The determinants of secondary copper production

An econometric analysis of European countries

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ABSTRACT

Copper is a metal that is commonly found in our society's infrastructure, such as cables and wires. In addressing the climate threat, society is facing a major transition towards electrification and digitization, and here copper plays an essential role. Since copper is a main component in the infrastructure, the demand for copper has increased rapidly due to the electrification of, for example, the automotive industry. Even though copper in the earth's crust is a scarce resource, it can be recycled an infinite number of times without losing its quality. For this reason, meeting future demand partly through secondary copper production is likely to be important.

The aim of this study is to investigate what factors influence the secondary refined copper production levels in nine different countries in Europe. Specifically, the study examines how electricity prices, copper scrap prices, primary production of copper, GDP per capita and cost of labor affect the supply of secondary refined copper. The empirical analysis is based on data from nine European countries and over a period of 21 years, 1998 – 2019, thus adopting a panel data approach. The results from the econometric analyses show that all five variables tend to influence the supply of secondary refined copper, some having a more profound effect than the others. For instance, the findings suggest the presence of a low and negative electricity price elasticity of secondary refined supply, while an increase in the copper scrap price appears to have significant deterring impact on secondary refined copper production.

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SAMMANFATTNING

Koppar är en metall som är vanligt förekommande i vårt samhälles infrastruktur, såsom kablar och ledningar. För att möta klimatförändringarna står samhället inför en stor omställning vad gäller elektrifiering och digitalisering, och här spelar koppar en väsentlig roll. Eftersom koppar är en huvudkomponent i samhällets infrastruktur har efterfrågan på koppar ökat i en snabb takt på grund av elektrifieringen av till exempel fordonsindustrin. Även om koppar i jordskorpan är en ändlig resurs kan den återvinnas ett oändligt antal gånger utan att förlora sin kvalitet. För att kunna möta den ökande efterfrågan på koppar, kommer den sekundära kopparproduktionen utgöra en viktig del av det totala utbudet av metallen.

Syftet med denna studie är att undersöka vilka faktorer som påverkar produktionen av sekundärt förädlad koppar i nio olika europeiska länder. Specifikt undersöker studien hur elpriser, kopparskrotpriser, primärproduktion av koppar, BNP per capita och lönenivåer påverkar tillgången på sekundärförädlad koppar. Den empiriska analysen baseras på data från nio europeiska länder över en period av 21 år, 1998 – 2019. Analysen grundar sig med andra ord på paneldata. Resultaten från de ekonometriska analyserna visar att alla fem variabler tenderar att påverka tillgången på sekundärt förädlad koppar, men vissa har en större betydelse än andra. Till exempel visar resultaten att priselasticiteten för elektricitet för sekundärt förädlat utbud är negativ men låg, medan en ökning av priset
på priset verkar ha en större negativ effekt på sekundärt förädlad kopparproduktion.

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CHAPTER 1
INTRODUCTION

The following background in this chapter will provide an overview of the metal market and how primary and secondary metals differ from each other. It will also give an overview on the market barriers that secondary metal recycling faces. Moreover, a problem discussion is presented, and this will lead to the purpose of the study. At last, the delimitations, the methodology and the outline for the study will be provided.

1.1 Background

With the expansion of the global economy during the last decades, the use of the earth's natural resources has increased rapidly and so has the concerns about the over exploitation of these resources. To reduce the current dependency on primary materials and delay the depletion of virgin natural resources, a well-established circular economy is needed. Here, recycled materials play an essential part (e.g., Söderholm och Ekvall, 2019). A circular economy can be described as an economy that builds on recycling and reuse as well as resource efficiency, this in contrast to the 'end-of-life' concept that tends to be associated with a more 'linear' use of resources (Moraga et.al, 2019).

According to Hagelüken and Goldmann (2022), metal is a resource that needs to be used much more efficiently than what it is today. This is because metal is a resource that is essential for society, not least given the current increase in digitalization and the ongoing clean energy transition. During the last decades, the consumption of metal has increased rapidly and since metals are finite resources, the usage needs to become more efficient. Since metal can be recycled an infinite number of times the circular economy is a useful approach to achieve an efficient resource use (Hagelüken and Goldmann, 2022).

Metals can be produced either from virgin ores or from scrap metals. The metals that come from the production of ores are often referred to as primary metals, and the metals that come from scrap (i.e., emerging from products that have reached the end of their lifetime and treated as waste) are referred to as secondary metals (Gómez et.al., 2007).

The primary and secondary metals compete in the same market, yet they differ from each other. Production of primary metals typically gives rise to more negative environmental impacts, e.g., carbon dioxide emissions, compared to the process of producing secondary metal. This is mainly because the extraction process in the former case is much more energy intensive (Tillväxtanalys, 2021a). On the other hand, secondary metal production is more labor intensive compared to primary production. This is because the components within various products have become smaller, more complex, and advanced over time; this makes the disassembly process more complicated and labor intensive. Thus, primary production is instead significantly more capital and energy intensive, while the secondary production is more labor intensive. However, since labor typically is taxed significantly higher in relation to capital or materials, the cost of secondary production can often be relatively high (Tillväxtanalys, 2021a).

As stated before, the demand for metals has increased rapidly during the last decades and will likely continue to do so. Furthermore, the demand is strongly linked to the economic development and especially in periods when this development is characterized by growth in buildings, infrastructure, and industrialization (Tillväxtanalys, 2021b). The supply of secondary metals will depend on historical economic activities, since the supply comes from the recycling of products that were manufactured and used in previous years. Hence, the products that were manufactured in the past and what types of products will be the foundation for the current supply of metal scrap. In other words, the supply of metal can be described as a function of past economic activity. If the activity in the economy is high, the production of products containing metal will increase and so will the metal scrap in the future when the products have reached their end-life and can be recycled (Blomberg and Söderholm, 2009). Since the aggregated economic activity globally was overall lower in previous years compared to today, the products that have reached its end-life and can be recycled today, will typically not be able to meet current demand for metals.

In this study, the focus is on the supply of secondary copper. According to Fu et al. (2017), copper is a metal that is valuable to recycle, this from two perspectives. First, copper is relatively scarce compared to other metals such as aluminum and iron. This means that the amount of virgin copper that is available for economic extraction is less compared to other metals. Furthermore, the current copper reserves are only sufficient to last 32 years compared to aluminum and iron, thus suggesting more than 100 years of production in the future (Alonso et al., 2007). Second, the energy that is required to produce copper from secondary materials is much less compared to the energy needs in the production based on primary sources (Fu et al., 2017). Copper is typically used in construction, telecommunications, and electricity generation, and for this reason, a country's use of copper is in part an indicator of its economic development (Fu et al., 2017). Since the use of copper has become more and more important in recent years due to the increased digitalization and the energy transition, the demand will likely continue to increase also in the future. According to Rivera et al. (2021), several studies have identified risks of primary copper shortage and possibility of depletion of the virgin resource if the demand continues to increase. Thus, secondary copper plays an important role in meeting the increased demand and delaying the depletion of the primary resource.

As emphasized above, the supply of secondary metals depends on the level of the consumption of products in previous years, the types of products that were consumed and their various lifespans. For copper, the lifespans vary among different products. For motor vehicles, the lifespan is 8-10 years, for cables it is 30-40 years and for budlings it is 60-80 years (Rankin, 2011). This means that when a motor vehicle is recycled, it will contribute to secondary copper supply faster than when a cable is recycled.

The supply for secondary copper can therefore be explained by a numerous amount of factors such as input costs (e.g., cost of labor, cost of capital), the available copper scrap and the overall economic activity. Since copper is a resource that is important in many perspectives for the society and the sustainable development, there is a global interest in increasing the usage of secondary copper. To achieve an increased usage of secondary copper, there is a need for a deeper understanding on the factors that tend to influence the production of secondary copper.

1.2 The objective of the study

The production of secondary refined copper is likely to be influenced by multiple factors. The aim of this study is to investigate what factors influence the secondary refined copper production levels based on data from nine different countries in Europe.

1.3 Method

Considering that the aim of the thesis is to identify a relationship between the secondary refined copper production and various factors, not least the prices of various factor inputs, a quantitative research approach will be used. The secondary refined copper production represents the supply side of the market, and the supply function is theoretically derived from the production function. To determine how the secondary refined copper production is affected by different factors, a regression analysis is applied. The dependent variable is the secondary refined copper production, and the independent variables are the identified factors that may influence the dependent variable. The analysis builds upon panel data from nine European countries over the time period 1998 – 2019, and the data are analyzed employing a fixed effect approach.

1.4 Delimitations

Certain delimitations have been made. First, this study is geographically limited to nine European countries: Austria, Belgium, Bulgaria, Finland, Germany, Italy, Poland, Spain, and Sweden. Second, the thesis is limited to the secondary refined copper (see further chapter 2). The thesis will also be limited to a the time-period between 1998 and 2019. Why these countries and years were investigated is based on the fact that there was the most available data. Further, this thesis will look at the short run changes based on the available data.

1.5 Outline

This thesis consists of nine chapter in total. In the next chapter, a brief background to the recycling process of copper is provided. The different stages in the process and the various types of copper scrap are explained, and an explanation of refined copper is provided. The literature review follows in chapter three where previous literature in this field is presented and discussed. Chapter four presents the theory that this thesis is based on, i.e., focusing on the demand and supply model for secondary material, with an emphasis on the production function. In chapter five, the data and the selected variables are presented. The method this thesis has employed is presented and discussed in chapter six with the econometric specifications. In chapter seven, the results from the regression analyses are presented. Furthermore, in chapter eight, results will be discussed in relation to the theoretical framework and the previous literature in this field. Finally, in chapter nine, the conclusions and avenues for further research are presented.

CHAPTER 2
COPPER

This chapter provides a background for the copper scrap and its market structure. The definition for the three different types of copper scrap is explained. Further, the recycling process for copper is provided followed by an introduction for refined copper.

2.1 Copper scrap

Copper is a material than can be recycled an infinite number of times without losing its quality. For this reason, copper is a favorable material to recycle. The recycling process of copper comes from scrap that is generated at all stages of the copper production and is shown in Figure 1. The process of where the scrap is generated is based on Slade (1980) explanation. The copper scrap that is generated at the metal production is called *home scrap*. Copper scrap that is generated from the manufacturing of the product is referred to as *new scrap*, and the copper scrap that is generated from products that has reach its end life is referred to as *old scrap*.

In Figure 1, the process of different copper scrap is displayed. In the primary production stage, two categories of scrap are generated, *home scrap* and *new scrap*. Home scrap will be directly reused in the primary production and at the fabricators. Therefore, home scrap will never enter the secondary copper market. The new scrap that is generated in the primary production will be recycled and contribute to the total supply of copper scrap. The use of new scrap is very high but will likely decrease in the future. This is because the scrap comes from waste in the production and the firms often have strong incentives to make the production more effective and decrease waste volumes. Lastly, old scrap is obtained in the last stage in the process when the product has reached the consumers and reached the end of its lifetime. Hence, *new scrap* and *old scrap* will contribute to the total supply of copper scrap, which will end up at scrap dealers and secondary producers.

