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# Development of Sustainable Mining Strategies in Chile with a Regionalized National Model

## Project introduction and overview.

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# Impressum

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# 1 INTRODUCTION

The research project “Development of sustainable strategies in the Chilean mining sector through a regionalized national model” inquires the socio-economic impacts of copper on the Chilean economy. The project is government-funded by the BMBF[1] and supports the cooperation and exchange in knowledge between the Chilean team of Prof. Dr. Aroca and the GWS, a German company for empirical economic research. In September 2016, the project started and it is planned for a term of three years.

Initially this discussion paper will introduce the joint research project and its question of interest. Afterwards basic information of Chile is given, this also includes a short summary about its economic history. Then the economic aspects of the mining sector will be presented and new economic, environmental and social challenges the Latin American country is facing will be discussed. The conclusion and the main results of this discussion paper are presented in the final section.

# 2 PROJECT “DEVELOPMENT OF SUSTAINABLE STRATEGIES IN THE CHILEAN MINING SECTOR THROUGH A REGIONALIZED NATIONAL MODEL”

## 2.1 QUESTION OF INTEREST

Chile is the world leader for copper production. It has the largest stock of copper with almost 30 % of worldwide copper reserves. In 2015, the mining sector still accounts for around 10 % of Chile’s GDP, originates half of the exports and represents 30 % of all investments in the country (Comelli & Pérez Ruiz 2016: p. 4). Thereby the copper production represents one of the main pillars in Chilean economy. Being export-oriented Chile’s economic growth and welfare is highly dependent on other countries that tend to trade with the Latin American state. The most important customer countries are located in Asia, especially China, Japan and South Korea have a great demand for copper. Booms and busts in these national economies can involve copper prices moving by up to 80 % (IMF: 2016: p. 1). The demand and the world price for copper have an impact on the share of added value in the country: In 2003, the added value was at 8 %, four years later, in 2007, it increased to 22 %. Latest developments of a widespread view that low copper prices will persist, have affected expectations and decreased investments.

In addition to impacts of international copper demand and price development, the copper production is facing new challenges: A lower copper grade increases production costs and lowers profits. To maintain the level of production the demand for water, energy and labor force will increase. This also means a further decline of acceptance of the affected popu-

[1] German Federal Ministry of Education and Research

lation. Hence a lot of mines are located in regions where water already is a scarce resource. Furthermore a higher use of water has an impact on Chile's biodiversity. The mining sector is one of the most energy-intensive industries: It consumes around 35 % of the electric generation. According to studies an increase by 60 % of energy consumption in 2025 is forecasted (Cerda 2015: p. 12). The state's electricity supply is subject to considerable risk associated with adverse weather conditions, given its reliance on hydro-electric plants and the recurrence of cuts from international energy suppliers like Argentina. Another problem is that only a small revenue remains in mining regions. According to the Chilean central bank 90 % of value added goes to investors mainly based in foreign countries (Cochilco 2015: p. 62-63).

All in all the global economic development has a great impact on Chilean prosperity. An emerging decline of the copper production increases the vulnerability of its economy. In addition copper operations have significant environmental and social implications. The interest of the presented project is to evaluate the magnitude of the vulnerability of the Chilean economy medium- and long-termed. Hence copper is a non-renewable resource. Copper-related regions, like Antofagasta, are facing mentioned challenges. The mining sector needs to become more adaptable to global competition and to changing global economic circumstances. Consequently the Chilean economy must be capable to react to short-term shocks and to long-term trends.

## 2.2 OBJECTIVES

The proposition of the project focuses on a sustainable use of the natural commodity copper. In the center of attention are economic-social aspects for a sustainable development in the Chilean copper mining sector. A macro-economic forecast and simulation model will help policy-makers to identify opportunities for actions. Using this model increases the capacity of adjustment to external changes and to economic, environmental and social challenges.

Results should be integrated during the process of decision-making of correspondent actors, because they can help finding a solution. Furthermore relevant issues will be presented and discussed in target group oriented workshops with stakeholders.

In addition the forecast and simulation model can be transferred to other countries facing similar challenges.

