# Chile: building a computable general equilibrium model with an application to the Bío Bío region

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**ABSTRACT**

This paper describes the building of a regional computable general equilibrium model applicable to the analysis of development policies and major economic shocks for specific regions of Chile. Then is generated an application for the Bío Bío region which reveals that the effects of the current fisheries crisis (caused by the scarcity of jack mackerel) can be expected to result in the production structure becoming further specialized in the wood and cellulose industries. It also finds that sectors with few production linkages to the fisheries sector are strongly affected through indirect channels that would be hard to identify without a general equilibrium approach.

**KEYWORDS**

Economic development, regional development, development policy, economic indicators, economic conditions, exports, imports, income, consumption, production specialization, industry, case studies, Chile

**JEL CLASSIFICATION**

C68, R11, R13

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# I

# Introduction

Analysing regional economic policies in a general equilibrium framework is intuitively attractive because it makes it possible to establish indirect links that would otherwise be hard to detect quantitatively. By capturing first- and second-order effects, computable general equilibrium (CGE) models can be used to identify transmission mechanisms and the total effects of a policy or shock on domestic, interregional, external and factor markets, with explicit consideration of the behaviour of economic agents in the form of adjustments via market-clearing prices. In practice, however, alternative regional evaluation tools are more commonly used, such as multipliers based on input-output matrices or econometric models. Partridge and Rickman (2010) argue that the limited use of regional CGE models is explained by their complexity and by shortcomings in their formulation, implementation and description.

Applications using CGE models at national level usually deal with international trade, public finance, energy, the environment, income distribution, and poverty, among other things (see Devarajan and Robinson, 2002). A variety of applications for Latin American countries can be reviewed in De Miguel and others (2010). The literature on regional CGE models is thematically diverse, but less plentiful.[1] Recent research includes the work of Julia-Wise, Cooke and Holland (2002), who analyse property taxes in the state of Idaho; Miguel-Vélez, Cardenete and Pérez-Mayo (2009), who study a rise in fuel taxes; Rickman and Snead (2007), who examine the growth and equity effects of subsidies to formal childcare for low-income families; Liu (2006), who deals with the economic repercussions of building an industrial science park in the south-eastern region of Taiwan; Conrad and Heng (2002), who discuss the role of public infrastructure in regional growth; Seung and others (2000), who evaluate the repercussions of reallocating water between the farming and tourism sectors; Patriquin and others (2002), who use an environmentally extended model incorporating natural capital in a region of Canada; Giesecke (2002), who identifies the causes of growth divergence between two regions of Australia; and Kim and Kim (2002), who consider the growth and equity effects of a regional development strategy based on investment incentives in the Republic of Korea.

In Latin America, applications of CGE models for regional impact analysis are relatively thin on the ground, and publications concentrate on countries such as Brazil and Colombia. In the case of Brazil, Haddad (1999) uses the B-MARIA model, based on the multiregional MONASH-MRF model of the Australian economy, to evaluate structural changes in the economy and changes in inequity in the event of unilateral liberalization of international trade; Haddad, Domingues and Perobelli (2002) consider alternative economic integration strategies on the basis of a national model and then, in a second stage, introduce an interregional model to generate a top-down disaggregation of the national results; Domingues and Lemos (2004) also focus on the regional consequences of trade liberalization strategies in Brazil, employing a multiregional model based on the MONASH-MRF model; Domingues and others (2002) explore changes in the interregional trade flows of 27 Brazilian states. In the case of Colombia, Iregui (2005) quantifies the welfare effects of a decentralization process using a multiregional CGE model; subsequently, Haddad and others (2009) construct a spatial general equilibrium model for the Colombian economy, including a detailed treatment of interregional trade, scale economies, market imperfections and transport costs.

The present study introduces a regional CGE model that is relatively easy to implement for other Latin American countries wishing to evaluate economic repercussions in a specific region.

In Chile, there have been empirical applications that have employed a general equilibrium approach, but only to investigate country-level impacts, as no studies have used a regional CGE there. The following may be cited as examples: Coeymans and Larraín (1994) analyse the repercussions following the signing of the United States-Chile Free Trade Agreement; Harrison, Rutherford and Tarr (1997, 1998 and 2005) investigate the effects of a policy of unilateral trade liberalization and the signing of free trade agreements (FTAs); Schuschny, Durán and De Miguel (2008) evaluate the effects of FTAs with Asian countries; O'Ryan and others (2011) examine the socio-economic and environmental effects

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[1] See Partridge and Rickman (1998), Rodríguez (2007) and Partridge and Rickman (2010) for an exhaustive review of the applications.

of FTAs; Holland and others (2005) study agricultural pricing policies and identify their effects on the economy and on urban-rural migration; O'Ryan, Miller and De Miguel (2003), O'Ryan and others (2005) and Dessus and O'Connor (2003) simulate environmental policies and their repercussions on the economy; Pereira and others (2009) focus on the introduction of copper mining royalties designed to attenuate "Dutch disease" and increase export diversification; and Mardones (2010 and 2011) analyses various reforms to the Chilean tax system.

The importance of having regional CGE models is that these can be used to analyse policies, shocks or both that are specific to a region, and likewise those of a national or international character, but concentrating on the economic repercussions for a particular region. Their usefulness becomes apparent when evaluating simulations of counterfactual scenarios that have effects on a variety of representative households, economic sectors and production factors which are impossible to capture with a partial equilibrium analysis.

General equilibrium effects can be important at the regional level insofar as policies and shocks affect sectors with strong production linkages or regions whose production structures are highly specialized. The specific issues that can be addressed with this tool are various, and may include determining how a region will be affected by social policies, stricter environmental regulations, energy price shocks, development policies aimed at particular economic sectors,[2] royalties on economic activities, and employment subsidies, among other things. Generally speaking, it is possible to model any impact on an exogenous variable or parameter represented in the model.