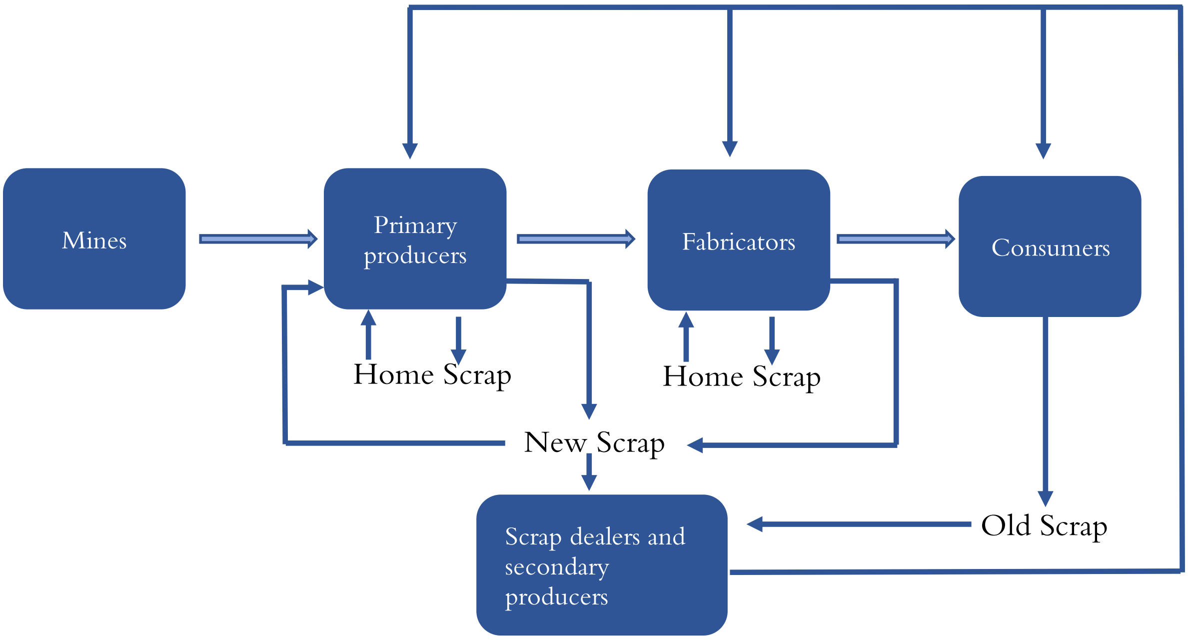

Figure 1. Scrap chart for home, new and old scrap (Slade, 1980)

2.2 Copper recycling

As stated above, the last stage that the copper scrap will enter as scrap is at the scrap dealers or the secondary producers. At this stage, the recycling process and the production of secondary copper will commence. This recycling process for copper is illustrated in Figure 2 (adopted from Norgate, 2013).

The process for old scrap starts when the product has reached its end-life where it can be collected and recycled. Of the total amount of products that has reached its end-life not all products are collected and can therefore not be recycled. The process for new scrap starts when there is waste from the primary production stage and the metal is recycled. The amount of new and old scrap represents the total scrap that is available for the recovery process, a share of the total available scrap will not be recovered and will therefore be left out from the recycling loop. The remaining scrap will further be sorted based on the quality, and the bulky products are then shredded into smaller and more manageable pieces. In this process scrap losses arises as well and will be left out of the recycling loop. The scrap will then go through a smelting process and a refining process. In the smelting process, the scrap is heated and melted into the copper metal, and then the refining process increases the grade of purity in the metal (Copper Alliance, 2023). In the manufacturing stage, the copper is transformed into various products that are used by consumers and business, which reflects the product useful life-stage at the end of the loop.

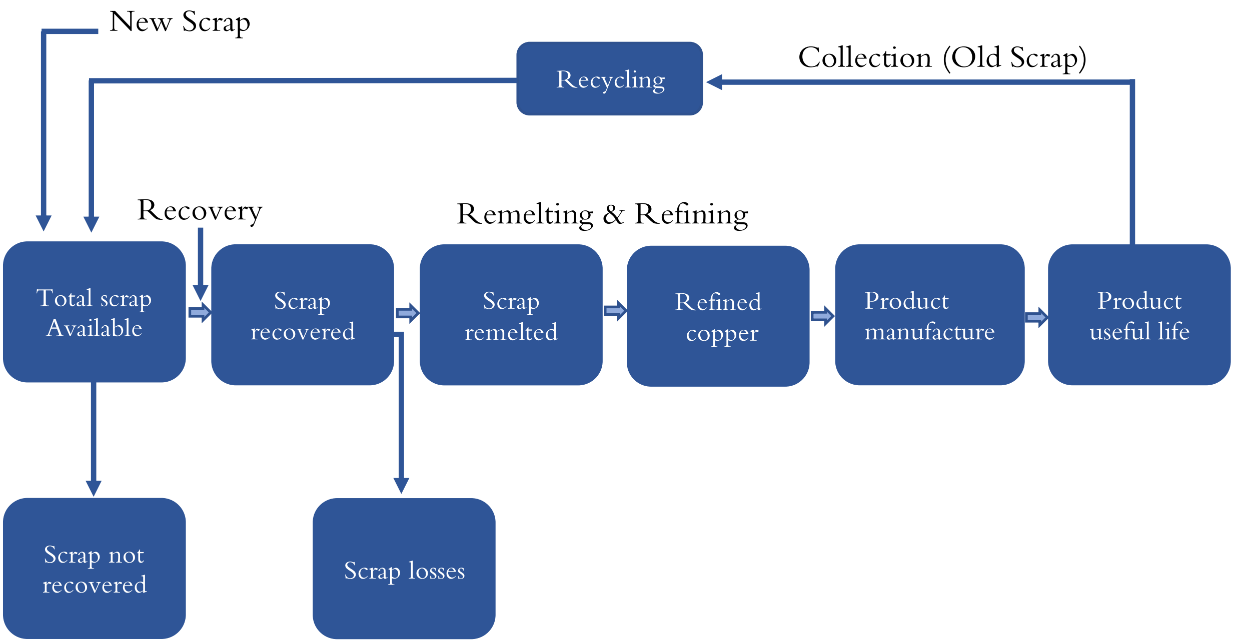

Figure 2. The recycling process for copper scrap (Norgate, 2013)

2.3 Refined copper

When primary copper is being extracted from copper sulfide, and when secondary copper is collected from copper scrap, it contains large amounts of impurities. To remove these impurities the copper needs to be refined to obtain pure copper. The process of refining copper includes melting, conversion, and fire-refining, and ends with electrorefining (e.g., USGS, 2023). Refined copper is therefore copper that has been fire-refined to obtain a more concentrated formula of its initial material. To be classified as refined copper, the material needs to contain at least 99% pure copper. The refined copper is then used in the production of product that the household demands. Refined copper is commonly used wires, cables, busbars, and windings (Calcutt, 2001).

In this thesis, the objective is to study the secondary refined copper production in nine different countries in Europe. The secondary refined copper production will act as our dependent variable in the regression analysis. In Figure 3, the secondary refined copper production levels for each country are presented from 1998 up until 2019. Germany has the highest production levels of secondary refined copper followed by Belgium. The countries that have the lowest production of secondary refined copper production are Bulgaria and Finland. Furthermore, the production levels for Germany and Belgium have decreased from 1998 until 2019, meanwhile, the production in other countries has either increased or remained unchanged.

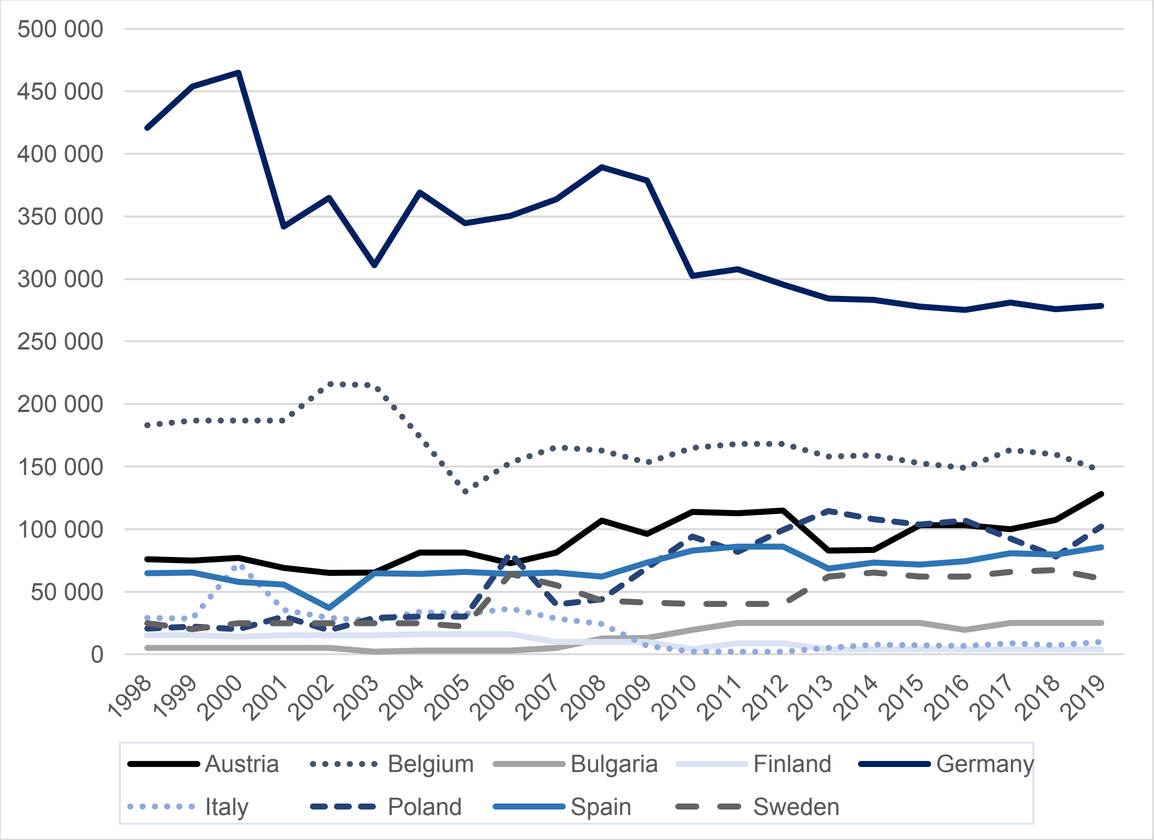

Figure 3. Secondary refined copper production in metric ton in nine European countries, 1998-2019

CHAPTER 3
LITERATURE REVIEW

This chapter discusses, illustrates, and summarizes previous relevant research within the area of secondary metals, its challenges and potential. The chapter also clarifies how this study aims to contribute to existing research within this field.

3.1 Search strategy

To be able to identify relevant studies for this thesis different search phrases have been used in different scientific databases. The databases that have been used are Google Scholar and Scopus. Since the aim of the study is to investigate what factors that can influence the production of secondary refined copper, the previous literature needs – in some way – to add to our understanding of this field. The most common search phrases that have been used in the scientific databases include “copper recycling”, “secondary metal market”, “copper supply”, “circular economy for metal”, and various combinations of these words. In the meantime, when searching for previous literature an increased understanding of the copper recycling has been received and additional search phrases have been used. The literature has also been found in the references list of the relevant literature. Since the secondary copper market is global, the previous literature does not only need to examine the copper recycling in the countries that this study is limited to. Previous literature that examines the recycling of copper or other raw material (if the arguments and discussions can be applicable to other materials according to the authors) is relevant for this study.

3.2 Literature review

Hagelüken and Goldmann (2022) remark that the consumption of raw materials has increased rapidly over the last decades. The increased consumption of raw materials has given rise to climate change, and to decrease the climate change problem, resource efficiency as well as the energy and mobility transition constitute important strategies. Hagelüken and Goldmann state that the use of raw materials needs to become much more resource efficient, and it is necessary to use raw materials as purposefully as possible instead of just consuming them. The resource that Hagelüken and Goldmann focus on in the article is metals. Since metals do not lose their properties when recycled, the circular economy is a key approach to make the use of the raw materials more resource efficient. Hagelüken and Goldmann emphasizes that the growing demand of metal cannot be met by either primary metals or secondary metals alone. Hence, the primary and secondary metal supply needs to complement each other in the future to meet the demand. Thus, due to the primary metals getting more complex to extract as the ore grades become lower, the share of secondary metals will increase. They also explain how various internal and external factors affects the circular economy. For instance, recycling infrastructures and public procurement policies are essential factors to achieve a circular economy. The objective of their study is to identify the general opportunities and challenges of metal recycling. Hagelüken and Goldmann explain that metal recycling gives rise to much more stable metal prices, reduces carbon dioxide emissions, and contributes to the conservation of raw materials. In summary, communication between industries, science, policy, and public is essential to establish a circular system.

