GWS DISCUSSION PAPER 2020/3

A regionalized national Input-Output Modell for Chile (COFORCE)

Methodology and Applications

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Imprint

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TITLE

A regionalized national Input-Output Modell for Chile (COFORCE) – Methodology and Applications

PUBLICATION DATE

DISCLAIMER

FUNDING

The results at hand have been prepared in the course of a research project for the German Federal Ministry of Research and Education (BMBF FKZ: 01DN16030).

PUBLISHER OF THE GWS DISCUSSION PAPER SERIES

Gesellschaft für Wirtschaftliche Strukturforschung (GWS) mbH

Heinrichstr. 30

49080 Osnabrück (Germany)

ISSN 1867-7290

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1 MOTIVATION

The research project "Development of sustainable strategies in the Chilean mining sector through a regionalized national model" – funded by the German Federal Ministry of Education and Research – analyses the socio-economic impacts of copper on the Chilean economy. For this, the model COFORCE (COpper FORecasting in ChilE, www.coforce.cl) was developed from scratch.

First, a macro-econometric input-output (IO) model for Chile (COFORCE) was built in line with the INFORUM (Interindustry FORcasting at the University of Maryland) modelling approach to forecast and simulate the impact of copper industry on the overall economy.

Second, due to the importance of Chilean copper exports, the COFORCE model is linked to the bilateral trade model TINFORGE which captures among other world trade of copper between 153 countries. The national COFORCE model receives export demand and import prices from the world model according to its global market shares.

Third, the COFORCE model was regionalized by using an Interregional Input-Output table developed by partners in Brazil (Haddad et al. 2018). The national and 15 regional models for Chile are linked via final demand components and industries by applying a top-down approach. Therefore, regional economic growth is mainly driven by the industry structure and inter- and intraregional trade.

This set of three projection and simulation models considers the main aspects regarding copper: 1. It is the main exporting product, 2. It has a huge impact on the economic development and 3. The copper industry is regionally differently concentrated. The modelling tools are applied for the evaluation of alternative economic scenarios, e. g. copper export scenarios at the national and subnational level.

The main focus of this paper is to introduce the methodology used to regionalize the national model COFORCE, to explain the main transmission channels and to present regional modelling results. The national model COFORCE and the underlying model philosophy and characteristics are explained in detail in Mönnig/Bieritz 2019.

Section 4 shows examples of applications and how to implement scenarios by using the graphical user interface solver(c) (see section 4.1). which includes the underlying data set (historic data and forecasted) and supports the user in scenario design, calculation and evaluation.[1] This paper ends with some conclusions and an outlook.

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1 The COFORCE model is handed over to the Chilean partners from the University Adolfo Ibañez in Viña del Mar, so that they can carry out scenario analyses independently by using solver©

2 APPROACHES TO ECONOMIC REGIONAL MODELLING

2.1 GENERAL OVERVIEW

According to Miller/Blair (2009), regional modelling is an important feature to consider as the structure of production in every region is specific and the smaller the region the more it depends on exports and imports. As regions have a strong interaction and interdependence with each other, spill over and feedback effects occur. National economic or trade policies have different impacts on different regions. Thus, regional modelling is an important tool for policymakers to determine economic effects at subnational level.

An important prerequisite for quantitative models is data. At national level, there is usually plenty of data available, at subnational level often only a limited set of data. Thus, the starting point for regional modelling is an economic model that represents the economy as a whole but neglects the regional specifics (such as size, economic structure, technology of production) and the interactions between regions.

The approach chosen for regionalization is highly dependent on data availability. *Simple regionalization approaches* use measures of spatial concentration and regional specialization (e. g. location quotient, Krugman-and Hirschman-Herfindahl indices, shift-share analysis) to derive the regional distribution of industries. Common indicators are production and employment by regions. Spatial concentration means the agglomeration of companies or employees in a sector in one or a few regions, while regional specialization describes the focus of one region on one or a few industries. Reasons for the concentration and specialization are usually not explained. Furthermore, interconnections between regions are neglected and spill over and feedback effects ignored. Nevertheless, the identified spatial patterns are used for the regionalization of national data.

Other, *more sophisticated, regional methods* are the approach of the shift-share analysis (Dunn 1960) and regional IO analysis (Miller/Blair 2009). The former approach analyses the relationship between regions, taking into account their importance and distance. Shift-share analysis examines the reasons for regional changes which is differentiated by overall economic factors ("share" effect), structural and specific locational factors ("shift" effect). Comprehensive regional IO approaches model the economic relations *between regions* and industries (e. g. (multi- and inter-) regional IO models).

Since 1950, different types of regional IO models were developed which differ with respect to (i) the number of regions taken into account and (ii) the consideration of as well as the degree of detail in interregional trade (Miller/Blair 2009, p. 69-118, Sargento 2009).

(i) Regional models can be distinguished by the number of regions. Single-region IO models comprise only one region of a nation ignoring regional interactions and therefore spillover and feedback effects. Interregional and multi-regional IO models consider two or more regions.

(ii) Models with more than one region capture usually[2] interactions and feedback effects between the regions. Trade flows can be modelled following e. g. the method of Isard (IRIO) or Chenery-Moses (Sargento 2009, Miller/Blair 2009) while the latter approach (MRIO) is a simplified and less data-intensive version of the Isard model by applying the import proportionality assumption.

A major prerequisite of a many-region IO model is a national IO table which serves as a starting point for regional modelling. The following two steps are the main issues in regionalizing national input-output tables: (a) the calculation of *regional technical coefficients* (no distinction between domestic production and imports) or *regional input coefficients* (consider only domestic flows) and (b) modelling of *interregional trade flows*.

The required techniques can be distinguished as survey-based, non-survey-based and hybrid approaches. Survey-based models demand a high requirement of data – which are partly difficult to obtain – but are most accurate compared to non-survey methods due to the use of real data. The disadvantages are – aside from being cost and time intensive – the possible errors related to data gathering and processing (Sargento 2009). Hybrid approaches combine both concepts to overcome the hurdles and at the same time combine the advantages of each approach (e. g. RIMS II, BEA 2013).

Non-survey approaches which deal with the regionalization of input coefficients and trade are amongst others the location quotients (LQ) approach and its extensions (e. g. purchases-only-LQ, cross-industry-LQ, Flegg location quotient[3] in Schröder/Zimmermann 2014, Flegg/Webber 1995) as well as the Supply-Demand-Pool (SDP) method and the cross-hauling adjusted regionalization method (CHARM, Többen 2017, pp. 7-32). While the CHARM and Fleggs' location quotient regionalize the national IO table and interregional trade step by step and care for cross hauling, LQ and Supply-Demand-Pool methods consider only net trade flows.

Depending on the number of regions in a model, the steps of estimating inter-regional trade flows differs: For constructing *single-region tables*, first, net inter-regional trade flows are calculated using the LQ or SDP method (commodity balance technique). Next, cross hauling – importing and exporting the same product (resp. products of the same product group) between regions – must be considered and gross export and gross imports estimated. In *multi-region models,* an origin-destination (OD) matrix for each product depicting intra and inter-regional trade has to be developed which is according to Sargento (2009), the minimum requirement for an Chenery-Moses (MRIO) model or an OD matrix comprises only of interregional trade. The CHARM method was further developed by Többen/Kronenberg (2015) to be applied for the multi-region case. Another possibility to model interregional flows in multi-regional models is based on the idea of gravity which says that regions closer

[2] An exemption is the intra-national model (or balanced regional model) of Leontief which considers spatial dimension by the market share of each region in providing the "national" product. This model does not determine the region of origin and destination and therefore takes only net trade flows into account (Miller/Blair 2009).

[3] Trade coefficients are determined by the relative size of the selling and purchasing industry as well as the size of a region in conjunction with its propensity to import.

to each other have more interactions (Leontief, Strout 1963). The estimation of the interregional flows of one good consists of the total output of this product in the exporting region, the total input of the other region and the distance between these two regions (Miller et al. 2009).

2.2 EXAMPLES OF REGIONAL ECONOMIC MODELLING APPROACHES

Regional models differ depending on the regional data available. If time series information is available a shift-share analysis can be applied. *Shift-share approaches* are used for the assessment of development dynamics of regions in the context of superior regions usually with regard to employment or production. The classical approach (Dunn 1960) has low requirements of data and is a descriptive and easily feasible technique to analyze regional growth. In the shift-share-analysis, the regional deviation from the total superior regional development is being measured in a top-down approach. The main assumption is that the growth of the superior region has a crucial impact on the growth of employment in each region. The employment factor consists of the national component, the sectoral/ structural component and the competition/ regional component (Farhauer et al. 2009).

The classical shift-share model has some points of criticism. One example is that it only determines the relation between the sub- and the superior region. The interdependence between structural and competitive component leads to an underestimation of the significance of an industry structure for the regional development (Fernandez 2005). Another disadvantage is the assumption that each region is independent from each other (Farhauer et al. 2009). The spatial dependence can be recognized with the implementation of a spatial weights matrix where spatial weights are assembled from criteria like distance, length of common borders, economic distance or commercial relations (Fernandez 2005).

For a full analysis of the explanation of regional development, the shift-share-regression is better suited than the classical shift-share approach though it requires more data. Sectoral effects can be separated from random influences, additional explaining variables can be included, the statistical significance of the coefficients becomes evident and various statistical tests can be performed. This approach is used for example in Zika et al. 2020, Ulrich/Wolter 2013.

Other regional approaches applying *regional IO multipliers* try to estimate impacts at subnational level. For example, the regional input-output modelling system of The U.S. Bureau of Economic Analysis (BEA) named RIMS II is a widely used tool to assess the economic impacts of e. g. investment projects not only at the national level but also on subnational levels. These *multipliers* are able to measure “the impact of an initial change in economic activity on industries in a region” (BEA 2013, p. 1-2). Regional multipliers can be employment-, income-, value added- or output multiplier.

The RIMS II model is a single-region IO model and produces regional multipliers based on the relationships observed between input and output at the national level under consideration of regional supply conditions. At regional level, local industries often need inputs from other regions to produce the regions’ output. In the RIMS II modelling approach, this is considered by measuring each industry’s concentration index in the region relative to the nationwide concentration of the particular industry. A disadvantage is that cross-hauling is not explicitly considered and the resulting impacts might be overestimated.

Multi-regional models like IMPLAN and REMI are using *regional purchase coefficients* to model regional impacts of national policies or shocks (Lindall et al. 2005, Mills 1993). This coefficient is defined “as the proportion of regional demand for that sector’s output that is fulfilled from regional production” (Miller et al. 2009). That means in turn that everything that cannot be produced in the region must be imported and causes interregional trade flows. The underlying national models differ with regard to their underlying modelling approach. While IMPLAN is a static model and does not account for price elasticities and changes in behavior of economic actors, the REMI model is a dynamic general equilibrium model which can be used for forecasting. This model combines input-output and econometric methods. The latter are used to describe the relationships between prices, income and demand which are derived empirically.

Some studies are using *backward and forward linkages* to analyze regional effects for particular industries. For example, Atienza et al. (2018) calculates first the total backward linkages (TBL) and total forward linkages (TFL) for the mining industry from OECD IO tables. Then, the linkages are regionalized with the simple location quotients method. Five mining regions were determined, namely Antofagasta, Atacama, Tarapacá, Coquimbo and O´Higgins. The intensity and quality of linkages is evaluated with the classification of the services. It turns out that mining service suppliers, especially large firms, are concentrated as a hub in Santiago with branches in mining regions. The same result of spatial concentration is seen in the specialization of services concluding that knowledge intensive mining services (KIMS) are located in the Metropolitan area.

There are also *regional CGE models* analyzing subnational effects of e. g. trade and tax policies at the national level (e. g. Haddad 2002, Julia-Wise et al. 2002) or sector-specific impacts (e. g. Poblete 2012). For example, Poblete analyses the economic consequences of the fishery crisis for the region Bío Bío by applying a regional CGE model. This regional model is constructed in a similar way as a country-level model. The difference lies in the modelling of trade with rest of the country and the world. A prerequisite for the regional modelling is a regional SAM which was constructed from regional information available such as Industry and socio-economic surveys and a regional IO matrix.

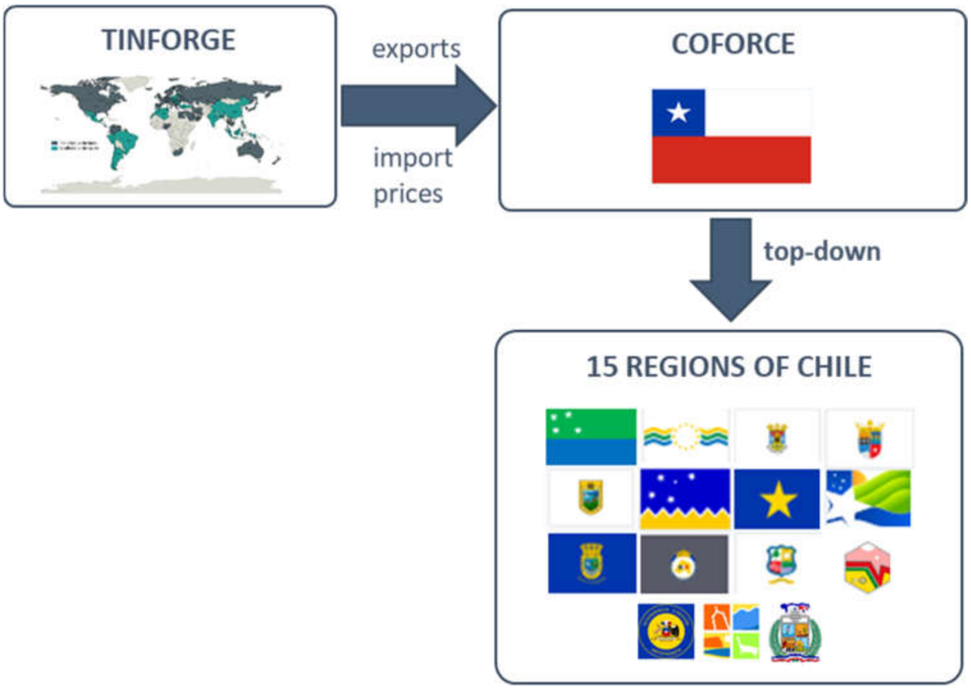
3 REGIONALIZING THE NATIONAL MODEL COFORCE

In this chapter, a regional economic modelling approach is presented that is based on an *interregional IO* (IRIO) table which was created by Haddad et al. (2018) for 15 regions and 10 industries in Chile.

The regional model is part of the COFORCE modelling framework. Before the regionalization is presented, an overview of the general modelling framework is given.

The modelling framework consists of three models which are interrelated: the world trade model TINFORGE, the national model COFORCE and the regional model for 15 Chilean regions (Figure 1). The TINFORGE model determines world trade for different countries, amongst them Chile and its trading partners. The national COFORCE model receives the export demand and import prices from the TINFORGE model which has the advantage of not being determined exogenously as in many national models. The regional economic development depends on the economic growth by industries as projected at the national level by using a top-down approach (section 3.1).

Figure 1: Modelling framework



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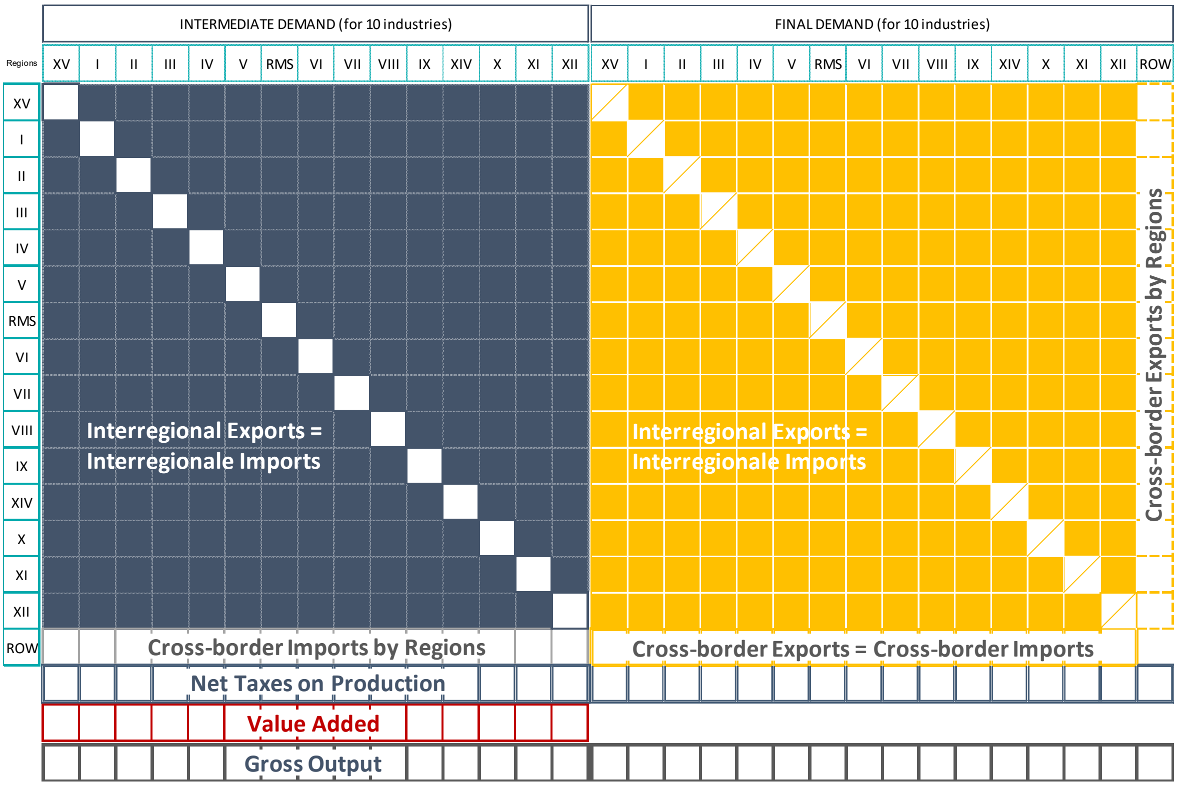
A more comprehensive description of the world trade model is given in Mönnig/Wolter (2019) and Großmann et al. (2015). Bieritz/Mönnig (2019) explain the underlying methodology of the macro-econometric IO model for Chile (COFORCE).

It is important to remember, that COFORCE is characterized by bottom-up modelling and total integration (Almon, 1991). This means that economic growth is determined at industry level considering supply and demand effects as well as the interindustry interdependency. Price, income and demand interact with each other. Therefore, COFORCE is able to capture direct, indirect and induced effects. Due to its dynamic nature, it is applicable for forecasting and scenario analysis. The current model version has a simulation horizon until 2035. The results of the COFORCE model are used as drivers for the economic development in Chile's 15 regions.

3.1 MODELLING APPROACH

The regionalization is carried out using a top-down disaggregation of the national results. The basis of the regional modelling is an interregional IO (IRIO) model for Chile with full specification of interregional flows (Haddad et al. 2002, 2018). The IRIO is given for the year 2013 and comprises the 15 Chilean regions and 10 industries (Annex 1 and Annex 2).

Figure 2: Schematic representation of the IRIO for Chile



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The intermediate demand flows are specified by industries and regions as well as the final demand components household consumption, government consumption, investments and exports.

