The Hague Centre for Strategic Studies

Futures for copper

Exploring plausible copper price scenarios and how to act on them

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The Hague Centre for Strategic Studies (HCSS)

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The Hague Centre for Strategic Studies (HCSS) seeks to advance international security in an era defined by geopolitical, technological and doctrinal transformation and new security risks. HCSS provides strategic analysis and offers concrete policy solutions to decision makers. HCSS serves as a strategic planning partner to governments, international organisations and the business community.

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Contents

Management summary

Currently, metals are at the heart of fierce competition worldwide. The growing populations in especially emerging economies put much stress on raw materials security. Among them is copper, which is a widely used metal with currently high prices. The high copper price leads to frequent reports about copper thefts. Besides the growth in demand from the emerging economies, the energy transition towards a more sustainable energy mix leads to this high price. This report is written especially for copper producers and users, as well as governmental actors in a European context, but may be interesting to any one aware of current mineral and metal scarcity issues.

HCSS, together with the Delft University of Technology, decided to publish this report in order to give insight in possible dynamics of the copper price and strategies to counteract undesirable dynamics. The research approach underlying this study, Exploratory System Dynamics Modelling and Analysis, makes it possible to systematically explore the effects of uncertainties surrounding this topic: Large sets of dynamic scenarios are generated and used to discover potential strategic options and test their robustness.

This report presents several plausible scenarios for the copper price related to the marginal costs of copper. These scenarios were generated by focusing on the structure and dynamics of the copper system under deep uncertainty. Examples of such deep uncertainties are the development of copper demand, prices of substitutes, the energy price, and the development of the copper ore grade. In these scenarios, besides understandable and stable price evolutions, heavy price volatility with periodic, crisis-like changes between high and low relative price levels, seem plausible. Exhaustion of all copper resources with these high prices does not seem likely, but a great reduction in copper use due to substitution is plausible. These are two distinct futures without a major role for copper.

In periods with low copper prices, copper producers, including recycling companies and deep sea mining companies, should ensure that their marginal costs of production are competitive with those of possible substitutes of copper. For copper users, flexibility regarding the material they use for the copper functionality is of key importance. There are also some strategic options for all actors in the copper system which may reduce potential undesirable behaviour of the copper price. Improving the collection rate of discarded products containing copper and the technical efficiency of the recycling process are such options. Building strategic reserves which are filled in times with low copper prices compared to the marginal costs and releasing these reserves in periods with high copper prices may further reduce price volatility and as such increase the availability of copper in periods of excessive demand.

1 Introduction

1.1 High copper prices

Frequently the Dutch media report about the theft of copper wire used by the Dutch railways: The word 'koperdief' (copper thief) has recently been added to the online version of the 'Grote Van Dale' due to the enormous rise in the use of the word in newspapers. It is also considered a growing problem, since the copper theft increased with 173% over the last year. The obvious reason for the rise in thefts is the high copper price of the last years.[1]

There seem to be two main causes for the high copper price: the energy transition towards a more sustainable mix of energy sources[2] and the growing demand for minerals in upcoming economies like China and India.[3] With the energy transition, a new energy mix and better fuel economy in cars, new material demands arise. For example, solar plants in the Sahara or offshore wind parks in the North Sea cannot function without an extended electricity transportation network, which requires enormous amounts of conductive material, like copper. Copper is, with its high conductivity, often the metal of first choice for electricity networks.[4] Another example is transportation: plug-in-hybrid-electric or hybrid-electric vehicles have a higher demand for copper, respectively over 70 and over 40 kg per car compared to around 25 kg per conventional car.[5]

Despite the fact that these major influences on the copper demand could be distinguished, it is uncertain how the demand will develop in the long term. Different views on the origins of the development of copper demand illustrate the deep uncertainty[6] existing in the copper system. In this report, a distinction is made between the terms copper market and copper system. The copper market covers the balance between copper supply and demand and the related copper price (in international dollar per metric ton). The copper system contains all geological, technical and economical aspects regarding copper and their mutual relations.

1.2 Copper supply and demand

Copper supply originates from two main sources, mining and recycling, also referred to as primary and secondary production.[7] Copper mining takes place on all continents, but Latin America, most notably Chile and Peru, account for over 40% of the global reserves,[8] while Chile accounted for around one third of the global mine production in 2009.[9] The smelter and refinery capacity is also heavily regionalised, since China produced around 24% of the global smelter output and a similar refinery output.[10]

The average relative part of the secondary copper supply, also called the Recycling Input Rate (RIR), is globally just over 30%, in Europe just over 40% and in Germany over 55%.[11] The RIR is mainly influenced by the collection of products at the end of their lifetime (EOL products) and the efficiency of the recycling process (Recycling Efficiency Rate or RER).