Robaina et al. (2020) also emphasize the importance of recycling to achieve a circular economy in Europe. The authors state that the usage of resources today resembles a linear material flow, where resources are extracted, used and lastly throwed away. The linear economy requires large quantities of materials. The circular economy on the other hand, intends to preserve products, components, or materials at their most valuable and useful point, something that makes the circular economy essential to promote a sustainable development. The aim of their study is to estimate the main determinants for the circular economy in Europe. In their article 26 European countries have been analyzed between the year 2000 and 2016.

The authors have used the resource productivity indicator as an approach to measure a country's performance in the transition to a circular economy. When measuring resource productivity, the gross domestic product (GDP) relates to the country's material use, either the raw material consumption or the domestic material consumption. Focusing on how various factors affect the performance of a country's resource productivity, the authors use a linear regression model with three complementary tests to determine the most appropriate model specification. The dependent variable is resource productivity, and the independent variables in the model are environmental taxes, share of renewable energy consumption, expenditures on R&D, recycling rate, population density, service sector share and industry sector share. The most appropriate model for the article was the vector autoregressive (VAR) model. All the independent variables are found statistically significant, and thus help explain resource productivity.

Söderholm and Ejdemo (2008) have studied the steel scrap market in Europe and in the USA. The study provides an overview on how the global steel scrap markets function. According to Söderholm and Ejdemo, recycling has occurred because it is economically beneficial from a private perspective, and the amount of steel that is recycled has been high even without any policy interventions. The global scrap industry has developed due to profit incentives and the price in the scrap market is determined by the demand and supply. Söderholm and Ejdemo argue that the decision-making process and the evolution of policy instruments for scrap markets can be challenging in various ways. Countries have their own national policy instruments to promote and improve the recycling and the scrap market, although the scrap market is international. Since the paper aims to provide an overview of the steel scrap market, the authors have used a theoretical framework of a supply model for aluminum scrap in the short and long-run.

In the article, Söderholm and Ejdemo (2008) explain two supply models, one for new scrap and one for old scrap. New scrap is, as noted above, scrap that is generated in the production of the final product, and old scrap is scrap that is obtained from products that have reached the end of their life. The authors discuss the supply for new and old scrap separately since the respective scrap supplies are determined by different factors. New scrap that is recycled is determined by the level of metal that is consumed and how much metal that is generated from the primary production. Old scrap will depend on the availability of product containing metal that is recycled in the given year and the stock which has not been recycled yet. In their analysis, the authors states that the steel scrap industry appears to be highly competitive and with a high global scope. Furthermore, the price in the steel scrap market is determined by demand and supply, and since the market is global, the demand will be affected by the steel production in other countries. The price in the short-run is volatile due to a low own-price elasticity of scrap supply and an income sensitive metal demand.

Berglund and Söderholm (2003a) have written an article that explores the recycling of global wastepaper. They analyzed both the recovery and utilization rates for 49 countries between 1990 up until 1996. The recovery rate measures how much recovered paper that is used from the total waste stream of paper. The utilization rate measures how much recovered paper that is being used in the production of new paper products. While the paper recovery rate shows the waste management and supply perspective, the utilization rate is linked to the demand side of the wastepaper market. The authors present two econometric models that aim to explore inter-country differences in both the recovery rate and the utilization rate for wastepaper. The first model uses the recovery rate as the dependent variable followed by GDP per capita, urbanization rate, population density and the domestic wastepaper (output) price as independent variables. The second model uses the utilization rate as the dependent variable followed by virgin forest supply, paper product mix, so-called structural effects and recovery rate as independent variables. The analysis shows that both the recovery rate and the utilization rate are affected by political and economic factors. The results show that depending on how rich a country is, they will have different influence on the recovery rate, thus, a richer country will have a greater impact on the recovery rate in comparison with a poor country. In other words, depending on how rich a country is, it is likely to be connected to the development of waste management systems. Furthermore, Berglund and Söderholm state that the utilization rate is largely driven by various economic factors.

Blomberg and Söderholm (2009) investigate secondary aluminum supply and how it will be affected by various factors. The aim of the article is thus to analyze the economics of secondary aluminum supply in western Europe. The model is based on pooled cross section and time series data for four different countries in Europe: Germany, France, Italy, and the United Kingdom. The period that the data come from is 1983-2000. Blomberg and Söderholm assume that the transformation from secondary aluminum to the final output is based on the use of a number of inputs such as capital, labor and energy. This analysis is theoretically grounded in the production function, and a cost function that can describe the underlying production technology. The model in the article is a regression analysis with the production of secondary aluminum as the dependent variable along with different independent variables. The independent variables are the price of secondary aluminum, price of labor, price of capital, price of energy and the stock of old scrap. The results indicate that the price of the output and the scrap stock have positive effects on the production of secondary aluminum. The prices of labor and energy have negative effects on secondary aluminum production. The own-price elasticity for the secondary aluminum supply appears as low while the income elasticity for demand appears as high. The result from this study provides further knowledge about market behavior and impacts of policies on the secondary market for aluminum. Blomberg and Söderholm emphasize that price-based policies may only have modest impacts on recycling rate for aluminum, also that a national collection of aluminum scrap is likely to only have a modest effect on the global recycling level.

Slade (1980) investigates the different factors that will influence the decision to recycle copper in the USA between 1977 and 1986. According to Slade, previous econometric studies have been made on copper recycling but none of these have used a model that rests on microeconomic foundations, including the dynamics of the scrap accumulation process. The article develops a theoretical model for secondary copper production with the basis of the microeconomic theory of production and cost. In the econometric analysis, the dependent variable is secondary copper that is produced from old metal scrap. The independent variables in Slade´s model is based on microeconomic theory and include the prices of secondary copper (output price), the stock of old copper scrap, capital cost, labor cost, energy cost, industrial chemical cost, and transportation costs. In the article, Slade states that the scrap metal is the principal input in the secondary metal production and the cost for this input price is highly correlated with its output price.

The results from the regression analysis shows that the price of secondary copper and the stock of old copper scrap will have a positive effect on the secondary copper production. Further, the remaining independent variables in the model will have a negative effect on the secondary copper production. This means that if the capital cost, labor cost, energy cost, industrial chemical cost, and transport costs increase, secondary copper production will decrease. Lastly in the article, Slade discusses and illustrates how different policies and future events will affect the recycling rate of copper, based on the econometric results. The first policy that is discussed is a per-unit price subsidy for the secondary copper production. If incorporating this subsidy, the secondary copper production will increase and so will the market share. Furthermore, an argument about changes in the energy prices is discussed. The results show that with high energy prices, the market share and the production for secondary copper will decrease, the opposite will happen if the energy price is low. To keep in mind, this argument is only based on the econometric results that Slade obtained from the regression analysis. To conclude the analysis on the energy price estimation, Slades states that the results is not surprising because the secondary copper price is the article is based on long-run average cost and does not fluctuate enough to relate to the supply and demand in the short run.

Rivera et al. (2021) have studied secondary refined copper, and how it tends to be affected by various variables in the world market. According to the authors, there is a risk of shortage of primary copper on mid-long term and further a risk of depletion of the primary copper, and copper is therefore included in the list of critical raw materials. By recycling copper after it has been used, the need to extract primary copper will decrease. In this article, the authors chose to limit the study to secondary refined copper since it has an essential impact on the global copper price. The analysis in the paper is divided into two parts. The first part consists of an analysis where the authors evaluate the explanatory variables that the earlier research has used. These explanatory variables are: 1) difficulty collecting copper scrap flow of scrap; 2) price of primary refined copper; 3) stock of scrap; 4) world gross domestic product; 5) mining index; 6) a time trend; and 7) secondary copper supply lag. The aim of this analysis was to examine the variables capacity to explain the secondary supply behavior.

In the second part, the authors re-estimated five of the econometric models in the short and the long run through annual data between 1960 and 2017. The reasons why the authors did not use all seven of them was because two of the models' contained data that were not available. The re-estimation was carried out with a regression analysis and according to Rivera et al. (2021), the regression analysis can estimate the variables that will have an effect of the supply for secondary refined copper. In the analysis, some of the data for the variables in the first part was changed. For example, the data for the gross domestic product was considered in GDP per capita. The analysis shows that the copper price and the gross domestic product were the only two variables that explained the short-run changes in the market. In the long run, all the independent variables (expect the mining index) explained the changes in the market conditions.

Elshkaki et al. (2016) studied the global copper market and how the component in the copper market, such as the demand, the supply, and the energy required for the primary and secondary production, will be affected with different scenarios. The United Nation has an Environment Program, UNEP, where they have developed four different plausible scenarios in 2050; Market First, Policy First, Security First and Equitability First. According to the authors, copper is one of the most widely used metal due to its unique properties, and it is an important material for many sectors such as infrastructure. Since copper is so important for society, the demand has increased rapidly over the last years. The demand has increased due to increased population, high economic growth rates, and the ongoing transformation to a more sustainable society. The growth in the demand is much higher than the growth of the secondary supply of copper, thus implying a higher demand for primary copper. Since the demand for primary copper has increased, so has the concerns about the copper stock and the environmental impacts. In the article, the authors use a regression analysis to analyze historical demand and supply for copper. In the regression analysis, the authors use GDP per capita, urbanization level, and time as independent variables to analyze the demand for copper. The demand for copper is met by the supply of both primary copper and secondary copper. The independent variables for the supply are the historical copper demand, the lifetime of copper applications, recycling rates of copper and efficiency.

The results show that depending on the four various scenarios, the demand for copper will increase between 275 and 350% from 2010 to 2050. The Equitability First-scenario is likely to cause the highest increased demand for copper while the Security First-scenario will cause the lowest increased demand. Nevertheless, all four scenarios will increase the demand for copper so rapidly that the demand exceeds the copper reserves. There is also a challenge where the copper producing countries might not be able to sustain their copper production by 2050. Looking at the required amount of energy, it is expected to increase from 0.3% of the total energy demand to around 1 and 2.4% by 2050. Hence, the expected increasing energy demand will cause higher requirements on both a clean energy supply and an efficient use of energy. The authors emphasize suggestions on policy options that could reduce copper-related impacts. On the supply side they suggest governmental encouragement and incentives for improving the recycling rates of copper. On the demand side, a more efficient copper cycle is needed, and this can be achieved through minimizing losses in the production, minimize the use of copper in unrecyclable products and encourage shifts towards a renewable technology.

Fu et al. (2017) analyzed copper scrap availability and the factors that could affect this availability. In the article, the authors state that copper waste is beneficial for two main reasons. First, copper is relatively scarce compared to other metals. Second, production of primary copper is more energy intensive compared to secondary copper production. Production of secondary copper can reduce the energy needs with 85 % compared with the production of primary copper. The copper scrap is divided into two groups, high-quality scrap (direct melt scrap), and low-quality scrap (refined scrap). Direct melt scrap is scrap that can be directly melted when the product has reached its end-life, and refined scrap is scrap that first needs to be refined.

Fu et al. (2017) state that earlier research has studied the supply side of the refinery sector, which only include the refined scrap and not the scrap that is directly melted. Their aim of the study is to investigate what variables will affect the availability of different qualities (high versus low quality) of scrap. In the article, the high-quality scrap corresponds to the direct melt scrap and the low quality scrap corresponds to the refined scrap. This is because scrap that needs to first be refined and then melted contains of more impurities and is therefore called low quality scrap. The authors use an econometric model to understand what factors will affect the availability of the different scrap qualities. In the model, the dependent variables are the quantities of copper produced from secondary sources. The independent variables include industrial activity, input prices and monetary conditions. The analysis shows that both the industrial activity, the price of primary refined copper and the world GDP affects the total supply of copper scrap. To conclude the article, the authors state that the direct melt scrap (high quality scrap) depends on supply shifting variables while the refined scrap (low-quality scrap) will depend on more demand shifting variables.