All these regional information are linked to the COFORCE model, so that the projected economic development at the national level can be transferred to the 15 regions according to the structure given by the IRIO.

3.1.1 FINAL DEMAND (INVESTMENTS, PRIVATE AND GOVERNMENT CONSUMPTION, EXPORTS)

The COFORCE model and the regional models are linked by the (nominal) final demand components household consumption *HCES*, government consumption *GCES*, investment *GICN* and exports *EGSS*. Additionally, a distinction is made between final demand that is imported cross-border or domestically produced.

First, each of the final demand components (distinguished by cross-border imports and domestically produced) at the national level is aggregated so that it fits the industry classification of the IRIO (Annex 1). Afterwards, the final demand by components and industries at the national level needs to be spilt accordingly to the demanding and supplying regions. For this a 'market share indicator' and a 'demand indicator' of a region and each industry is determined from the given IRIO data.

The regional 'demand share indicator' $RDSI_i$ shows the final demand share (investment, household or government demand) by industries *i* of a demanding region $fd_{i,rd}$ in final demand determined at the national level fd_i without specifying the (interregional) supplying regions.

$$RDSI_i^{rd} = \frac{fd_i^{rd}}{fd_i}$$

$$\forall \in i, i = [1; 10], \qquad \forall \in rd, rd = [1; 15]$$

The regional 'market share indicator' $RMSI_{i,rd,ro}$ considers the origin (within Chile) of the final demand by industries. For each demanding region *rd* and final demand by industries $fd_{i,rd}$, the share of the supplier regions (regions of origin) *ro* are calculated.

$$RMSI_i^{ro,rd} = \frac{fd_i^{ro,rd}}{\sum_{ro=1}^{15} fd_i^{rd}}$$

$$\forall \in i, i = [1; 10], \qquad \forall \in rd, rd = [1; 15]\,, \qquad \forall \in ro, ro = [1; 15]$$

By multiplying the regional 'demand share indicator', the regional 'market share indicator' and the domestically produced final demand components at the national level, the final demand as given in the IRIO can be projected. Both indicators are constant over time.[4]

Cross-border imported final demand at the regional level is calculated as follows: Given from the IRIO, the cross-border import shares by industries for investment and household demand and all Chilean regions are known for 2013. These import shares are applied to derive future regional imports from the respective final demand projections at the national level.

3.1.2 INTERMEDIATE DEMAND, GROSS OUTPUT AND VALUE ADDED

From the regional flow matrix, input coefficients are calculated by dividing regional intermediate demand by industries and regions $IRIO_{ir,ir}$ by regional gross output by industries $GOR_{i,r}$.

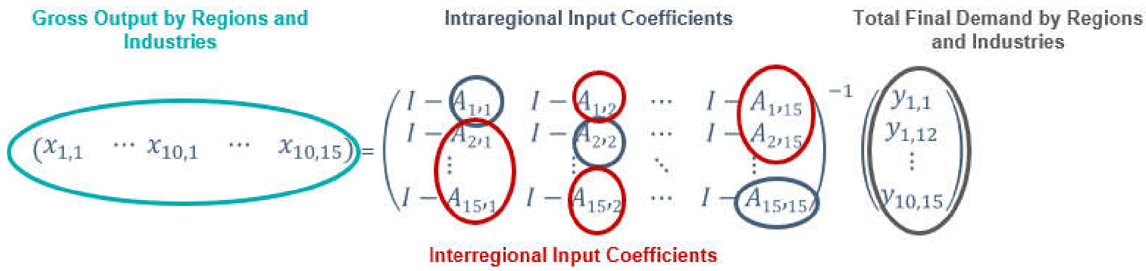
Afterwards, regional input coefficients $ICT_{,ir,ir}$ are linked to the national input coefficients $DINCT_i$ (see Mönnig/Bieritz 2019, p. 14 ff.) assuming that irrespective of the region, input required for producing one unit of output is the same in all regions of Chile. Thus, it is assumed that technological progress prevails amongst all regions.

Gross output by regions and industries can be derived by applying the following equation (Miller/Blair 2009), whereas *IR* is the identity matrix, frd_{ir} is the total regional final demand and $^{-1}$ indicates the inverting of the parenthesis expression.

$$GOR^{i,r} = \left(IR - ICT^{ir,ir}\right)^{-1} \cdot frd^{ir}$$

$$\forall \in i, i = [1; 10], \qquad \forall \in r, r = [1; 15]$$

[4] Section 4.2 and 4.4 describe the procedure how to adjust the RMSI and RDSI.



According to the IRIO, in the production process domestically produced inputs and also cross-border imported intermediate inputs are used. To derive the future development of regional imports, the historically given ratio of intermediate imports and interregional intermediate inputs by industries for each demanding region are applied. A scaling routine assures the match between intermediate imports at the national level and for all Chilean regions.

In a next step, value added is calculated by subtracting the intermediate inputs by industry and region from regional gross output of the respective industry.

3.1.3 EMPLOYMENT

For the calculation of employment effects at the regional level, first, employment and production by industries at the national level are aggregated to the same classification as used at the regional level. Second, labor productivity by industries at the national level lp_i is derived. The same is done for the regions and results in the regional labor productivity by industries $lp_{r,i}$. In the next step, the labor productivity by industries from the national level is transferred to the regional level. It is assumed that in each region the growth rate of labor productivity by industry is the same. From the regional production by industries and the regional labor productivity, employment for all 15 Chilean regions is derived. A scaling procedure ensures that employment by industries at the national level is equal to the sum over all regions by industries.

$$lp_t^{i,r} = lp_{t-1}^{i,r} \cdot \frac{lp_t^i}{lp_{t-1}^i}$$

$$\forall \in i, i = [1;10], \qquad \forall \in r, r = [1;15]$$

$$EMPLR^{i,r} = lp^{i,r} \cdot GOR^{i,r}$$

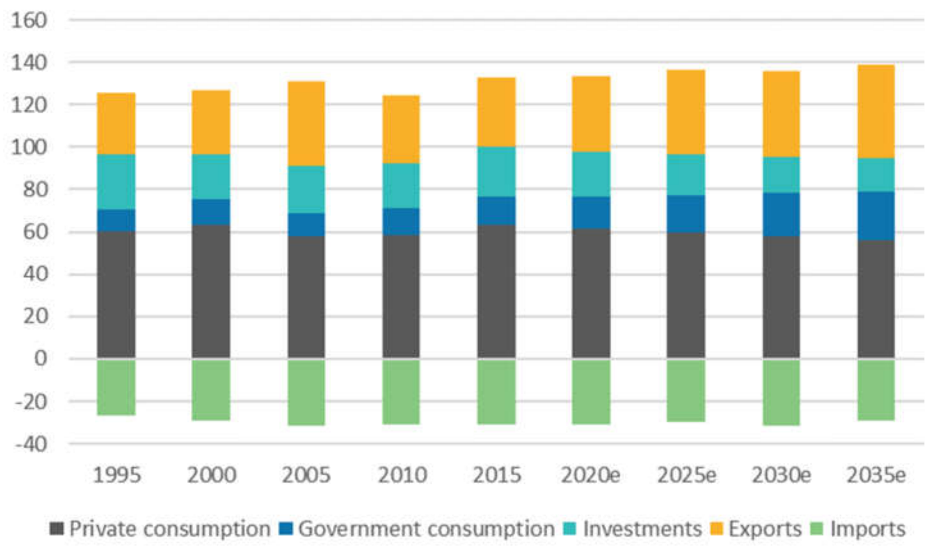
3.2 REGIONAL BASELINE RESULTS

This section describes the baseline results at the regional level which are the outcome of the applied modelling approach at national and regional level. The projection of the Chilean economy is presented in Mönnig/Bieritz (2019) and is summarized here in short to explain the superordinate economic drivers for the regions.

3.2.1 FINAL DEMAND BY DEMANDING REGIONS

The baseline forecast for Chile shows an increasing real GDP growth path although growth rates are declining from 4.5% in 2020 to around 3% in 2035. The most important factors of economic growth are household consumption and exports that account for almost 60% respectively approx. 40% of total nominal GDP (Figure 3). Chile exports especially copper (46% in 2018), followed by fish (6%) and fruits (5%).

Figure 3: GDP structure in % based on nominal values



Source: own calculations with COFORCE

At the regional level, Antofagasta has with around half of total mining exports the largest share[5], followed by Atacama (9%), Coquimbo (9%), Valparaiso (8%), Región Metropolitana (8%) and Tarapacá (7%, Figure 4 above). Mining exports are thus very much concentrated in one region. The situation is different for agricultural products and fish. The regional export shares are largely evenly distributed especially in the geographical center of Chile (Figure 4 below) but the export volume is much lower than in the mining sector (43 bn. vs. 4.6 bn. Peso).

Other relevant export-oriented industries are "manufacturing" and "trade, hotels, restaurants". In these two sectors, the regional shares are again more concentrated in a few regions. Manufactured products are especially traded from Región Metropolitana (44%), Biobío (14%) and Valparaíso (13%) to the rest of the world. It is also not surprising that the Región Metropolitana has more than two thirds of its exports in "trade, hotels, restaurants", as this region is very well developed for tourism.

Based on the expected foreign demand for the different 73 product groups specified for Chile until 2035, regions that are active in the respective sector profit from export growth according to their regional share. Total nominal exports grow at a rate of 3.8% p.a. while, for example, mining exports increase by 2.6% and agricultural and fish exports by 4.8% per year.

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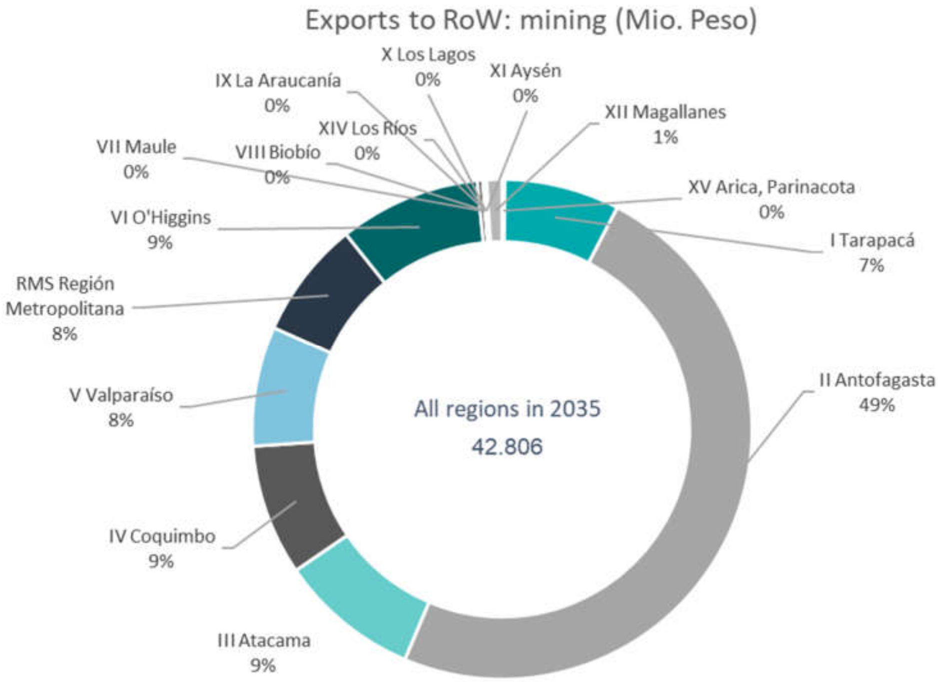
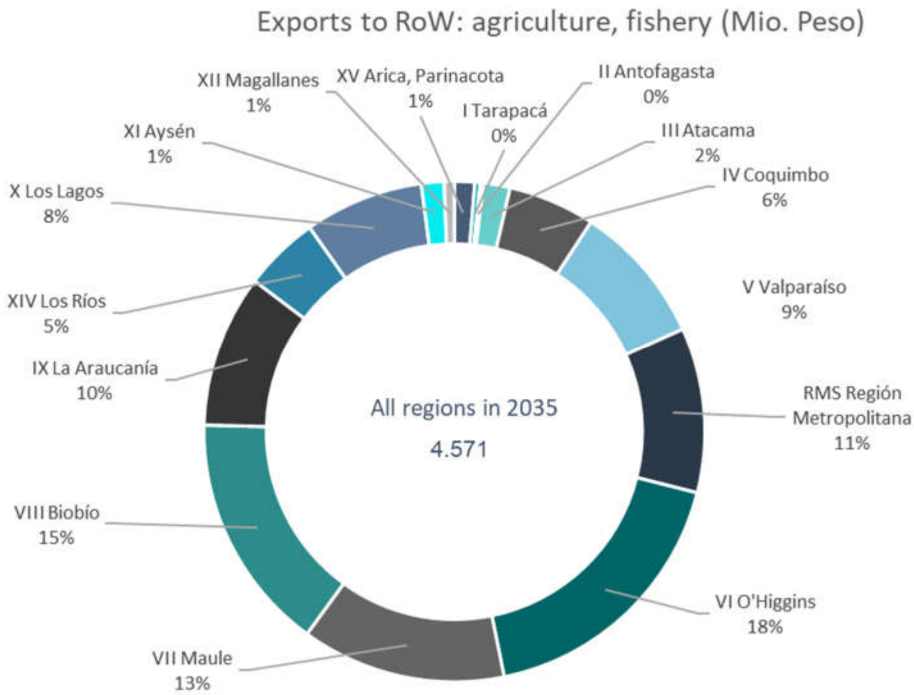
[5] According to the modelling approach, the regional shares will not change in the projection period.

Figure 4: Mining exports (upper figure) and exports of agricultural products and fish (lower figure) to rest of world (RoW) by regions



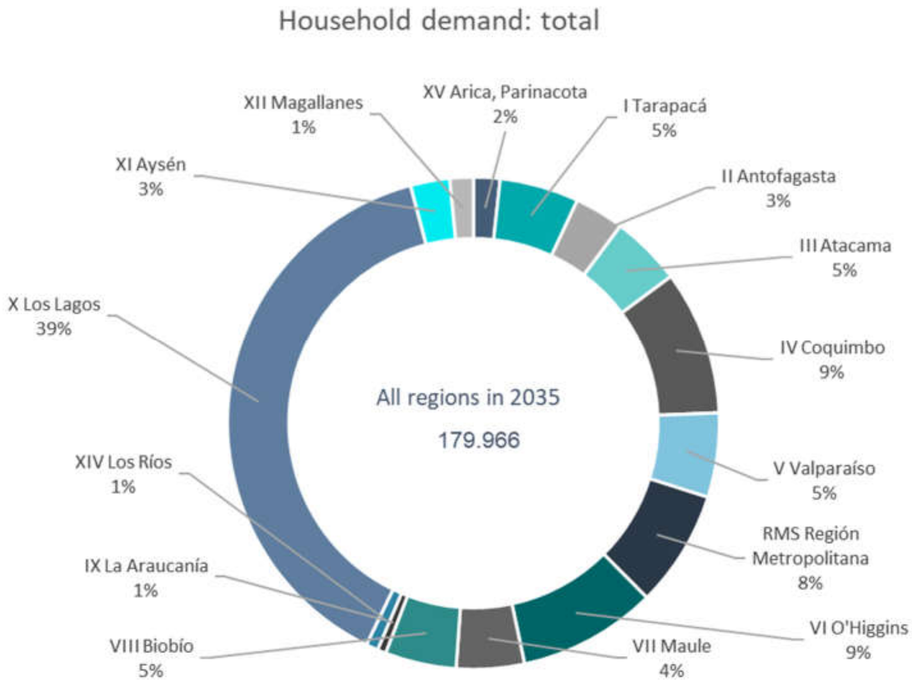


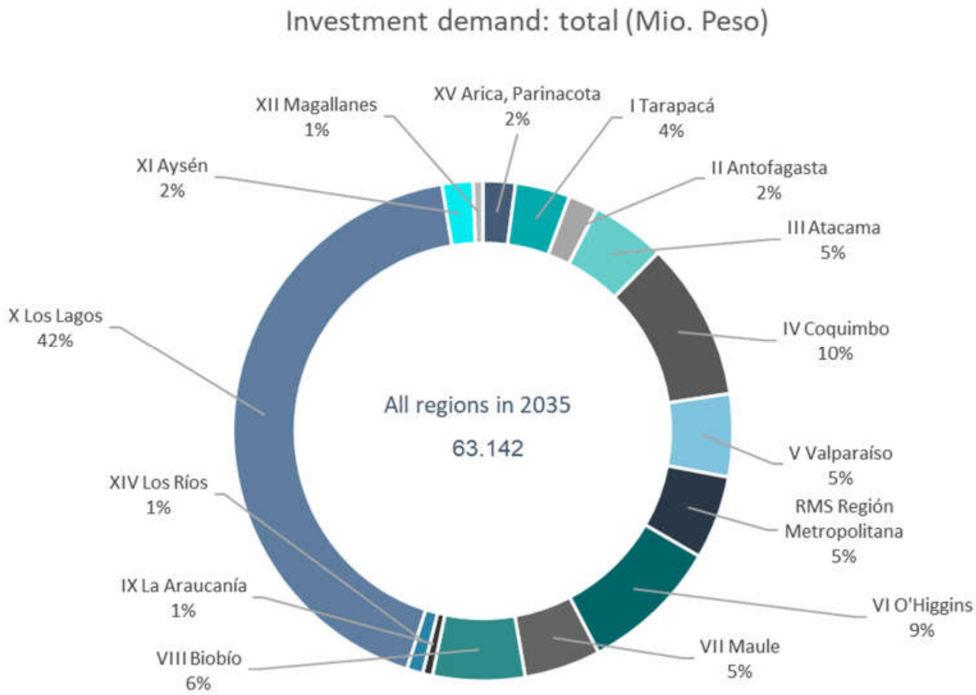
Source: own calculations with COFORCE

An important domestic growth factor is private household demand (approx. 60% of nominal GDP, Figure 3) which is affected by population growth and structure, consumer prices and income, which in turn is determined by economic growth and employment at the national level. Total household demand at the national level increases further until 2035. The annual average growth rate is 3.8% but differs for the different household expenditure purposes.

The regional shares according to IRIO 2013 show only small deviations for the consumer demand for the 10 industries. Therefore, in absolute terms, – irrespective of type of demand– it changes the most in Los Lagos due to the high share of 39% (Figure 5 upper figure).

