ABSTRACT
Considering the past few years rapid increase in the demand for minerals and metals, mainly stemming from the strong economic growth in China and India, an understanding of the historical development of steel demand is of importance. The purpose of this paper is to analyze the trends and developments of steel consumption in the world by applying the so-called Intensity-of-Use method. The empirical analysis is performed using data for 61 countries over 35 years. What is the shape of the intensity-of-use curve, and at which GDP level does the steel use peak? Are China and India close to the peak of the intensity-of-use curve? These are questions that are addressed in this paper. The results show that the inverse U-shaped form of the intensity of use curve, predicted by the hypothesis, is confirmed. This implies that the steel use in the fast developing countries, China and India, eventually will start to decline. However, the result also shows that the peak of the curve is reached at a per capita income of about 28,000 US dollar. Considering that China’s GDP per capita in 2008 was about 5,500 US dollar, and India’s equivalent was about 2,800 US dollar, the results suggest that the steel demand will continue to increase for many years to come.

Additional Key Words: Intensity-of-Use, Steel demand, Economic growth, GDP, Metal consumption.

INTRODUCTION
Following the Great Depression and World War II, the worldwide consumption of metals increased rapidly. This increase in consumption led to a concern about the supply of metals, and a fear of early depletion. In the 1970s, largely due to the oil crises and a general decline in world economic growth, the rate of the consumption of metals began to decline. The metals market is known to be responsive to booms and recessions in the general economy, which is why the decline in metals consumption at first was believed to be temporary. However, the decline of the metals industry turned out to be persistent (Radetzki and Tilton, 1990).

One possible explanation for this development was given by the intensity of use hypothesis, first introduced by Mulenbaum (1973). This hypothesis states that the intensity of metal use depends on the economic development in a country, i.e., GDP per capita. The relationship between steel consumption and economic growth is however not believed to be linear. The reason for this is that the quantity of metals required changes over the development cycle of an economy. In relatively poorer countries, high economic growth is often related to an industrializing phase, which implies high growth in mineral
consumption. When the economy matures metal consumption declines as the service sector grows. This sector is demand less material, therefore, the intensity of use of metals first slows down and then starts to decline when GDP per capita increases. The intensity of use curve has thus an inverted U-shaped form. The level of GDP per capita where the intensity of use starts to decrease is called the peak (Radetzki and Tilton, 1990).

Steel is regarded to be one of the most important and useful metals. The industrial revolution in China and India has had a major impact on mineral raw material demand and has contributed to the rapid increase of the growth in metal consumption. The consumption of steel is no exception (Humphreys, 2007). The major impact these countries have on the steel market makes it interesting to investigate if these countries are close to the peak of the intensity of use curve. What is the shape of the intensity-of-use curve, and at which GDP level does the steel use peak? Are China and India close to the peak of the intensity-of-use curve? These are questions that are addressed in this paper.

The purpose of this paper is to investigate the relationship between the intensity of steel use and the economic development, and empirically test if it exhibits an inverted U-shape. The intensity of use hypothesis has been tested on several metals, for example aluminium, copper, lead, steel, zinc and nickel (Tilton, 1990; Roberts, 1996; Guzmán et al., 2005). However, most of the studies examine the metal consumption in only one country, and for rather short periods of time. This paper will examine data, and the intensity of use hypothesis, for several countries, and for a longer period of time. An econometric approach to analyze the steel consumption will be applied using Ordinary Least Squares regressions. Statistical data on steel consumption as well as GDP and population data from 61 countries between 1970 and 2004 will be collected and used as a panel data set.

The paper proceeds as follows. Section 2 describes the relevant background such as metal demand history, what steel is and the developments on the steel market. Section 3 presents the theory of intensity-of-use, and discusses earlier studies of this phenomenon. In section 4 the empirical results are presented and analyzed. Finally in section 5 the final conclusions are made and implications are discussed.