1.3 Exploring plausible dynamics

Deep uncertainties about the copper system result in a wide variety of plausible price dynamics. The exploration of these dynamics over time provides insight for designing specific strategies that counteract undesirable price dynamics. For that reason, a study was performed at Delft University of Technology using a novel method, Exploratory System Dynamics Modelling and Analysis,[12] which refers to the combination of System Dynamics modelling[13] and Exploratory Modelling and Analysis approach.[14] More information about the methodology and the models used here can be found in box I.

The goal of this study is to find plausible dynamic scenarios, especially for the copper price, but also for other important factors in the copper system. These scenarios are not predictions of the future price of copper,[15] they only sketch plausible futures. The scenarios can be used to develop robust and adaptive strategies to deal with the complex and uncertain copper market.

The copper price scenarios are linked to the marginal costs of copper production, since this relation will have an implication on the strategies both producers and consumers could choose given an occurring scenario. The term 'marginal costs' traditionally means in economics the costs that arise when one more unit of a good is produced. In this case, the marginal costs are the lowest costs at which producers are able to meet demand.

The drivers of the behaviour are coupled to the different scenarios to explain the dynamics of the system. In this way, some more light will be shed on the origins of the dynamic behaviour visible in the copper system. Finally, some potential strategic options are introduced which may have an effect on the copper systems behaviour and which could reduce potentially undesirable trends visible in the copper scenarios described here.

BOX I **EXPLORATORY MODELLING AND ANALYSIS WITH SYSTEM DYNAMICS (ESDMA)**

The study underlying this report was performed by using the Exploratory Modelling and Analysis or EMA approach.[16] By using this methodology, not only known elements in a system are taken as a starting point, but also parts of the system where experts disagree about the way different factors influence each other or the probability distribution of uncertain parameters. These types of uncertainties can be called deep uncertainties. Lempert, Popper and Bankes define deep uncertainty as those situations: 'where analysts do not know, or the parties to a decision cannot agree on, (1) the appropriate conceptual models that describe the relationships among the key driving forces that will shape the long-term future, (2) the probability distributions used to represent uncertainty about key variables and parameters in the mathematical representations of these conceptual models, and/or (3) how to value the desirability of alternative outcomes.'

By combining the effects of several deep uncertainties in a system with certainties, it is possible to 'explore' plausible dynamic scenarios that result from this combination. Thus, compared to traditional modelling approaches, uncertainties are far more important in this methodology. Any of the scenarios generated in this way, describes a future world that would exist if all assumptions about structure, parameter values and structural uncertainties were true. Due to the fact that the probability of the occurrence of a situation is unknown, it is not possible to tell how likely the scenarios are. These scenarios are dynamic, since they change over time. They thus bring our focus on the effects of changes in the copper price, rather than the consequences of certain static price levels in a certain year.

One way of performing EMA studies is by using System Dynamics models. This multi-method is currently under development at the Delft University of Technology.[17] System Dynamics in itself is a quantitative modelling method which was originally developed in the 1950's by professor Jay Forrester at the Massachusetts Institute of Technology and focuses on the stocks, flows (to, from, or between stocks) and feedback relations which are present in a system.[18] In the case of the copper system, a stock could be the stock of refined copper at the London Metal Exchange, a flow could be the production of primary copper, while a feedback loop could be the looped relation between price and demand: a higher price leads to a lower demand, while this lower demand leads to a higher price. The most famous publication in which System Dynamics was used is the report 'The Limits to Growth' by the Club of Rome.[19]

For this study, three different System Dynamics models were built to explore the consequences of deep uncertainties in the copper system.[20] These models correspond to different perspectives on the copper system. These perspectives were a global versus a regional view on supply, use and demand of copper, or a top down versus bottom up view on the use of and the related development of demand. Combinations of these two perspectives have led to the three models used.

By sampling over the different uncertainties in each model, a set of 9000 scenarios was generated for the dynamics of the copper price and several other indicators. These scenarios are visualised her over time, but without time or price values on the axes, since they may happen throughout time and in any magnitude. However, it should be noted that these trends envision long term effects in the copper system, placing their effects in the period of years to decades.