Although it is possible to use input-output models to obtain these proxies for a region, Rickman (1992) and Gillespie and others (2001) have shown that these overestimate economic repercussions in the absence of oversupply, since the assumptions of fixed prices and perfectly elastic supply do not allow the displacement of other economic activities and employment creation to be estimated. Furthermore, the lack of an economic structure means that fiscal policies cannot be evaluated in input-output models (Partridge and Rickman, 2010).

The regional CGE models used in the literature can be classified into two major categories: region-specific and multiregional. The main constraint causing models of the first type rather than the second to be chosen (apart from the difficulty of developing and programming them) is the availability of region-level data, in particular up-to-date input-output matrices for each region and interregional trade data. Chile does have regional input-output matrices (base year 1996) that fit the region-specific model, but interregional trade is not available, and even in the methodological detail of their construction (Riffo and others, 2006) it is mentioned that the data on a region's trade with other regions are not direct but are simply an adjustment account.

A CGE model for a specific region is designed with reference to a particular area within a country and is characterized by its similarity to a country-level model, with the difference lying in the treatment of the external sector, which in this case consists of the rest of the country and the rest of the world. Its main limitation is the inability to evaluate effects on other regions and on the country as a whole, something that becomes more important when the region is highly integrated into the rest of the national economy, since the picture of impacts that it provides is incomplete owing to the failure to capture interregional feedback effects. This limitation would not be completely removed with a multiregional CGE model, however, since in empirical applications the number of regions and sectors is usually small because of computing and data constraints (Wittwer and Horridge, 2010).

The present study sets out to fill the gap in this area by implementing a region-specific CGE[3] for the analysis of Chile's regional economies, modifying the equations of a standard country-level CGE model for this purpose (Löfgren, Harris and Robinson, 2001); this new model is called REGCGE. To show the benefits of this tool for the evaluation of regional public policies or economic shocks, an application specific to the Bío Bío region is generated. This analyses the macro, intersectoral, employment and household effects of the current fisheries crisis caused by the scarcity of jack mackerel, this choice being guided by the recent availability of a social accounting matrix (base year 2006) (Mardones and Saavedra, 2011) to calibrate the proposed model.

This paper is novel, and not only at the regional and national level, since the literature contains just one published study using the same methodology to model falling fish catches and rising fuel prices in Alaska (Waters and Seung, 2010), although neither model specifies

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[2] In Chile, for example, there has been a growing concern in recent years to produce long-term development strategies for the country's regions based on efforts to use regional development agencies to consolidate and fortify certain sectors of the economy.

[3] The strategy of modelling a specific region that has commercial ties with the rest of the country and the rest of the world fully concords with the structure of the databases of regional input-output matrices for Chile made available to the public by the National Statistics Institute (INE) in 2004.

endogenous interactions between fishing activity and changes in the biomass (stock) of the resource. Although there are other models specifying dynamic interactions in ecological and economic systems, such as Eichner and Pethig (2007) and Finnoff and Tschirhart (2005), these possess different characteristics to multisectoral CGE models like the one analysed in this study.

The rest of the article is structured as follows. Section II details the structure of the proposed regional CGE model and the regional social accounting matrix used to calibrate it. Section III details the application of the model to the Bío Bío region, using simulations of negative impacts affecting fishing productivity to represent the scarcity of jack mackerel, catches of which have fallen by over 45% since 2006. The aim is to determine the effects of this crisis on regional economic development. Lastly, section IV presents the main conclusions and future extensions of this study.

# II

# Methodology

## 1. Social accounting matrix

A basic condition for applying a CGE model is to have data available to calibrate it. In Chile, INE (2004) has published regional input-output matrices (base year 1996), which are essential for constructing regional social accounting matrices (Pyatt and Round, 1985), these in turn being the data needed to calibrate a regional CGE model. Although CGE models do not generally use a very recent base year (trusting that alterations in the economic structure take place in the medium and long term), 15 years is too long for the model application to constitute a reasonable proxy for the regional economy.[4, 5] Consequently, use is made of a social accounting matrix for the Bío Bío region (base year 2006) constructed by Mardones and Saavedra (2011), who updated the INE regional input-output matrix with information from the 2006 Annual National Industry Survey (ENIA), national accounts, customs, the sixth Family Budget Survey and the 2006 National Socio-economic Survey (CASEN), among other sources, using the indirect cross-entropy method[6] developed by Robinson, Cattaneo and El-Said (2001).

The methodology used to construct it consisted, in a first stage, in obtaining a regional social accounting matrix (SAM) for 1996, this being the initial element required to apply the updating methods. It was based mainly on the input-output matrix for the Bío Bío region, with base year 1996 (details of its construction in Riffo and others, 2006). Given the limited availability of regional sectoral information, the SAM included 20 production sectors. Information on value added and regional intermediate consumption by sector, updated to 2006, was then incorporated and this, along with the use of some estimates, allowed the intermediate consumption matrix (a component of the SAM) to be updated using the RAS method, which is an indirect method for obtaining an input-output matrix. The vector of value added updated to 2006 was based on Central Bank of Chile statistics on regional gross domestic product (GDP) by class of economic activity in the 2003-2006 period. In the case of manufacturing industries, both value added and total expenditure on intermediate purchases in these sectors were obtained from ENIA 2006, prepared by the INE. The use of this matrix, some known information (such as exports to the rest of the world and public investment) and proxies that mainly involved taking as constant some regional proportions from 1996 or some national proportions allowed an updated regional SAM to be obtained using the cross-entropy method. Besides using the 1996 SAM as a starting element, this method required the definition of constraints given by known (or reasonably estimated) information, much of which came from estimates arrived at using the RAS method. Each of these constraints was programmed using the cross-entropy method, following which the trial and error process was initiated with a view to implementing

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[4] MIDEPLAN (2005) provides a description and analysis of Chile's regional economies based on regional input-output matrices (base year 1996).