Gomez et al. (2007) analyzed the secondary copper production and how the growth in the secondary production has failed to match the growth of available old copper scrap. The authors state that previous economic research has contributed to the understanding of copper and the metal market. In previous studies, it is typically assumed that an increase in available old copper scrap will increase the supply of secondary copper production from old scrap. According to Gomez et al., though, the old copper scrap has tripled over the last decades, but the secondary production of old scrap has increased much less. The secondary production has instead decreased over the last years. The authors bring up that one explanation for the decrease in the production of old scrap according to previous research is the decline in the real price of copper over the last decades. Furthermore, the low growth of the secondary production compared to the primary production can be explained by the progress that primary producers have made in terms of reducing their production costs.

The authors analyze another explanation to why secondary copper production has failed to match the growth in available stock. Old scrap depends on the old scrap flow and the old scrap stock. The old scrap stock is the scrap that has not been recycled in previous years, and which will be available to recycle in the present year. Old scrap flow on the other hand includes the scrap that becomes available during the present year when copper-containing products reach end-of-life. Their hypothesis is that the stock of old copper is more costly to recycle compared to the old scrap flows. The model that Gomez et. al. use to test their hypothesis assumes that secondary copper production will depend on the real price of refined copper, available old scrap stocks, the old scrap flows, and the lagged value of the secondary copper production. To estimate the model, the authors use data between 1966 and 2005. The analysis shows that the old scrap stock has a modest impact on the secondary production and the old scrap flows are much more important. This is because the old copper scrap consists of the old scrap flow and the old scrap stocks. The old scrap stocks were not recycled in the prior years and according to the authors the recycling cost is relatively high. This means that the growth in the old scrap stock will increase secondary production less than the same growth in old scrap flows.

3.3 Conclusions from the literature review and relevance for our study

Considering that the aim of this study is to obtain a deeper understanding of how various factors affect the production of secondary refined copper among European countries, the previous papers are useful for this thesis, both to get an understanding of relevant factors to investigate but also theoretical frameworks and methods that this thesis can use. Some studies have looked at the recycling rate, the amount of metal scrap, the recovery rate, and the utilization rate. Some of the different research areas that have been examined in the literature include the supply and the demand sides of the scrap metal market, and the production for secondary metal from a business perspective.

Previous literature has used different econometric models to analyze factors that will affect the market for secondary materials. Berglund and Söderholm (2003a) analyze different factors that will affect both the recovery and utilization rate, Blomberg and Söderholm (2009) analyze the secondary aluminum supply and how it will be affected by various factors, Slade (1980) investigates the different factors that will affect the decision to recycle copper, Rivera et al. (2021) studied the secondary refined copper and how different factors will affect it, Elshkaki et al. (2016) analyzed how the copper market will be affected with different scenarios, Fu et al. (2017) examined what factors that will affect the availability of copper scrap, Gomez et al. (2007) studied secondary copper production and what factors that may affect this production.

A common factor among the literature is that several of them have done inter-country analyses with limitations to a certain resource, such as recycled wastepaper or aluminum. These studies have given good insight on what factors that could have a relevance for this thesis, but also the method that is applied. This literature has analyzed what will affect the secondary metal market with different approaches. Still, none of the previous studies have investigated the factors that affect the supply of secondary refined copper production in European countries during recent years.

CHAPTER 4
THEORETICAL FRAMEWORK

In this chapter, the theoretical framework is presented. This framework includes a conceptual description of the copper market, with an emphasis on the supply of new and old scrap, and the production function for secondary refined copper based on which a supply function for secondary refined copper dan be derived.

4.1 The market for primary and secondary metal

The equilibrium market model for metal is based on the demand and the supply functions for metal. The supply consists of both the primary and the secondary metal. Furthermore, the demand for the metal is a *derived demand.* This is because households are generally not particularly interested in buying the metal itself; instead, the demand comes from the consumption of products which consist of metal. To be able to meet the demand from the household for products containing metals, the manufacturing companies need to use metal in their production (Tillväxtanalys, 2021b).

Figure 4 shows a simple partial equilibrium for a given material e.g., copper. According to Söderholm and Ekvall (2019), this simple model is based on four assumptions. *First*, it is assumed that the primary and the secondary materials are perfect substitutes. *Second*, the total demand for the material is perfectly own-price inelastic. *Third*, the own-price elasticity for the secondary supply is low. *Fourth*, they assume that there exists a global market where the primary and secondary material can be traded freely across national borders. In the model, the aggregate demand (D) curve shows how much quantity that is demanded. The supply curve for the primary material is represented by S_V and the supply for the secondary material is represented by S_S. The underlying cost function for the supply curves is assumed to be convex, thus leading to an upward-sloping marginal cost curve. The aggregate supply curve shows the aggregate metal supply from S_V and S_S. The point at which the aggregate demand curve intersects the aggregate supply curve gives the long-run market price. At this market price, the quantity for the secondary material supplied equals Q_S. The supplied quantity for the primary source is $Q – Q_S = Q_V$, where Q shows total material demand. This indicates that the marginal cost for secondary supply is low enough to crowd out some of the primary materials to meet the aggregate demand.

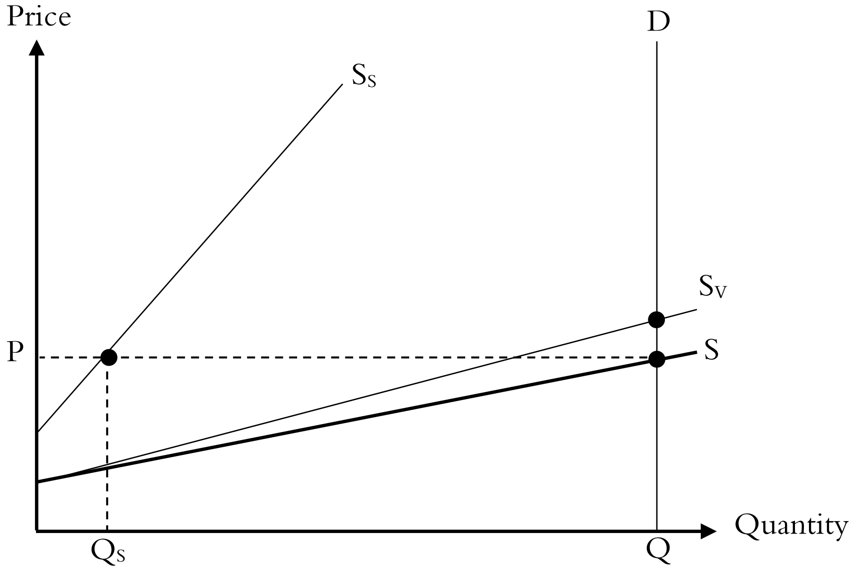

Figure 4: Market equilibrium model for metal

4.2 The supply of metal scrap

The supply for secondary metal is based on the metal scrap that can come from various sources. *Home scrap* is metal scrap that comes from the primary production stage. *New scrap* is metal scrap that can be found in the producing stage of the product containing metal. *Old scrap* is metal that comes from metal-containing products and is recovered when these products have reached their end-life. Furthermore, the supply for *old scrap* will depend on two different factors. First, it will depend on the *flow* on how much product containing metal that has reached its end-life during the year. Second, the supply will depend on the total *stock* of metal products that is no longer in use at the beginning of the year, but which has not been recycled yet. The metal that has not reached its end-life and not been recycled will therefore contribute to an increase in the scrap stock in the future, which consist of the accumulated flow of previous years (Tilton, 1992). Since the new scrap and old scrap is the scrap that will contribute to the secondary copper supply, each of these supply curves will be presented below.

4.2.1 New scrap

The supply curves for new scrap in the short- and long-run are presented in figure 5 and is based on Tilton (1992). The marginal cost of identifying, collecting, and processing new scrap is represented in the long-run supply curve. Most of the new scrap is cheap to recycle, thus the supply curve is relatively low and flat when the production level is low. However, when the curve approaches the constraint, the supply curve becomes much steeper. This is because the new scrap becomes more expensive when the total amount of available scrap decreases. Since the cost of recycling new scrap is relatively cheap, the constraint in the short run, will essentially be the same as in the long run. Hence, the short- and long-run supply curves will become vertical at almost the same level of output. In the short run, the producers only need to cover their variable cost, therefore the short-run supply curve will lie below the supply curve in the long-run.

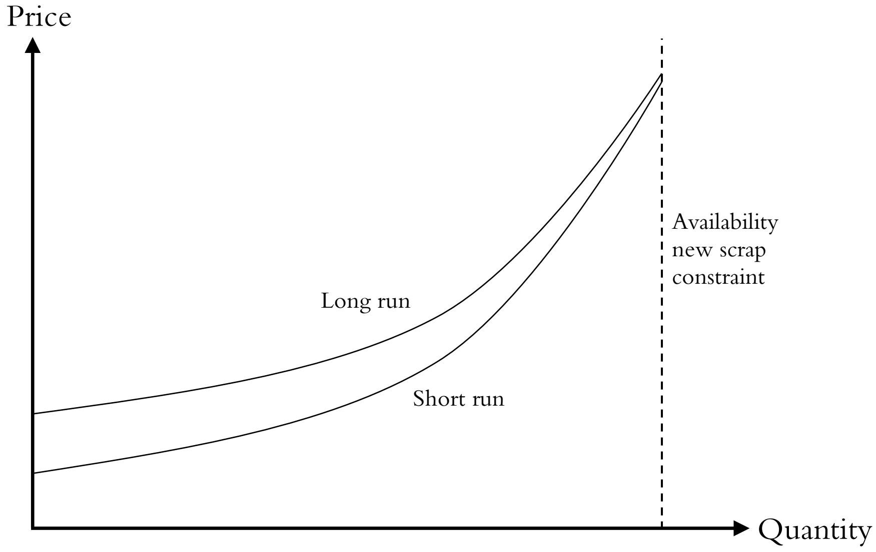

Figure 5: The supply curves for new metal scrap

4.2.2 Old scrap

The short- and the long-run supply curves for old scrap are shown in Figure 6 which is based on Tilton (1992). The long-run curve only shows the old scrap flow, since there is no long-run supply curve from the stock of old scrap. This is because producers will recover the old scrap stock if this is economically profitable, and they can cover their variable costs. Since the old scrap stock stems from the earlier amount that is collected but has not been recovered yet, that amount will be recovered and the stock in the long run will therefore deplete. The short-run supply curve on the other hand only shows the flow of old scrap until P_1. Above this price, it is economically profitable for producers to recover both the flow and the stock of old scrap, thus the supply curve above P_1 shows both the flow and the stock for old scrap.

Furthermore, the old scrap stock is constrained both in the short-run and in the long-run. In the short run, the availability of old scrap depends on the *flow* and the *stock* from the old scrap. In the long-run on the other hand, the availability of old scrap only depends on the *flow* of old scrap, since the *stock* will gradually deplete in the long-run. Thus, the constraint of the availability of old scrap is less in the long-run compared to the short-run. If the price increases above P_1 to P_2, the supply from the old scrap *stock* must be taken into account and at P_2 the production from old scraps equal Q_2^{SR} in the short-run. As stated above, the production from the old scrap *stock* will gradually deplete the *stock* and what is recycled in one period will not be available for recycling in the next period. Therefore, the price at P_2 will lead to a lower level of production at Q_2^{LR} in the long-run compared to the short-run.