## 2.3 METHODS

The project is organized in three work packages. First of all an econometric input-output-model will be developed for Chile, in particular addressing the mining sector and the copper production within a macroeconomic context on national level. This model helps making statements about economic development. In a second work package the forecast and simulation model will be expanded on Chiles 15 regions. Based on that that the different socio-economic impacts of the regions can be measured, hence not all regions are linked equally to the mining sector. Results of the second working package are of particularly interest to the survey of added value. In the last sequence of work, scenario simulations will be performed both on national and on international level. At current stage, three simu-

lations will be run on national level, addressing (i) taxes of copper and its effect on investment, (ii) energy consumption and costs as well as (iii) water consumptions and costs. The impacts of increased or decreased investments or costs can be measured. Results will contribute to economic recommendations of action that will help to create a more sustainable copper production in the mining sector.

Based on its clearness, objectivity, comparability and systematic quantitative methods, it offers more advantages than qualitative methods. The chosen quantitative method in this project is a macro-econometric input-output-model: Input-output-models are based on input-output-tables that represent the independencies between different branches of a national economy. They can show separately the direct, indirect and induced effects that are an important aspect for the project.

### 2.4 STATE OF THE ART

Although copper is a limited and non-renewable resource which has a great importance to Chile's economy, Chilean research institutions do not focus on quantifying the economic impact of copper on Chile's economy. There are only a few economic analyses existing in Chile with a focus on sectors and on regions. Equilibrium models (Chumacero & Schmidt-Hebbel 2005, Banco Central de Chile 2003) which evaluate taken measures in financial and economic policies do not put a specific focus on the copper production. Only Fuentes & Garcia (2014) have analyzed the mining sector and its impact on economy with a Dynamic Stochastic General Equilibrium model. Other studies focus only on one determining factor like foreign direct investments, effects on wages caused by national labor migration and by economies of scale.

The project differs to other studies in following aspects:

- The use of input-output-tables for Chile and its regions allows measuring direct spill-over effects and indirect effects of the copper production.
- The forecast and simulation model has dynamic character. Also induced effects can be taken into account.
- An expanded model that focuses on the regions of Chile can detect regions that are affected by the copper production. This helps to measure interregional effects of distribution.
- Furthermore fluctuations in demand for copper can be observed by taking the world trade dynamic into account.

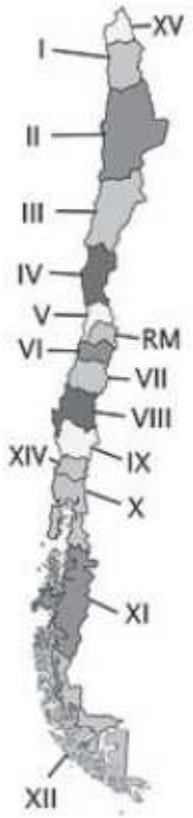
## 3 CHILE – ITS ECONOMY AND COPPER DEPENDENCY

### 3.1 ECONOMIC OVERVIEW

Chile is a country on the south-western side of South America running for more than 4.200 km along the western seaboard. Thereby the west-eastern extent is on average less than 200 km. The country has borders to Peru in the north and, Bolivia and Argentina in the east. In far south it is limited by the Drake Passage. Due to its very long, but narrow

strip, Chile encompasses a variety of climates. Whereas the northern regions range from the world's driest desert, the center has a Mediterranean climate. In the southern regions of Chile the climate is temperate oceanic. At present, around 18 million people live in Chile. In the central regions, the share of population is the highest, the capital, Santiago de Chile, contains more than 5 million inhabitants (Barandíarán 2012: p. 166-165, p. 170). Northern regions, like Antofagasta or Atacama, contain great mineral wealth, primarily copper and nitrates. Lithium, a resource of increasing interest which is used for rechargeable batteries, can be found in Chile's salt lakes.

**Chile's Regions**




| N° | Region | Capital city |
|---|---|---|
| I | Tarapacá | Iquique |
| II | Antofagasta | Antofagasta |
| III | Atacama | Copiapo |
| IV | Coquimbo | La Serena |
| V | Valparaíso | Valparaíso |
| RM | Metropolitan Region | Santiago |
| VI | O'Higgins | Rancagua |
| VII | Maule | Talca |
| VIII | Bío-Bío | Concepción |
| IX | Araucanía | Temuco |
| X | Los Lagos | Puerto Montt |
| XI | Aysén del General Carlos Ibáñez del Campo | Coyhaique |
| XII | Magallanes y la Antártica Chilena | Punta Arenas |
| XIV | Los Ríos | Valdivia |
| XV | Arica-Parinacota | Arica |

Figure 1: Chile's Regions. Source: OECD (2009, p. 9).