Figure 5: Total household demand (upper figure) and investment demand (lower figure) by regions



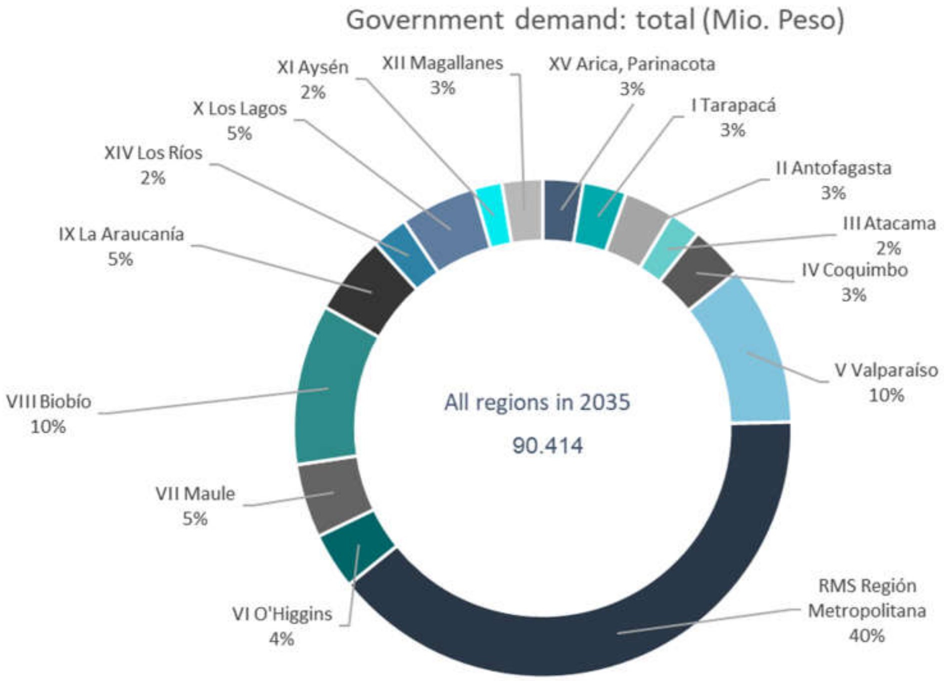


Source: own calculations with COFORCE

The regional shares in investment demand show a very similar result compared to the consumer demand. Los Lagos is the region with the highest share and accounts for more than one third of investments (Figure 5 lower figure). The contribution to the GDP is less and accounts for 16–20% (Figure 3).

The shares of government demand in GDP are in the same order of magnitude. Government demand grows by 7.2% per year. In contrast to household and investment demand, Región Metropolitana has the highest regional share with 40%, followed by Biobío and Valparaíso each of them with 10% (Figure 6[6]). Therefore any variation in i.e. public administration and personal services (e. g. health and education) leads to the greatest changes in these regions.

Figure 6: Total government demand by regions



Source: own calculations with COFORCE

3.2.2 INTERREGIONAL, CROSS-BORDER IMPORTS AND THE DEGREEE OF SELF-SUFFICIENCY OF THE REGIONS

The final demand in a region causes effects in the region itself and other regions within Chile as well as abroad. The import shares differ for final and intermediate demand as well as for particular products and regions. According to the modelling approach (section 3.1), the import shares observed in the past are also expected in the future.

In contrast to imports, the regional purchase coefficient (RPC) indicates what proportion of regional demand for that sector's product will be fulfilled by producers within the region (Treyz 1993, p. 281). The RPC can have values between zero and one where zero indicates that the local demand is fully imported and one indicates that the local demand is fully satisfied by regional supply. In general, both service and construction industries tend to have

[6] Again, the shares do not differ when comparing across different sectors.

high RPCs while agriculture, mining, and manufacturing industries usually have low RPCs.

The RPCs calculated for Chiles regions are shown in Table 1. The numbers in green indicate values above 0.5, the numbers in bold green have values above 0.75. The data shows that the level of self-sufficiency is particularly high in the service sectors “public administration” and personal services” as well as in the sector “electricity, gas, water”. In agriculture and mining the RPCs are the lowest.

With regard to the regions, Región Metropolitana, BioBío, Valparaíso and La Araucanía show a very high degree of self-sufficiency in a number of sectors. In contrast, the regions Los Lagos, Aysén and Coquimbo in particular have a high dependency on imports either from interregional or cross-border imports.

Table 1: Regional purchase coefficients

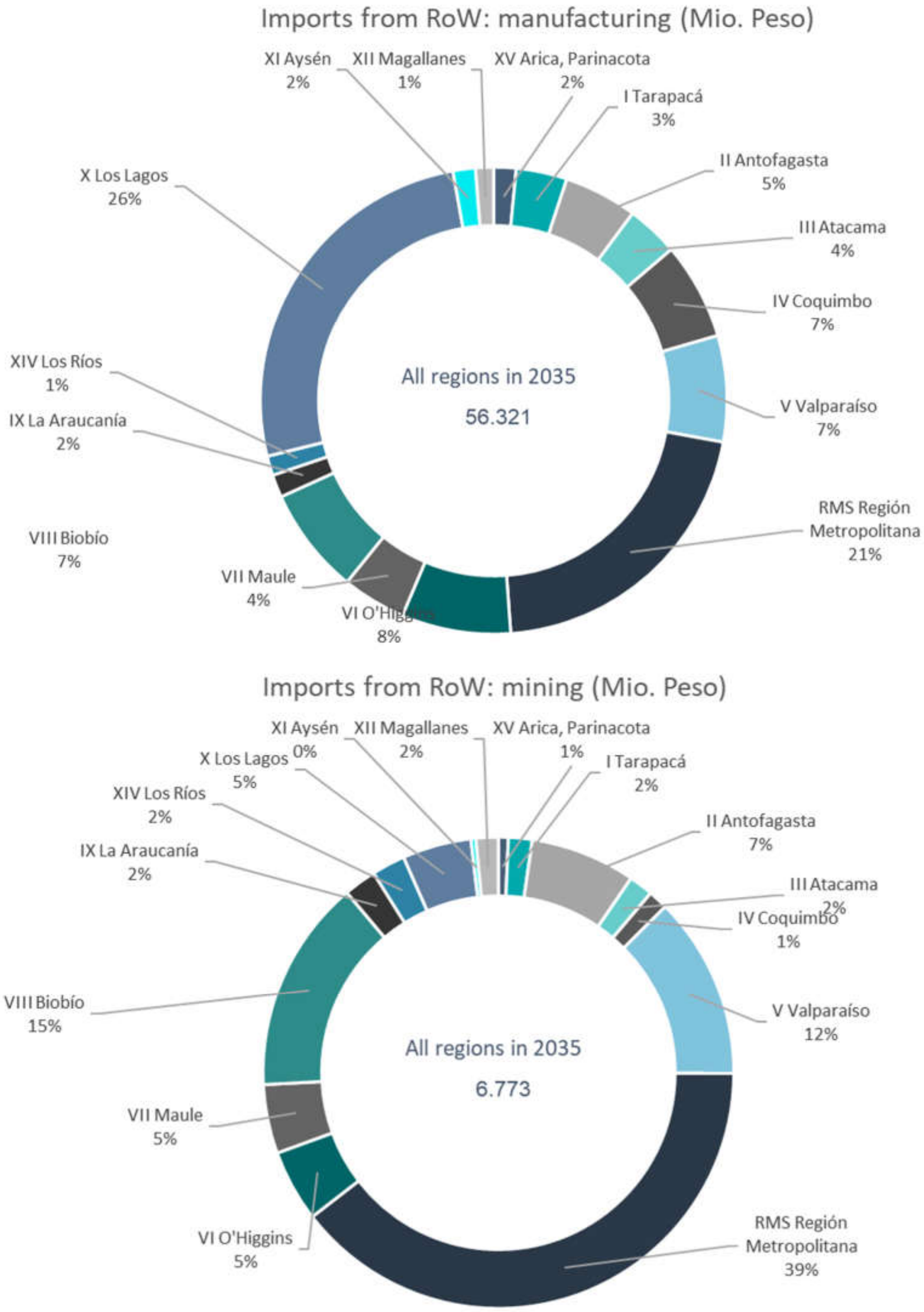
	Agriculture, forestry	Mining	Manu-facturing	Electricity, gas, water	Construction	Trade, hotels, restaurants	Transport, communication, information services	Business-related services	Public administration	Personal services
XV Arica, Parinacota	0,63	0,18	0,40	0,47	0,33	0,29	**0,91**	0,37	**0,94**	0,45
I Tarapacá	0,04	0,46	0,31	0,36	0,71	0,49	0,50	0,33	**0,89**	0,36
II Antofagasta	0,02	0,67	0,50	0,72	**0,97**	0,49	**0,85**	0,68	**0,89**	**0,87**
III Atacama	0,47	0,41	0,08	**0,86**	**0,88**	0,18	0,37	0,40	**0,86**	0,28
IV Coquimbo	0,41	0,37	0,07	0,25	0,18	0,15	0,28	0,22	**0,80**	0,27
V Valparaíso	0,28	0,25	**0,83**	**0,87**	0,71	0,42	**0,84**	0,57	**0,85**	0,74
RMS Región Metropolitana	0,14	0,12	**0,92**	**0,82**	**0,90**	**0,95**	**0,93**	**0,94**	**0,92**	**0,94**
VI O'Higgins	0,43	0,38	0,51	0,58	0,49	0,26	0,33	0,30	**0,81**	0,52
VII Maule	0,50	0,05	0,75	**0,92**	0,70	0,37	0,64	0,50	**0,89**	**0,80**
VIII Biobío	0,54	0,00	**0,95**	**0,96**	**0,89**	0,59	**0,91**	0,71	**0,92**	**0,93**
IX La Araucanía	0,66	0,00	**0,93**	**0,86**	**0,97**	**0,93**	0,39	**0,76**	**0,94**	**0,96**
XIV Los Ríos	0,74	0,00	**0,98**	**0,95**	**0,92**	0,69	0,29	0,51	**0,95**	**0,96**
X Los Lagos	0,20	0,00	0,19	0,23	0,05	0,05	0,08	0,09	0,07	0,12
XI Aysén	0,18	0,14	0,11	0,15	0,22	0,11	0,02	0,03	0,06	0,04
XII Magallanes	0,25	0,40	**0,89**	0,74	**0,94**	0,44	0,05	0,08	0,13	0,10

Source: own calculations based on IRIO 2013.

The dependence on imports from outside Chile varies considerably depending on the industry. Manufactured products are imported to a large extent. 72% of all imports are manufactured products, followed by 11% mining products.

The Región Metropolitana and Los Lagos have the highest shares in total cross-border imports with 27% resp. 20%. All other regions have shares between 1% and 9%. The regional shares vary depending on the products of a sector under consideration. Manufactured products are mainly imported from Los Lagos (26%) and Región Metropolitana (21%), mining products in especially by Región Metropolitana (39%) and BioBío (15%, Figure 7).

Figure 7: Cross-border imports of manufactured products (upper figure) and mining products (lower figure) by regions

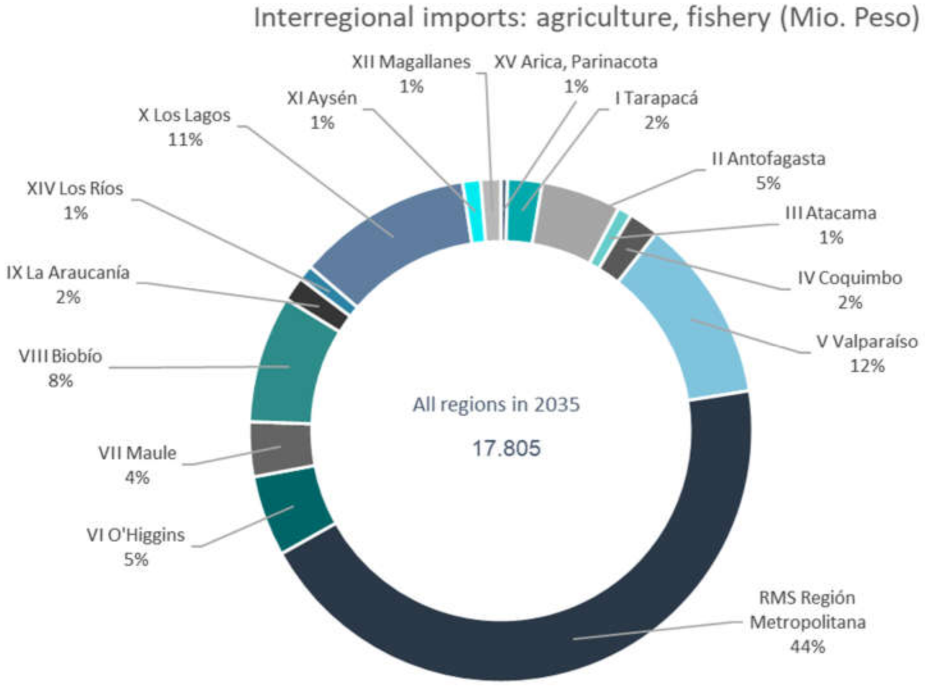


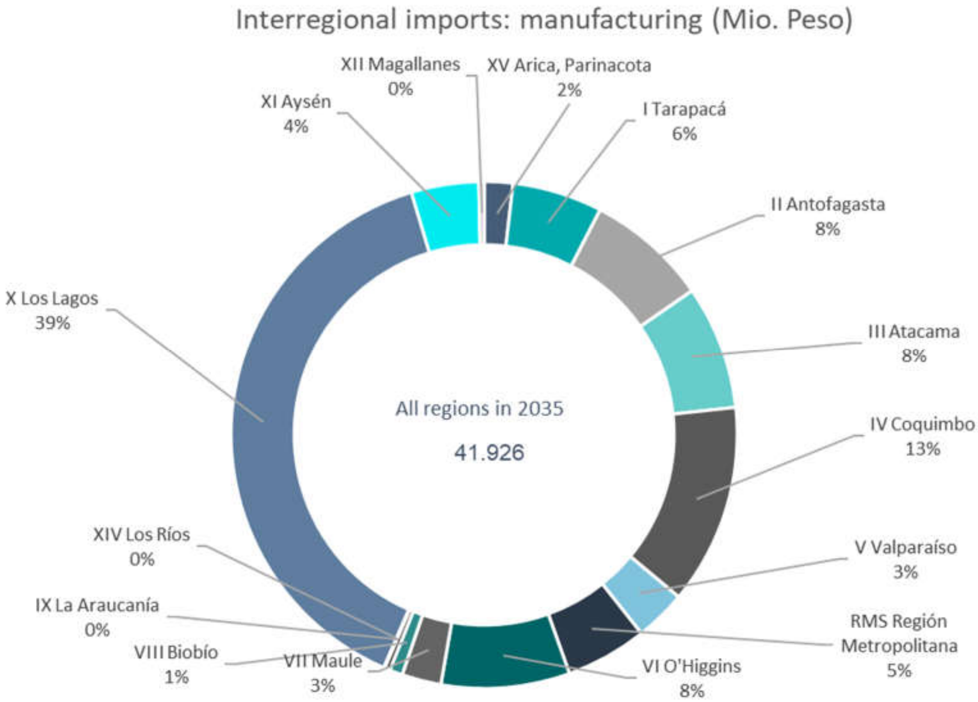
Source: own calculations with COFORCE

Final products and intermediate goods are also traded within Chile. Most of total interregional imports take place in trade in “services” (22%), “trade, hotels, restaurants” (18%), “manufactured products” (15%) and construction (12,5%). The regions that are highly dependent on interregional imports are Los Lago (39% of all interregional imports) and Coquimbo (10%).

The magnitude of interregional imports varies according to the presence of an industry in the region and the ability to meet the regional demand on its own. For example, interregional imports of agricultural products and fish is most important for Región Metropolitana (44%,Figure 8). In contrast, manufactured products are mainly imported by Los Lagos (39%).

Figure 8: Interregional imports of agricultural products and fish (upper figure) and manufactured products (lower figure) by regions





Source: own calculations with COFORCE

By relating the interregional (intermediate and final demand) imports of a region to its own production, the interregional trade coefficient is obtained. This indicator can be used to determine the level of self-sufficiency of a region. The higher the value, the lower the degree of self-sufficiency. According to the interregional trade coefficient, the regions Los Lagos, Aysén and Coquimbo are highly dependent on other regions output. The result corresponds to the findings from the RPC.

3.2.3 REGIONAL OUTPUT MULTIPLIER, OUTPUT AND EMPLOYMENT

Regional output multipliers are important indicators to estimate the total economic impact per unit of direct economic change in a region caused by a change in economic activity (Stevens/Lahr 1988).

For the 10 industries which are distinguished for the 15 regions in Chile, regional output multipliers are calculated from the IRIO (section 3.1.2). The regional output multipliers by industries (*LEO*) are summarized in 10 matrices (*ROM_A, ROM_M* etc.) which show the different regional impacts over all industries depending on the region causing the change in a particular economic activity.

Two examples are given in Annex 3. Comparing the impacts by a change in “agriculture, forestry, fish” reveals that economic impacts are the highest if the change occurs in Antofagasta, Aysén del General Carlos Ibáñez del Campo and Tarapacá (column 2, 3 and 14). The analysis of impacts on mining shows the greatest effects in Antofagasta, Atacama and Tarapacá (column 2 to 4 in lower table).

The economic effects for the regions are different depending on initial changes in a particular region. In the case of “agriculture, forestry, fish”, the regions that are affected most are Arica y Parinacota, Región Metropolitana and Biobío if the initial impact occurs in Arica y Parinacota. If the shock happens in Coquimbo, Coquimbo itself, Valparaíso and Región Metropolitana show the greatest impacts. In general, it turns out that the strongest interregional relationships have the regions with Región Metropolitana and BioBío.

Regional production is the result of final demand changes, regional production structures and the economic interdependence of the regions. At national level, total production increases by 4.5% per year. The dynamics at the regional level are different due to the economic structures and ranges from 3.4% p.a. in Antofagasta to 5.2% in La Araucanía.

Table 2: Output shares by regions and industries (2035)

	Agriculture, forestry	Mining	Manu-facturing	Electricity, gas, water	Contruction	Trade, hotels, restaurants	Transport, communication, information services	Business-related services	Public administration	Personal services
De Arica y Parinacota	10%	2%	13%	2%	5%	8%	12%	13%	12%	22%
De Tarapacá	4%	24%	12%	2%	7%	14%	7%	15%	5%	11%
De Antofagasta	0%	42%	10%	4%	11%	4%	5%	15%	1%	7%
De Atacama	4%	27%	3%	7%	19%	5%	4%	19%	3%	7%
De Coquimbo	9%	23%	5%	2%	7%	10%	6%	18%	5%	14%
De Valparaíso	4%	6%	27%	6%	5%	7%	11%	15%	4%	15%
Región Metropolitana de Santiago	1%	1%	17%	2%	4%	18%	8%	30%	3%	15%
Del Libertador General Bernardo O'Higgins	16%	14%	18%	3%	6%	8%	4%	14%	3%	13%
Del Maule	15%	1%	19%	8%	7%	8%	6%	13%	5%	19%
Del Biobío	8%	0%	29%	8%	5%	7%	7%	13%	4%	19%
De La Araucanía	14%	0%	14%	2%	7%	8%	7%	14%	7%	27%
De Los Ríos	14%	0%	29%	4%	4%	7%	6%	11%	5%	20%
De Los Lagos	19%	0%	28%	3%	4%	7%	7%	13%	5%	14%
Aysén del General Carlos Ibáñez del Campo	43%	2%	7%	1%	4%	5%	6%	11%	9%	12%
De Magallanes y de la Antártica Chilena	4%	6%	25%	3%	7%	8%	7%	17%	9%	14%
Chile	5%	7%	18%	4%	5%	12%	8%	22%	4%	15%

Source: own calculations with COFORCE

The output shares by regions and industries are shown in Table 2. For each region the TOP 3 shares are highlighted in turquoise. While business-related services and personal services are more or less equally distributed over the regions, mining is concentrated in the north of Chile and agriculture and forestry in the middle and south of Chile.