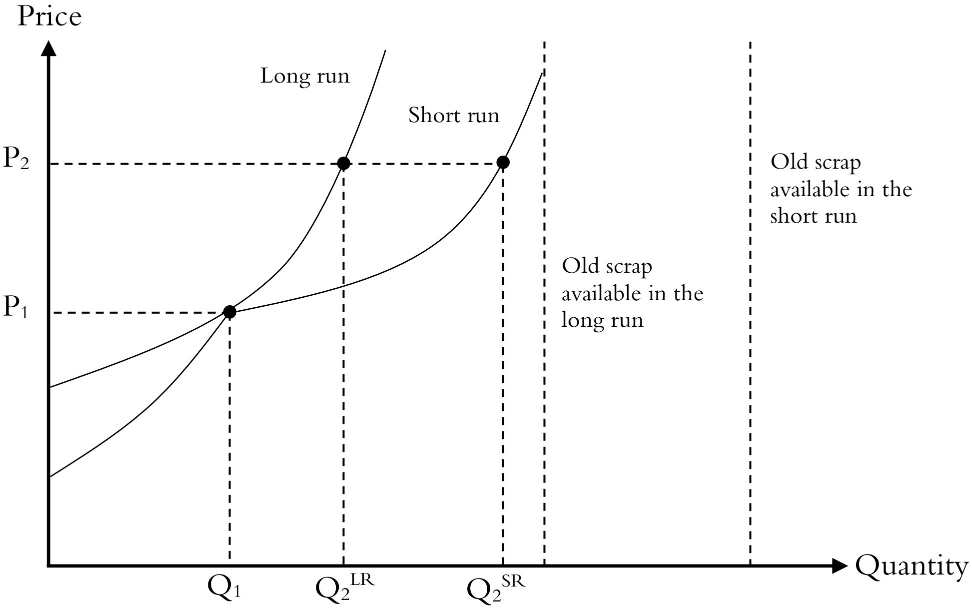

Figure 6: The supply curves for old metal scrap

4.3 Deriving the Supply of Secondary Metal from the Production Function

To produce different goods and services, the firm uses various production factors and different production technologies. To illustrate the relationship between the different production factors and output (Q), a production function can be specified. The production functions indicate the maximum production level the firm can obtain with the different production factors. If the price for one of the production factors will increase, the produced output will decrease based on the theory of the production function. In this thesis, the production factors that will transform copper scrap to secondary refined copper is assumed to be labor (L), electricity (E) and copper scrap (S). This assumption is based on earlier econometric studies that have analyzed the secondary metal supply with the production function as a basis in their model. For our purposes, the general production function can therefore be expressed as:

$$Q = f(L, E, S) \tag{1}$$

Dual to the production function, there exist a cost function that describes the underlying production technology. Based on the stated production function, the firm's total cost (TC) is expressed as follow:

$$TC = \alpha_0 L + \alpha_1 E + \alpha_2 S \tag{2}$$

where α indicates the unit cost for each of the production factors in the function. Since the aim of this study is to analyze the secondary copper supply, the supply function can be derived from the profit function. The profit is defined as the difference between the total revenue (TR) and the total cost (TC). The total revenue shows the total output that has been sold multiplied with the market price. Furthermore, it is assumed that the firm wants to maximize its profits and that it operates in a competitive market. Based on the above-mentioned production function, the profit function can be described as follow:

$$\pi = TR - TC = P \cdot q - TC = p \cdot f(L, E, S) - (\alpha_0 L + \alpha_1 E + \alpha_2 S) \tag{3}$$

The input prices in the profit function for a firm that operates in a competitive market are exogenous. Hence, the firm chooses the inputs to maximize their profit, and the output price and the prices for the inputs are fixed. From the profit function, the supply function can be derived. The Hoteling's lemma states that the supply function can be obtained by differentiating the profit function with respect to the output price. This is because a change in the output price will change the profits in proportion to how much the firm is producing. In other words, it equals the net supply for the firm. Hence, the supply function will be determined by the output price and the respective input prices.

This means that the supply function for secondary refined copper in this thesis is a function of the cost of labor, cost of energy and the scrap price.

$$Q = f(\alpha_0 L, \alpha_1 E, \alpha_2 S) \tag{4}$$

Furthermore, it can be argued that the copper supply will be influenced by more factors than just the underlying production technology. Earlier studies have identified that the supply for secondary copper will be affected by the gross domestic product (GDP). According to Rivera et al. (2021), GDP approximates the income growth rate and reflects the general demand for products and services. Therefore, this thesis will also include the gross domestic product as a factor that will affect the supply for secondary refined copper. Blomberg and Söderholm (2009) explain that primary metal often is as close substitutes to secondary metals. Hence the primary production level (PR) of the metal can influence the secondary supply for the material in question. Thus, this thesis will also include the primary production of refined copper in the supply for secondary refined copper. Based on the above-mentioned factors, in chapter 6, we specify the econometric models that form the basis of the empirical investigation.

CHAPTER 5
DATA

In this chapter, the chosen variables are presented and explained. These variables all form part of the supply function. For each of the variable, a discussion is presented based on its relevance for this study.

5.1 Data and variables

The variables that the regression analysis consists of are based on the above-mentioned theory about the economic supply of secondary metals, the production function, and economic factors that earlier studies have identified. The data that are used in this paper is panel data, which is defined as a data set based on many analysis units, at many points in time (e.g., Hasiao, 2003). The data that are used to investigate the supply for secondary refined copper cover nine countries in Europe over the period 1998-2019.

5.1.1 Secondary refined copper production

The secondary refined copper production level is the dependent variable in the regression model. Refined copper is the last stage in the copper production before it is used to produce various finished products to meet consumer demand (USGS, 2023). The term secondary refers to the refined copper that is produced by copper scrap. The data on secondary refined copper production are obtained from United States Geological Survey. In the data set it is not specified which scrap that is included in the secondary production. But according to several documents and articles that USGS have published, the majority of the home scrap that is generated back in the manufacturing of the primary metal, and does therefore not enter the market (e.g., Goonan, 2009; Papp, 2016). In addition, the secondary refined copper is measured in metric tons. The secondary refined copper production levels over the period for each of the countries are presented in Figure 7.

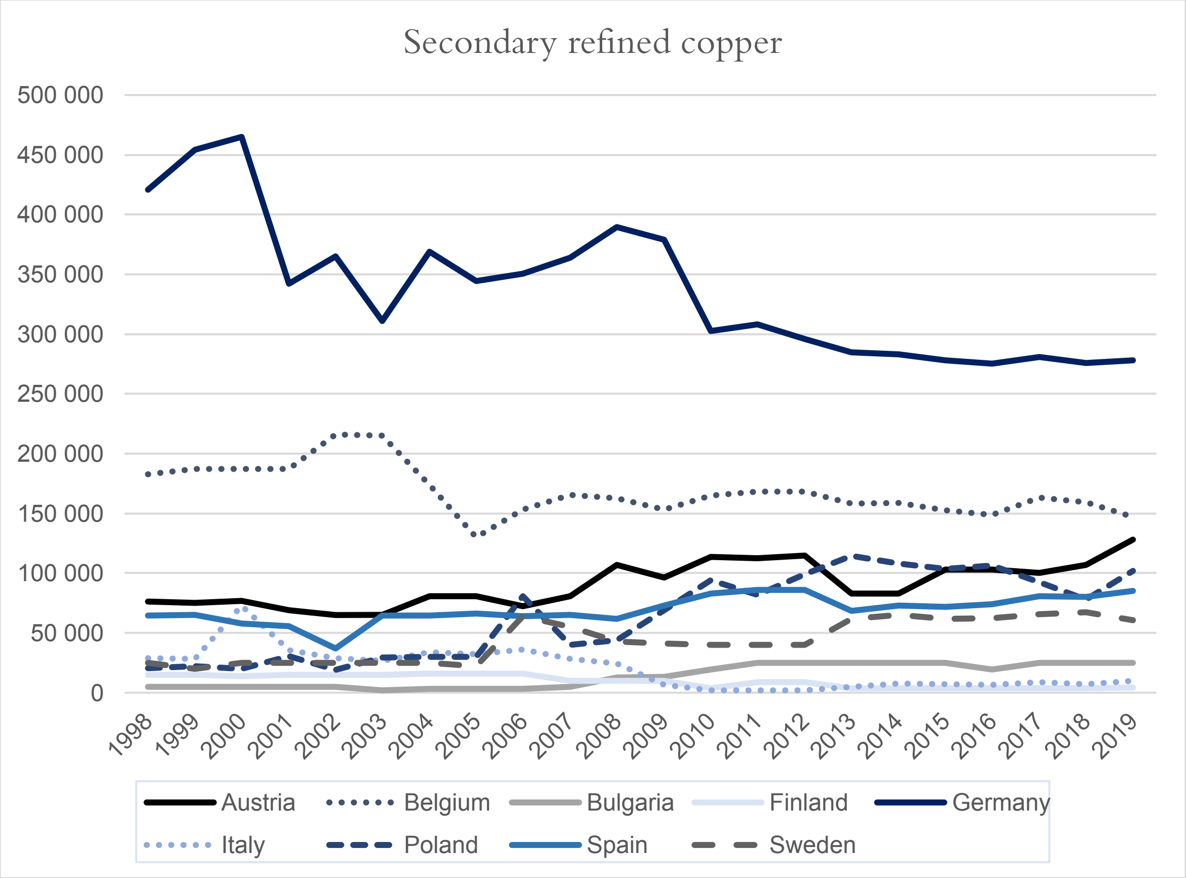

Figure 7: Secondary refined copper production (metric tons) in nine European countries

5.1.2 Gross domestic product per capita

The gross domestic product per capita is one of the independent variables in the analysis. According to earlier studies, GDP per capita is a variable that can influence the supply of raw material in general, including the supply for refined copper (e.g., Fu et al., 2017). Furthermore, the GDP per capita can also capture the labor cost in a country and the environmental attitudes and hence the waste management policies (e.g., Berglund and Söderholm, 2003). Therefore, in this study the GDP per capita will be used to measure different factors, such as income, environmental attitudes, and standard of living.[1] The data for the GDP per capita variable for the countries are obtained from the World Bank, and the data show the GDP per capita in US dollar.

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[1] According to SCB (2019), GDP per capita can be explained as a measurement of a country's wealth.

5.1.3 The price of copper scrap

The price level of copper scrap is another independent variable in the regression analysis. Tan (1987) stated the importance of the copper scrap in the supply function for secondary copper, this since the scrap is the basis for the production. Blomberg and Söderholm (2009) have also included the aluminum scrap price in their analysis. Similarly, the price level of copper scrap is an important component within the industry for secondary copper and will hence influence the produced amount of secondary copper. A higher scrap copper price would increase the cost of production of refined secondary copper, and thus a lower supply. According to Stena Recycling (2023), the price for scrap metals is determined by several factors such as the quality of the scrap, the amount, the global metal prices, and the transportation distance. In this analysis, data from U.S Bureau of labor statistics have been used, showing a producer price index of copper scrap prices between the studied years. This index measures the average change in the domestic producers selling prices over time. The index displays the average annual copper scrap selling prices in the U.S. Since the market for secondary copper is globally traded, these data are still relevant in this study. Moreover, given that the market for copper scrap is global, it is reasonable to assume that each country is a price taker, thus allowing us to treat the scrap prices as an exogenous variable.

5.1.4 Labor cost

The cost of labor is another independent variable in the regression analysis. Based on earlier studies, the supply of refined secondary copper will depend on the labor cost in the production (Tillväxtanalys, 2021a; Blomberg and Söderholm, 2009; Slade, 1980). If the labor is expensive, the production of secondary copper will be lower compared to if the labor cost is low. The data that will represent the labor cost for the countries are based on the annual Labor cost index that is obtained from Eurostat (Eurostat, 2023; Eurostat, 2009).

This shows the total expenditures that is borne by employers for employing staff. These expenditures are salaries, employers' social security contributions, employment taxes, which are seen as labor cost minus subsidies (if received). The quarterly Labor cost index is calculated by taking the total labor cost within a country divided with the total hours worked, thus ending up with the average hourly labor cost. Moreover, the annual Labor cost Index are calculated by taking the arithmetic mean of the quarterly values. In this data set, the index is weighted by the country, and the annual labor cost index is given in relation to the total labor cost for the whole country.