2 Plausible futures for copper

In this chapter some scenarios for the real price of copper will be presented in relation to the marginal costs of copper. In these scenarios the economic growth is averaged over the years, since in this study it was found that short term fluctuations in the economic growth only have a limited impact on the copper demand. The effects of short term price speculation have not been taken into consideration. Real price changes may therefore well be more capricious than those shown in this report.

2.1 Copper price scenarios

The first set of scenarios, which can be found in figure 1, occurs when the copper supply and demand are balanced, while the continuously higher price compared to the marginal costs assures that copper producers will succeed in achieving a steady profit. These scenarios show relatively gradual changes in prices over time. Mostly, they show an exponential growth, which can also be negative.

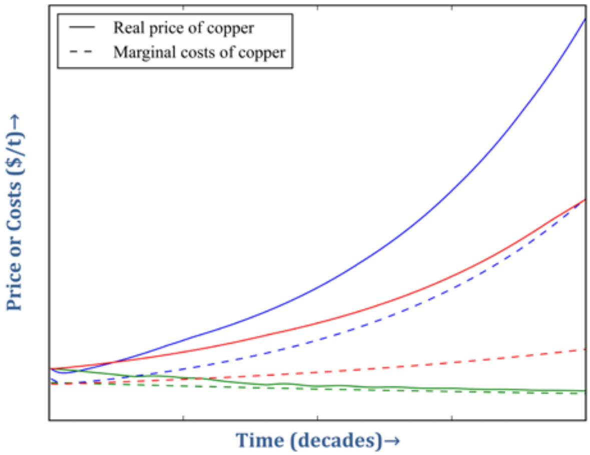


FIGURE 1: SCENARIOS WITH GRADUAL TRENDS FOR THE PRICE OF COPPER. EACH SCENARIO CORRESPONDS TO ONE COLOUR, WITH THE CORRESPONDING MARGINAL COSTS (DASHED) IN THE SAME COLOUR

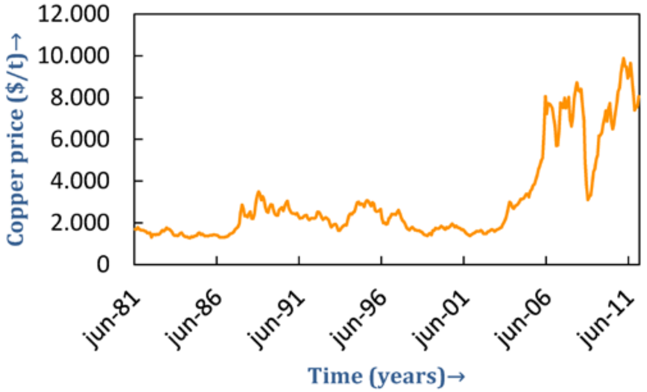
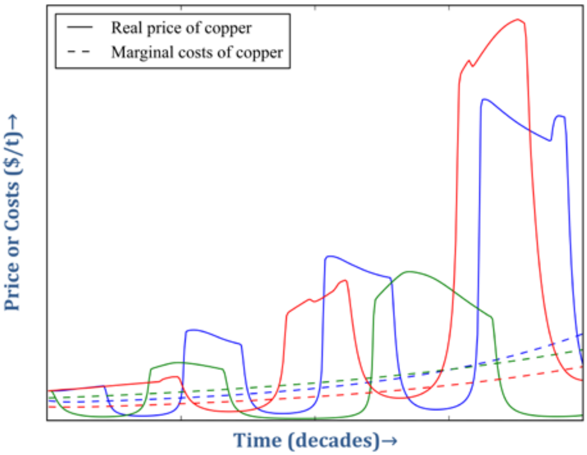


FIGURE 2: COPPER PRICE FROM JUNE 1981 - JANUARY 2012, SOURCE: INDEX MUNDI[21]

The marginal costs and their trend are heavily influenced by two deeply uncertain factors. The first factor is the decline of the ore grade. Despite possibilities in which either large new copper deposits are found, or a stabilised political situation in for example the Democratic Republic of Congo allows for mining copper at a higher ore grade, it does not seem very likely that the ore grades will increase. The ore grade is heavily linked to the amount of energy needed for producing copper. The energy price is therefore the second influential factor on the marginal costs. Energy prices may both rise and decline. As a consequence, the same applies to the marginal costs.