METAL DEMAND HISTORY
In the years that followed after the Great Depression and World War II the industrial development caused the consumption of metals to increase rapidly, and so did the consumption and production of steel. The countries who led the growth in the steel market were Western Europe, North America, Japan and former Soviet Union (Labson, 1997). During this period many countries were destroyed by the war, especially in Eastern Europe, and the industrial development was low in developing countries. The increase in metal consumption led to concerns about the supply of metals and a fear of early depletion. However, in the beginning of the 1970s the growth rate in the consumption of metals began to decline. The metal market is known to be responsive to booms and recessions in the general economy (Tilton, 1990). The two oil shocks that occurred during the 1970s affected the overall economy, and hence the consumption of metals. The per capita consumption declined significantly after 1973 and again after 1979, though not as significantly as after the first one. The metal prices were also affected by the two oil shocks and the prices rose considerably both around 1973 and 1979. This rapid increase in prices is most likely one of the reasons why metal consumption decreased (Tcha and Takasina, 2002). As the world economic growth
declined during this period, the decline in metal consumption was at first believed to be temporary. But the decline of the metal industry turned out to be persistent (Tilton, 1990).

In the 1980s and 1990s many believed that most metal industries, among those the steel industry, had expanded as much as it could, and would not continue to grow (Humphreys, 2007). The increase in oil prices and macroeconomic policy implementations are reasons for the decline in growth of metal consumption traced to the 1970s. The first decline in 1973 was mainly caused by decline in economic growth and that the intensity of metal use fell in the developed countries. The second decline was caused by a new decline in economic growth and further falls in intensity of metal use in the developed countries together with a decline in economic growth also in the developing countries, partly because of the international debt crisis (Tilton, 1990).

As discussed above, the metal demand appears to be sensitive to variations in oil prices, and thus, the energy prices. The energy price can affect the metal demand in three ways. Firstly, through macroeconomic effects, secondly, as costs of synthetic substitutes increase when the energy costs goes up. Thirdly, as energy is both material and capital complements, this has effect both within a given production technology and the development of new technology because of higher energy prices. It has been shown that the first and third effects had the greatest impact on metal demand after the two oil shocks in the 1970s (Choe, 1991).

Recent Developments of the Steel Market

The steel market, as many other metal markets, has during the last decades undergone big regional changes, and these changes are still in progress. Steel consumption, production and trade patterns have changed dramatically and the new situation affects the whole world. Regions such as China, India and South Korea currently gains shares on the steel market, and now lead the growth. At the same time industrialised regions, previously dominant, such as the European Union, North America and Japan declines. However, they continue to be important operators on the steel market (Labson, 1997). This geographical shift in the steel market is caused partly by faster economic growth and partly by increased intensity of use in developing countries. It is believed that developing countries and especially the emerging developing countries will be the new engine of the growth in metal demand (Tilton, 1990).

The overall economic growth has been exceedingly high the last few years, the growth rates are the highest since the early 1970s. The most important factors that have influenced this unusually high economic growth are globalization and the positive development in China and other developing economies. The steel market has been a part in this expansion (OECD, 2008). The world steel consumption has increased every year since 1999, and has accelerated rapidly since 2002, as can be seen in Figure 1 (OECD, 2004). The growth in steel consumption rates in low and high income countries have moved in opposite directions (Choe, 1991). The rapid growth in China’s domestic steel consumption is the preliminary reason for the boost in steel demand (OECD, 2004). As steel is an important commodity used in construction it is one of those who have benefited the most from China’s industrialization, about 70 per cent of the steel consumed in China is used for construction (Humphreys, 2007).
Between 1995 and 2000 the annual growth of China’s steel consumption was 6.1 per cent on average, and between 2001 and 2004 the growth was 19.3 per cent (IISI, 2007). China’s rapid steel consumption growth during the last years can be seen in Figure 2. The world total steel consumption has increased by 6.5 per cent on average each year over the period 2001 to 2004, the increase during the same period not including China is 3.4 per cent. In 2004 China’s steel consumption made up 27.9 per cent of the world’s total steel consumption (IISI, 2007). This means that China’s contribution to steel consumption has led to an increase in the world consumption of steel. Along with China, India has increased its metal demand as well. The reason is an increase in per capita income together with an increase in the domestic consumption. There are, however, many differences between the two emerging economies. The intensity of metal use is unusually high in China whereas the increased consumption of metals in India has followed the GDP growth (Humphreys, 2007).