5.1.5 Primary refined copper production

The amount of primary refined copper in the chosen countries will be an independent variable in this analysis. According to earlier studies the secondary production comes from the product that was manufactured in the primary production (e.g., Blomberg and Söderholm, 2009; Tan 1987; Slade, 1970). This means that the secondary production will be determined by the primary production. Also, the availability of the virgin resource in the country is an important determinant in the production decision. If the amount of the virgin material is high within a country, it is likely to be a cheaper resource to use in the production in comparison to the secondary material. The secondary material will not be as economically attractive as the primary material to use, leading to the production of the secondary material in that country is likely to be lower.

If a country on the other hand is not rich in the primary resource and consumes more of the resource than it produces, it needs to import instead. In such countries, the primary material is not as easily accessible which can make secondary material a more optimal input in their production. This indicates the importance of considering a country's amount of the primary resource and the primary production which in this analysis is copper. The data come from the National minerals information center at USGS, and show the yearly amount of primary refined copper production measured in tons. Data on the primary refined copper production could be found in almost every studied country except for Austria and Italy. When investigating the industry for primary copper production and copper mines in those two countries, no information could be found. Hence the primary refined copper production in Austria and Italy are assumed to be zero over the period.

5.1.6 The price of electricity

According to previous literature the energy that is required to produce secondary copper is much less compared to producing primary copper from ores. Furthermore, the energy that both primary and secondary copper needs in the production process comes from different types of energy sources, for example heavy fuels, electricity, or water (Rankin, 2011). The most commonly used energy sources in the production of both primary and secondary copper are fuel and electricity (U. S. Congress, 1988). At the mining stage, the energy source that is used the most is fuel and in the other stages such as smelting and refining, electricity is used as the energy source (Rankin, 2011). Since the process of producing secondary copper does not include the mining stage the, for our purposes, most relevant energy source is electricity.

In this thesis the electricity price for the different countries will be used as an independent variable in the analysis. The data are obtained from Eurostat. Between the years 1998 and 2007, the data show the electricity price for industrial consumers, and between the years 2008 and 2019, the data show the electricity prices paid by non-household consumers (Eurostat, 2021a; Eurostat, 2021b). The electricity prices are reported twice a year and shows the average electricity price per kilowatt-hour in Euro. As the other price variables are measured in US Dollar, the exchange rate has been converted from Euro to US dollar. Furthermore, when measuring electricity prices, US cent is a more appropriate unit when analyzing kilo watt per hour. To obtain the yearly electricity price, the semesterly reported prices are summed and then divided by two. For some countries there are no reported data for certain periods, so when the country is missing both the semesterly prices, the reported average values of the entire European Union are used instead and when the country lacks one of the semesterly price, the one semesterly price for the country is used and then the semesterly price for the European Union is used.

5.2 Descriptive statistics

The descriptive statistics for the variables that were introduced above are presented in Table 1. For each of the variables, there are 198 observations.

Table 1: Descriptive statistics

Variable	Unit	Obs	Mean	Std. Dev.	Min	Max
Secondary production	Metric tons	198	90 795.96	102 208.7	2 000	465 000
Electricity price	US cent	198	8.9952	2.7826	3.22	16.1
Labor cost	Index	198	81.10253	100.0057	1.4	367.3
Primary production	Metric tons	198	189 651.2	151 507.6	0	530 000
GDP	US dollar	198	31 085.85	15 797.21	1 621.24	61 126.94
Price copper scrap	Index	198	299.1195	144.1768	97.7	528.69

Table 5.1 shows that there are big variances among the different variables that are used in this thesis. The secondary refined copper production levels span from 2 000 metric tons to 465 000 metric tons. The primary refined copper production level has an even higher variation since it reaches from 0 metric tons to 530 000 metric tons. The labor cost, gross domestic product and the copper scrap price also display high variations in terms of the minimum and maximum values.

5.3 Correlation

Correlation indicates the extent to which two variables are statistically linked to each other. To be able to analyze the correlation between the variables in the regression, a correlation matrix has been made (see Table 2). The correlation matrix can lead to three different results. There can be a positive relationship, a neutral relationship and lastly a negative relationship. A positive relationship indicates that the two variables move in the same direction and that therefore there is a linear relationship between the variables. A neutral relationship indicates that there is no relationship between the variables, while a negative relationship indicates that the variables tend to move in the opposite directions.

Table 2: Correlation matrix

	Secondary production	Electricity price	Labor cost	Copper scrap price	Primary production	GDP
Secondary production	1.0000					
Electricity price	0.2220	1.0000				
Labor cost	0.7688	0.2473	1.0000			
Copper scrap price	0.0065	0.7012	- 0.0075	1.0000		
Primary production	0.3837	0.0505	0.2408	0.0864	1.0000	
GDP	0.2261	0.3255	0.2013	0.4261	- 0.2732	1.0000

The first correlation matrix in Table 2 shows the correlation between the variables in their form. The correlation rates between most of the variables are not high, but with a few exceptions. The copper scrap price and the electricity price have a positive relationship with a correlation rate of 0.70, which is high when compared with the other correlation rates in the matrix. This is not unusual since both the copper scrap price and the electricity price will both be driven by the aggregate demand and the inflation rate. The labor cost and the secondary refined copper production also have a high positive correlation rate at 0.77.

In the second correlation matrix, in Table 3, the variables in their natural logarithmic form have been tested. As in Table 5.2, the correlation rates between the variables is not very high, with a few exceptions. The copper scrap price and the electricity price do also have a high correlation rate at 0.71 in their natural logarithmic form. Furthermore, the labor cost and the GDP per capita have a high positive correlation at 0.62.

Table 3: Correlation matrix logarithmic value

	Secondary production	Electricity price	Labor cost	Copper scrap price	Primary production	GDP
Secondary production	1.0000					
Electricity price	0.2680	1.0000				
Labor cost	0.5545	0.3129	1.0000			
Copper scrap price	0.0410	0.7076	0.0198	1.0000		
Primary production	0.1814	- 0.1643	-0.1479	0.0225	1.0000	
GDP	0.3530	0.3310	0.6176	0.3672	- 0.2054	1.0000

From the two correlation matrixes, it is shown that most of the variables do not have high correlations. One important exception is the GDP per capita and the labor cost in the second correlation where the variables is written in their natural logarithmic form. As stated above, this can be explained in the why that the GDP per capita is a type of income measure which indicates that if a country has a high GDP per capita their labor cost will also be high. Therefore, in the regression analysis, the labor cost index will be removed since the GDP per capita can measure the affect the labor cost has. Thus, the regression analysis will have two regressions including the labor cost and two regressions where the labor cost is removed to see if the result will change.

CHAPTER 6
METHOD

In this chapter, the chosen method is presented. The method is selected with the aim to get a deeper understanding on how different factors affect secondary copper production. To be able to answer this, a regression analysis will be used. The chapter introduces the econometric model specifications that the empirical analysis builds on.

6.1 Panel data estimation

Regression modelling is a useful tool when exploring a potential relationship between a dependent variable and several independent variables (Elshkaki et al., 2016). The multiple linear regression is an extended model of the simple linear regression that includes at least two explanatory variables. The regression model estimates the statistical significance level for each applied variable, both separately and combined. As stated before, our aim is to estimate the statistical relationship between the secondary copper production and the five independent variables. In this thesis, the Ordinary Least Squares regression model have been used to analyze how the independent variables will affect the dependent variable.

Since this analysis builds on the use of more than one independent variable, a multiple linear regression was performed. Still, the analysis uses the linear term in the regression since the explanatory variables are assumed to be clearly related to the response variable. The secondary refined copper production represents the dependent variable followed by GDP per capita, copper scrap prices, labor cost, primary refined copper production and electricity prices as the five independent variables. Also, the analysis has explored nine European countries over the period 1998-2019. For the multiple linear regression model, the general econometric expression is:

$$Y = \alpha + \beta_1 X_1 + \cdots + \beta_n X_n + u_i \tag{5}$$

In the above equation, the dependent variable appear as Y and the independent variables appears as X_i. In the equation, the terms α and β are the intercept and the slope terms, respectively. The intercept α shows what the dependent variable, Y, would be if the independent variables all would equal zero. Furthermore, the slope terms β shows how much the dependent variables will change if X_i increases with one unit. The variable u_i is the error term and shows the factors that may affect the dependent variable but that are not considered in the model (Kahane, 2007).

Furthermore, the data that are used in this thesis represent panel data. Panel data are data that consist of observations on the same n entities at two or more time periods t (Stock and Watson, 2020). Panel data can either be balanced or unbalanced, and in this thesis the panel data are balanced because there exist observations for each entity and each time period. When using panel data, the regression differs from the regular time-series and cross-section regression, in the way that panel data regression has a double subscript on its variable. The econometric expression for panel data regression is:

$$Y_{it} = \alpha + \beta_1 X_{it} + \cdots + \beta_n X_n + u_{it} \tag{6}$$

In the above equation, i denotes the studied entities, in our case countries. Moreover, t is the time period. Therefore, i represents the cross-section dimension and t denotes the time-series dimension. The variable u_{it} is the error term in the regression (Baltagi, 2005), and in panel data settings, one can decompose the error term based on the assumption of the presence of fixed effects (see below).

6.1.1 Fixed effects

When trying to explain a dependent variable through a regression analysis, there might be variables that are difficult to identify, observe and/or measure (Torres-Reyna, 2007). According to Stock and Watson (2020), there are two types of effects that can manage variables that are difficult to observe or are not available but are correlated with the dependent variable. Entity fixed effects imply variables that are the same over time but varies among entities, such as countries or areas. In the case of country-level data, this could constitute variables such as geography, climate, and institutional structure. Time fixed effects manage variables that do vary during time but are the same among entities.

In our context, examples could include changes in the global market for copper scrap, and geopolitical changes in the world economy.

In this study, multiple variables have been used to explain the level of secondary refined copper production by country in a certain time period. It is however difficult to identify every influencing factor across the countries and in the time-period that are being studied. Hence, by applying fixed affects into the analysis those (unobservable) variables can be captured. Since this analysis consists of variations both across time and among countries, the influencing factors that could not be captured within the chosen variables will both varies among entities and in time. Therefore, this study has used the combined entity and time fixed effect regression model. The econometric expression for the combined entity and time fixed effect regression model is:

$$Y_{it} = \alpha_i + \beta_1 X_{it} + \cdots + \beta_n X_{nt} + \lambda_t + u_i + e_{it} \tag{7}$$

where Y_{it} is the dependent variable for entity *i* at time period *t,* α_i is the unknown intercept for each entity, X_{it} is a vector of predictors for entity *i* at time *t,* λ_t is the unobservable time effects, u_{it} is the unobservable entity (country-specific) effects, and e_{it} is the overall error term (e.g., Torres-Reyna, 2007). When using the combined entity and time fixed effect regression model, the model eliminates the omitted variable bias that arise both from the unobservable variables that are the same (fixed) over time and the variables that are the same over the entities in each time period (Stock and Watson, 2020).

6.1.2 Goodness of fit test

In order to determine how well the data fits the selected models, two goodness of fit tests and measures were applied, the F-test and R-squared value. The F-test was performed to understand the overall significance for each model. The F-test tests the whole model by determining whether the null hypothesis can be rejected or not. If the F-value in the model is higher than the critical value of F, the null hypothesis can be rejected, meaning that at least one of the independent variables influences the dependent variable.

Furthermore, the regression model consists of three R-squared values (within, between and overall) since the regression model have used time and entity fixed effect. The R-squared values aims to clarify how much of the dependent variable that can be explained by the independent variables. The within value shows how much of the variation within countries that can be explained by the independent variable. The between value indicates how much of the between-country variation that is explained by the various independent variables, and the overall value shows the mean R-square value.