[5] Rojas (2009) develops a social accounting matrix for the Metropolitan Region of Santiago (base year 1996), the key inputs being the regional input-output matrix and assumptions about known linear relationships between national and regional data.

[6] The optimization method can be used to obtain a social accounting matrix from an older matrix by incorporating errors in the variables, inequality constraints and updated information on some parts of the matrix and not only the row and column totals.

the greatest possible number of constraints, so that the method would converge on a solution.

A problem that can arise when an indirect method is used to update the SAM is that the original ratio between technical coefficients is maintained. This means that even if the data are updated, the effects and ratios will be the earlier and not the latest ones. This point was addressed by employing an optimization procedure for updating the SAM, which included constraints associated with the intermediate consumption and value added of each activity on the basis of ENIA data or, if these were lacking, ratios based on regional sectoral GDP.

This can be corroborated by observing the change in the technical coefficients of the 2006 and 1996 SAMs. To simplify the results, table 1 presents an aggregation of the 20 original sectors into just five, labelled natural resources, industry, construction, commerce and services.

By way of example, it is concluded that an economic transformation took place over the decade, with capital intensity declining in the natural resource sector and increasing in the industrial sector, which fits with what has been observed in the region. Specifically, this trend towards lower capital intensity and rising intermediate consumption of inputs can be seen in the fishing sector (see figure 1).

Regarding inclusion of the government in the SAM, in Chile all taxes and operating surpluses raised, among other revenue, are transferred to the central government (except for the collection of municipalities' autonomous revenues not transferred from the centre). These resources are then transferred from the centre to each region via a number of instruments such as the Regional Development Fund, Regionally Allocated Sectoral Investment and Locally Allocated Regional Investment (see Rojas, 2009, for further details). The output of the public administration is valued on a cost basis.

Because of the above, it is considered that the revenues of the central government and municipalities are consolidated in the Government Account of the Bío Bío region's SAM with a view to carrying out spending on goods, benefits, allocations or direct transfers, with the difference (saving/dissaving) being transferred to the central government via the current account balance with the rest of the country. By virtue of this, the CGE model includes just a single agent called Government that explicitly redistributes these resources, without modelling the central government. This approach is usual in region-specific models (see, for example, Miguel-Vélez, Cardenete and Pérez-Mayo, 2009). Conversely, bottom-up models that model a number of regions tend to explicitly differentiate a central government and a regional one (Giesecke, 2002), while authors such as Kim and Kim (2002) model a government for each region.

Another important point about the economy of the Bío Bío region is the question of where corporate profits go. Because the parent companies are outside the region but inside the country, 68% of the payment to capital of firms established in the region flows to the rest of the country through the capital account.

Basically the aggregate schema the regional SAM must have to calibrate the model is as shown in table 2.

TABLE 1

**Comparison of technical coefficients in the 1996 and 2006 sams**

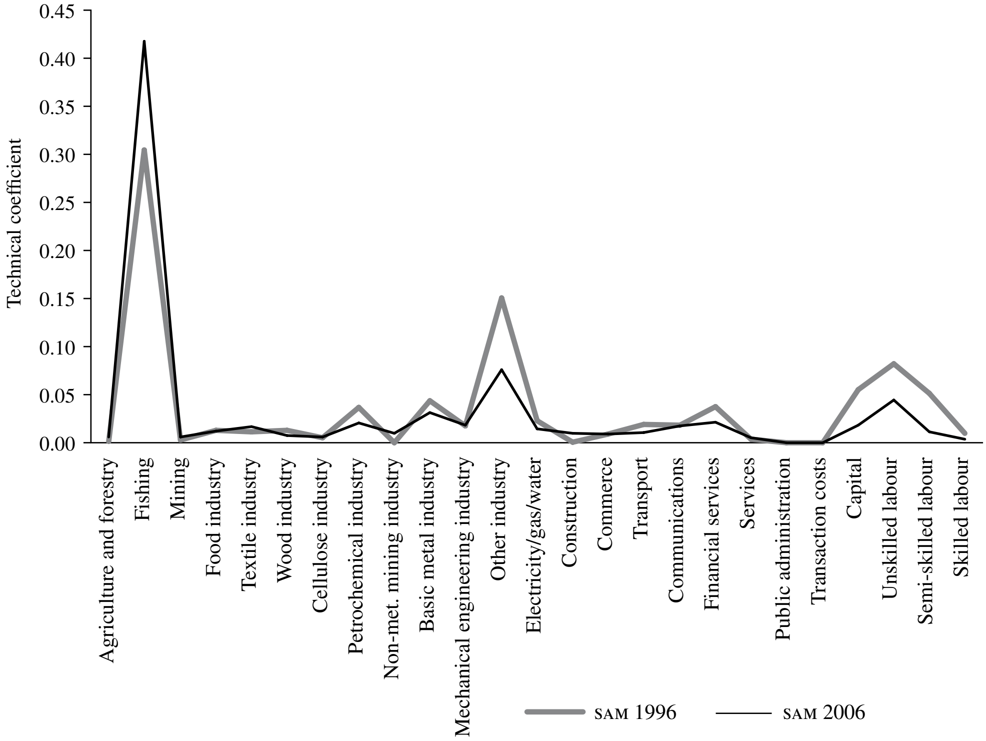
| | Nat. res. 1996 SAM | Nat. res. 2006 SAM | Industry 1996 SAM | Industry 2006 SAM | Construction 1996 SAM | Construction 2006 SAM | Commerce 1996 SAM | Commerce 2006 SAM | Services 1996 SAM | Services 2006 SAM |
|---|---|---|---|---|---|---|---|---|---|---|
| Natural resources | 0.21 | 0.23 | 0.21 | 0.16 | 0.02 | 0.03 | 0.01 | 0.04 | 0.00 | 0.02 |
| Industry | 0.20 | 0.25 | 0.20 | 0.23 | 0.37 | 0.38 | 0.17 | 0.27 | 0.16 | 0.20 |
| Construction | 0.00 | 0.02 | 0.00 | 0.03 | 0.00 | 0.02 | 0.01 | 0.02 | 0.02 | 0.03 |
| Commerce | 0.01 | 0.03 | 0.01 | 0.03 | 0.00 | 0.02 | 0.03 | 0.04 | 0.03 | 0.03 |
| Services | 0.09 | 0.11 | 0.11 | 0.10 | 0.06 | 0.07 | 0.29 | 0.32 | 0.12 | 0.12 |
| Capital | 0.29 | 0.20 | 0.25 | 0.28 | 0.25 | 0.21 | 0.22 | 0.13 | 0.35 | 0.29 |
| Unskilled labour | 0.15 | 0.10 | 0.06 | 0.04 | 0.20 | 0.15 | 0.18 | 0.08 | 0.13 | 0.07 |
| Semi-skilled labour | 0.02 | 0.02 | 0.02 | 0.04 | 0.04 | 0.06 | 0.05 | 0.06 | 0.05 | 0.07 |
| Skilled labour | 0.01 | 0.01 | 0.02 | 0.02 | 0.04 | 0.03 | 0.04 | 0.02 | 0.10 | 0.12 |