Along with the positive development on the world steel market the steel prices have increased a great deal which makes the steel industry profitable. However, the increase in steel prices has lead to difficulties for the industries that consumes steel. China affects the whole steel market and especially the steel prices. The steel prices movements are closely correlated with the developments in China (OECD, 2004).
INTENSITY OF USE HYPOTHESIS

To make long-term forecasts in metal demand the intensity of use (IU) hypothesis is a simple model that easily can be applied. The intensity of use, \( IU_t \), is defined as the ratio of metal consumption, \( D_t \), to a county’s national income, \( Y_t \), in year \( t \) (Radetzki and Tilton, 1990):

\[
IU_t = \frac{D_t}{Y_t}
\]

In this model all the economic sectors are aggregated into a single measure, the entire economy. The real gross domestic product, GDP, measures the output of all goods and services in the economy (Roberts, 1996). The hypothesis states that the level of economic development in a country explains its intensity of metal use. A country’s economic development is represented by its per capita income, that is, \( GDP_t / \text{Capita}_t \). Thus, the intensity of metal use is a function of per capita income and is generally expressed:

\[
IU_t = f(GDP_t / \text{Capita}_t)
\]

Empirical measurements are needed to specify the exact nature of the relationship and there are usually variations among countries and materials. However, the relationship generally exhibits an inverted U-shaped curve, such as that shown in Figure 3 (Radetzki and Tilton, 1990).

![Figure 3. Intensity of steel use and per capita income in South Korea, 1970-2004.](image)

Source: IISI (various years)

The underlying assumption of the intensity of use hypothesis is that the consumption of metal in a country depends on how economically developed it is. When the income per capita is low, and the economic growth is in its early phases, the economy requires small volumes of material and thus metal, since it is mainly based on unmechanized agriculture. As the economic development continues, and the industrialization begins, material intense activities such as construction and manufacturing will increase, and more and more material will be required. When the economy expands further, and the income per capita grows, the consumer demand will shift towards a service based economy. The service sector is presumed to require less material than the construction and manufacturing sectors. The economy is satiated with houses, factories, roads, cars, and less material will be required, as the income per capita increases the shift will lead to a slowdown and eventually to decreasing intensity of metal use (Radetzki and Tilton, 1990).
The simplicity of the intensity of use hypothesis is its biggest advantage. The variables needed for estimating the intensity of metal use are relatively easy to obtain (Roberts, 1996). The income per capita works as an estimation of a country’s economic development and is readily available as GDP and population. With historical data on these and the metal consumption the relationship between intensity of use and the income per capita can be easily estimated (Radetzki and Tilton, 1990). It is, however, not unlikely that the assumption underlying the intensity of use hypothesis, that there is a stable relationship between intensity of use and income per capita, is rather weak. The intensity of use is assumed to be connected to economic development through the shifts in the economy from agriculture to construction and manufacturing to services (Radetzki and Tilton, 1990). However, it is possible that other factors, such as new production technology, material substitutions, and long-run price trends, influence the intensity of use as well. These events do not seem to be linked to the per capita income, but rather with time (Guzmán et al., 2005). These events are usually separated and the occurrence is usually unevenly distributed in time. The speed of adoption and impact on metal use of new technology and material substitutions vary greatly due to a number of factors (Radetzki and Tilton, 1990).

Because of these events and other that are not linked to per capita income, the inverted U-shaped curve that the relationship between intensity of use and per capita income exhibits will shift over time. New technology and material substitutions can shift the curve both upwards and downwards. However, as new technology generally leads to a decrease in material requirement these factors will generally shift the curve downwards, as illustrated in Figure 4. This means that an analysis of metal data will give an estimated intensity of use curve, illustrated by the heavy black curve in Figure 4, which is a mixed combination of the true intensity if use curves and is not necessarily a good approximation for any of them. The estimated curve tends to underestimate the level of income per capita where the intensity of use is maximized and give a false estimation of the shape of the curve (Guzmán et al., 2005).