Due to many reforms demanded by Chilean citizens and carried out in 1980s and 1990s, the economy has made significant improvements during the past two decades. However the taken measures had strengthened the inequality among the income distribution. Not until the end of the dictatorship of Augusto Pinochet, the government leaded by Patricio Alywin made an effort to social adjustments. From 2002 the Gini coefficient decreased slowly from 0.564[2] to 0.495 in 2015, though it still remains high compared to the OECD

[2] Absolute inequality is hypothetically reached by 1.0

average of 0.315 (Hartmann 2017: p. 82; OECD 2017b: p. 17). Nevertheless Chile caught up with most advanced economies. Chile now reckons among the most opened national economies in the world with its low tariffs and has 22 trade linkages. In 2010, it became the first South American country to join the OECD. The state is also member of the Pacific Alliance and is an associated member of the Mercosur. This allows Chile concluding its own free trade agreements (Spillan & Virzi 2017: p. 83; SDSG 2010: p. 21).

As a resource-rich country Chile has focused its exports on commodities and agricultural products. Though the share of primary goods in exports has fallen from 95.7 % in 1970 to 85.9 % in 2014, it still remains high (Hartmann 2017: p. 73). Consequently the state is extremely dependent on the economic development of trading partners and world market prices for commodities. A slower or higher growth of Chile's trade partners can decrease or increase the demand (OECD 2017a: p. 131). Today Chile has a steady GDP growth of around 2 % in recent years and one of the highest GDP per capita in South America. Compared to the "golden 1990-1994" the GDP growth in Chile has more than halved. Consequently Chile is in a transition process as the expectation for copper prices have weakened and growth and investment have decelerated sharply (OECD 2016: p. 28-29).

## 3.2 ECONOMIC HISTORY

During the presidency of Allende from 1970 to 1973 most of the commodities were nationalized and protectionist economy was pursued. One of the most important issues of the left-wing coalition was reducing the unequal income distribution. Due to the expropriation without compensation of American copper mines, a political conflict had risen up between Chile and the U.S.. The American government put pressure on banks to stop Chilean lending. At this point of time the inflation has surpassed 200 %, while the fiscal deficit has surpassed 13 % of GDP and real wages have fallen 25 %. In the year of the military coup GDP growth decreased by 4 % (FFrench-Davis 2002: pp. 4-9). In 1973 the average tariff barriers were at a level of 94 % and sometimes reached up to 500 % (Spillan & Virzi 2017: p. 75).

The remarkable shift that brought economic growth to Chile was the introduction of liberal economy policies by the Pinochet regime after the military coup in 1973. Expropriation and protectionism of the Allende government were withdrawn. The economy with a protected market and with strong interventions of the government transformed drastically into a liberalized world-integrated economy. The opening of the market was particularly appreciated by open national economies, while socialist countries severed diplomatic relations with Chile. Notably the relations with the U.S. improved, the junta government was promptly recognized and supported economically. Certainly the decline of real wages while freeing prices and the prohibition of independent unionized activity caused a shifting of the unequal income distribution at the expense of wage-dependent employees. Lower tariffs, liberalization of sectors and a controlled inflation were taken measures initiated by the so called Chicago Boys, a group of Chilean economists whom trained at the Department of Economics of the University of Chicago. In addition the education, health and pension system were privatized, the public sector remained more supportive functions such as setting the ground rules and maintaining macroeconomic stability. Main results of these taken measures were an increasing GDP growth, higher foreign direct investment

primarily in the mining sector and more competition, because privatization forced public companies to be more competitive. These policy changes had an unexpected side effect on small- and medium-sized companies which had to deal with price competition of imported goods (Hartmann 2017: p. 203-209; Spillan & Virzi 2017: p. 73-77).

## 3.3 MINING SECTOR AND ECONOMIC ASPECTS

Mining is an essential process to make raw material available. Chile has the world biggest stock of copper and also other valuable natural resources like gold, silver, molybdenum, iron and lithium. Nevertheless copper represents the biggest share of the total production in the Chilean mining sector (Aroca 2001: p. 122). It originates almost the half of exports in Chile's economy. In contrast to Chilean exported agricultural products which are relatively reliable in prices, the copper prices dropped 50 % between 2011 and 2016 (Comelli & Pérez Ruiz: p. 4). These fluctuations have a notable impact on the GDP growth of Chile. In general the mining sector is important in terms of its volume for the Chilean economy and not of its linkages within a region. Backward and forward linkages persist relatively low. Main linkages are with the three sectors with the highest backward and forward linkages: utilities, retails and business services (Aroca: impacts p.125). Besides the high volatility of copper prices, the sector is highly dependent on the global demand. Principal buyer countries of Chile's exported goods have shown in the past that a slower growth in those countries can decrease the international demand which again can put a downward pressure on commodity prices. Particularly China has a dominant global role as a copper importer, according to structural and regression analyses shocks to the Chinese industrial production have large effects on commodity prices (IMF 2016b: pp. 11-12, p. 29).