*Source:* prepared by the author.

SAM: social accounting matrix.

FIGURE 1

**Technical coefficients for the fishing sector in the 1996 and 2006 sams**



*Source:* prepared by the author.

## 2. Modelling design

A relative fast way of attempting to model a region economically using the data structure of table 2 is to use a standard country-level model. However, the drawback of this option is that the region's trade interaction and capital flows with the rest of the world and the rest of the country have to be aggregated. This aggregation means that international shocks cannot be simulated independently of the region's trade with the rest of the country; furthermore, the results obtained would be skewed by the exchange rate, since proper modelling ought to take explicit account of the fact that trade with the rest of the country is conducted in the domestic currency (one to one fixed exchange rate between the region and the rest of the country), while trade with the rest of the world is carried out with a different exchange rate reflecting the product of the foreign currency by the country's domestic currency.

Dividing trade with the rest of the country from trade with the rest of the world entails incorporating new equations, variables, parameters and elasticities into the standard country-level model (see appendix 1) and thereby turning it into an explicitly regional model, the most salient alterations being in the features that model export and import quantities and prices, with differentiated tariffs for the rest of the country and the rest of the world. It is also necessary to include two exchange rates and two current account balances, one for the rest of the country (which will be in deficit, for example, if the capital is owned by the rest of the country) and one for the rest of the world (which will be in surplus, for example, if the region is a net exporter). Interregional migration should be taken into account to reflect labour mobility if there are pay differentials between the region and the rest of the country; given the complexity of the process and the fact that only one region is being explicitly modelled, it is assumed that the labour supply relates positively to movements in the region's wages relative to those of the rest of the country. The regional consumer price index (CPI) is determined endogenously in the model, while the national CPI is assumed to be exogenous (this assumption is facilitated by the region's share of total national GDP, which is about 9%, and its strong export orientation). It is also necessary to modify the region's macroeconomic variables and rules of closure so that the

TABLE 2

**Aggregate regional social accounting matrix (sam)**

| Accounts | Activities | Goods | Factors | Institutions | Capital accounts | Rest of country | Rest of world |
|---|---|---|---|---|---|---|---|
| Activities | | Domestic sales | | | | | |
| Goods | Intermediate consumption | | | Final consumption and government spending | Gross capital formation and stock changes | Exports to rest of country | Exports to rest of world |
| Factors | Payment to factors of production | | | | | Payment to factors from rest of country | Payment to factors from rest of world |
| Institutions | Production taxes, value added tax | Import taxes | Household factor income | Transfers between institutions | | Transfers from rest of country | Transfers from rest of world |
| Capital accounts | | | | Household and government saving | | Rest of country saving | Rest of world saving |
| Rest of country | | Rest of country imports | Rest of country factor income | | | | |
| Rest of world | | Rest of world imports | Rest of world factor income | | | | |

*Source:* prepared by the author.

macroeconomic aggregates reflect the above changes. Although the model permits different rules of closure, just like the standard country-level CGE version, for this regional application it is assumed that investment is a proportion of absorption, that exchange rates are fixed and current account balances flexible, and that government saving is flexible in the presence of fixed tax rates. All these characteristics make it possible to obtain a model that provides a more realistic fit for a regional economy.

The rest of the design decisions for the region-specific CGE model are similar to those for a standard country-level CGE model (Löfgren, Harris and Robinson, 2001). They include basic aspects such as the number of representative consumers, production sectors, factors of production, institutions and the region's external sector. This is followed by the selection of the functional forms to be used to model consumer preferences, firms' production technologies and the flow of resources between institutions, which affect problems of optimization for economic agents.