As the historical data of the last thirty years demonstrate (figure 2) in contrast to the gradual scenarios, the copper price has shown some fluctuation over the last 30 years. This volatility indicates a disbalance between supply and demand. In many scenarios generated in this study, similar trends are visible (figure 3). In these scenarios, the copper price fluctuates around the level of the marginal costs. High copper prices are related to the size and turnaround times of refined copper stocks, like the stocks of the London Metal Exchange. Short turnaround times of these stocks indicate a supply shortage and have as a consequence a high copper price.[22]



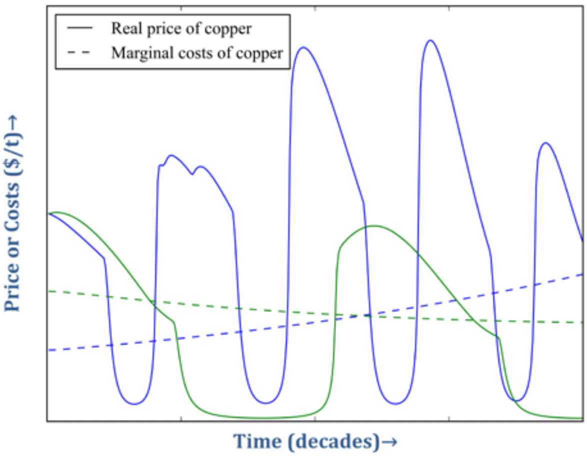


FIGURE 3: SCENARIOS WITH FLUCTUATING PRICES OF COPPER. THE CORRESPONDING MARGINAL COSTS ARE DASHED AND IN THE SAME COLOUR

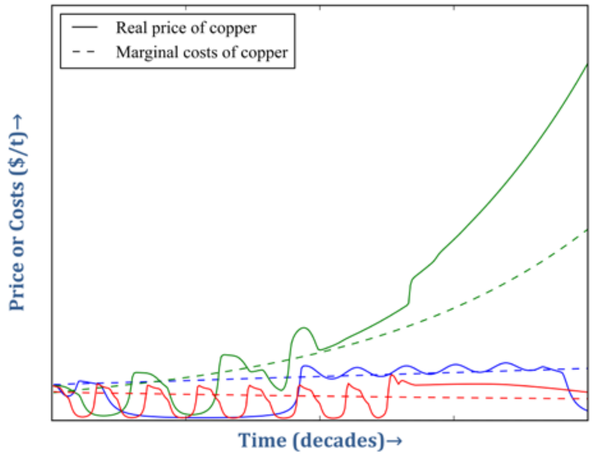


FIGURE 4: SOME NON-TYPICAL SCENARIOS FOR THE COPPER PRICE. THE CORRESPONDING MARGINAL COSTS ARE DASHED AND IN THE SAME COLOUR

These volatile copper prices often show block wave behaviour, where periods with relatively stable high price alternate with low prices. In the next cycle, the relative difference between the marginal costs and the price may increases, stays stable or decreases. This indicates that the disbalance between supply and demand is also subject to change. This effect occurs even more strongly in the scenarios in figure 4. In this figure, it is visible that oscillating behaviour could change (without policy changes) into different types of behaviour.

2.2 Drivers of behaviours

To get more insight in the dynamics behind these price fluctuations, it is important to think about the way in which demand is formed. The change in demand could be related to both the amount of wealth people have and their related copper use[23] or the uses of copper and their respective growth.[24] This could be called an intrinsic demand for copper in a particular situation. In a way, the intrinsic demand should be seen as demand for the functionalities of copper.

For these functionalities, substitutes exist. Examples of substitutes for copper are aluminium for copper wiring (especially medium and high voltage), plastic for copper water piping and glass fibre for telecommunication lines. These substitutes are not necessarily as effective as copper.[25] Substitution therefore takes place at a copper price level or threshold value related to the price of the substitute, the amount of substitute needed for replacing the original copper use and the effectiveness of the substitute. However, this change in copper demand does not occur instantaneously when the threshold price is reached. Rather, it is subject to short and long term effects. Some reasons for this may be either because users are accustomed to the use of copper and are reluctant to change, or because regulation and permits do not allow using a different material. In a period with copper prices below the substitution threshold, this effect may also be reversed, causing 're-substitution' of the substitute with copper. Extensive substitution may however eventually lead to availability of copper far below what would be desirable, since low prices due to heavy substitution have a negative effect on the profitability of copper production.