In general resource-rich countries tend to rely on commodity revenues to fund their budgets. During commodity price booms a pro-cyclical reaction can lead to painful fiscal adjustments with long periods of low economic growth. When a country has not built up financial buffers, it may face hard policy choices in case of large financing gaps. After the Latin American Debt crisis Chilean authorities enabled to implement a counter-cyclical fiscal policy. So instead of scaling up during a boom that also involves poor-quality projects and low efficiency with only little impact on growth, Chile saves the money for so called rainy days. In Chile the accumulation of buffers is linked to fiscal rules; reducing gross debt during the boom in order to shield the budget by borrowing when prices fall and allowing monetary policy to be conducted in a counter-cyclical manner within a framework that combines inflation targeting with exchange-rate flexibility. However those accumulated buffers provide coverage for only a limited number of years and can absorb short-termed shocks but not long-termed trends (IMF 2016: pp. 5-8; OECD 2007: pp. 11-12). The government budget is planned on the basis of revenues like taxes, royalty fees, tariffs and price development of non-volatile export goods. Surpluses as above mentioned are used for building up a buffer and for funds for disability and old-age insurance. These are all mechanisms that stabilize the open economy with macroeconomic measures of Keynes (Hartmann 2017: p. 218).

Based on the expropriation of the mining sector during the Allende era, some of the mining companies still work as public authorities. Most of the private mines are now in the possession of foreign investors, because Chilean companies could not afford the high risk

and take up capital during the re-privatization. Since 1982, mines have been subsidiary, if a private company does not claim an authorized concession after the mine's exploration. Production conditions for copper and other resources are compared to other resource-rich countries like Peru or Bolivia very good and attract foreign investors. A law adopted during the 1980s gives foreigners the same property rights as Chilean citizens (SDSG 2010: p. 5). Nowadays it is even possible to purchase property without being physically in Chile. In addition the use of land or water is not charged. Since the Water Code of 1981, water is a privatized good and sometimes can be even acquired gratuitously (Aroca: 2001 p.125-126). Private and public copper mines differ in their productivity, taxation and management:

Although the private copper production has exceeded the state copper production since 1995, state owned firms pay around 75 % of the collected tax in the mining sector. This can be explained by different tax rates: whereas state companies pay up to 55 % taxes, consisting of a 15 % tax on profits and a 40 % extra tax, the private mining firms can deduct the tax of 15 % on profits. The additional taxation on remittances of profits to the exterior is only 35 %. However private mining companies have to pay an annually amount to receive concept of mining patents. This so called royalty payment can also be conducted. Whereas tax revenues go to a national fiscal budget, the money of the royalty fee for private mining companies stays within the region and is distributed between municipalities and the National Fund of Regional Development (F.N.D.R.) that has the objective to improve the quality of life (Aroca 2001: pp. 125-126). Private firms in the mining sector are more market-orientated and tend to outsource fields of work to smaller private firms. That way around 2,000 people are employed at a private company, while on same level of production the number of employees at a public firm is at around 7,000 people. On one hand indirect employees of private firms do not show up on the pay roll of a company and are characterized by lower incomes compared to permanent employees and people employed in public firms. On the other hand outsourcing has the advantage establishing small- and medium-sized companies that provide their services to the mining sector, but can also expand their economic tasks on other branches of industry (Aroca 2001: p. 124-125).

According to one estimate, the central regions have a great potential for mining: About 50 % of copper resources can be found here. The population density is high tough, around 60 % of Chile's population lives in the regions IV - VI (Boman 2014: p. 4). In the past decade until today more than the half of the copper production takes place in region II, Antofagasta, located in the north of Chile. Region II borders on the Atacama Desert, one of the driest places on earth, consequently Antofagasta has a dry arid climate where water is a scarce resource. Here are the seven biggest mines located, two of them are state owned (Chuquicamata, Radomiro Tomic), four are private (Mantos Blancos, Michilla, Minera Escondida Ltda., Zaldivar) and one is a joint venture (El Abra) between the state and a private company (Aroca 2001: p.119).