This result is confirmed by the analysis of the Krugman's concentration index (KCI) and the location quotient (Palan 2010). The KCI gives an indication if single industries are concentrated in certain regions. Table 3 shows that in especially "agriculture, forestry" (0.8) and "mining" (1.0) – are strongly concentrated in certain regions. In contrast, "construction", "trade, hotels, restaurants" and "transport, communication, information services" with a value of 0.1 have no geographical focus.

Table 3: Krugman concentration index

	Krugman concentration index (possible values between 0 to 1,8)
Agriculture, forestry	**0,8**
Mining	**1,0**
Manufacturing	0,2
Electricity, gas, water	0,3
Contruction	0,1
Trade, hotels, restaurants	0,1
Transport, communication, information services	0,1
Business-related services	0,4
Public administration	0,2
Personal services	0,1

Source: own calculations based on employment data

A more detailed view on individual industries in the regions provides the localization quotient (LQ). If the LQ is greater than one, the industry in the region shows a relatively high share of the respective variable compared to national average.

In Table 4 the most important industry for a region is colored in red and all industries which have a more than average value (greater than one) are colored in blue. For most of the regions the mining and agricultural sector is of major importance compared to the national average. The northern regions are highly specialized in mining, while regions located in the geographical center are mainly specialized in agriculture.

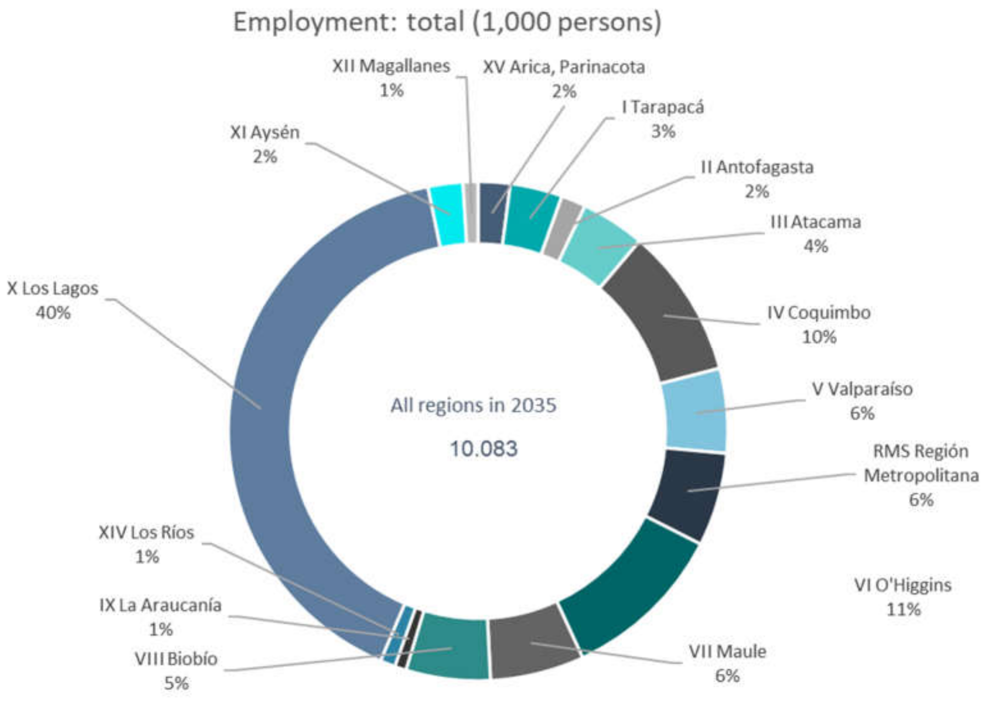
Table 4: Location quotient

	Agriculture, forestry	Mining	Manufacturing	Electricity, gas, water	Contruction	Trade, hotels, restaurants	Transport, communication, information services	Business-related services	Public administration	Personal services
XV Arica, Parinacota	0,7	3,7	0,6	0,9	1,0	1,0	1,2	0,7	1,5	0,9
I Tarapacá	0,2	6,5	0,7	1,8	0,7	0,9	1,1	0,9	0,8	0,9
II Antofagasta	0,8	5,2	0,6	1,9	0,8	1,0	1,0	0,5	1,4	0,8
III Atacama	1,5	3,5	0,6	1,0	1,2	1,0	0,8	0,6	0,9	0,9
IV Coquimbo	0,8	1,2	0,7	1,4	1,0	1,0	1,2	0,9	1,2	1,1
V Valparaíso	2,4	1,4	0,8	1,1	0,9	0,9	0,8	0,6	1,0	0,9
RMS Región Metropolitana	2,8	0,5	0,8	1,2	0,9	0,9	0,7	0,7	0,9	0,8
VI O'Higgins	1,4	0,7	1,1	1,4	1,0	1,0	0,9	0,5	1,3	1,0
VII Maule	2,3	0,1	0,9	0,6	1,0	0,9	0,8	0,6	1,0	1,0
VIII Biobío	1,6	0,0	1,3	1,1	1,0	0,9	1,0	0,6	1,2	0,9
IX La Araucanía	0,9	0,7	1,3	1,6	1,0	0,8	0,9	0,5	2,7	0,9
XIV Los Ríos	0,9	1,7	0,9	1,6	1,1	0,9	1,0	0,8	2,4	0,8
X Los Lagos	0,2	0,3	1,1	0,7	1,0	1,1	1,1	1,5	0,8	1,1
XI Aysén	2,2	0,2	1,2	0,8	1,0	0,6	0,9	0,6	1,0	1,1
XII Magallanes	1,3	2,3	0,7	0,9	0,7	1,0	1,4	0,6	1,2	0,8

Source: own calculations based on employment data

The development of employment follows the output, taking into account the sector-specific labor productivity. The interplay between output and labor productivity results in changes in employment. 28% of total employment is in “personal services”, 20% in “trade, hotels, restaurants” and 12% in manufacturing. “Electricity, gas, water” accounts only for 1% and ”Mining“ for 3%.

Figure 9: Employment by regions



Source: own calculations with COFORCE

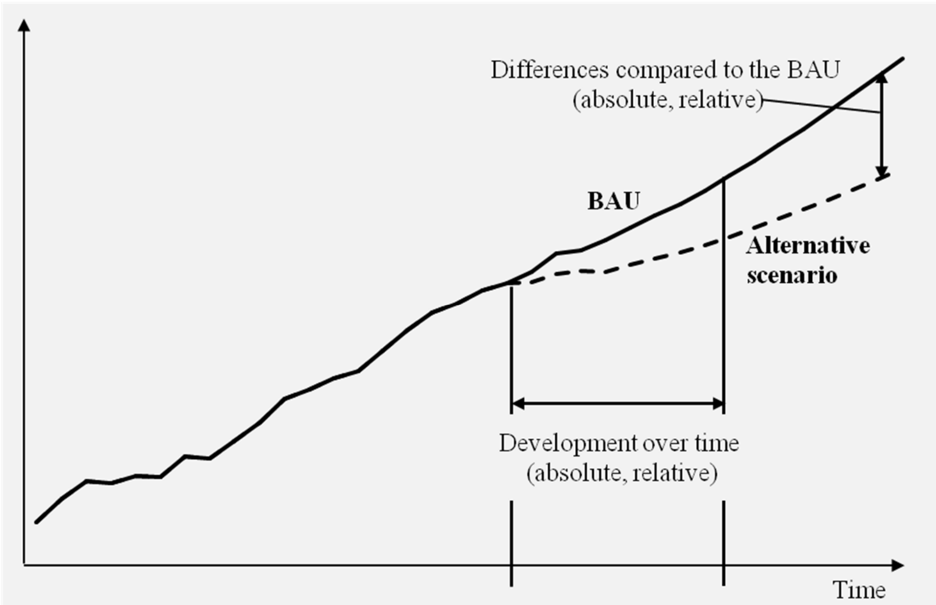
The high share in total employment for Los Lagos reflects the industry structure in that region. The same applies to Antofagasta with its strong mining sector and low employment share of 2% (Figure 9).

4 SCENARIO ANALYSIS

The COFORCE modelling framework can be applied for projections and scenario analysis. The most basic projection assumes that past behavior is also effective in the future and it relies on a few exogenous assumptions such as the population forecast from Chilean experts (baseline scenario[7]).

To analyze the impacts ("what if") of exogenous assumptions on future developments or policy measures, so-called scenarios are developed. A scenario consists of one or a set of consistent assumptions which are fed into the model. The alternative scenario will be compared to the results of the baseline scenario. Comparing two scenarios reveals differences that can be interpreted as reactions to the impulses induced by the assumptions. The differences in results illustrate the impacts of the initial changes at a specific point in time and over time (Figure 10).

Figure 10: Comparing scenarios



Source: own representation

Even if the GWS experts have developed and implemented the COFORCE model, non-model makers can also use COFORCE for scenario analysis. For this, GWS has developed a user-friendly interface named *solver*©.

In the next subsection, *solver*© is introduced in short. Subsequently, an export scenario which was already evaluated at national level is documented for the 15 regions as well. Then, two examples are used to show how the assumptions of constant regional demand share and regional market share indicators can be eliminated and what influence this has on important economic variables in the regions.

[7] The results of this scenario is described in Bieritz/Mönnig 2019 (section 5) for the macroeconomic and in section 3.2 for the Chilean regions.

The design and results of all scenarios are documented and evaluated. In addition to the description of the scenario assumptions and the rationale behind, the technical implementation is also briefly described.

4.1 GRAPHICAL USER INTERFACE “SOLVER”

Macro-econometric IO models such as COFORCE are complex mathematical tools. They contain large amounts of historical and forecasted data, hundreds to thousands of equations and require expert knowledge about the underlying set of programs and programming languages. Therefore, such models usually can only be used and maintained by those people who build them. Collaborated work becomes more difficult than it’s supposed to be: Field experts have to pass their assumptions to the model builders which have to “translate” these assumptions into model code. Then, the model output has to be translated into a form which can be understood by the field experts. Usually, this process has to be carried out several times until the model output can be considered as final.

solver© was designed to give both model builders and field experts the opportunity to focus their work on data analysis and scenario building without having to know every detail of the model structure.

solver© can be used to carry out the following tasks

- data analysis
- scenario building
- scenario analysis

Data analysis: Historical and forecasted data is stored in a unified database format. The database contains time series (e. g. population), vectors (e. g. exports by kinds of products) and matrices (e. g. interregional input-output table). To speed up navigation, variables are combined into groups (e. g. REGIO). solver© also offers several visualization options: Table views, graphs, absolute values, growth rate, difference between years/variables, index. Users can select any of these options and instantly see the results.

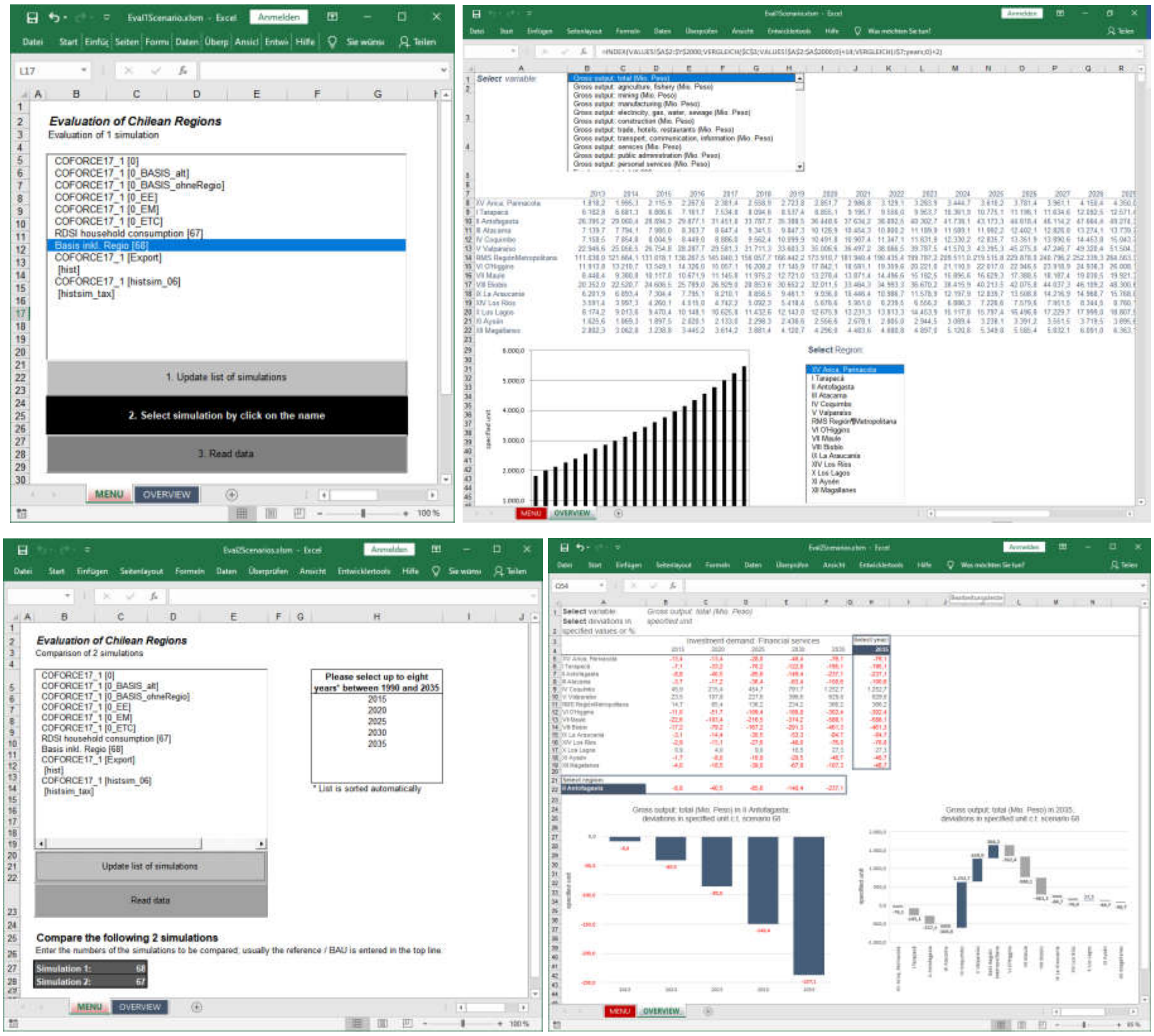
Scenario building: solver© is equipped with an easy-to-use assistant which guides the user through the necessary steps to build a scenario. The user is presented a set of parameters which can be changed to build a certain scenario. To minimize the effort for building complex scenarios, users can select already computed scenarios as a template. solver© collects the parameter changes, configures and runs the model in the background, stores the results and adds them the list of available scenarios.

Scenario analysis: solver© automatically stores every scenario that gets computed. Users can choose any of the visualization options listed under data analysis to compare up to four scenarios.

Evaluation tools in Microsoft Excel are accessible through the graphical user interface (GUI) solver©. In addition to the evaluation tools at the national level, the following Microsoft (MS) Excel evaluation tools are available for the 15 Chilean regions:

- For one simulation (REGIO_Eval1Scenario.xlsm)
- For comparison of 2 simulations (REGIO_Eval2Scenarios.xlsm)

Figure 11: Evaluation of 1 simulation (upper figures); Comparison of 2 simulations (lower figures)



Source: own presentation

4.2 EXPORT SCENARIO

4.2.1 GENERAL DESCRIPTION OF THE SCENARIO

To analyse the copper dependency and vulnerability of the Chilean economy and its regions, a demand shift towards the rising copper supply of its northern neighbor Peru has been developed. The rationale behind the export scenario is that copper demand is still increasing worldwide especially due to the growing markets for electromobility and renewable energy (Toyama 2017, Warren Centre 2016, McHugh 2017). Chile will probably lose world market shares because Peru increases its copper production through the exploitation of the Las Bambas mine (Chong et. al. 2016, La República 2017, Taj 2018).

This scenario was already calculated with the national model COFORCE and documented in Bieritz/Mönnig 2020. Thus, the scenario settings and the results at the national level are only described in short below.

4.2.2 SCENARIO SETTINGS

The starting point is a reduction in Chilean copper exports to India and China of 5% each p. a. for a period of five years (2018–2022) compared to the baseline scenario. Chileans copper exports are still increasing but at a lower growth rate than in the baseline scenario (Table 5).

In 2017, the year before the intervention, the export shares of China amount to 33.8% and the Indian shares amount to 12.9%. The export shares of copper going to India and China decrease over time and amount to 31.7% for China and 12.7% for India in 2022. After the five years period, a return to the former export demand is assumed.

Table 5: Development of Chilean copper exports in the baseline and copper export scenario (upper figure) and China's and India's share in Chilean copper exports (lower figure)

	2017	2018	2019	2020	2021	2022
	Development of Chilean copper exports to the world in baseline and in the scenario (2017 = 100)					
baseline	100,0	106,1	109,1	112,3	115,5	119,0
scenario	100,0	103,5	103,9	104,4	104,8	105,3

	2017	2018	2019	2020	2021	2022
China	33,8	33,7	33,0	32,7	32,3	31,7
India	12,9	12,9	13,1	12,9	12,8	12,7

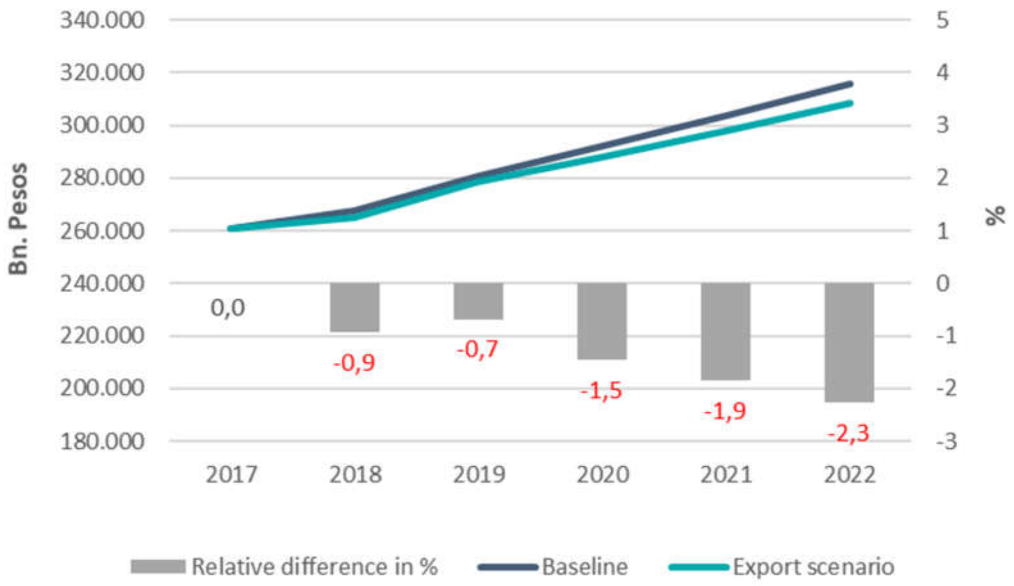
Source: own calculations with COFORCE

4.2.3 SCENARIO RESULTS

The initial change in copper exports leads to a decrease of total export in constant prices of -5.8% compared to the baseline scenario (Figure 13).