### 3. The regional cge model

In the regional CGE (REGCGE) model proposed, the production of goods and services creates demand for factors of production that generate value added and for intermediate goods and services that are used as inputs. Intermediate inputs can be produced locally in the region or imported from the rest of the country, the rest of the world, or both. The demand for labour and capital as factors of production interacts with the regional supply of factors of production in factor markets, determining the market-clearing prices for these factors. Payments to factors of production determine income levels for the region's households, which in turn (and depending on the preferences of these households) determine demand for goods and services. Equilibrium occurs when the prices allow equaling the supplies and demands in all the markets (of goods and factors).

The model recreates an economic system characterized by the interaction of different agents whose behaviour, based on microeconomic optimization, is defined by the specification of linear and non-linear equations. These economic agents modify their consumption and production decisions when there are changes in the relative prices of products, inputs or factors of production, or when exogenous shocks occur.

Like any model, the REGCGE requires specific functional forms to be defined for its variables and parameters. The functional forms are the standard ones in economics. The demand functions are based on Stone-Geary utility functions, while the production functions are based on constant elasticity of substitution (CES) or Leontief functions. There are also CES functions that allow a degree of substitution between regional and external production; this latter also nests a CES function which can be used to substitute external production in the rest of the country and the rest of the world. The general behaviour of the model is illustrated and described below (see figure 2).

Production $Y_i$ may be destined for exports $X_i$ or domestic sales $D_i$, the transformation occurring via a constant elasticity CES function ($\sigma_{cet}$) subject to the relative prices of the two destinations. Furthermore, exports may be destined for the rest of the country $X_i^{restofcountry}$ or the rest of the world $X_i^{restofworld}$, and this depends on a CES transformation function with elasticity ($\sigma^x$) subject to the relative prices of the two destinations external to the region. Goods and services ($A_i$) for intermediate or final use may be produced domestically or imported ($M_i$), the composition varying in accordance with their relative prices and a CES function with elasticity of substitution $\sigma_{armington}$. In turn, imports may come from the rest of the country $M_i^{restofcountry}$ or the rest of the world $M_i^{restofworld}$, and this depends on a CES transformation function with elasticity ($\sigma^m$) subject to the relative prices of the two suppliers external to the region. The final uses of goods and services are private consumption ($C$), investment ($I$), government spending ($G$) and exports ($X$).

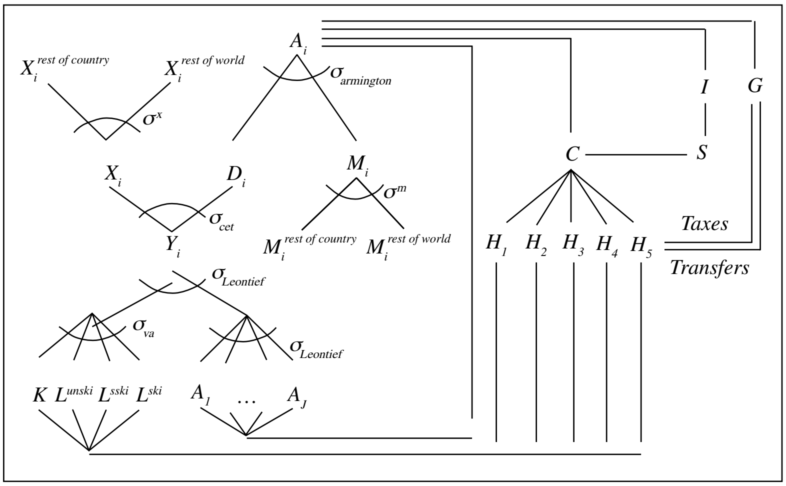
Private consumption is carried out by households representative of the income quintiles ($H_q$), which maximize their (Stone-Geary) utility function subject to their budget constraints, giving rise to an extended linear expenditure system. In addition, households make transfers to other households, pay taxes and receive government transfers, while the remaining income is saved. The saving generated by households, government, rest of country and rest of world in the region is used as capital for private, public and foreign investment.

External saving or dissaving is represented by two current account balances and two exchange rates, one for the rest of the country and one for the rest of the world. If the current account balance is fixed, then the exchange rate is endogenous, while if the current account balance is variable, the exchange rate is fixed.

The factors of production possessed by households are capital and labour (skilled, semi-skilled and unskilled), for the use of which they receive payment from the firms that employ them alongside intermediate goods to produce other goods and thus maximize benefits given the technological constraint available, this being a Leontief production function that nests functions of value added (CES function of production factors with elasticity of substitution $\sigma_{va}$) and of aggregate intermediate consumption (Leontief function of the inputs of each economic sector). To provide an indirect

FIGURE 2

**Simplified illustration of the workings of the regcge model**



*Source:* prepared by the author.

$\sigma_{armington}$: Armington elasticity.
$\sigma_{leontief}$ : Leontief function.

*cet*: constant elasticity of transformation.
*ski*: skilled work.
*unski*: unskilled work.
*sski*: semi-skilled work.
$H_1$: quintile 1, $H_2$: quintile 2, $H_3$: quintile 3, $H_4$: quintile 4, $H_5$: quintile 5.

measure of migration, a labour supply function linked to the region's wages relative to those in the rest of the country is generated.

All this recreates an economic general equilibrium model in which prices are determined endogenously within the model and clear the markets for goods, inputs and factors of production.

The equations, variables and parameters of the proposed REGCGE model are presented in appendix 2. Once it has been ensured that the model can be solved by checking that it presents the same number of equations and variables, the next step is programming, which consists in codifying the new system of non-linear equations representing the model. Then, during the calibration stage, the value of the parameters of the behavioural equations is inferred from the SAM values and the values for the elasticities are determined. It is also necessary to programme the outputs or reports with the results to assess whether the model replicates this matrix in the baseline scenario. Lastly, the counterfactual scenarios are generated as simulations by changing the values of an exogenous variable or parameter.