The distribution effect that is caused by the taxation system of the government, is also strengthened by commuters as Aroca has shown in his studies (2001). Compared to other sectors, the mining sector has a relatively high commuter rate: the average of Chilean employees who commute was at 2.5 % in 2002. In the mining sector the commuting rate was at 13 % at the same point of time. Main reason for the high commuting rate is the shift system: It allows taking off a few days in a row after working several days. Conse-

quently the earned salary is mainly spent in the region of residence and not in the region of work. An explanation for the decision of non-migration to the region of work is a higher concentration of opportunities such as educational establishments, infrastructure, services and a variety of goods. Antofagasta is about 1,400 km north from the capital, Santiago de Chile, and is highly specialized in the mining sector. The town receives more than three times as many commuters from the mining sectors than all of the rest in the country. Around 75 % of commuters in Antofagasta are willing to commute more than 800 km due to previously mentioned infrastructure in other regions. Regions that benefit from commuting are mostly main urban agglomerations, neighbored regions and Coquimbo with amenities like weather, low cost of living and the proximity to Santiago de Chile (Aroca 2011: p. 12).

| Region | Residencial Region | Working Region | Wage Earned by Commuters (US$ 2007) | FNDR 2007 (US$ 2007) |
|---|---|---|---|---|
| | | Antofagasta (Workers) | | |
| I | Tarapaca | 1,828 | $ 48,752,760 | $ 32,767,329 |
| II | Antofagasta | 148,753 | | $ 55,537,337 |
| III | Atacama | 2,624 | $ 69,982,080 | $ 24,047,670 |
| IV | Coquimbo | 3,288 | $ 87,690,960 | $ 53,435,968 |
| V | Valparaíso | 1,503 | $ 40,085,010 | $ 41,008,196 |
| MR | Metropolitana | 3,530 | $ 94,145,100 | $104,110,240 |
| VI | OHiggins | 492 | $ 13,121,640 | $ 43,429,704 |
| VII | Del Maule | 621 | $ 16,562,070 | $ 51,773,065 |
| VIII | Bio Bio | 2,189 | $ 58,380,630 | $ 72,708,714 |
| IX | Araucania | 272 | $ 7,254,240 | $ 44,200,321 |
| X | Los Lagos | 157 | $ 4,187,190 | $ 87,833,411 |
| XI | Aisen | 2 | $ 53,340 | $ 28,763,484 |
| XII | Magallanes | 11 | $ 293,370 | $ 34,953,246 |
| | Total | 165,270 | | |
| | Commuters | 16,517 | $ 440,508,390 | |

Table 1: Total Wage Earned by Commuters by Residential Region and FNDR. Source: Aroca (2010, p. 13).

Commuting has direct and indirect implications, especially in the mining sector due to high wages in this branch of industry. Commuters sort of strengthen the distribution effect of the benefits of the mining sector. Effect of commuting is benefits of mining are spread to the whole country, furthermore it creates employment and incomes in other sectors of the region where the money is spend. On the one hand commuting saves investments for constructing costly mining camps. It also reduces absenteeism, the potential to unionize, because there is barely a possibility to establish social contacts, and it can alleviate poverty and inequality. On the other hand it reinforces distribution effects and can cause violent conflicts. Due to commuting the development potentialities in far situated mining re-

gions have further declined: the standard of living remains low while the cost of living persists high (Aroca 2011: pp. 11-15). The total amount of wages earned by commuters and brought to their residence is in almost every region higher than the amount of money the regions receive from the main body reducing regional disparities.

## 3.4 CHALLENGES FOR THE MINING SECTOR

The set of problems is, besides the decreasing demand for copper on the world market and the high volatility of copper prices caused by slower GDP growth of copper buying countries, new challenges that put additional pressure on production costs and lower expectations of investors. High energy prices decrease margins in small- and medium-sized companies. In addition to that, the mining sector is more criticized by the general public for its impacts on the environment, on the health of workers and citizens, and on human rights.