This lower demand reduces the whole Chilean production in constant prices by -2.3% in 2022 compared to the baseline scenario. In Figure 12 the development of production in constant prices is contrasted for the baseline scenario (blue line) to the export scenario (green line). The grey bars show the relative difference of the production between both scenarios (right axis).

Figure 12: Production in constant prices, 2016–2022 in Bn. Peso



Source: own calculations with COFORCE

Focusing on the industry level, the relative decrease of the production of the copper industry itself by nearly 15% compared to the baseline scenario is notable. The production of the manufacturing of machinery and electrical equipment are strongly affected as well as electricity supply and iron mining (Table 6). To summarize, the industries which are strongly related to the copper mining industry are affected most.

Table 6: Top ten affected industries in production (constant prices) in the export scenario compared to the baseline scenario in % (2018–2022)

	2018	2019	2020	2021	2022
Copper Mining	-3.9	-5.3	-9.1	-11.9	-14.7
Manufacture of machinery and electrical	-2.4	-2.3	-3.7	-4.7	-5.7
Electricity supply	-1.4	-1.9	-3.4	-4.4	-5.3
Iron Mining	-2.8	-0.6	-2.8	-3.7	-4.6
Gas supply	-1.7	-1.2	-2.7	-3.4	-4.2
Railway transport	-1.2	-0.9	-2.0	-2.5	-3.0
Manufacture of transportation equipment	-0.3	-2.4	-2.0	-2.5	-3.0
Manufacture of machinery and non-electrical	-0.7	-1.4	-1.6	-2.1	-2.6
Manufacture of rubber products	0.3	-2.0	-1.6	-2.1	-2.6
Oil Extraction	-1.2	-1.2	-1.4	-1.9	-2.3

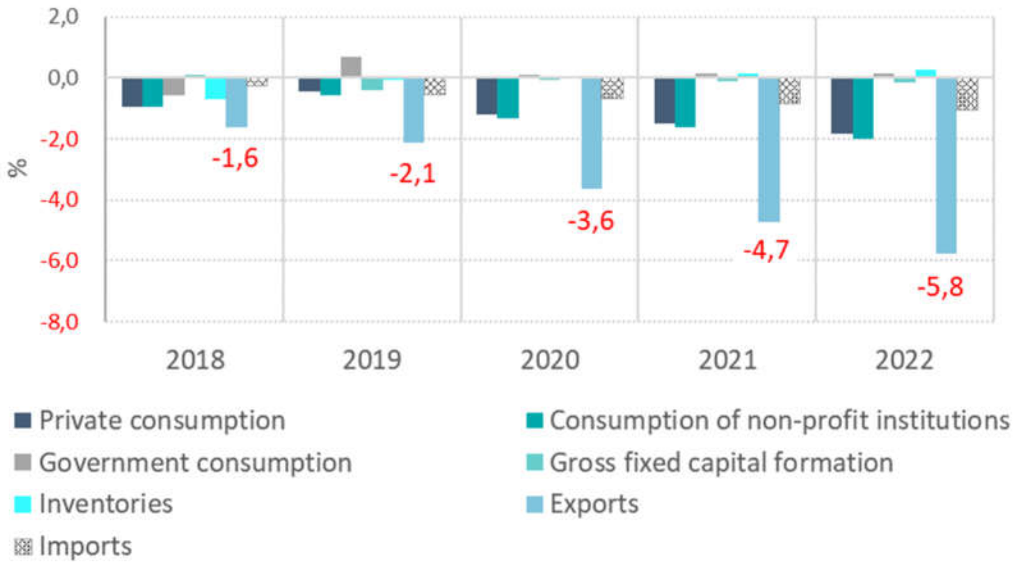
Source: own calculations with COFORCE

Lower copper exports weaken the Chilean GDP which decreases up to -2% compared to the baseline scenario. One consequence of the weaker copper production is a decline in total employment of up to -0.8%. As a result, the income and consumer demand (-1.8% compared to baseline in 2022, Figure 13) of private households is lower. Decreasing imports (-1.1% in 2022) compared to the baseline scenario dampen the negative effect on the GDP.

Government revenues in Chile are heavily dependent on copper mining. Due to lower copper exports, governmental disposable income is reduced by 4.5% (2022). Codelco as a state-owned company has to deliver around 90% of its profits to the government, 10% remains for the company to invest. If governmental income decreases, government spending and investments will decline as well.

Additionally, lower economic and employment growth reduce revenues from income and product taxes. Consequently, its possibilities to enforce intended policy measures are limited.

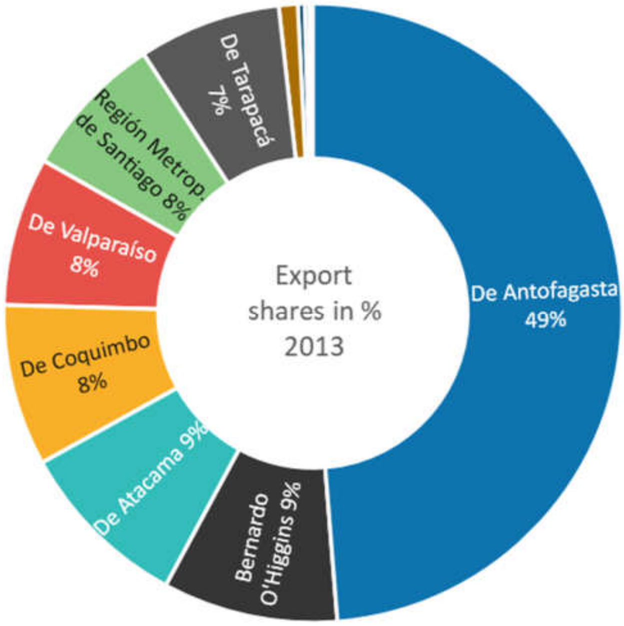
Figure 13: Relative differences in price-adjusted GDP components compared to the baseline scenario



Source: own calculations with COFORCE

The nation-wide effects impact the 15 regions differently due to their economic structure. The export shares of mining products (incl. copper) are highest in Antofagasta 49% resp. eleven billion Peso. In this region, one of the biggest copper mines worldwide "Chuquicamata" is located. Six other regions have an export share of about 7 to 9% which accounts to at max two billion Peso (Figure 14).

Figure 14: Regional export shares in % (2013)

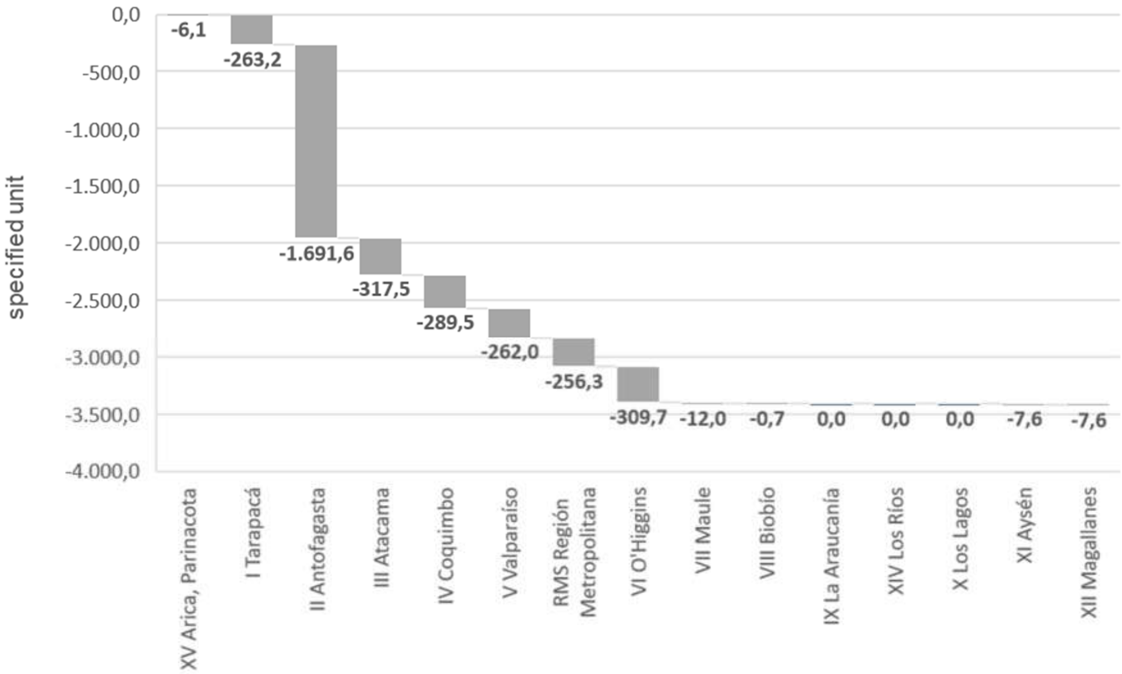


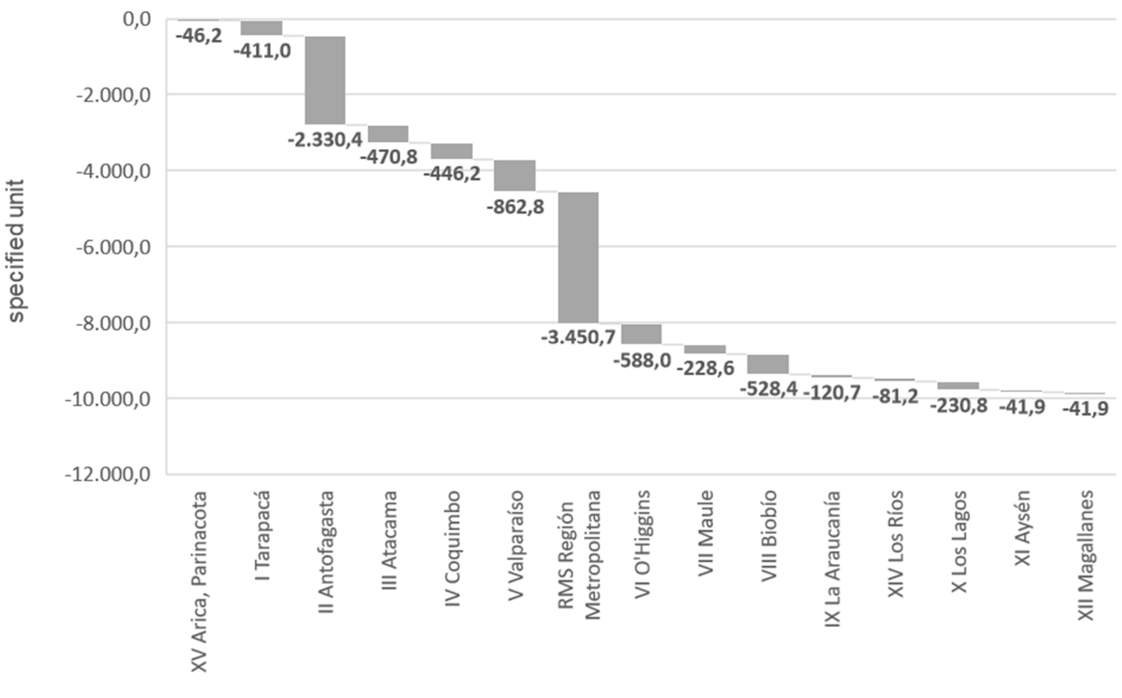
Source: IRIO 2013

Thus, the weakened copper exports affect Antofagasta the most. Production and employment are negatively affected as well. While gross output in mining affects only regions with mining industry (direct impacts), all regions are effected when looking at total output due to inter-industry and inter-regional effects (Figure 15 and Figure 16). The regional employment impacts show the same direction as production but the magnitude is different due to diverse sectoral labour productivity and regional economic structure. Strong interindustry linkages exists between the mining sector and “commerce” and “electricity, gas, water” sectors (see IO data and for example, Fernandez 2018).

Having a closer look at the mining industry reveals differences in the relation of output and employment i. e. for Tarapacá and Antofagasta. The reason is that labour productivity in Tarapacá is low and relatively high in Antofagasta. Thus, a small change in production is reflected in a big change in employment for Tarapacá while the employment effect for Antofagasta is relatively low compared to the production impact.

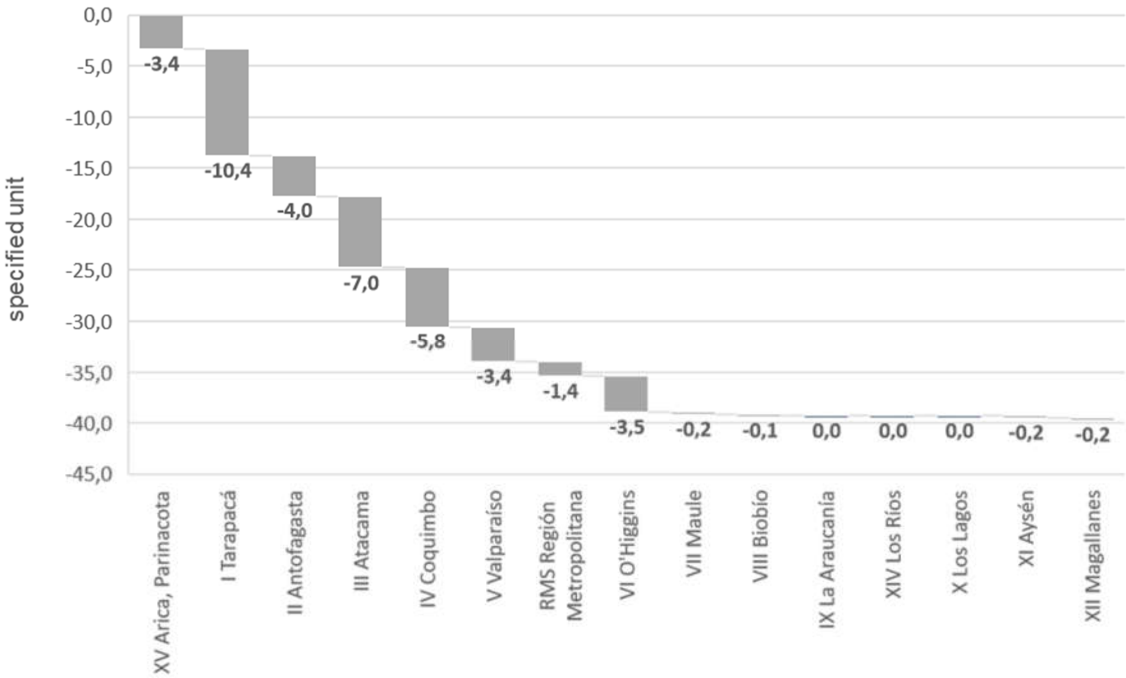
Figure 15: **Impacts on nominal gross output for mining industry (upper figure) and all industries (lower figure) in the export scenario compared to the baseline scenario, 2022 in Bn. Peso**

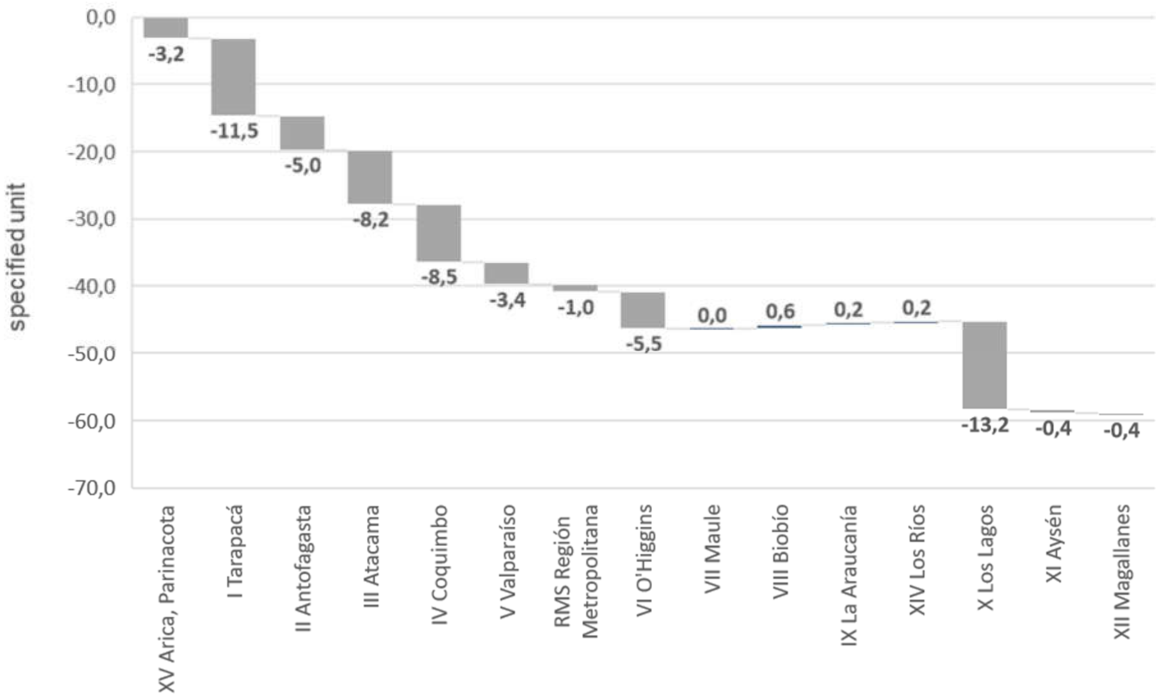




Source: own calculations with COFORCE

Figure 16: Impacts on employment in the mining industry (upper figure) and all industries (lower figure) in the export scenario compared to the baseline scenario, 2022 in 1,000 persons



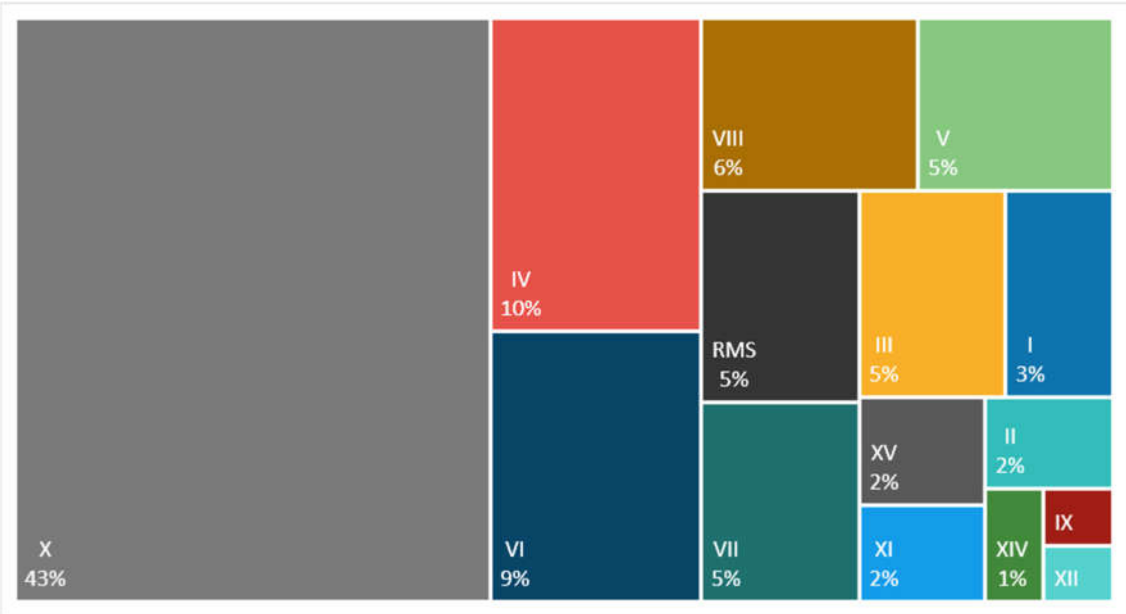


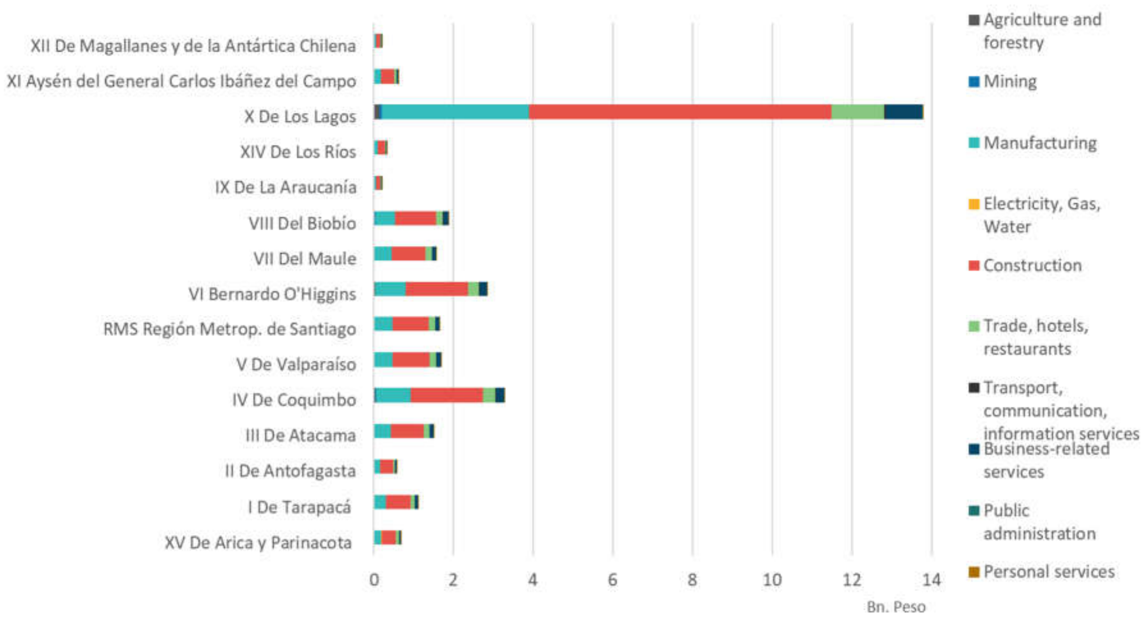
Source: own calculations with COFORCE

Depending on the economic importance of a region, the income-induced demand effects determined at the national level influence, among others, investment and private consumer demand at the regional level.