The consumers' direct reaction to the price may be another influence on the price, also subject to short and long term influences. Low prices may cause additional uses for copper to be found, while high prices may lead to a lower demand because these extra, non-essential copper uses fall away or because some copper use is postponed. This and the other factors have a profound impact on the actual demand for copper at a certain time and for a certain price, besides the extra effects that speculation may have on the copper prices.

The supply for copper reacts to copper demand through its effect on the copper price. However, long term influences play an important role here. In the case of a period with prices higher than the marginal costs of copper, primary copper producers (mining companies) try to create new copper mining capacity, but it takes time due to develop a mine, e.g. due to reserve classifications, permit terms and building efforts. Traditionally, this delay is assumed to be around 10 years. The exact period is however dependant on local conditions. For secondary copper production, or recycling, roughly the same applies.

The combinations of all these factors make that a balance between copper supply and demand is difficult to achieve. The simultaneous reactions to substitution, price, primary and secondary copper supply make that overshoots easily occur.

2.3 Reactions of other factors

The price dynamics from these scenarios also have an influence on other important performance indicators of the copper system. When the copper price increases further, or even when periods of high and low prices alternate, while the prices of substitutes do not increase in the same amount, it is likely that copper consumption gradually decreases over the coming decades.

Copper does not degrade when recycled; therefore one of the interesting performance indicators in the copper system is the Recycling Input Rate (RIR).[26] This rate is defined as the part of secondary production as a total of the refined copper production. Copper recycling can be split largely into two categories: recycling of primary scrap (losses during production) and recycling of secondary scrap (end-of-life products). The availability of primary scrap is linked directly to the production of copper products. Due to the long average lifetime of copper uses – around 8 years for electro motors, around 80 years for water treatment[27] – the secondary scrap flow is related to historic copper consumption of years to decades ago. An increased consumption of copper will consequently lead to a lower RIR, if the recycling process efficiency and collection rate of end-of-life products does not increase. With a decreasing consumption, the RIR will most likely increase and could be accountable for a considerably larger part of the refined copper supply than presently the case.

The dynamics just described will not lead to the exhaustion of copper resources, since if the copper market 'decides' that copper is too expensive and demand is reduced, this could lead to reduction in mining capacities, but not necessarily to a reduction in the size of the reserves. This way, the often used number of 'years left in mining',[28] is counter intuitively linked to copper demand. Dynamically, a low number of years left, which is often calculated by taking the reserves and dividing them by the production, or by taking constant (or slow growing reserves) and assuming constant growth for the production, may indicate production growth, while a high number of years left, may indicate production decline. Either way, this does not indicate scarcity. High prices, however, do.
A better definition for exhaustion relates to the demand side. When prices of a commodity reach a level at which practically all use is substituted or abandoned, one may consider the *use* of the metal exhausted. This is a plausible scenario for the coming decades.

3 How to react to these scenarios

When all scenarios are taken into consideration, as well as the fact that the future is fundamentally uncertain, it is interesting to explore what stakeholder actions, either by copper producers or by copper consumers could be taken to counter potentially undesirable dynamics. The next sections discuss several options for actors in the copper system to face the deeply uncertain future.

Many scenarios (especially those visible in figure 3 and 4) showed price trends alternating between periods with high and low prices, which are separated by short crisis-like situations in which the copper price rises or declines sharply. For producers and consumers of copper, it is important to remain competitive even under changing conditions. A robust strategy for the producers is to operate at marginal costs which are near the threshold value for the substitutes of copper. This will allow them to sell their products even when other producers are losing market share due to substitution.

Copper consumers should try to be flexible and able the switch between the use of copper and its substitutes, which means substitution, but also re-substitution. Consequently, the system could be able to react faster to the ever changing environment. This would dampen the oscillatory behaviour of the price.

The development of deep sea copper mining is likely to have a marginal effect on reducing the price fluctuations. It is however a method of expanding the availability of copper, although it does not seem likely that the level of output of conventional onshore copper mining will even be met. Considering the profitability of deep sea copper mining, it should also be noted that the real competition does not come from other copper producers, but from potential copper substitutes. The costs of substitutes could heavily influence the demand and price of copper, and should be taken seriously as an indicator for the long term profitability of copper.