6.1.3 Method criticism

The analysis consists of secondary data only, which is beneficial in a way that most of the data can be obtained relatively easily from various statistical databases. There were however difficulties finding data regarding certain years. In addition, when searching for primary refined copper production no data could be found in two of countries. When data could not be found, a broader search was applied to clarify if the countries had any copper mining operations. Since no information of copper mining operations appeared, those countries are assumed to have zero primary refined copper production. Further, when the variables are written in their log-linear form in the models the countries with zero primary refined copper production will also be assumed to be zero. This is because when taking the logarithmic value for 0, the natural logarithm will be undefined.

When determining which variables to include in this regression analysis the relevance between the variables needed to be clarified (Nyman, 2014). Hence, the variables used in this analysis are based on what previous literature has shown to be relevant in the empirical context of secondary metal production. The regression analysis does not show causes or explain why the relationships look the way they do. The analysis only clarifies the statistical relationship (correlation) between the variables. To understand the causes of the relationship, other methods need to be used. There is no aim to further understand the causes of the relationship, hence, no other method needs to be applied in this study. However, in the discussion chapter, discussion about potential explanations of the causes is carried out based on previous literature.

6.2 Econometric specification

In this thesis, several model specifications have been tested and analyzed before choosing the models that gives the most reasonable result in econometric and theoretical terms. This has resulted in four different model specifications that have been estimated and chosen to explain what may affect the secondary refined copper production. The countries that are applied in the models are assumed to be price takers, meaning that the countries have no influence on the world prices for the variables. In the four different models, two of them consist of five independent variable and two of them consist of four different independent variables. In the latter models, the variable that explains the labor cost have been removed. Furthermore, the variables in two of the estimated models have been written in their natural logarithmic form to be able to directly estimate the elasticities of the variables. The initial regression model that this thesis has estimated is:

$$SRC_{it} = \alpha_i + \beta_1 GDP_{it} + \beta_2 PRC_{it} + \beta_3 PCS_{it} + \beta_4 LC_{it} + \beta_5 EC_{it} + \lambda_t + u_i + e_{it} \quad (8)$$

where SRC is the secondary refined copper production, GDP measures the gross domestic product per capita, PRC is the primary copper production, PCS indicates the copper scrap price, LC shows the labor cost, EC is the electricity price. Furthermore, the variables show the value of each variable for country *i* at time period *t*. As stated before, α_i is the intercept, λ_t is the unobservable time effect u_{it} is the unobservable entity effect, and e_{it} is the overall error term.

In the second regression model the labor cost variable has been removed from the regression, this because the variable for GDP per capita is likely to capture the labor cost. This is because when the income is high so is the labor cost for the waste management activities (Berglund and Söderholm, 2003). The second model is therefore expressed as follow:

$$SRC_{it} = \alpha_i + \beta_1 GDP_{it} + \beta_2 PRC_{it} + \beta_3 PCS_{it} + \beta_4 CS_{it} + \lambda_t + u_i + e_{it} \quad (9)$$

The third regression model that have been estimated uses the same independent variables as the main model, the difference being that the variables are now written in their natural logarithmic value. The third model can thus be expressed as follow:

$$\ln(SRC_{it}) = \alpha_i + \beta_1 \ln(GDP_{it}) + \beta_2 \ln(PRC_{it}) + \beta_3 \ln(PCS_{it}) + \beta_4 \ln(LC_{it}) + \beta_5 \ln(CS_{it}) + \lambda_t + u_i + e_{it} \quad (10)$$

where both the dependent variable and the independent variable is written in their natural logarithmic form. When interpreting the regression model a 1% change in the independent is associated with a β_n% change in the dependent variable (Stock and Watson, 2020). In other words, β_n is the elasticity of the dependent variable with respect to the independent variable. The fourth regression model uses the same variables as the second model but the with the variables written in their natural logarithmic form. The fourth model is specified as follow:

$$\ln(SRC_{it}) = \alpha_i + \beta_1 \ln(GDP_{it}) + \beta_2 \ln(PRC_{it}) + \beta_3 \ln(PCS_{it}) + \beta_4 \ln(CS_{it}) + \lambda_t + u_i + e_{it} \quad (11)$$

These four models have been chosen to analyze what factors that may affect the secondary copper production. The results from the four regression models are presented in the next chapter.

CHAPTER 7
EMPIRICAL RESULTS

In this chapter, the results from the regression analyses are presented and explained. The chapter starts with a goodness of fit test where each of the regression models are tested. Furthermore, the results for each of the four regression models are presented. The chapter aims to test if the different independent variables appear to influence secondary refined copper production.

7.1 Goodness of fit results

An F-test was performed to test the statistically significance level for the whole models. In our case, the critical value for F at a significance level at 5 % is 1.5173. The hypotheses are presented below, and the results are presented in Table 4.

$$H_0: \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$$
$$H_1: at\ least\ one\ of\ the\ \beta's \neq 0$$

Table 4: Results of F-test

	Model 1	Model 2	Model 3	Model 4
F-value	2.53	2.48	5.26	5.34
F-crit	1.5173	1.5173	1.5173	1.5173
Reject H_0	Yes	Yes	Yes	Yes

In Table 4, F-tests were performed for each regression model. The critical value of F is based on a five-percentage significance level. When comparing the F-values to the critical values of F, each F-value occurred as larger than the critical value. For these reasons, the null hypothesis could be rejected in all models. This implies that at least one independent variable in each model influences the dependent variable. In order to understand which independent variables that influence the dependent variable, the coefficients for each of the independent variables will be analyzed individually in the next section.

In Table 5, the R-squared values for the models are presented. The within value shows how much of the variation within countries that can be explained by the independent variable. The between value indicates how much of the between-country variation that is explained by the independent variables. The overall value is a weighted average between the two values.

Table 5: R-squared values

	Model 1	Model 2	Model 3	Model 4
R-squared overall	0.0102	0.2174	0.1675	0.1032
R-squared within	0.2781	0.2650	0.4451	0.4371
R-squared between	0.0050	0.2958	0.1712	0.0947

Among the four models, the second model appears to have the highest overall value where the variance for the dependent variable, secondary refined copper production, can be explained by 21.74 % of the independent variables. This is followed by the third model, where the independent variables explain as much as 16.75% of the observed variance in the dependent variable. In the fourth model, 10.32% of the variance for the dependent variable can be explained by the included independent variables. Lastly, the first model occurs to have the lowest overall value 1.02%, meaning that only 1% of the variance in the dependent variable is explained by the independent variables.

7.2 Regression results

7.2.1 Regression results – Base model

The results from the first regression model are presented in Table 6. In this regression model each variable appears as statistically significant at the 1% level, meaning that there is a 1% probability that there is a false correlation. This model shows that if the electricity price increases by one cent, the secondary refined copper production will increase with roughly 7 000 metric tons. Moreover, if the copper scrap price increases by one unit, the secondary refined copper production level will increase by about 200 tons. The primary production coefficient is negative, meaning that if the primary production increases by one ton, the secondary refined copper production will decrease by 0.31 tons. Likewise, the GDP per capita coefficient appears as negative as well; if GDP per capita increases with one dollar, the secondary refined copper production will decrease by roughly 3 tons. Lastly, if labor cost increase by one unit, the secondary refined copper production will increase with approximately 400 tons.

Table 6: Model 1 (Base model)

Variable	Coefficient	Standard error	T-value	Significance level
Constant	94 392.51	25 178.29	3.75	0.000***
Electricity price	6 907.206	1 639.799	4.21	0.000***
Copper scrap price	199.611	71.483	2.79	0.006***
Primary production	- 0.311	0.054	- 5.76	0.000***
GDP	-2.718	0.625	-4.35	0.000***
Labor cost	373.06	216.925	1.72	0.087*

Note: ***p<0.01, p**<0.05, p*<0.1.

7.2.2 Regression results – Modified model excluding the labor cost

The results of the modified regression model without labor cost are presented in Table 7. The results indicate that all the four independent variables are statistically significant.

Table 7: Model 2 (Modified model)

Variable	Coefficient	Standard error	T-value	Significance level
Constant	122 560.6	19 235.35	6.37	0.000***
Electricity price	6 402.098	1 622.821	3.95	0.000***
Copper scrap price	174.805	70.426	2.48	0.014**
Primary production	- 0.297	0.054	- 5.54	0.000***
GDP	- 2.369	0.595	- 3.98	0.000***

Note: ***p<0.01, p**<0.05, p*<0.1.

The electricity price, the primary production and the GDP per capita is statistically significant at the 1 % level, while the copper scrap price is significant at the 5 % level. The signs of the coefficients for the electricity price and the copper scrap price, respectively, are positive, and for the primary production and the gross domestic product the signs are negative. This indicates that if the electricity price increases by one cent, the secondary refined copper production increases about 6 400 ton. If the copper scrap price increases with one dollar, the secondary refined copper production increases with roughly 175 metrics tons. Furthermore, if the primary production increases by 1 ton, the secondary refined production decreases with approximately 0.3 ton. If the gross domestic product increases by US 1 dollar, the secondary refined production deceases about 2.4 ton.

7.2.3 Regression results – Base model using natural logarithms

The results for the initial model with variables in natural logarithmic form is presented in Table 8. The results indicates that three of the five independent variables are statistically significant, all at the 1 % significance level. The coefficients for the electricity price and the gross domestic product are positive, and for the copper scrap price, the coefficient is negative. This indicates if electricity price increases by 1 %, the secondary refined copper production will increase with 0.939%. If the copper scrap price increases by 1 %, the secondary refined copper will decrease by 1.468%. Lastly, if the GDP per capita increases by 1 %, the secondary refined copper production will increase by 2.015 %.

Table 8: Model 3 (Base model using natural logarithm)

Variable	Coefficient	Standard error	T-value	Significance level
Constant	- 5.431	2.364	- 2.30	0.023
Ln Electricity price	0.939	0.263	3.57	0.000***
Ln Copper scrap price	-1.468	0.390	- 3.76	0.000***
Ln Primary production	- 0.154	0.168	- 0.92	0.360
Ln GDP	2.015	0.566	3.56	0.000***
Ln Labor cost	0.882	0.575	1.53	0.127

Note: ***p<0.01, p**<0.05, p*<0.1.

7.2.3 Regression results – Modified model using natural logarithms

In Table 9, the regression model is written in log-linear form and the labor cost variable is excluded. In this regression model, three of the four included variables appear as statistically significant, all at the 1% level. The three statistically significant variables are the electricity price, the copper scrap price, and the GDP per capita. This means that if the electricity price increases by 1% the secondary refined copper production increases by 0.990%. The copper scrap price coefficient occurs as negative in the model, meaning that if the copper scrap price increases by 1% the secondary refined copper production will decrease by 1.877%. Finally, if the GDP per capita increases by 1%, the secondary refined copper production will increase by 2.718%.

Table 9: Model 4 (Modified model using natural logarithm)

Variable	Coefficient	Standard error	T-value	Significance level
Constant	- 7.589	1.908	- 3.98	0.000***
Ln Electricity price	0.990	0.262	3.78	0.000***
Ln Copper scrap price	-1.877	0.286	- 6.55	0.000***
Ln Primary production	- 0.111	0.166	- 0.67	0.504
Ln GDP	2.718	0.332	8.18	0.000***

Note: ***p<0.01, p**<0.05, p*<0.1.

7.3 Summary of results

The results from the four different regression model are summarized in Table 10. The result for the electricity price is positive and statistically significant in all models. The coefficients for the copper scrap price are also statistically significant in all models. this coefficient appears as positive when the variables is in their natural form, but when the variable is written in the natural logarithmic form, the coefficient appears as negative. The coefficient for the primary production is negative in all four models. In the models when the variable is written in the natural logarithmic form, the coefficients are not statistically significant. The GDP per capita coefficients are all statistically significant and negative in the models when the variables are in its natural form, and positive when it is written in natural logarithmic form. The coefficient for the labor cost is positive in all models where the variable is included, but only statistically significant in the model where the variables are written in their natural form. The third and fourth model is written in log-linear form, meaning that the changes in the variables are presented in percentage. Hence, these models can be used to analyze the supply elasticity. The supply elasticity measures how the supply of secondary refined copper is affected by changes in its input prices.

