage does not seem to play a role in the steel sector since the developing countries, which can be assumed to have lower environmental standards, tend to import steel and thus also pollution intensive products from advanced countries and not the other way around. Moreover, as the developing countries import a high share of their steel intensive products, the global steel use and also the overall emissions intensity of the steel sector will benefit from steel and pollution saving technologies in the advanced economies.

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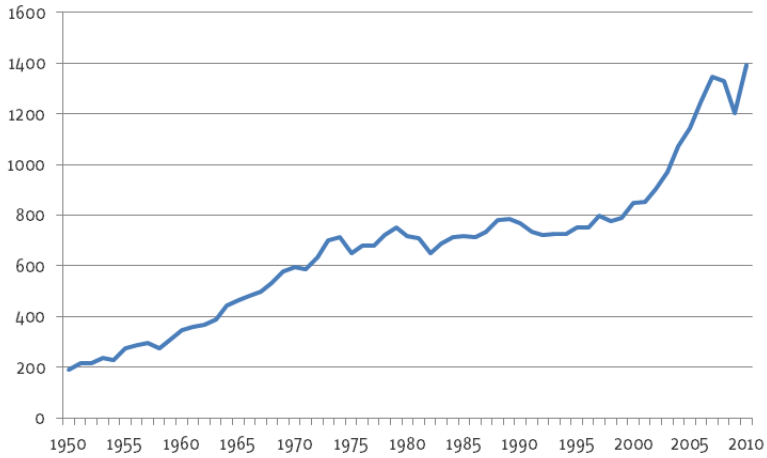
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Graph 1

World Steel Production
1950 – 2010, mill. metric tons



Source: Worldsteel.

Table 1
Regional distribution of world steel production
1950 - 2010, %

	1950	1960	1970	1980	1990	2000	2010
European Union	25.2	28.4	23.0	17.7	17.8	19.2	12.2
USA	47.1	26.1	19.9	14.1	11.6	12.0	5.7
Japan	2.5	6.4	15.5	15.5	14.3	12.5	7.7
China	0.3	5.3	3.0	5.1	8.6	15.0	44.3
India	a	a	1.0	1.3	1.7	3.1	4.7
USSR/CIS	14.2	18.9	19.3	20.5	20.0	11.6	7.6
Other countries	10.9	14.7	18.3	25.7	25.9	26.4	17.8

Source: Worldsteel. – ^aIncluded in "Other countries"

Table 2
Estimates of apparent steel consumption per capita for different GDP measures
 1980-2009, unbalanced panel of 44 countries*

	PPP	Current US-Dollars	US-Dollars 2000
Constant	-183.503 (9.6)	-22.994 (1.2)	-108.788 (5.7)
GDP/capita	35.427 (27.3)	21.237 (25.4)	32.82 (23.5)
GDP/capita squared	-0.632 (19.4)	-0.294 (18.2)	-0.663 (16.3)
Investment quota	7.022 (10.9)	5.707 (8.1)	7.161 (10.5)
R ² adj.	0.497	0.402	0.447
GDP/capita max (1000 \$)	28,0	36,1	24.8

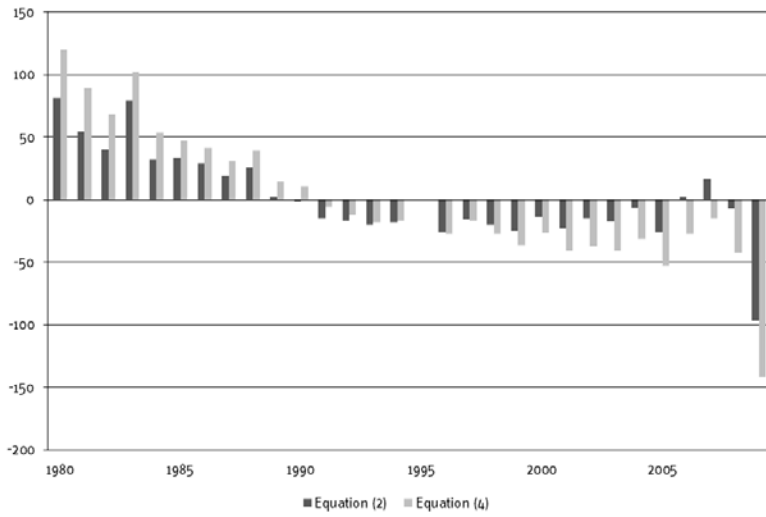
*Author's computations, *values in brackets are t-values*

Table 3
Estimates of apparent steel consumption per capita with country and time fixed effects
 1980-2009, unbalanced panel of 44 countries*

	(1)	(2)	(3)	(4)
Constant	-183.503 (9.6)	-200.933 (10.3)	-33.257 (1.8)	-150.457 (5.7)
GDP/capita	35.427 (27.3)	36.701 (27.9)	24.173 (16.5)	38.958 (16.2)
GDP/capita squared	-0.632 (19.4)	-0.639 (19.1)	-0.416 (13.6)	-0.612 (16.0)
Investment quota	7.022 (10.9)	7.066 (10.9)	4.570 (6.6)	3.113 (4.5)
Country fixed effects	No	No	Yes	Yes
Time fixed effects	No	Yes	No	Yes
R ² adj.	0.497	0.508	0.790	0.805
GDP/capita max (1000 \$)	28.0	28,7	29,0	31.8

*Author's computations, *values in brackets are t-values*

Graph 2
Time fixed effects in equation (2) and (4)



Author's computation

Table 4
Estimates of apparent steel consumption per capita for advanced and developing economies
 1980-2009, unbalanced panel of 44 countries*

	(5)	(6)
Constant	-98.500 (3.7)	-216.01 (4.9)
Dummy Developing	-84.849 (5.7)	52.168 (1.2)
GDP/capita	31.674 (20.1)	31.71 (20.245)
GDP/capita squared	-0.601 (17.8)	-0.605 (18.0)
Investment quota	7.336 (11.4)	12.683 (7.3)
Investment quota*Dummy Developing		-6.149 (3.3)
Country fixed effects	No	No
Time fixed effects	Yes	Yes
R ² adj.	0.520	0.524
GDP/capita max (1000 \$)	26,4	26,2

*Author's computations, *values in brackets are t-values*