NR	NAME	GOAL
1	Recycling: collection rate	Improving the collection rate copper products
2	Recycling: efficiency	Improving the efficiency of the recycling process
3	Strategic reserve	Building strategic reserves for copper by counter-cyclical investments
4	Cheaper substitutes	Making substitutes cheaper
5	Encouraged substitution	Encouraging substitution of copper
6	Deep sea investments	Lowering the marginal costs deep sea mining

TABLE 1: STRATEGIC OPTIONS FOR THE COPPER SYSTEM. THE FIRST AND SECOND RECYCLING POLICIES TOGETHER FORM THE 'RECYCLING POLICIES' AND THESE POLICIES TOGETHER WITH THE STRATEGIC RESERVE POLICY FORM THE 'STRATEGIC RECYCLING POLICIES'.

In this study, several strategic options which could counter undesirable behaviour of the price in the copper system (table 1, description in box II) have been modelled and tailored from a European perspective. The effects of the recycling policies, the strategic recycling policies and all policies combined are visualised in relation to the original scenarios.

BOX II **STRATEGIC OPTIONS** FOR COUNTERING UNDESIRABLE DYNAMICS OF THE COPPER PRICE

Recycling strategies

Recycling affect on the availability of copper in two ways. Firstly, a higher recycling input rate increases the overall availability of copper, thus lowering copper market prices. Since the recycled material becomes available on locally, it may also have a positive impact on the security of supply of copper.

Collection rate

Products first need to be collected, before they can be recycled. Since the total recycling input in a stable market can never be higher than the collection rate of end-of-life products, having a high collection rate is essential for effective recycling. In this analysis, it is assumed that the collection rate of copper products will increase over a decade to 95% collection of all end-of-life products. This strategic option is a political choice to stimulate collection of old products containing copper.

Recycling efficiency

After the collection, the recycling process starts. This is a technological process in which the products are separated, pre-treated and finally material is being recovered. In this analysis, the recycling process is made more efficient up to a total efficiency of 95%.

Strategic reserves

When security of supply is not guaranteed, building strategic reserves may be a good choice. Usually, this choice is made during periods of scarcity or high prices. It would be better to build strategic reserves when shortages are to be expected, but are not present yet. In the case of volatile price behaviour with alternating low and high prices (compare Figure 2 with Figure 3), building reserves should happen in periods when prices are low, ensuring availability of the metal in periods with demand exceeding supply. In the analysis, strategic reserves are built when copper prices are below marginal costs, and are used when the copper prices are above marginal costs.

Substitution strategies

Cheaper substitutes

Reasons for not switching to substitutes for copper are substitute prices and the effectiveness of the substitute in replacing copper. The combination of these two factors determines the substitution threshold. The current stress on the copper market could be reduced by a structural reduction in the costs of substitutes, which would result in a structurally lower substitution threshold.

Encouraged substitution

Security of supply is a major issue for scarce metals like copper. Substitution of copper demand for substitutes which are less scarce may seem a sensible solution. Aluminium is in the case of copper transmission lines a good example of such a substitute. Therefore, national governments may try to encourage local copper consumers to switch to more abundantly available substitutes for copper. This could have a positive influence on the security of supply for these consumers.

Deep sea investments

While conventional onshore copper mining has a long tradition, deep sea copper mining is of potentially interesting. Presently, one tangible project is under development near Papua New Guinea for mining copper and gold.[29] Deep sea mining could well increase the availability of copper. In this strategy, technological investments would focus on cost reductions in deep sea mining, making it more feasible.

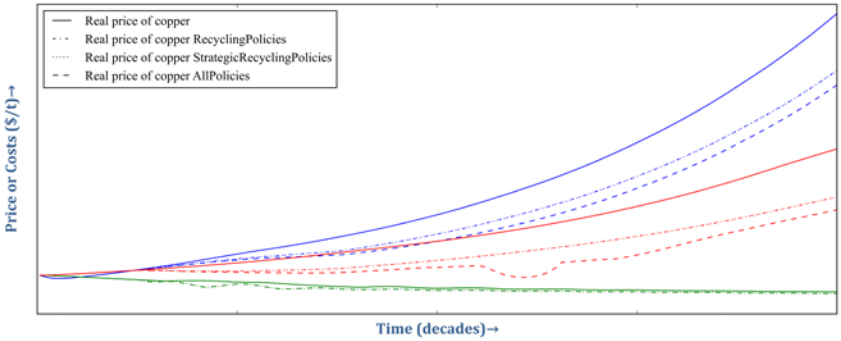


FIGURE 5: SCENARIOS WITH GRADUAL TRENDS WITH POLICY OPTIONS

A possibly effective way to reduce high prices or fast crisis-like changes between periods of low and high copper prices, would be to make the different stages in the recycling process more effective, which would increase the percentage of recycled (or secondary) copper available. Copper recycling starts with the collection of old, discarded products which contain copper. Examples may be old electrical or electronic equipment, cars, and old electricity transmission lines. From these collected goods the valuable materials, like copper, are then reprocessed. This happens in different stages, all at a specific efficiency. The product of all these elements in the recycling process makes that the total efficiency can never be higher than the lowest efficiency of either one of the process stages and the collection. In short, this makes it relatively hard to reach a high recycling input rate.