Furthermore, the results indicate that the secondary copper production level is relatively insensitive to changes in the input price. This argument is based on models 3 and 4 where the variables is in log-linear form. A one (1) percent increase in the electricity price will increase the supplied quantity by approximately 0.95 percent. This indicates that the supply is inelastic with respect to changes in the electricity price. If the copper scrap price increases with 1 percent, the supply for the secondary refined copper will decrease with roughly 1.5 percent. The supply will increase with about 2.5 percent if the GDP per capita increases with 1 percent. This means that the supply is elastic if the copper scrap price or the GDP per capita changes.

Table 10: Summary of regression models

	Constant	Electricity price	Copper scrap price	Primary production	GDP	Labor cost
Model 1	94 392.51*** (25 178.29)	6 907.206*** (1 639.799)	199.611*** (71.483)	- 0.311*** (0.054)	-2.718*** (0.625)	373.06* (216.925)
Model 2	122 560.6*** (19 235.35)	6 402.098*** (1 622.821)	174.805** (70.426)	- 0.297*** (0.054)	- 2.369*** (0.595)	-
Model 3	- 5.431 (2.364)	0.939*** (0.263)	-1.468*** (0.390)	- 0.154 (0.168)	2.015*** (0.566)	0.882 (0.575)
Model 4	-7.589*** (1.908)	0.990*** (0.262)	-1.877*** (0.286)	- 0.113 (0.166)	2.718*** (0.332)	-

CHAPTER 8
DISCUSSION

In this chapter, the results from the regression analysis are discussed in relation to the theoretical framework and the previous literature in this field.

8.1 The electricity price

The results from the four different regression models indicate that the coefficient for the electricity price is positive. This means when the electricity price increases by one (1) cent the secondary refined copper production will also increase. This result contradicts the results of previous literature. For instance, Blomberg and Söderholm (2009) did a study on the supply of the secondary aluminum production and their results indicate that the energy price has a negative effect on the supply of secondary aluminum. Worth noting is that the energy source that Blomberg and Söderholm used was the oil price, and in this study the electricity price has been used.

As stated in the literature review and in the theory chapter, the primary and secondary refined copper compete in the same market. However, the primary copper requires more energy in the production compared to the secondary copper. Since electricity occurs as a cost in the production, higher electricity prices will affect the total cost of the production. Furthermore, since the primary production is more electricity intense, increased prices could be argued to have a larger effect on the cost for the primary production compared to the secondary production. Since the primary and secondary copper are substitutes to each other, it will be more profitable to produce secondary copper compared to primary copper. Thus, while it can be expected that higher electricity prices will lead to a lower level of secondary copper production (due to higher input costs), the results in our analysis contradict this notion. One interpretation here is that our results likely capture a long-run effect of electricity prices, namely that for countries with refined copper production, higher electricity prices will tend to stimulate capacity expansions of secondary rather than primary production of refined copper.

8.2 Copper scrap price

The coefficients for copper scrap price vary depending on whether they are written in the log linear format or not. The coefficient is negative when it is written in log linear format and positive otherwise. The results imply that if copper scrap increases by one (1) unit the secondary refined copper production will increase. However, the coefficients that are written in the log linear form show that scrap price increases will decrease the secondary refined copper production.

These results tend to differ from earlier research. Blomberg and Söderholm (2009) studied the supply of the secondary aluminum production, and in their results, they discuss the importance the scrap prices have on the produced quantity, even though it is not a direct variable in their regression analysis. In the article, the authors use the scrap stock as an independent variable and states that the variable for the scrap stock measures an indirect effect of scrap cost when the scrap stock is changing. When the scrap stock increases over time, it should be less expensive for the producers to produce secondary metal since the availability of scrap is high. Even though the variable in this thesis uses the scrap price as an input cost, the same argument can be applied. Since the scrap price is an input cost for the producers, it will decrease the produced quantity due to the increasing production cost. Furthermore, according to Fu et al. (2017), the price for copper had a positive effect on the refined copper supply. However, these authors used the price for the refined primary copper as the price variable but stated that the correlation between secondary and primary prices is very high. The variable was also written in their natural format.

Since the results from the regression analysis show the effect on secondary refined copper production in the short run, a comparison between the theoretical framework of copper scrap can be made. As showed in the theoretical framework, the amount of available copper scrap will differ in the short run compared to the long run. Since the price of new scrap is relatively cheap in the short-run, the producers will not be affected that much by price changes for copper scrap compared to in the long-run. In the case of old scrap, the available quantity for production in the short run is larger compared in the long run, since the quantity includes both the flow and the stock of old scrap. This means that in the long run, when the quantity of old scrap is low, it will become more expensive for the producers since they can no longer produce the same amount as in the short run. The above argument shows that based on the theoretical framework, a price increase for copper scrap tends to affect the production in the long run more compared to in the short run. Since the results from the regression analysis in this thesis suggest a relatively low elasticity for the copper scrap price and shows the short run responses, the above discussion can be applied. Since, the thesis only consists of a period of 21 years, the result can therefore differ if the studied years increases and examines the long run changes.

Still, the copper scrap price is the cost for one of the input factors in the production function for the output of secondary refined copper. If the price for copper scrap increases by one unit, the total cost for secondary refined copper production will increase. Thus, when the total cost increases, the output is likely to decrease, ceteris paribus.

8.3 Primary refined copper production

The results from the regression models indicate that each coefficient for the primary refined copper production is negative. However, in the models where the variable is written in the natural logarithmic form, they appear as insignificant and significant when in their natural form. This result implies that when the primary production increases with one ton, the secondary refined copper will decrease. These results could be explained by primary and secondary copper being close substitutes, thus meaning that if the price increase for one product, the consumption for the other product will increase (and vice versa). However, in these results, only the production level is shown. It can be assumed that when the production for primary copper increases the average cost per unit decreases, since the fixed costs can be spread out across larger volumes. When the production cost decreases, the producer can offer a lower output price.

As primary and secondary copper are stated to be close to substitutes and compete in the same market, the reduced price for primary copper will decrease the consumption of secondary copper, which may further lead to decreased production of secondary copper. Moreover, a country's availability of a primary resource is likely to affect the decision regarding whether to use primary or secondary material in the production (Berglund and Söderholm, 2003a). If a country's access to the primary material is high, the primary material tends to be an economically more attractive option than the secondary material, which in this case is virgin copper. The countries that are rich in primary copper ore further tends to export the resource to countries who aren't as rich in copper. If a country's supply of primary copper isn't as high, they need to import the copper. In countries where the primary copper is not as easily accessible, the secondary copper can turn out to be a more economically input in their production.

8.4 GDP per capita

The variable for the gross domestic product per capita appears as negative in the models when the variable is written in their natural format and positive when the variable is written in the natural logarithmic form. In the previous literature that this thesis has discussed, the variable has only been analyzed in the natural logarithmic value. In Rivera et al. (2021), the gross domestic product appears as negative. Furthermore, in the study that Fu et al. (2017) did, the GDP appears as positive. The difference between the two studies is that Rivera et al. (2021) used GDP per capita and Fu et al. (2017) used the world GDP.

In comparison with the literature, the result in this thesis, is the same as the results that Fu et al. (2017), the variable for the gross domestic product appears as positive in log-linear form. As stated earlier in this thesis, the GDP per capita can be explained as a measurement of a country's wealth. A country's wealth reflects its standard of living and the quality of the society's various functions, such as well functioning institutions. Hence, when GDP per capita increases, it could be argued that institutions for waste management become developed or improved, and this could help increase the secondary refined copper production. On the other hand, GDP per capita captures various number of factors in our society, such as income, and when the income is high so is the cost of labor in the country.

Based on the results in this thesis, the secondary refined copper production will increase if the cost of labor increases, assuming that GDP per capita captures labor cost. This result is the opposite based on economic theory that suggest when an input price increases (e.g., labor cost) the production will decrease. It could also be argued that in countries with lower GDP per capita, the recycling value of copper is perceived to be higher. Since these countries cannot afford to miss out on the value that the copper scrap can contribute to if it is recycled. In countries with a higher GDP per capita, it can be assumed that the value of the copper scrap isn't as necessary in comparison with countries with a lower GDP per capita. Therefore, if the GDP per capita increases in a country, the marginal utility for each unit of recycled copper can be assumed to decrease, so that the secondary refined copper production decreases. Since the GDP per capita captures different factors, it can be argued that the secondary refined copper production will be affected differently when the GDP per capita changes depending on which aspect is used.

8.5 Labor cost

Due to a potential risk of the labor cost being captured by the gross domestic product, different regression analysis was performed with and without the variable for labor cost. The variable for labor cost was therefore included in two of the four regression models and showed to be statistically significant in the first model. The result from the regression analysis shows that the coefficient for the labor cost is positive, meaning that if the labor cost increases, the secondary refined copper production will increase. In comparison with Blomberg and Söderholm (2009) and Slade (1980) articles, their coefficient for labor cost is negative when the labor cost variables are in natural logarithmic form. The result in this thesis is also the opposite based on economic theory that suggest when the input prices increase, the output will decrease. On the other hand, increasing labor cost will increase the total production cost. When labor cost is higher it could potentially pressure firms into finding and developing new production technologies within secondary copper production. With new effective production technologies, the total output of secondary refined copper could perhaps increase.

CHAPTER 9
CONCLUSION AND FURTHER RESEARCH

This chapter compiles the results of the study, what the results contribute to and puts forward suggestions for further studies.

The aim of this study was to investigate the various factors that influence secondary refined copper production levels in nine European countries. To be able to analyze the secondary refined copper production, a supply function was derived from the production function. From the regression analysis, the following conclusion can be made.

In this thesis all the independent variable showed to be significant in at least one of the four models. However, only in the first and second model all the variables appeared as significant. Both models are performed in their natural form, the first model includes all five independent variables while the second model excludes labor cost. The results from the regression analysis confirms that the secondary refined copper production is affected by the five independent variables. In the third and fourth model where the variables were written in their natural logarithmic form, the labor cost and the primary production appeared as statistically insignificant.

As explained in the introduction and in the previous literatures, copper is a material that is important for the society in many aspects and the secondary copper supply will have an essential role in the future total copper supply. The need for an understanding on how different factors affects the secondary supply is therefore important. To increase the secondary supply for copper, one alternative is to investigate market intervention. It may be of interest to analyze how different policy instruments affect the supply of secondary refined copper. In this thesis, the following conclusion can be made on policy instruments by using the logarithmic value for the coefficient in the regression. The elasticity for the electricity price is relatively low. This means that if implementing a price-based policy to decrease the electricity cost which could perhaps increase the supply for secondary refined copper production, will have a modest effect on the supply for refined copper production. On the other hand, if implementing a policy to decrease the copper scrap price, such as a subsidy, it will have a greater effect on the secondary production for refined copper. Since the copper scrap appeared to be more sensitive to price changes compared to the electricity price.

This thesis has contributed to our knowledge within the copper recycling industry, how the market for the secondary copper works and what drives the supply for secondary refined copper. This knowledge is essential to meet the increasing demand for copper and furthermore manage climate change through the digitization and electrification transition. To get a deeper understanding on how the secondary refined copper production market works, additional research will be needed. In this thesis, there have been no attention on how much the scrap stock affects the production for refined copper. For instance, how a country's supply of copper is estimated to vary depending on how large assets of copper they hold in their infrastructure, and the long run effects of that. In addition, since the copper market is global there is a need for increased understanding about how the international trade between countries affect the production.

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