### 3.4.1 ECONOMIC

The declining quality of copper grade has increased the production costs. To maintain the level of production the demand for water, energy and labor force has to increase. The most recent economic challenge that is faced by the mining sector, is the energy supply. According to estimates the Chilean mining sector is one of the most energy-intensive sectors: it consumes already 35 % of electric generation of the whole country. It is forecasted that by the year 2025 the energy demand will increase by 60 % (Cerda 2015: p. 12). Chile's own electricity supply is extremely dependent on the climate since it only has small hydroelectric plants and some small oil fields. A scarcity of water has a direct effect on the electric generation, because the hydro-power generation has a share of 40 % of the Chilean energy matrix. The rising "La Niña"-effect confronts the country with periods of drought and cold, so snow and glaciers in the mountains do not melt and supply water reservoirs. The precipitation remained during the last few years at record lows with resulting low water levels at reservoirs. Another big part of energy supply Chile receives from international suppliers like Argentina. Recent incidents like the economic crisis in Argentina at the beginning of 21st century have a large impact on the supply. Argentina increased energy prices and restricted gas exports on some days at only 50 % of contracted volumes. Due to the possible case of an energy outage, many companies already have their own sources of backup power generation. The use of those backup generators during a local power shortfall adds significantly to the production costs. It is necessary for Chile to diversify its energy matrix to become a more independent energy purchaser, to be more competitive in energy prices and to enable a sustainable copper production (SDSG 2010: pp. 12-15).

Another issue that will be faced by the mining sector is that mines have to be deeper in order to prevent a stagnation of copper production. This also increases costs because of greater distance transport and of safety issues that have to be met by the companies (Cerda 2015: p. 9). Hence the government agency responsible for supervising mining safety standards, SERNAGEOMIN[3], has become stricter after several incidents at mines

[3] Servicio Nacional de Geología y Minería

during the past decade.

### 3.4.2 ENVIRONMENTAL

The mining sector takes notably place in the arid northern regions of Chile, in Antofagasta and in Atacama. Here, water is a scarce resource but the commodity stocks are large. As already mentioned, the Atacama Desert ranks among the world's driest places. Some areas there record only an annual average rainfall of 0.6 mm to 2.1 mm. Water reservoirs are supplied by meltwater from the Andean glaciers. There are also salt lakes that are habitats and feeding grounds for the vulnerable species, the Andean Flamingo. Other water resources are dew and a costal dense fog known as Camanchaca (SDSG 2010: p. 8).

The mining sector's excessive extraction of groundwater, soil and water contamination and hazardous waste represent great risks to the biodiversity. The use of both ground and surface water has threatened to dry out wetlands and that again has a significant impact on the species living in Atacama Desert. The mining industry has responded to the water scarcity with an increase in seawater use. But this also means sharp expansion of energy needs and may have incalculable impacts on the environment like altered salt concentrations in soil and waters as well chemical compositions with unknown effects on ecosystems and biodiversity. The water contamination with heavy metals and sulfates in surface water from mining effluents would be strengthened by an increased use of seawater (OECD/ECLAC 2016: p. 234).

Glaciers are a significant source of freshwater and often are headwaters for rivers. Considerable cloud dusts of the mining operations can be carried long distances by the wind and can cause a faster melting of the glaciers. Experts believe that already a covering dust layer of 1 mm can cause glacier shrinkage of up to 15 %. Farmers and habitants in the mountains rely on the snowmelt water for their livelihood and have expressed their concerns. Furthermore the smelter's dust emissions cause a toxic air pollution that not only threatens the biodiversity but also the health of the citizens living close to mines (SDSG 2010: p. 10). The rate of respiratory problems in regions specialized on mining have increased. In the case of Chuquicamata one of the largest open pit copper mines in the world and owned by the public company Codelco, toxic air pollution has forced the residents to migrate to another town (Aroca 2001: p. 128). Another environmental controversy over damming major free flowing rivers in southern regions to fill the lack of hydroelectric-generated energy due to changed weather conditions highlights again the fact that Chile needs to diversify its energy matrix.

In the context of becoming a member of the OECD, Chile has also addressed some concerns of the organization with the creation of an environmental ministry in 2009. This is a great development progress for Chile. From the point of view of the mining companies it will raise the bar of environmental and social performance. Hence regulators are now required to look at the entire environmental impact of large projects. A piecemealed presentation of projects by companies to receive permission for planned projects is no longer possible. Prior to this companies had to provide an evaluation study of the project to the regional (COREMA) or national environment authority (CONAMA) depending on number of affected regions. In particular a Canadian company, called Barrick Gold, took advantage of this process by neglecting to mention moving three glaciers which are im-

portant source of water for the Huasco valley's farmers: The valley is home to around 70,000 people, the protection of the glaciers and a sustainable water use were central campaigns against the project. So the mining company minimized the overall impact of the project to avoid a national evaluation of the authority CONAMA. In 2013, the mining company received the highest possible fine under Chilean law for violations to its environmental permit (SDSG 2010: pp.19-21; Li 2016).