# III

# Application to the Bío Bío region of Chile

## 1. Economic description of the Bío Bío region

Between 2003 and 2009, the Bío Bío region's share of national economic activity dropped from 9.5% to 8.7%. The average rate of regional GDP growth in the period was 2.5%, which was below the national average of 3.8%. Manufacturing industry is the main economic activity in the region, contributing 36.2% of regional GDP, i.e., more than a third, while nationally manufacturing contributes just 16.2% of GDP.

The fishing sector accounts for only a small share of regional GDP (averaging 2.7% between 2003 and 2008), but has the strongest backward linkages in the region, which means that some of the region's poor economic performance in recent years can be put down to the decline in fishing activity resulting from the scarcity of jack mackerel.[7]

Services and commerce account for 56.1% of employment in the region, industrial activity for 13.6% and fishing for just 1.6%.

From an international trade standpoint, economic activity in the region has a strong export base (in 2009, exports represented 38.3% of the Bío Bío region's GDP), the mainstays of which are wood, cellulose, the food industry, fishing, agriculture and petrochemicals.

## 2. An application of the model to a regional shock: the jack mackerel crisis

Industrial fish catches in the Bío Bío region have fallen steadily over recent years. According to figures from the National Fisheries Service (SERNAPESCA), the catch was 1,600,132 tons in 2006, falling to just 1,100,690 tons in 2009 (preliminary figures for 2010 give a catch of 487,901 tons, a substantial drop on 2009, but this partly reflects the consequences of the earthquake of 27 February that year). The main species implicated in the decline is jack mackerel, catches of which fell by 45.4% between 2006 and 2009 (and by 83% between 2006 and 2010). The non-industrial catch has experienced substantial fluctuations, rising from 808,667 tons in 2006 to 948,470 tons in 2009 before dropping back to 596,676 tons in 2010, with the bulk of the catch consisting of sardines, while the jack mackerel catch represented just 1.7% of the total in 2009 and 4.8% in 2010.

In percentage terms, there has been an average annual decline of 11.8% in the total catch (industrial and non-industrial) and 16.3% in that of the industrial sector taken by itself (see tables 3 and 4).

The sector's export volumes have been heavily affected in all product categories (see table 5).

With the scarcity of jack mackerel, the current situation in the fishing industry is very difficult. The long-run sustainability of the activity has been compromised by over-exploitation of stocks, and this has led recently to a discussion of changes in the quota system. A brief historical summary will now be given to explain the situation.

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[7] Activity in the fishing sector has declined, with negative growth rates of 11.1% in 2007 and 9.3% in 2008 (there are as yet no official figures for 2009 and 2010).

TABLE 3

### Bío Bío region: industrial fish catch, 2006-2010

*(Tons)*

| Year | Total | Jack mackerel | Anchovy | Sardine | Atlantic mackerel | Hake | Hoki | Alfonsino | Other fish |
|---|---|---|---|---|---|---|---|---|---|
| 2006 | 1 660 132 | 1 147 200 | 161 100 | 67 747 | 221 613 | 37 506 | 20 110 | 2 371 | 2 487 |
| 2007 | 1 564 794 | 1 062 622 | 157 986 | 82 401 | 210 677 | 30 473 | 16 595 | 2 629 | 1 412 |
| 2008 | 1 139 731 | 646 314 | 173 980 | 205 782 | 56 635 | 30 190 | 22 488 | 2 608 | 1 734 |
| 2009 | 1 100 690 | 626 806 | 154 418 | 219 153 | 46 175 | 27 766 | 24 897 | 1 108 | 367 |
| 2010 | 487 901 | 195 151 | 70 413 | 148 522 | 8 834 | 26 286 | 16 982 | 810 | 20 904 |

*Source:* National Fisheries Service (SERNAPESCA).

TABLE 4

### Bío Bío region: non-industrial fish catch, 2006-2010

*(Tons)*

| Year | Total | Sardine | Anchovy | Bacaladillo or mote | Atlantic menhaden | Jack mackerel | Pomfret | Pompano | Other fish |
|---|---|---|---|---|---|---|---|---|---|
| 2006 | 808 667 | 288 918 | 185 404 | 283 793 | 21 678 | 16 495 | 1 809 | 7 344 | 3 227 |
| 2007 | 518 746 | 126 666 | 339 169 | 14 587 | 13 118 | 15 865 | 2 742 | 2 778 | 3 820 |
| 2008 | 740 586 | 485 249 | 163 452 | 52 733 | 17 112 | 8 045 | 3 137 | 4 667 | 6 191 |
| 2009 | 948 470 | 493 869 | 241 492 | 158 486 | 22 956 | 10 594 | 9 969 | 3 222 | 7 881 |
| 2010 | 596 676 | 386 719 | 121 440 | 29 445 | 6 408 | 28 513 | 9 233 | 1 957 | 12 961 |

*Source:* National Fisheries Service (SERNAPESCA).

TABLE 5

### Bío Bío region: fishing sector exports, 2003-2010

*(Tons)*

| Product | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|
| Tinned jack mackerel | 72 258 | 86 770 | 99 722 | 88 477 | 87 225 | 50 023 | 48 629 | 22 832 |
| Hake fillets | 36 838 | 18 219 | 10 859 | 8 330 | 9 074 | 6 760 | 9 214 | 6 511 |
| Fresh and frozen products | 100 792 | 140 138 | 170 730 | 156 858 | 172 594 | 82 258 | 135 801 | 60 657 |
| Fishmeal | 307 886 | 259 537 | 289 016 | 264 583 | 250 485 | 222 281 | 358 194 | 142 184 |
| Other (not otherwise specified) | 40 375 | 38 274 | 31 145 | 18 187 | 12 002 | 29 372 | 33 705 | 17 872 |

*Source:* National Institute of Statistics (INE), Bío Bío region.