Figure 4. True and estimated intensity of use curves.
Source: Guzmán et al. (2005)

Models of Steel Consumption
Three models will be used to estimate the intensity of steel use curve. The first model is a traditional intensity-of-use model, without any consideration to technological change. This model is similar to the one used in Mulenbaum (1973) and others, and assumes that
the intensity of steel use is a function of the per capita income in the country. To account for the intensity of use curve’s inverted U-shape a quadratic relationship between the variables is assumed:

\[ IU_t = \alpha_0 + \alpha_1 \left( \frac{GDP_t}{\text{Capita}_{t}} \right) + \alpha_2 \left( \frac{GDP_t}{\text{Capita}_{t}} \right)^2 + \sum_{c=1}^{N-1} \alpha_{c+3} D_c \]  

(3)

In equation (3) the \( \alpha \)'s are parameters. Considering the shape of the curve \( \alpha_1 \) should be positive while \( \alpha_2 \) should be negative, as it first rises and then falls when per capita income increases. \( C \) represents each country and \( N \) is the total number of countries, \( N-1 \) country-specific dummy variables are used with country 61 being used as the base. \( D_C \) represents the dummy variables included in the model (Dougherty, 2007). The second model tries to avoid the weaknesses of the first model that does not include a time variable. As discussed earlier new production technology, material substitution and long-run price trends are not correlated with per capita income, but rather with time, see Figure 4. This means that estimations from a model that disregards a time variable will probably be biased. Therefore, a time variable to function as a proxy for these factors is introduced in the time trend model:

\[ IU_t = \alpha_0 + \alpha_1 \left( \frac{GDP_t}{\text{Capita}_{t}} \right) + \alpha_2 \left( \frac{GDP_t}{\text{Capita}_{t}} \right)^2 + \alpha_3 t + \sum_{c=1}^{N-1} \alpha_{c+3} D_c \]  

(4)

Also in equation (4) the \( \alpha \)'s are parameters and \( D_C \) represent the dummy variables for the countries. \( \alpha_3 \) is expected to be negative as new technology usually is material saving, as discussed earlier. \( t \) is the time variable, it has the value one for 1970, two for 1971, and so forth until the value 35 for 2004. In this model it is assumed that the variables correlated with time changes the intensity of use with a fixed quantity each year, for example by a given amount of kilos per US dollars of real GDP (Guzmán et al., 2005).

The third model is specified in a way that makes it possible to avoid the influence of changes in steel prices caused by events such as the oil crises in the 1970s. This model thus reflects that steel consumption may have been affected differently at different years. To account for this, another dummy is added to equation (4) instead of the time trend variable. This results in a new equation:

\[ IU_t = \alpha_0 + \alpha_1 \left( \frac{GDP_t}{\text{Capita}_{t}} \right) + \alpha_2 \left( \frac{GDP_t}{\text{Capita}_{t}} \right)^2 + \sum_{t=1}^{M-1} \alpha_{T+t} D_T + \sum_{c=1}^{N-1} \alpha_{c+3} D_c \]  

(5)

\( T \) represents each year and \( M \) is the total number of years. \( D_T \) represents the time dummy variables. The first dummy has the value one for 1970 and zero for the rest of the years, the second dummy has the value one for 1971 and zero for the rest of the years, and so forth.

RESULTS
The empirical results are based on annual apparent steel consumption data measured in kilos from the International Iron and Steel Institute (various years), annual GDP data, measured in real (1990) US dollars from the United Nations (2008), and annual population data from the United Nations (2006). There are a total of 61 countries in the data set. Equations (3), (4) and (5) were used to estimate the intensity of steel use for all
countries in the data set under the period 1970 to 2004. Table 1 shows the results from the regressions.

Table 1. Regression results for all models

<table>
<thead>
<tr>
<th></th>
<th>Traditional model</th>
<th>Time trend model</th>
<th>Time dummy model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>t-value</td>
<td>Coefficient</td>
</tr>
<tr>
<td>Constant</td>
<td>0.058</td>
<td>12.59’’</td>
<td>0.065</td>
</tr>
<tr>
<td>GDP per capita</td>
<td>-0.132*10^{-5}</td>
<td>-2.10’’</td>
<td>0.165*10^{-5}</td>
</tr>
<tr>
<td>(GDP per capita)^2</td>
<td>0.911*10^{-11}</td>
<td>0.62</td>
<td>-0.292*10^{-10}</td>
</tr>
<tr>
<td>Time trend</td>
<td>-</td>
<td></td>
<td>-0.001</td>
</tr>
<tr>
<td>Adjusted R^2</td>
<td>0.7513</td>
<td></td>
<td>0.7686</td>
</tr>
<tr>
<td>F-value</td>
<td>104.38</td>
<td></td>
<td>112.89</td>
</tr>
<tr>
<td>Optimum</td>
<td>28,253 (max)</td>
<td></td>
<td>27,193 (max)</td>
</tr>
</tbody>
</table>