The effects of the recycling policies on the gradual scenarios from figure 1 are a reduction in price (figure 5), since more copper will become available, while the effectiveness of this measure depends on the original recycling efficiency. The overall behaviour of these scenarios is generally not affected by the implementation of these strategic options, but in cases with fluctuating prices, the speed with which the price changes as well as the price difference, may well be reduced (figure 6, 7 and 8).

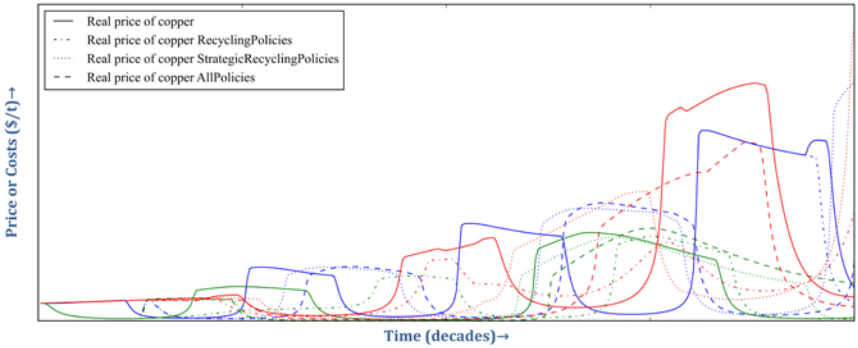


FIGURE 6: SCENARIOS WITH FLUCTUATING PRICES WITH POLICY OPTIONS

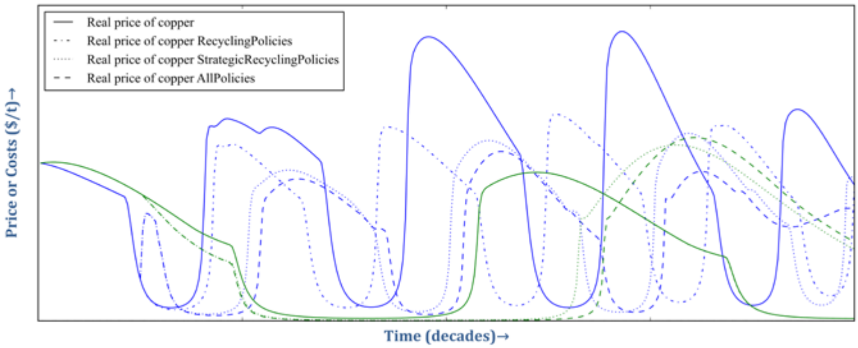


FIGURE 7: SCENARIOS WITH FLUCTUATING PRICES WITH POLICY OPTIONS

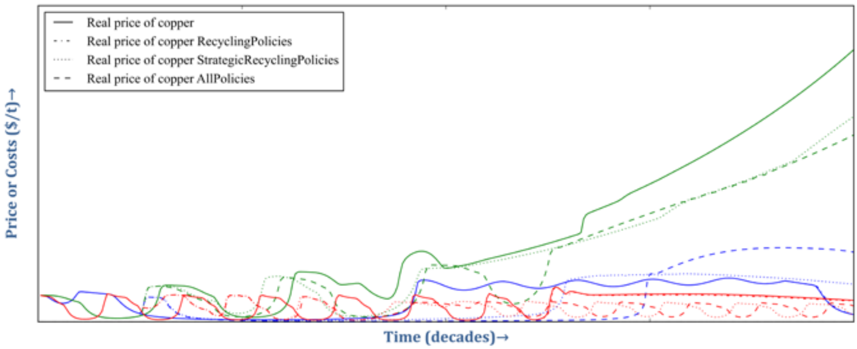


FIGURE 8: NON TYPICAL SCENARIOS WITH POLICY OPTIONS

Another effective policy option is to build and use strategic copper reserves. To make strategic reserves functional, counter cyclic investments in these reserves are essential. Strategic copper reserves could be built when the price is below the marginal costs. The preferred size of the reserves should be linked to the use of copper of the reserve commissioning actor. Use of copper in the strategic reserves occurs here when the price of the commodity is well over the marginal costs. When normal economics apply, periods with prices higher than the marginal costs correspond with times of scarcity. This approach thus reduces the scarcity for as long as the strategic reserves last.