Fishing grew strongly in the first half of the 1990s, with catches reaching some 4 million tons a year. Activity then slowed in the second half of the decade, however, owing to rising sea temperatures caused by El Niño in 1997, which drove jack mackerel away from the coasts. Furthermore, fishing outside the exclusive economic zone by the Chilean, Russian and Chinese fleets (these latter two using factory ships) led to a substantial decline in biomass. In 1999, Chile established catch quotas to bring some order to the industry, but the current situation is so precarious that although a jack mackerel quota of over 1.3 million tons was authorized in 2010, just 224,000 tons were caught that year. To preserve stocks, the National Fishing Council approved a cut in the jack mackerel quota to just 315,000 tons in 2011.

The consequences of the jack mackerel crisis have been particularly serious in the Bío Bío region, as it accounts for 90% of the national catch.[8] Thus, the reduction in stocks has directly affected the productivity of the fishing industry. A priori, the expectation must be

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[8] A report providing background can be seen at http://24horas.cl/videos.aspx?id=92311

that this would affect the rest of the region's economic system because of the close production linkages that exist with the food, chemical, metal-mechanical industries, among others, and because of the effects on employment and household incomes. Given these circumstances, the present study applies the REGCGE model, simulating a negative impact on the productivity of the fishing industry in order to identify the indirect economic effects of the jack mackerel crisis.

The following arguments can be made to justify treating the decline in jack mackerel productivity as a decline in the productivity of the fishing sector as a whole for modelling purposes.

In the Bío Bío region, jack mackerel, sardine and anchovy, all pelagic species, account for about 80% of the total industrial catch. Fishing grounds are "multi-species", so it can be concluded that the production structure of the industrial catch is similar. Furthermore, all three species are used mainly for the manufacture of fishmeal, suggesting that production linkages are similar in the region. Nonetheless, Peña, Basch and Vergara (2003) argue that there is a significant degree of production heterogeneity in the fleet in terms of differences in the fishing yields achieved by boats of different sizes and displacements.

Just one article was found in the published literature studying the 31% reduction in the walleye pollock allowable catch in Alaska and a 125% increase in fuel prices using the IMPLAN computable general equilibrium model (Waters and Seung, 2010). The application proposed in this document is novel, since it does not use an existing model, as the above-mentioned study does, but constructs the model it employs.

### 3. Calibrating the model with a sam, Bío Bío region

The Bío Bío region SAM used to calibrate the regional CGE model has a sectoral disaggregation of 20 economic sectors: agriculture and forestry; fishing; mining; food, beverages and tobacco; textile, wearing apparel and leather; wood and furniture; cellulose and paper; petrochemical; production of non-metallic mineral products; basic metal; metal-mechanic; other industry; electricity, gas and water; construction; commerce, restaurants and hotels; transport; communications; financial services; services; and public administration. The labour factor is disaggregated into three occupational categories (skilled, semi-skilled and unskilled labour) and households are divided into income quintiles.

This matrix was updated by Mardones and Saavedra (2011) from the 1996 regional input-output matrix (see section II, point 1). The aggregate detail of this matrix can be seen in appendix 3.

### 4. Simulation results

The calibrated model replicates the baseline scenario for the Bío Bío region in 2006. Given the information about the overall decline in the jack mackerel catch (industrial and non-industrial) from 2006 to 2009 (2010 is excluded because of the effects of the February earthquake), catch volumes are projected as a trend over the medium term. The results project a cumulative drop of 40.8% for the region's total catch, with jack mackerel stocks being almost wholly depleted by 2012 (see table 6).

Lack of availability of fish stocks could thus be simulated as declining productivity in the sector, since with the same factors of production there is a smaller catch (or, alternatively, as an alarming decline in the size of the specimens caught, which is what is observed). To make the results more sensitive, reductions of 30%, 40% and 50% in the fishing sector's total factor productivity (relative to base year 2006) are considered.

Furthermore, given that a static CGE model is being used, scenarios with lower and higher elasticities are tried out in order to vary the reaction speed of resource reallocation with a view to assessing the temporary

TABLE 6

**Bío Bío region: projected fish catch, 2006-2012**

*(Tons)*

| Year | 2006 | 2007 | 2008 | 2009 | 2010 (p) | 2011 (p) | 2012 (p) |
|---|---|---|---|---|---|---|---|
| Total | 2 468 799 | 2 083 540 | 1 880 317 | 2 049 160 | 1 754 919 | 1 608 705 | 1 462 491 |
| Jack mackerel | 1 163 695 | 1 078 487 | 654 359 | 637 400 | 382 732 | 182 431 | 1 264 |

*Source:* prepared by the author.

(p): projection.

effects of the shock over the shorter and longer term (see appendix 4).[9] For the shorter-term effect, specifically, use is made of lower elasticities between capital and labour (0.6); value added and aggregate intermediate inputs (0); elasticity of spending in the linear expenditure system (LES) demand system (0.6); and trade elasticities of 0.6 for primary sectors, 0.4 for industry and 0.3 for services. For the longer-term effect, use is made of larger elasticities between capital and labour (1.2); value added and aggregate intermediate inputs (0.4); elasticity of spending in the LES demand system (1.4); and trade elasticities of 1.8 for primary sectors, 1.2 for industry and 0.9 for services.

The main effects on the region's economy of a negative impact on fisheries productivity resulting from the jack mackerel crisis will now be described.