The increased public awareness for environmental issues have arisen conflicts over the availability of water to preserve biodiversity. The topic is also addressed by the government: It has already reacted to environmental concerns of the public and organizations like OECD, so that obtaining an environmental permit has become a slower, stricter and a more uncertain process for mining companies. New policies, regulations and environmental specifications impede the realization of new mining projects and increase mining operation costs (SDSG 2010: p. 19-21).

### 3.4.3 SOCIAL

During the past decades the environmental awareness of the public has increased. Especially the impact on the use of water, the use of energy and the violation of human rights by the mining industry are questioned. Today more influence in decision-making processes is demanded, the local community opinion has become a major issue for the mining sector. Hence during the environmental evaluation of a planned project with an impact on more than one region, local municipalities can review, comment and vote on the Study of Environmental Impact (EIA) provided from the project owner. However the public's view was often side-stepped and projects were pushed through the evaluation process by the mining companies using the simpler Statement of Environmental Impact (DIA) that is used for smaller projects with impacts on only one of Chile's 15 regions and does not take the public's opinion into account (SDSG 2010: p. 15-16).

A turning point in Chilean attitudes toward mining activity marks the Pascua Lama project. Pascua Lama's deposits are situated at crest of the Andes at an altitude of around 5,000 meters which pushed the limits of human labor and technology. The Barrick Gold company neglected to mention essential information to expedite the process at the expense of the environment and human rights. The campaigns against the project with disputable working conditions and great impacts on environment attracted worldwide attention and international solidarity. The Pascua Lama project represents a new reality for Chile's mining sector: increased environmental oversight by new established authorities, pressure from international solidarity movements, new activists strategies and forms of resistance have reshaped the dynamics in the mining sector (bpb 2008; Li 2016).

On international level the organizations OECD and ILO have put more pressure on the country and have strengthened awareness for environment and public respectively human rights. The conflict potential increases in the Chilean society, when mining creates an intense competition for water and energy. The way how the Chilean political system adapts to the increased demand for participation and conflicts over resources plays a decisive role: In 2008, Chile ratified the ILO 169 convention ensuring that indigenous and tribal people are consulted and fully participate at all levels of decision-making processes regarding to their grounds and resources. One year later the Chilean Supreme Court an-

nounced the ruling on indigenous water use rights against a company seeking the rights to bottle and sell freshwater from a source used by indigenous residents of Aymara. The ruling grants a water flow of 9 liters per second to Chusmiza and Usmagama communities and opposes private water licenses. Environmental groups appreciated the ruling calling it the first step in reclaiming resource rights from private mainly foreign-owned companies and restoring them to the public realm (Richter 2009; SDSG 2010: pp. 18-19). With the growing force of resistance to mining activity and the political system reacting to that, the copper sector is facing an additional obstacle that companies have to overcome.

In addition to the demand of local participation, the mining sector has become a more unattractive place of work. The lack between demand and offer of highly qualified workers has become another major issue for the mining sector. Besides low amenities in mining regions, several incidents in mines have harmed the image. Large mines generally meet international safety standards, but especially small and medium mines have poor safety conditions. Notably the San José mine, that attracts workers with higher than average wages and benefits due to its poor safety record, registered several accidents partially deadly accidents. The Chilean mining accident in 2010 raised international alertness after men were trapped 700 meters underground for more than two months (Uco 2010). High health risks and incompatible working hours strengthen the manpower shortage. Region II, Antofagasta, has to deal with high toxic air pollution that has increased the rate of respiratory illness. Even the citizens of Chuquicamata located next to a division had to be moved to another city due to the harmful toxic emissions. Typical problems of mining regions are increased prostitution rates and alcoholism that can also explain the biggest quantity of AIDS infections in Region II. The incongruity of profession and family is reflected on one hand by above-average commuter rates and high rates of divorces and suicides (Aroca 2001: p. 128).

## 3.5 TAKEN MEASURES

The above mentioned economic, environmental and social challenges have put pressure on the Chilean mining sector to adjust its production. The protection of the environment and of human rights as well the increased production costs can offer great chances for improvements.