’s statistically significant at a 10 per cent level
’’ statistically significant at a 5 per cent level
’’’ statistically significant at a 1 per cent level

The results for the traditional model, without a time trend, shows that the coefficient for GDP per capita is negative, and the coefficient for squared GDP per capita is positive. This result does not support the intensity-of-use hypothesis. However, this model is miss-specified since it fails to consider the influence of technological change which is associated with time. The results for the time trend model confirms this as it shows that the coefficient for GDP per capita is now positive and the coefficient for the squared GDP per capita is negative. This implies that the relationship between intensity of use and GDP per capita exhibits the inverse U-shape. Both coefficients are statistically significant and thus support the intensity of use hypothesis. The optimum level of per capita income is a maximum at 28,253 US dollars, which means that the intensity of steel use first increases with increasing per capita income and after a peak at 28,253 US dollars decreases with increasing income per capita. The level at which the per capita income peaks is relatively high, but still quite plausible. Seven out of the 61 countries had achieved this per capita income level in 2004.2

The time trend coefficient is negative as expected, and it is statistically significant. Thus, the intensity of use curves shifts downwards over time. This is probably caused by developments in production technology towards more steel-saving production and the emergence of new steel substitutes. Then less steel is demanded for producing the same products. When looking at the country specific dummy variables they are statistically significant for almost all countries. Of interest is that the dummy variable for China is significantly positive, indicating that the intensity of steel use in China is considerably higher than in other countries without considering the level of GDP per capita. Similar results are found for Poland and Romania. The opposite holds for countries like Switzerland, Norway, Denmark and Finland where intensity of steel use is lower than in other countries. This result indicates that individual countries industry structure is an important determinant of intensity of steel use. Note, the analysis is based upon apparent steel consumption and does not regard how much steel that is part of the country’s export.

In the time dummy model a time dummy for each year is introduced. This dummy tries to correct the model for external events like the oil crises in the 1970s that influence the steel demand and hence the intensity of steel use. The estimated coefficient for GDP per capita and squared GDP per capita in this model has a positive and negative sign

\(^2\) Norway, Switzerland, Finland, Sweden, Denmark, USA and Ireland.
respectively, and the relationship thus also exhibits an inverse U-shape. The optimum is in this case a maximum at 27,193 US dollars. This per capita income is slightly lower than in the time trend model, and a few more countries had reach this level of income in 2004. When studying the time dummy coefficients they correctly indicate that steel consumption decreases over time. Overall the result is similar to the time trend model, and we thus conclude that it is most important to consider the influence of changes over time, and less important how this is done.

**CONCLUSIONS**

The purpose of this paper was to empirically test the intensity of steel use for 61 countries and 35 years to empirically investigate the shape of the relationship between the intensity of steel use and economic development. The analysis shows that the inverse U-shaped form of the intensity of use curve that the intensity of use hypothesis suggests is supported, when including a variable that accounts for changes over time. According to the results the point where the intensity of use peaks is at a per capita income of about 28,000 US dollars. This is a relatively high level of per capita income, which in 2004 only seven of the countries in the data set had reached. This result suggests though that there exists an income level where steel consumption starts to decline. During recent years developing countries such as China and India has grown rapidly. The consumption of steel has increased dramatically, especially in China, and it is believed that these countries now will follow the already industrialized countries. The results further show that differences in the countries industry structure, i.e., end-use of steel, has a significant impact on the intensity of steel use.

The hypothesis that variables correlated with time, such as new technology and material substitution, are important for the intensity of use curve to be estimated correctly, is supported by these results. These findings implies that even though new technology and material substitution will reduce the demand for steel, the rapid growth and the massive increase in steel demand in developing countries will contribute to a continued growth on the steel market. The results further show that the intensity of steel use in China is considerably higher than in other countries, regardless of the level of GDP per capita. This indicates that individual countries industry structure is an important determinant of intensity of steel use. However, the analysis is based upon apparent steel consumption and does not consider how much of the steel consumption that later on goes to export. To summarize, although countries like China and India are growing fast they still probably are far from the peak of intensity of steel use. In 2008, China’s GDP per capita was 5,500 US dollars, and the equivalent in India was 2,800 US dollars. This has important implications for both steel exporting countries and steel producing companies.

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