The majority of the investments take place in the construction (55% resp. 17.5 Bn. Peso) and the manufacturing industry (27% resp. 8.5 Bn. Peso). From a regional point of view, the regions "X De Los Lagos" with 43% (corresponds to 14 Bn. Peso), followed by "IV De Coquimbo" (10%), "VI Bernardo O'Higgins" (9%) and "VIII Del Biobío (6%)" are the top investment regions. The first three regions together account for 62% of total investment demand (Figure 17).

Figure 17: Regional investment shares in %, 2013 (upper figure) and regional investments by industries and regions (lower figure); 2013 in Bn. Peso

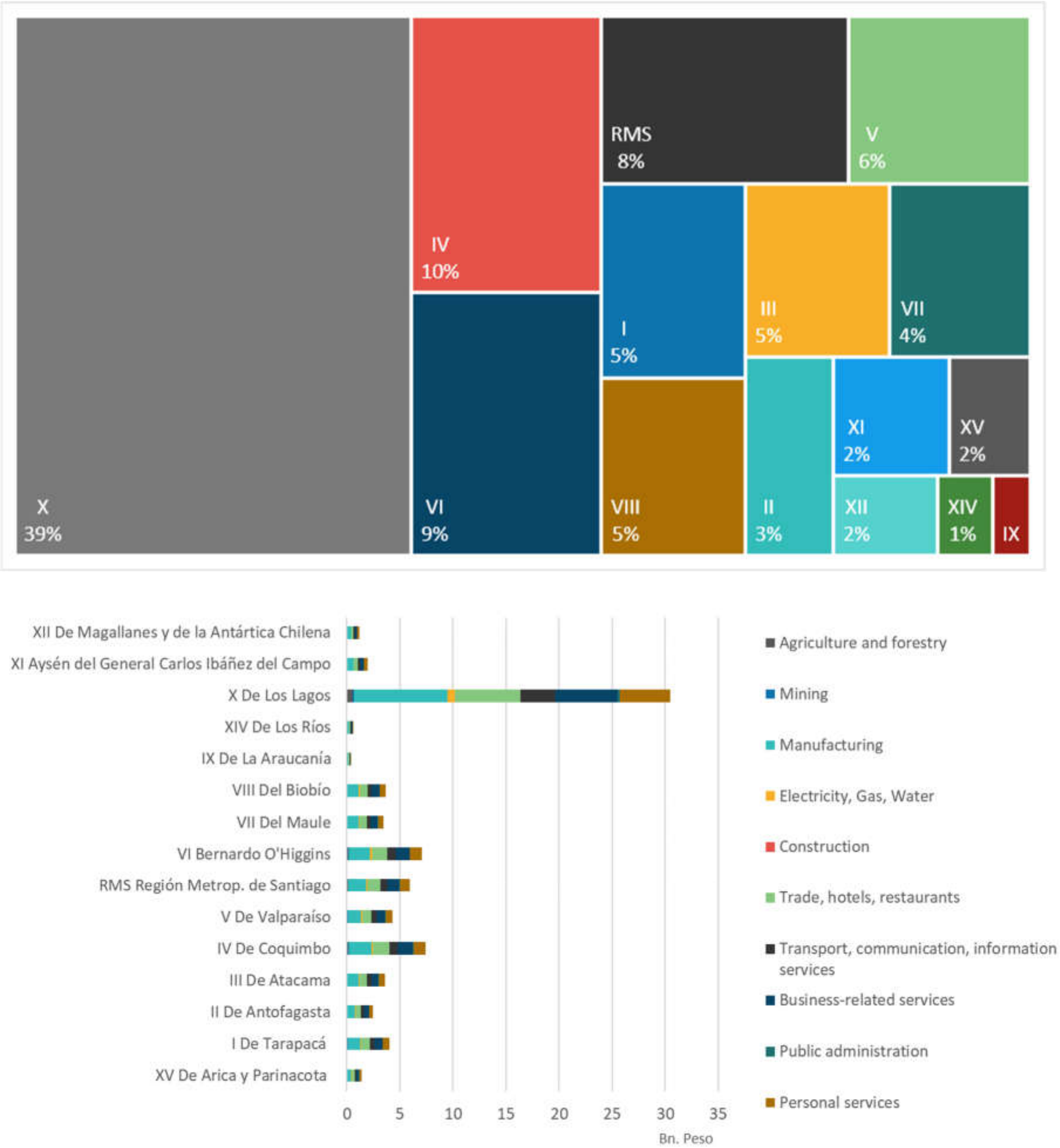




Source: IRIO 2013

Private consumer demand is distributed more evenly between industries as observed in investment demand. Manufacturing has the largest share at 29%, including the food industry. Together with 'trade, hotels, restaurants' (20%), 'business-related services' (19%), 'personal services' (16%) and 'transport, communication and information services' (11%), these industries cover 95% of total household demand (Figure 18).

Figure 18: Private consumption shares by industries in % (upper figure) and regional private consumption by industries and regions in Bn. Peso (lower figure), 2013

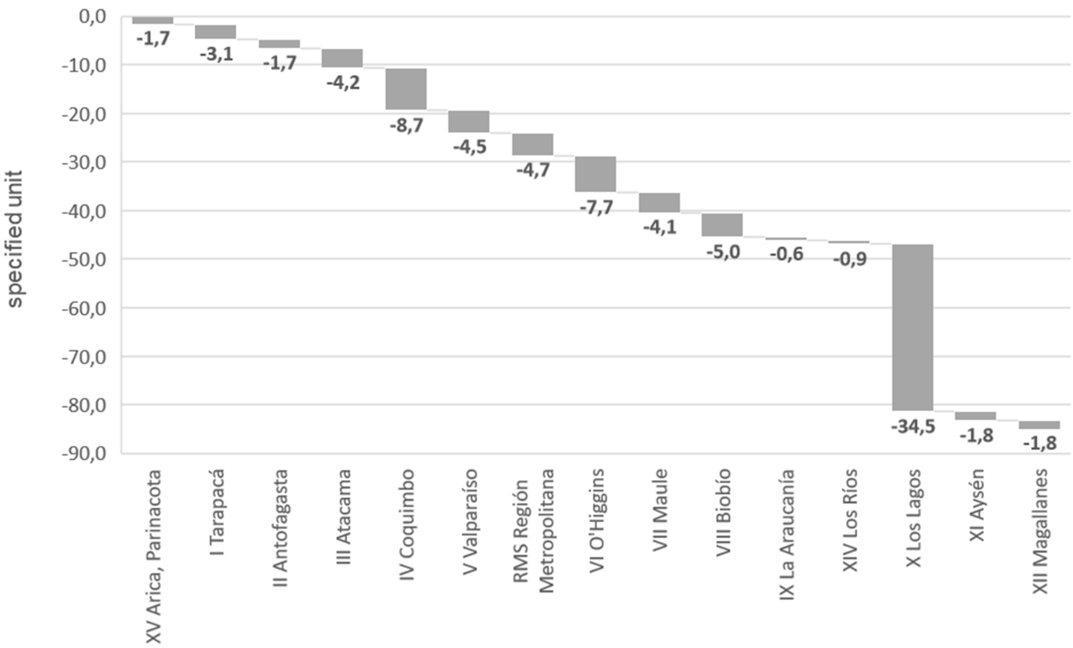


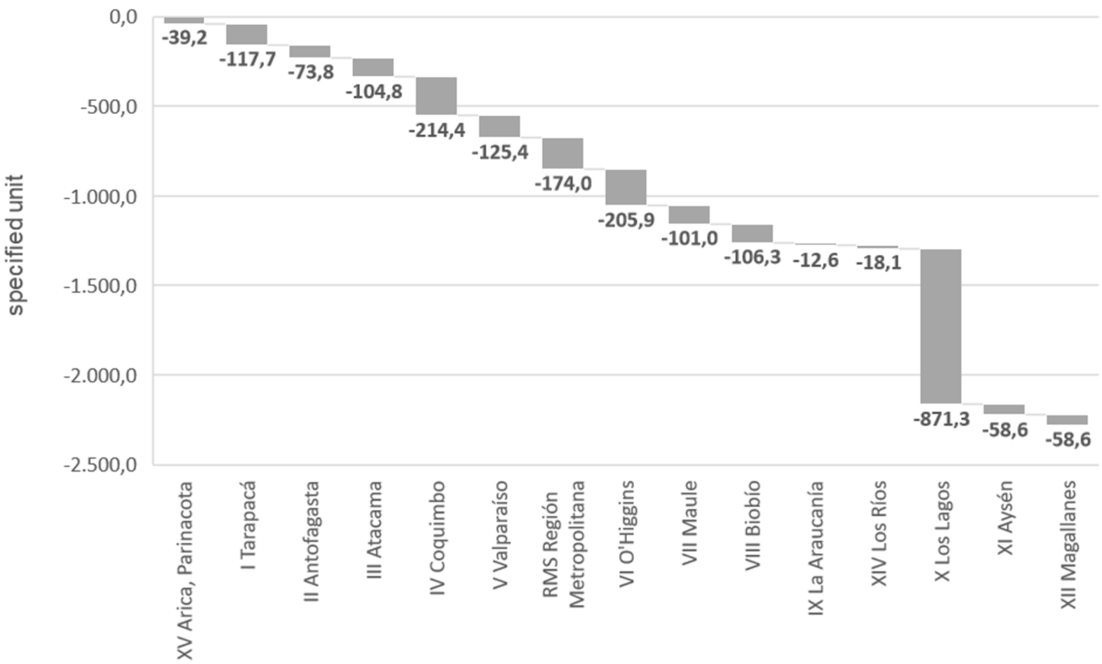
Source: IRIO 2013

The analysis of the regional distribution shows the dominance of the central and central southern regions such as "X De Los Lagos" (39%), "IV De Coquimbo" (10%), "VI Bernardo O'Higgins", "RMS Región Metrop. de Santiago" (8%) and "V De Valparaíso" (6%). The distribution thus follows the industrial occupation of the regions rather than the population structure. The Región Metropolitana de Santiago is home to 41% of the population, but only 8% (4th place in the regional ranking) of the demand for private households is generated in the region. In contrast, "X De Los Lagos" ranks 5th with 5% of the population, but 1st in the ranking of private consumption shares. In this region, the agriculture, forestry and fisheries as well as the associated manufacturing industries and tourism are strongly represented in this region.

The effects calculated at the national level for the demand of private households, the government and investments are transferred top-down to the regions. Figure 19 shows the regional results.

Figure 19: **Impacts on investment (upper figure) and household demand (lower figure) in the export scenario compared to the baseline scenario (2022, in Mio. Peso)**





Source: own calculations with COFORCE

In terms of investment demand, the region "X Los Lagos" shows the strongest decline in comparison to the baseline due to the high importance of investment demand in this region. Government consumption in "RMS Región Metropolitana" is declining the most, as Santiago de Chile, the capital, is home to the largest number of public institutions. In absolute terms, apart from the exports, private consumer demand has the greatest economic impact for the regions. "X Los Lagos" shows the strongest reaction with around 0.8 bn. Peso. All other regions show a maximum decline of 0.2 bn. Peso compared to the baseline (Figure 19).

The scenario results can be summarized as follows: it can be shown that not only the northern regions where the copper mining industry is located are affected. Other regions are affected as well especially due to the inter-industrial and interregional effects.

The supplying industries of mining i.e. manufacturing which are concentrated in Los Lagos show the greatest direct impacts. Additionally, also induced effects are impacting the same region the most. Nevertheless, the total output of Los Lagos does not show the greatest decline because it is highly dependent on interregional and cross-border imports (upper Figure 7 and lower Figure 7) which are declining as well. Thus, Región Metropolitana has greater impacts on production because that region is the main supplier region with regard to manufactured products.

4.3 ADJUSTING THE REGIONAL DEMAND SHARE INDICATORS

4.3.1 GENERAL DESCRIPTION OF THE SCENARIO

As described in section 3.1.1, the 'regional demand share indicator' $RDSI_i$ shows the ratio of final demand components by industries i of a demanding region $fd_{i,rd}$ and the counterpart at the national level fd_i as stated in the IRIO from 2013. In the baseline scenario, the *RDSI* for investment, household and government demand remains constant over time. According to the historical IRIO data for 2013 the regional distribution is the same for all industries.

In this scenario, the initial *RDSI* for household demand is adjusted according to changes in the population structure.[8]

It is important to mention that the following condition must be fulfilled at any time when changing the shares: The total of all regional shares per final demand and industry is equal to one. Therefore, a maximum 14 out of 15 regions can be adjusted in a scenario. A scaling routine ensures compliance with the condition by adjusting all non-exogenously modified regional shares.

8 Adjustments can be made for investment and government demand as well, but these are not part of that scenario.

Table 7: Regional demand share indicator *RDSI* by final demand components in 2013

	Investment demand	Household demand	Government demand
XV De Arica y Parinacota	0,02	0,02	0,03
I De Tarapacá	0,04	0,05	0,03
II De Antofagasta	0,02	0,03	0,03
III De Atacama	0,05	0,05	0,02
IV De Coquimbo	0,10	0,10	0,03
V De Valparaíso	0,05	0,06	0,10
RMS Región Metropolitana de Santiago	0,05	0,08	0,40
VI Del Libertador General Bernardo O'Higgins	0,09	0,09	0,04
VII Del Maule	0,05	0,05	0,05
VIII Del Biobío	0,06	0,05	0,10
IX De La Araucanía	0,01	0,01	0,05
XIV De Los Ríos	0,01	0,01	0,02
X De Los Lagos	0,43	0,39	0,05
XI Aysén del General Carlos Ibáñez del Campo	0,02	0,03	0,02
XII De Magallanes y de la Antártica Chilena	0,01	0,02	0,03
All regions	1,00	1,00	1,00

Source: calculations based in the IRIO 2013 compiled by Haddad et al. 2002, 2018

4.3.2 SCENARIO SETTINGS

It is assumed that the *RDSI* for household demand is changing according to the developments in population structure from 2014 onwards. All other model variables are not adjusted exogenously and change only according to the modelling context.

Figure 20: Percentage changes in regional population shares 2035 compared to 2013

	average annual growth rate in % (2014/2035)
XV De Arica y Parinacota	-0,19
I De Tarapacá	-0,19
II De Antofagasta	-0,19
III De Atacama	-0,19
IV De Coquimbo	0,00
V De Valparaíso	0,27
RMS Región Metropolitana de Santiago	-0,19
VI Del Libertador General Bernardo O'Higgins	-0,19
VII Del Maule	-0,42
VIII Del Biobío	-0,19
IX De La Araucanía	-0,19
XIV De Los Ríos	-0,19
X De Los Lagos	-0,19
XI Aysén del General Carlos Ibáñez del Campo	-0,19
XII De Magallanes y de la Antártica Chilena	-0,19

Source: own calculations

The average annual growth rate between 2014/2035 of the regional population shares 2013/2035 is applied to the *RDSI* for household demand for all 10 industries except for Coquimbo (Figure 20). The scaling routine will automatically adjust the value for the region(s) that is (are) not adjusted exogenously (here: Coquimbo) by ensuring that the condition mentioned above is fulfilled.

4.3.3 SCENARIO RESULTS

Applying the population share growth rates to the RDSI for household demand results in slightly higher shares for Valparaiso and Coquimbo. All other regions will lose shares. At the national level, the economy does not change.