The effectiveness of the strategic reserves policy is of course limited when the prices are continuously above the marginal costs, as figure 5 demonstrates. However, in scenarios with fluctuating prices this policy is more effective. When comparing it for instance to the effects of the recycling policies alone in figure 7, it becomes clear that the strategic reserves policy decreases oscillatory behaviour. Another potentially undesirable situation would be a copper price considerably lower than the marginal costs would also be a potentially undesirable situation, since this will make it difficult for copper producers to maintain their output. Investing in strategic reserves in these moments would also decrease potential risks on the supply side, since at periods with demand above supply, more copper will be available. This is demonstrated in figure 7 and 8.

A policy measure that is not effective in reducing price volatility or the price level as such is the reduction in marginal costs of deep sea mining. This is explained by the fact that investing in deep sea mining does not reduce the instability of the system. This does not mean however that it is unwise to invest in deep sea mining of copper. When the marginal costs of the deep sea copper are competitive with regard to possible substitutes, there is a plausible future for this production method.

There are many more options available to counter undesirable scenarios in the copper system. Adaptive policies could be one way of improving the policy design. In adaptive policies, the behaviour of the policy is adjusted in response to the behaviour of the system. The strategic reserves policy just described is a simple form of such a policy, since the decision to fill or use the reserve depends on system indicators.

Trying to find early warning indicators for undesirable system behaviour, could be another way of coming to more effective strategies. The research method applied for this study (see box I) could be used to find these indicators. By using these indicators as triggers for policy implementation, or by explaining them to both copper producers and consumers, more robust strategic options could be developed which allow a responsible and sustainable use of copper in the future.

Conclusions

In this report some scenarios are presented for possible dynamics in the copper system. These scenarios indicate that despite the present strong rise in demand the copper price may be very volatile, besides the possibility of a rather stable growth of the copper price in the coming decades.

In the case of price fluctuations, periods with prices well above the marginal production costs may alternate periods with prices well below this level, while between these rather stable periods, copper prices rise or fall sharply. It is therefore of vital importance for copper producers and consumers to have insight in the marginal costs related to copper production, since these produce insight in the current price level and how to react on it.

All the possible origins of scenarios were generated from the complex structure of the copper system and existing deep uncertainties, including the development of demand and the development of the ore grade, and deeply uncertain external factors, like the development of the energy price and the prices of substitutes. The high marginal costs for copper could very well lead to a decrease in copper demand in the coming decades, if copper is being substituted by other materials with similar functionalities.

There are several options for counter acting undesirable scenarios:

1. Actors in demand of copper should be able to quickly react to the situation, allowing flexible changes to materials that could substitute the functionality of copper. For copper producers, this means that they should be able to compete with the substitutes of copper, and not so much their competitors in the copper market;
2. Increasing the collection rate of end-of-life copper products and (further) improving the efficiency of the technical recycling process would decrease potentially undesirable behaviour in the copper system are. It would

substantially increase the availability of the metal and reduce the severity of price fluctuations;

3 The wise use of strategic reserves in particular in combination with these recycling policies is another measure that could reduce price volatility. When the copper price lies below the marginal costs of copper, strategic reserves should be built. These reserves should be used as soon as the price rises above a certain level relative to the marginal costs;
4 Investing in deep sea mining will not necessarily reduce the price volatility in the copper market, but may be an option when marginal costs become competitive with possible substitutes.

While instability in the copper system may lead to severe copper price fluctuations or high copper prices in the coming decades, implementing robust policy measures may lead to both responsible and sustainable copper use. The strategic options just presented do not eliminate all possible undesirable scenarios for the copper price. Trying to find more options that emphasize adaptation to the situation, possibly with regard to early warning indicators in the system for undesirable (price) behaviour, would help in that respect. This should be further investigated.

Besides the fact that the scenarios in this report may seem plausible, they do not contain any prediction about the future. At best, they are simplification of copper system and the copper price dynamics. In any way it can be concluded however, that even when physical exhaustion of copper may seem unlikely, careless use now may well lead to lower availability in the future.

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