In particular a sustainable energy generation has come into the focus of attention of policy makers. In 2014, the Ministerio de Energía launched its program “Energy 2050” which constructs a long-term vision in the Chilean energy system to 2050. It consists of four pillars proposing the vision of the energy sector in 2050 as reliable, inclusive, competitive and sustainable. To make the energy supply and quality more reliable, more flexibility and independence shall be reached by concluding more supply agreements with countries of Latin America. Also in case of energy outages emergency plans and sufficient energy reserves will be developed. Secondly the energy sector should be characterized by an equitable access, territorial coordination and being capable of competing prices, hence without energy there is no growth. Due to its geographical position Chile’s northern regions are privileged in terms of solar radiation. This offers the opportunity to become a global leader of solar generation, the most promising renewable energy technology, because hydroelectric energy has become extremely dependent on weather conditions since

the more and more frequently arising event of the “La Niña”-effect: During the 1980s, hydroelectric plants generated around 80 % of energy, while during the past decade the average share of hydroelectric generation has sunken to only 32 %. One of the goals of the Chilean Energy Policy is that renewable energy sources constitute 60 % of electricity generation by the year 2035 and at least 70 % in 2050 (Ministerio de Energiá 2014: p. 14). A stronger focus on solar energy can consequently help maintaining these objectives of the third pillar. The last goal of a sustainable energy sector is mainly pursued by promoting an efficient use of energy at all levels of society. The educational system must incorporate cross-cutting contents on energy development (id: pp. 11-15).

In the white paper of the Ministerio de Energía the very controversy topic of the use of nuclear energy is not discussed. But there is considerable talk of Chile being forced to develop nuclear power, because uranium is transportable at low cost while having highly concentrated energy. It is examined to diversify the energy matrix through a combination of renewable energy sources like solar energy generation and hydroelectric plants and nuclear energy to decrease the independence to international energy suppliers and to compete with lower energy prices (Torres-Silva 2007: pp. 121-123). However the use of nuclear energy in earthquake-prone regions creates new problems such as the high risk of operations and the disposal of radioactive waste.

The great environmental pressure that is put on the large water use and water contamination of mining operations, have enabled to develop an innovation making it possible to catch water from the Camanchaca fog in the arid regions in the north. In mesh nets water is trapped and is carried off via pipes into storage tanks. The fog-catchers are able to supply an average of 10,000 liters of water every day (SDSG 2010: pp. 8-9). Certainly the mining industry has also responded to the worsening water scarcity. Mining companies have optimized the water-use efficiency and have increased massively their seawater use. An increase of seawater-use in copper mining from 16 % to 36 % between 2014 and 2025 is expected (Cochilco 2014 quoted in OECD/ECLAC 2016: p. 234). On the part of governmental authorities and institutions environmental issues such as air and water pollution were not recognized and addressed in policy processes until the 1990s. A national environmental agency, Comisión Nacional del Medio Ambiente (CONAMA), has been introduced in 1994. It declares basis environmental requirements, reviews and approves environmental impact evaluations. In preparation for becoming a member of the OECD, the Chilean government introduced a series of environmental laws and established a ministry for environment. Since its accession in 2010 policy-makers still improve environmental policies.

# 4 CONCLUSION

The Chilean mining sector is facing a new set of economic, environmental and social challenges. A lack of energy generation, a new environmental awareness of the public for water use and biodiversity, and consequential adaptation by policy-makers have increased cost pressure. In addition to that the mining sector becomes a more and more unattractive workplace due to high health risk, partially low safety standards and bad working condi-

tions in mines. Thereby the manpower shortage of highly skilled workers is reinforced. Low amenities in regions specialized on mining increase the willingness of workers to commute. Regional disparities are additionally strengthened by the different taxation of private and public mining companies. Besides that, Chile's copper production is still affected by the copper price volatility and the economic dependence of the international demand. By reason of its counter-cyclical fiscal policy Chile can absorb short-termed shocks by using accumulated buffers.

To maintain its position as the world's biggest copper exporter, Chile needs to develop strategies to adjust the above mentioned long-termed changes. The development of three forecast and simulation models with international, national and regional dimensions will make it possible identifying opportunities for actions to create a more sustainable copper production and additionally to evaluate policy plans and inured measures. The new challenges require a rethinking in the mining sector and enable chances in the use of new technologies, energy efficiency, sustainable use of water and environmental protection.

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