Figure 21: Regional demand share indicator *RDSI* for household demand 2013 and 2035

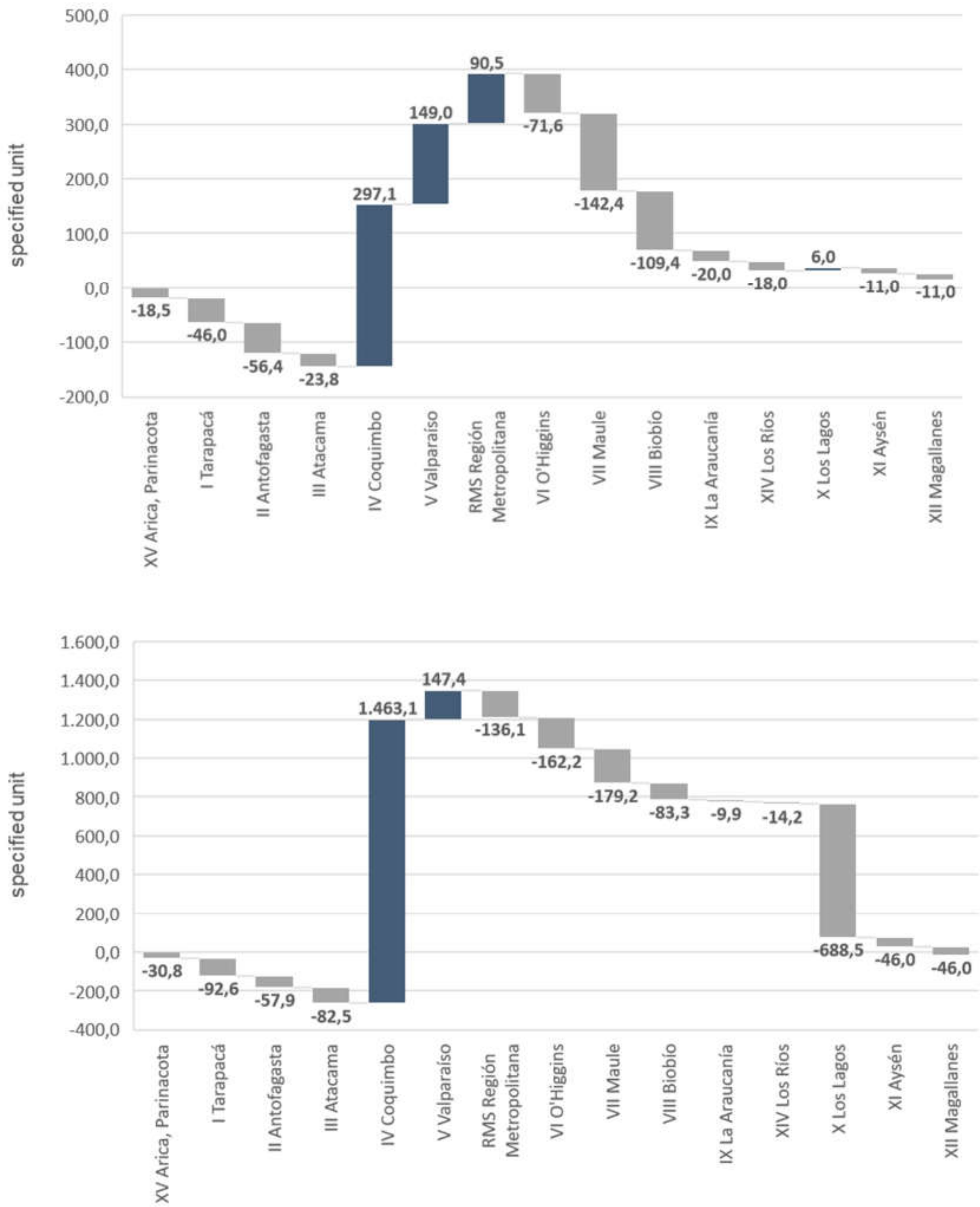
	Regional household demand shares		annual growth rate in %
	2013	2035	(2014/2035)
XV De Arica y Parinacota	0,017	0,017	-0,19
I De Tarapacá	0,051	0,049	-0,19
II De Antofagasta	0,032	0,030	-0,19
III De Atacama	0,046	0,044	-0,19
IV De Coquimbo	0,095	0,128	1,36
V De Valparaíso	0,055	0,059	0,27
RMS Región Metropolitana de Santiago	0,076	0,073	-0,19
VI Del Libertador General Bernardo O'Higgins	0,091	0,087	-0,19
VII Del Maule	0,045	0,041	-0,42
VIII Del Biobío	0,047	0,045	-0,19
IX De La Araucanía	0,005	0,005	-0,19
XIV De Los Ríos	0,008	0,008	-0,19
X De Los Lagos	0,391	0,375	-0,19
XI Aysén del General Carlos Ibáñez del Campo	0,025	0,024	-0,19
XII De Magallanes y de la Antártica Chilena	0,015	0,015	-0,19
All regions	1,000	1,000	

Source: own calculations with COFORCE

Given the same development for household consumptions at the national level, the demand impulse has a positive effect in Valparaiso and Coquimbo. All other regions have a lower level of household demand.

The household consumption structures are affected differently when comparing levels of consumption which in turn have impacts on the regional production (Figure 22). Depending on the interregional trade, the effects are for example positive for the Región Metropolitana and Los Lagos which do not profit from the initial increasing household demand.

Figure 22: **Regional differences for household demand (lower figure) and gross output (upper figure); in comparison to the baseline scenario (2035, in Mio. Peso)**

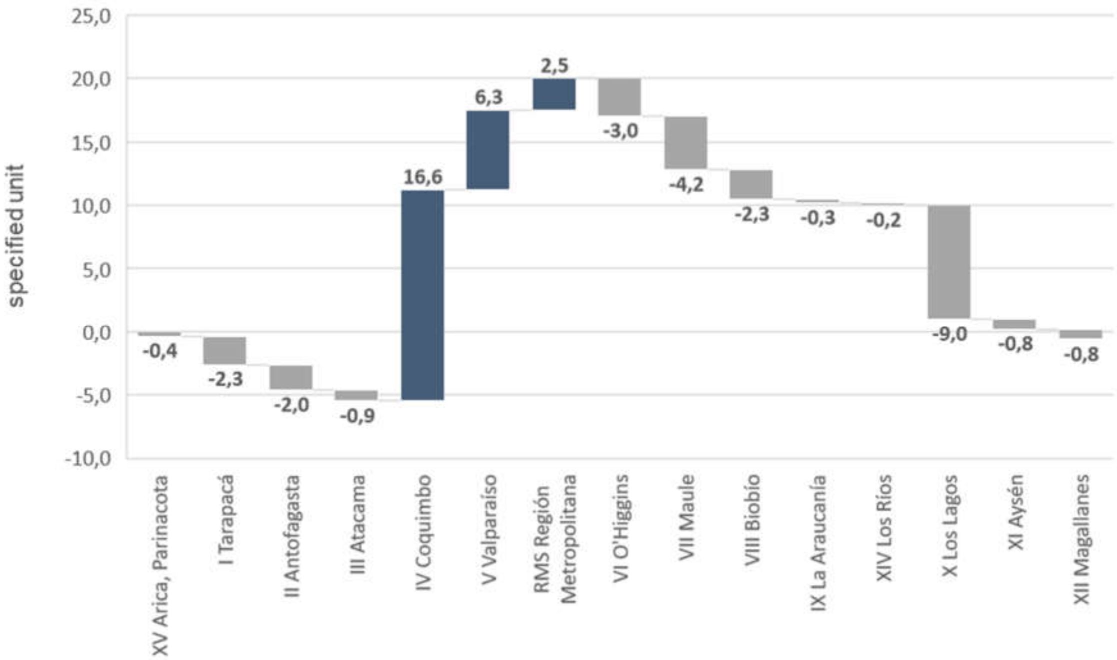


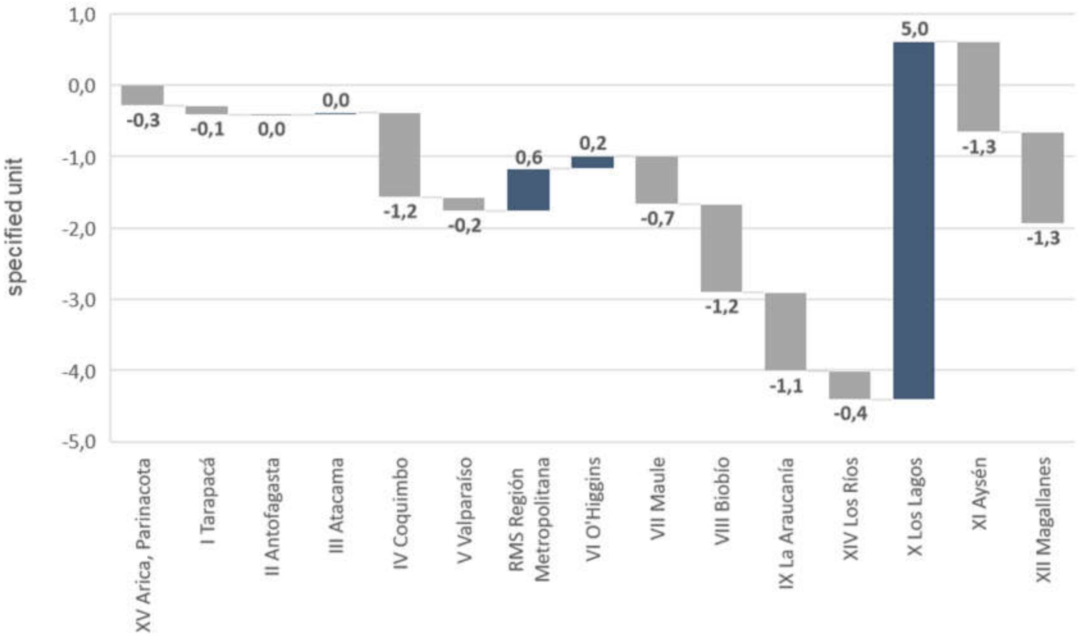
Source: own calculations with COFORCE

The degree of self-sufficiency in Coquimbo is not high enough to satisfy the additional household demand of e. g. agricultural products and fish. Thus, Coquimbo needs to import these products i. e. from other Chilean regions (upper **Figure 23**). The main interregional exporter of these products is Los Lagos (lower **Figure 23**).

This analysis can be done for the other regions and industries. The results for the total output is guided by these interregional relationships.

Figure 23: Differences in interregional exports (upper figure) and imports (lower figure) of agricultural products and fish; in comparison to the baseline scenario (2035, in Mio. Peso)

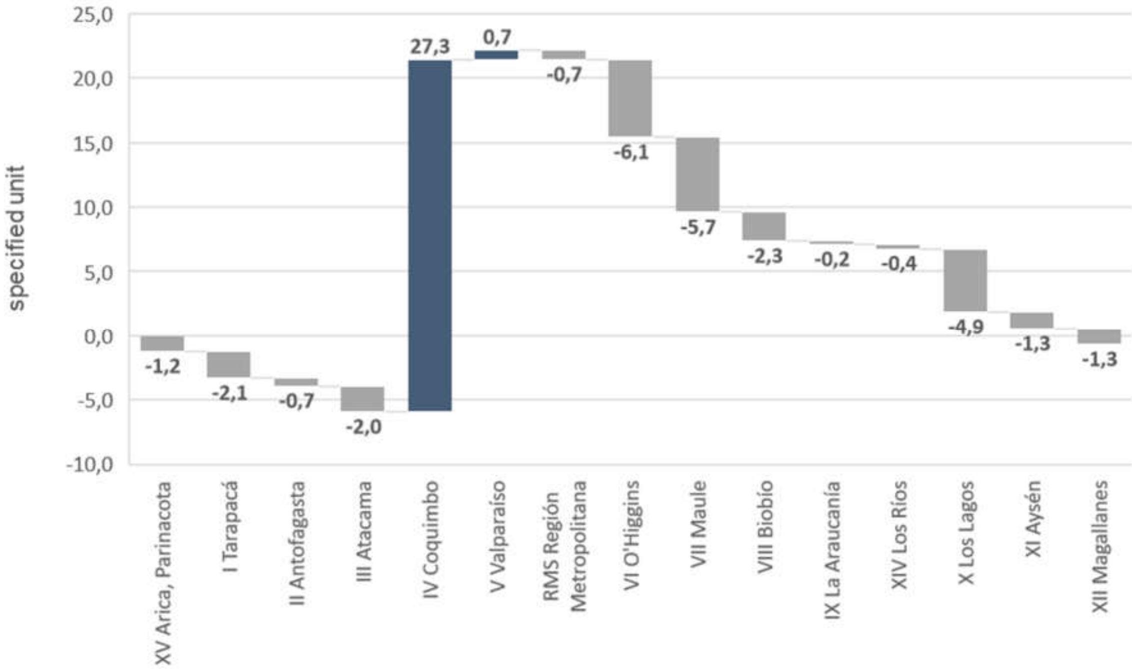




Source: own calculations with COFORCE

The results for employment shows Figure 24. The change in regional production as well as the labor productivity by industries and regions impacts the employment accordingly. The lower the labor productivity given an output, the more the employment is affected.

Figure 24: **Regional differences in total employment; in comparison to the baseline scenario (2035, in 1,000 persons)**



Source: own calculations with COFORCE

4.4 ADJUSTING THE REGIONAL MARKET SHARE INDICATORS

4.4.1 GENERAL DESCRIPTION OF THE SCENARIO

In the baseline scenario, the regional 'market share indicator' $RMSI_{i,rd,ro}$ which considers the origin of the final demand[9] by industries in each region, is assumed to remain at the historically given value. In this scenario, this assumption will be revoked.

There are in total 7,360[10] RMSI, which cannot be investigated all. Therefore, for each final demand component only the most important industry and region is selected which is supposed to have the highest impacts on its regional suppliers.

According to the underlying IRIO for 2013, the most important industry with respect to investment demand is construction (55%). For household demand, the manufacturing industry (29%) is relevant. In both cases, the demand comes first of all from Los Lagos. The sector "public administration" (49%) has a slightly higher share than "personal service" (48%) if government demand is in focus. In the Región Metropolitana, the demand for public goods is the highest due to the fact, that most of the public institutions are located in that area. For the exports, mining (50%) is the most important industry. The following figures show the shares by industries for each final demand component.

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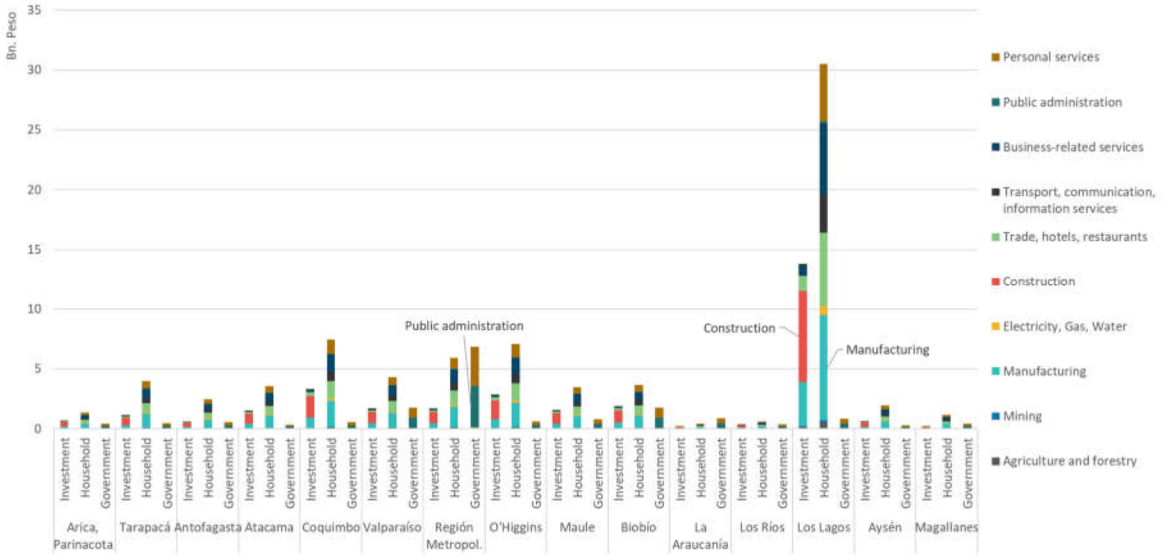
[9] Not to be confused with the intermediate consumption in the production process.

[10] This number results stems from the investment, household and government demand for 10 industries and exports which is produced in 10 industries and 16 regions (15 Chilean regions incl. rest of world).

Figure 25: Investment, household and government demand by industries and regions; Bn. Peso in 2013



Source: IRIO 2013 compiled by Haddad et al. 2002, 2018

For these four variables, Table 8 shows the RMSI. The top five regional suppliers for each demand are colored in turquoise. For example, the investment demand in Los Lagos in construction is mainly satisfied from the Region Metropolitana de Santiago (36%) and Antofagasta (24%). The household demand for manufactured products in Los Lagos is met in particular by imports from abroad (55%) and by interregional imports from the Region Metropolitana de Santiago (20%). Not surprisingly, government demand in public administration in the Region Metropolitana de Santiago is mainly satisfied in the same region (91%) where the largest number of public institutions are located. Export demand of mining products is mainly delivered by Antofagasta (49%).

In the following scenario, the initial *RMSI* for investment demand of the construction sector in Los Lagos is adjusted. Of course, adjustments can be made for each regional final demand by industry.

As described in the previous scenario, the following condition must be fulfilled at any time: The total of all regional shares per final demand and industry is equal to one. Therefore, a maximum 14 out of 15 regions can be adjusted in scenarios. A scaling routine ensures compliance with the condition by adjusting all non-exogenously modified regional shares.

Table 8: Selected regional market share indicators in 2013

	Investment demand: construction, Los Lagos	Household demand: manufacturing, Los Lagos	Government demand: public administration, Region Metropolitana	Exports: mining, Rest of World
XV De Arica y Parinacota	0.00	0.00	0.00	0.00
I De Tarapacá	0.01	0.00	0.00	0.07
II De Antofagasta	0.24	0.01	0.00	0.49
III De Atacama	0.08	0.00	0.00	0.09
IV De Coquimbo	0.05	0.00	0.01	0.09
V De Valparaíso	0.10	0.09	0.02	0.08
RMS Región Metropolitana de Santiago	0.36	0.20	0.91	0.08
VI Del Libertador General Bernardo O'Higgins	0.03	0.01	0.01	0.09
VII Del Maule	0.01	0.00	0.01	0.00
VIII Del Biobío	0.03	0.04	0.01	0.00
IX De La Araucanía	0.03	0.00	0.01	0.00
XIV De Los Ríos	0.00	0.01	0.00	0.00
X De Los Lagos	0.05	0.09	0.01	0.00
XI Aysén del General Carlos Ibáñez del Campo	0.00	0.00	0.00	0.00
XII De Magallanes y de la Antártica Chilena	0.01	0.00	0.00	0.01
Rest of World (imports)	0.00	0.55	0.00	0.00
All regions	**1.00**	**1.00**	**1.00**	**1.00**

Source: calculations based in the IRIO 2013 compiled by Haddad et al. 2002, 2018

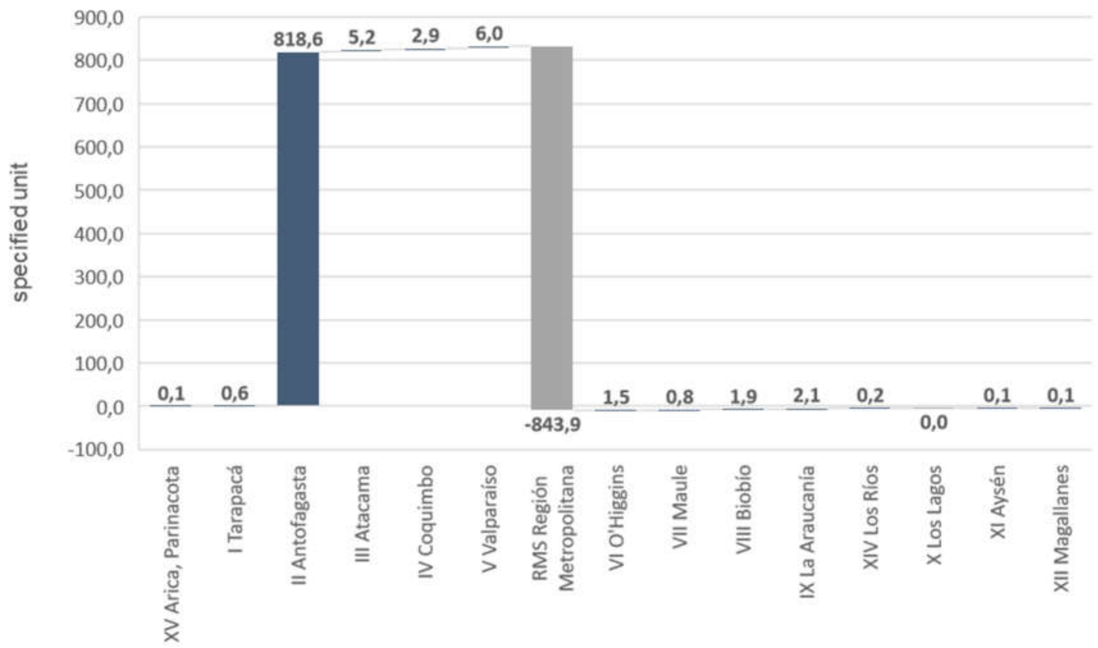
4.4.2 SCENARIO SETTINGS

It is assumed that the regional suppliers for investment demand of the construction sector in Los Lagos are changing from 2014 onwards. It is assumed that Antofagasta is able to increase its production capacities for investment goods for the construction sector while the Región Metropolitana de Santiago loses market share. The $RMSI_{25,13}$ for Antofagasta increases from 0.24 to 0.3 in 2035 and the $RMSI_{65,13}$ for RMS decreases in equal proportions which leads to a share of 0.3 in 2035 instead of 0.36. All other model variables are not adjusted exogenously and changes only occur according to the modelling context.

4.4.3 SCENARIO RESULTS

With the adjustment of the regional market shares, the supply of investment goods for the construction sector changes accordingly but not the total investment demand which is determined at the national level (Figure 26). That impacts, of course, the output in the construction sector which is similar to the initial change.

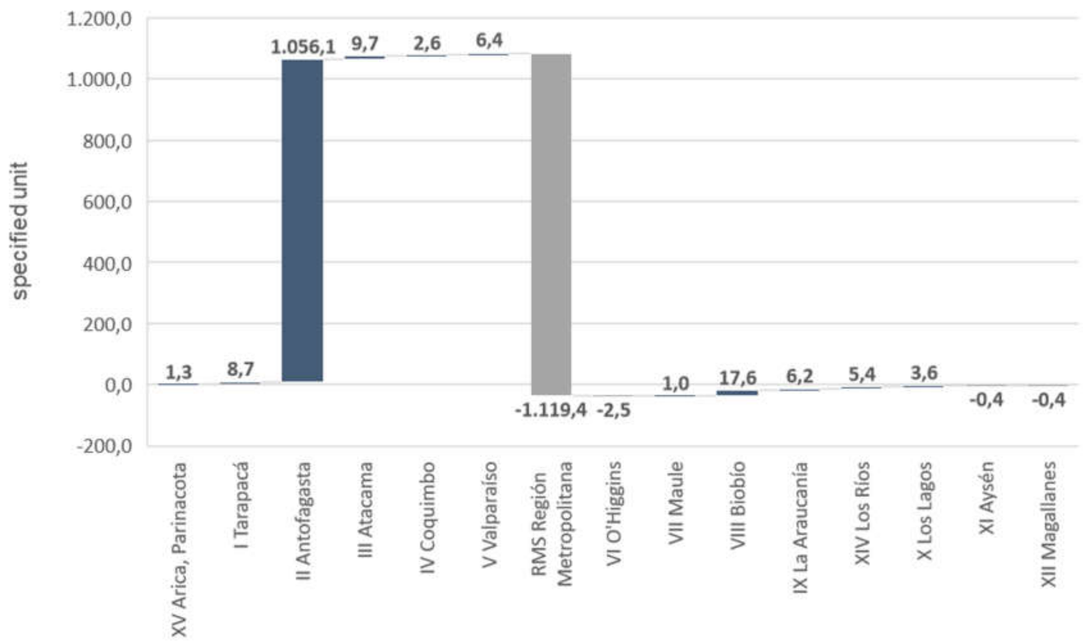
Figure 26: **Regional differences in interregional exports of investment goods for the construction sector; in comparison to the baseline scenario (2035, in Mio. Peso)**



Source: own calculations with COFORCE

The inter-industry relations also influence other sectors, including the manufacturing industry (e. g. cement, metals, business service activities) and thus regions. The total regional output changes compared to the baseline scenario are shown in Figure 27.

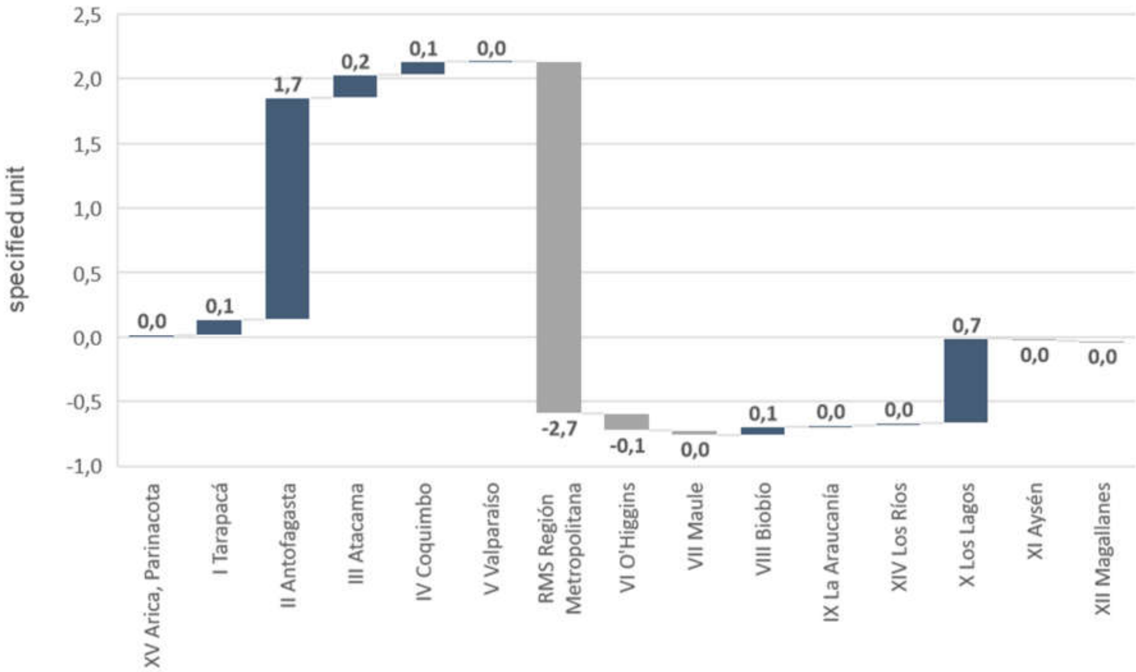
Figure 27: **Regional differences in total gross output; in comparison to the baseline scenario (2035, in Mio. Peso)**



Source: own calculations with COFORCE

Depending on the labor productivity and output changes, employment changes accordingly (Figure 28). The greatest effects are seen for Antofagasta and Región Metropolitana.

Figure 28: Regional differences in total employment; in comparison to the baseline scenario (2035, in 1,000 persons)



Source: own calculations with COFORCE

One might expect also changes for household demand due to regional income effects. Due to the straight top-down approach that is not the case here, but the model user can adjust these effects exogenously.

5 CONCLUSIONS AND OUTLOOK

This report gives an overview of the regionalization approach of the Chilean model COFORCE, which is based on an IRIO. The main transmission channels are explained and regional modeling results presented.

The results for the 15 Chilean regions are driven by the economic development at the national level. Depending on the regional industry structure and the interregional relationships, the macroeconomic effects are transmitted to the regions. The results of the regional analysis show that the strong presence of an industry in a region increases its vulnerability to shocks – positively and negatively (see also Mancini/Sala 2018).

A focus was on the mining industry due to its high importance with regard to economic growth and its geographical concentration in the northern regions of Chile. It is not surprising that these regions in particular are affected by changes in copper production. However, due to inter-industrial interdependencies, supplier industries such as “electricity supply”, “business service activities”, “commerce” and “fuel production” are affected as well. The spatial concentration of these industries then also influences other regions.

Due to limited data availability, the regional modeling approach is a simple, pure top-down approach without any regional economic cycle effects which might be caused by regional income effects. If there is no change at the national level, no effect will be seen in the regions.

The data and assumptions used to create the IRIO have a strong influence on the regional results presented in this report. The underlying data set is based on data for 2013. An updated data set might impact the interregional relationships. Additionally, the selected approach to regionalize the national input coefficients and to model the interregional trade flows impacts the regional results as well.

Nevertheless, this regionalization approach gives first insights on subnational impacts. By embedding the regional model in a comprehensive economic modelling approach at national level, price and income effects on demand and production are also taken into account at the regional level. An improvement of the regional modelling approach could be the integration of time series of IRIO. The observed historical development over time could then be projected into the future instead of using constant relationships or introducing expected changes as exemplified in section 4.3 and 4.4.

Another important outcome of this project is that the regionalized national model for Chile COFORCE was handed over to the Chilean partners from the University Adolfo Ibañez in Viña del Mar. The model is equipped with a graphical user interface solver© for carrying out scenario analysis and Microsoft Excel tools for evaluation purposes. Thus, the partners can carry out scenario analyses independently and are therefore not limited to the precalculated scenarios.

ANNEX

Annex 1: Assignment of industry classification at national and regional level

No.	Industry classification (National Accounts)	No.	Industry classification (IRIO)
1	Agriculture	1	Agriculture, Forestry and Fishing
2	Fruitculture		
3	Farming		
4	Forestry		
5	Extractive Fishing		
6	Coal Extraction	2	Mining and quarrying
7	Oil Extraction		
8	Iron Mining		
9	Copper Mining		
10	Other Mining Activities		
11	Meat Production	3	Manufacturing industry
12	Fishing Industry		
13	Canning Processing		
14	Oil Production		
15	Milk Industry		
16	Milling		
17	Manufacture of animal feed		
18	Bakeries		
19	Sugar		
20	Manufacture of other food products		
21	Manufacture of spirits and liqueurs		
22	Wine making		
23	Beer making		
24	Manufacture of non-alcoholic beverages		
25	Manufacture of tobacco products		
26	Manufacture of textiles		
27	Manufacture of clothing		
28	Manufacture of leather and its products		

29	Manufacture of footwear		
30	Production of wood and its products		
31	Manufacture of paper		
32	Printing and publishing		
33	Fuel production		
34	Manufacture of basic chemical substances		
35	Manufacture of other chemical products		
36	Manufacture of rubber products		
37	Manufacture of plastic products		
38	Glass manufacture and its products		
39	Manufacture of other non-metallic mineral products		
40	Basic industries of iron and steel		
41	Basic industries of non-ferrous metals		
42	Manufacture of metallic products		
43	Manufacture of machinery and non-electrical equipment		
44	Manufacture of machinery and electrical equipment		
45	Manufacture of transportation equipment		
46	Furniture manufacturing		
47	Other manufacturing industries		
48	Electricity supply	4	Electricity, gas, water and waste management
49	Gas supply		
50	Water supply		
51	Construction	5	Construction
52	Commerce	6	Trade, hotels and restaurants
53	Hotels		
54	Restaurants		
55	Railway transport	7	Transport, communications and information services
56	Other land passenger transport		
57	Freight transport		

58	Marine transport		
59	Air transport		
60	Related transport activities		
61	Communications		
62	Financial intermediation	8	Financial intermediation, business services, housing and real estate services
63	Insurance companies		
64	Real estate activities		
65	Business service activities		
66	Home ownership		
67	Public administration	9	Public administration
68	Public education	10	Personal services
69	Private education		
70	Public health		
71	Private health		
72	Recreational activities		
73	Other service activities		

Annex 2: Chilean Regions

No.	Regions
1	XV Arica, Parinacota
2	I Tarapacá
3	II Antofagasta
4	III Atacama
5	IV Coquimbo
6	V Valparaíso
7	RMS Región Metropolitana
8	VI O'Higgins
9	VII Maule
10	VIII Biobío
11	IX La Araucanía
12	XIV Los Ríos
13	X Los Lagos
14	XI Aysén
15	XII Magallanes

Source: https://www.kooperation-international.de/uploads/_processed_/9/6/csm_Chile-gross_e1f4da418c.jpg, accessed May 5, 2020.

Annex 3: Regional output multiplier for "agriculture, forestry, fish" (upper figure) and mining (lower figure)

Solver - COFORCE17_1

Datei Analyzer Fenster Hilfe

ROM_A - Regional output multiplier: agriculture, forestry, fishing, De Arica y Parinacota / De Arica y Parinacota (COFORCE17_1 [0])

2013	ROM_A		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
			De Arica y Parin	De Tarapacá	De Antofagasta	De Atacama	De Coquimbo	De Valparaíso	Región Metropol	Del Libertador G	Del Maule	Del Biobío	De La Araucaní	De Los Ríos	De Los Lagos	Aysén del Gener	De Magallanes y
	Werte	Summe	1,789	1,977	2,009	1,809	1,726	1,715	1,722	1,711	1,700	1,741	1,725	1,731	1,823	2,002	1,861
1	De Arica y Parinacot	1,334	1,270	0,014	0,010	0,003	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,004	0,003	0,022
2	De Tarapacá	1,433	0,019	1,298	0,042	0,010	0,004	0,002	0,002	0,002	0,002	0,003	0,003	0,003	0,010	0,008	0,024
3	De Antofagasta	1,799	0,042	0,084	1,433	0,043	0,021	0,012	0,013	0,014	0,013	0,013	0,016	0,017	0,023	0,023	0,033
4	De Atacama	1,294	0,008	0,011	0,017	1,201	0,008	0,004	0,004	0,004	0,003	0,003	0,003	0,004	0,010	0,006	0,007
5	De Coquimbo	1,216	0,006	0,007	0,008	0,011	1,113	0,012	0,008	0,005	0,004	0,003	0,003	0,003	0,022	0,006	0,005
6	De Valparaíso	1,747	0,023	0,038	0,035	0,043	0,061	1,310	0,028	0,020	0,014	0,009	0,007	0,008	0,106	0,029	0,016
7	Región Metropolitana	5,490	0,265	0,315	0,268	0,337	0,382	0,280	1,549	0,359	0,271	0,186	0,127	0,161	0,430	0,369	0,189
8	Del Libertador Gener	1,466	0,015	0,019	0,019	0,021	0,021	0,017	0,034	1,201	0,028	0,014	0,009	0,008	0,020	0,027	0,013
9	Del Maule	1,514	0,013	0,015	0,015	0,015	0,014	0,012	0,020	0,029	1,277	0,019	0,009	0,007	0,014	0,044	0,012
10	Del Biobío	2,299	0,054	0,077	0,069	0,058	0,039	0,021	0,029	0,044	0,054	1,439	0,042	0,023	0,049	0,269	0,032
11	De La Araucanía	1,704	0,015	0,018	0,015	0,016	0,012	0,009	0,013	0,013	0,014	0,023	1,486	0,020	0,011	0,025	0,015
12	De Los Ríos	1,609	0,015	0,019	0,016	0,013	0,007	0,004	0,006	0,006	0,006	0,007	0,011	1,466	0,008	0,016	0,009
13	De Los Lagos	1,336	0,013	0,026	0,034	0,027	0,038	0,027	0,012	0,009	0,006	0,006	0,004	0,005	1,096	0,025	0,011
14	Aysén del General C	1,247	0,005	0,011	0,015	0,007	0,004	0,002	0,003	0,004	0,007	0,014	0,004	0,004	0,017	1,146	0,005
15	De Magallanes y de	1,552	0,029	0,024	0,012	0,004	0,002	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,003	0,003	1,467

ROM_M - Regional output multiplier: mining, quarrying, De Arica y Parinacota / De Arica y Parinacota (COFORCE17_1 [0])

2013	ROM_M		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
			De Arica y Parin	De Tarapacá	De Antofagasta	De Atacama	De Coquimbo	De Valparaíso	Región Metropol	Del Libertador G	Del Maule	Del Biobío	De La Araucaní	De Los Ríos	De Los Lagos	Aysén del Gener	De Magallanes y
	Werte	Summe	1,509	1,558	1,583	1,561	1,547	1,507	1,519	1,532	1,497	1,494	1,000	1,000	1,000	1,554	1,527
1	De Arica y Parinacot	1,163	1,149	0,003	0,001	0,001	0,001	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,001	0,006
2	De Tarapacá	1,232	0,013	1,160	0,017	0,006	0,004	0,002	0,003	0,003	0,003	0,003	0,000	0,000	0,000	0,004	0,013
3	De Antofagasta	1,780	0,060	0,091	1,308	0,063	0,045	0,024	0,027	0,030	0,024	0,025	0,000	0,000	0,000	0,040	0,044
4	De Atacama	1,285	0,009	0,010	0,016	1,200	0,012	0,005	0,005	0,006	0,004	0,004	0,000	0,000	0,000	0,007	0,006
5	De Coquimbo	1,145	0,004	0,004	0,006	0,007	1,088	0,009	0,006	0,005	0,004	0,003	0,000	0,000	0,000	0,005	0,003
6	De Valparaíso	1,495	0,018	0,023	0,021	0,026	0,061	1,258	0,024	0,019	0,010	0,007	0,000	0,000	0,000	0,017	0,011
7	Región Metropolitana	3,211	0,152	0,160	0,130	0,180	0,238	0,164	1,392	0,227	0,160	0,108	0,000	0,000	0,000	0,196	0,104
8	Del Libertador Gener	1,287	0,009	0,010	0,010	0,010	0,013	0,008	0,015	1,161	0,017	0,009	0,000	0,000	0,000	0,020	0,006
9	Del Maule	1,376	0,012	0,013	0,011	0,008	0,013	0,006	0,010	0,021	1,227	0,008	0,000	0,000	0,000	0,038	0,008
10	Del Biobío	1,800	0,047	0,051	0,039	0,034	0,040	0,015	0,022	0,042	0,033	1,311	0,000	0,000	0,000	0,142	0,025
11	De La Araucanía	1,067	0,006	0,007	0,006	0,006	0,005	0,002	0,003	0,005	0,005	0,007	1,000	0,000	0,000	0,010	0,005
12	De Los Ríos	1,052	0,007	0,008	0,006	0,006	0,004	0,002	0,002	0,003	0,002	0,002	0,000	1,000	0,000	0,006	0,004
13	De Los Lagos	1,085	0,006	0,007	0,007	0,010	0,020	0,011	0,006	0,005	0,003	0,002	0,000	0,000	1,000	0,005	0,004
14	Aysén del General C	1,083	0,001	0,002	0,002	0,002	0,002	0,001	0,002	0,002	0,004	0,003	0,000	0,000	0,000	1,062	0,001
15	De Magallanes y de	1,326	0,016	0,009	0,004	0,002	0,001	0,001	0,001	0,001	0,001	0,001	0,000	0,000	0,000	0,001	1,289

Source: own calculations with COFORCE

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