Fishing activity is drastically curtailed by the shock, but while this was expected to impact sectors directly connected to this activity, such as the food and metal-mechanic, other sectors are even more affected, including other industry, construction, commerce, financial services, transport and communications, among others. These results may not seem very intuitive a priori, and they would be unlikely to be identified by a partial equilibrium analysis (the indirect link accounting for many of these effects will be identified in the following paragraphs). Conversely, activity in a few sectors increases, among them mining, cellulose, wood and chemicals. This reinforces the idea of the production structure of the Bío Bío region becoming increasingly specialized in the wood and cellulose industry as a result of the jack mackerel crisis (see table 7).

The decline in fishing activity leads to a marked reduction in fisheries exports both to the rest of the country and to the rest of the world. Because of relative price changes and resource reallocation, however, there is a rise in the exports of the wood, cellulose, chemicals, non-metallic mining, basic metal, metal-mechanics, and agriculture and forestry sectors, among others. The percentage changes in the volumes exported to the rest of the country and the rest of the world (see tables 8 and 9) are fairly small between the two regions, which

TABLE 7

**Bío Bío region: sectoral activity level**

| Activity | Baseline scenario[a] | Low elasticities *(percentages)* | | | Medium elasticities *(percentages)* | | | High elasticities *(percentages)* | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Fish 30 | Fish 40 | Fish 50 | Fish 30 | Fish 40 | Fish 50 | Fish 30 | Fish 40 | Fish 50 |
| Agriculture and forestry | 677.1 | 0.0 | -0.2 | -0.6 | 0.1 | -0.1 | -0.6 | 0.1 | -0.1 | -0.5 |
| Fishing | 548.0 | -25.2 | -32.2 | -38.5 | -24.2 | -30.7 | -36.5 | -23.6 | -29.8 | -35.3 |
| Mining | 128.0 | 1.0 | 1.8 | 3.4 | 1.0 | 1.7 | 2.9 | 1.0 | 1.7 | 2.6 |
| Food industry | 921.5 | -0.1 | -0.3 | -0.7 | -0.1 | -0.3 | -0.7 | -0.1 | -0.3 | -0.8 |
| Textile industry | 213.8 | -0.1 | -0.2 | -0.5 | -0.2 | -0.3 | -0.7 | -0.2 | -0.5 | -0.8 |
| Wood industry | 992.3 | 0.4 | 0.8 | 1.4 | 0.7 | 1.1 | 1.7 | 0.9 | 1.4 | 2.1 |
| Cellulose industry | 784.5 | 0.3 | 0.6 | 1.0 | 0.5 | 0.8 | 1.3 | 0.7 | 1.1 | 1.6 |
| Petrochemical industry | 1 039.2 | 0.2 | 0.4 | 0.9 | 0.2 | 0.4 | 0.8 | 0.2 | 0.4 | 0.8 |
| Non-metallic mineral industry | 250.3 | -0.3 | -0.6 | -1.0 | -0.4 | -0.7 | -1.1 | -0.4 | -0.7 | -1.2 |
| Basic metal industry | 417.4 | -0.3 | -0.3 | -0.1 | -0.4 | -0.5 | -0.5 | -0.5 | -0.6 | -0.7 |
| Metal-mechanic industry | 283.0 | -0.2 | -0.4 | -1.0 | -0.3 | -0.6 | -1.2 | -0.4 | -0.8 | -1.4 |
| Other industry | 80.5 | -2.1 | -2.8 | -3.8 | -2.1 | -2.8 | -3.7 | -2.1 | -2.8 | -3.7 |
| Electricity/gas/water | 589.7 | 0.0 | -0.1 | -0.4 | 0.0 | -0.2 | -0.5 | -0.1 | -0.3 | -0.6 |
| Construction | 921.5 | -0.8 | -1.7 | -3.5 | -1.0 | -1.8 | -3.2 | -1.0 | -1.8 | -3.1 |
| Commerce | 1 234.1 | -0.8 | -1.3 | -2.1 | -0.9 | -1.3 | -2.1 | -0.9 | -1.4 | -2.1 |
| Transport | 760.2 | -0.6 | -1.1 | -1.9 | -0.7 | -1.1 | -1.9 | -0.7 | -1.2 | -1.8 |
| Communications | 288.1 | -0.5 | -1.0 | -1.8 | -0.6 | -1.1 | -1.9 | -0.7 | -1.2 | -1.9 |
| Financial services | 788.4 | -0.8 | -1.3 | -2.1 | -0.9 | -1.4 | -2.1 | -0.9 | -1.4 | -2.1 |
| Services | 1 251.7 | -0.4 | -0.8 | -1.7 | -0.5 | -1.0 | -1.8 | -0.6 | -1.1 | -1.9 |
| Public administration | 402.2 | 0.0 | -0.3 | -1.2 | -0.2 | -0.6 | -1.4 | -0.3 | -0.8 | -1.6 |

*Source:* prepared by the author.

[a] Millions of pesos.

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[9] Regarding this way of looking at the repercussions of a 40% decline in productivity, it should be pointed out that this does not actually happen all at once but is gradual, so it would be more accurate to divide the drop in productivity into annual declines and use a dynamic model to simulate it, since the static model will overstate the impact. One way of dealing with this problem is to allow greater long-term substitution with greater elasticities. However, this approach is only an approximation that does not include dynamic processes or capital accumulation (this footnote has been included in response to an anonymous referee who picked up strongly on this point).

TABLE 8

### Bío Bío region: volume of exports to the rest of the country

| Activity | Baseline scenario[a] | Low elasticities *(percentages)* | | | Medium elasticities *(percentages)* | | | High elasticities *(percentages)* | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Fish 30 | Fish 40 | Fish 50 | Fish 30 | Fish 40 | Fish 50 | Fish 30 | Fish 40 | Fish 50 |
| Agriculture and forestry | 61.0 | 0.575 | 1.057 | 2.038 | 0.600 | 0.933 | 1.427 | 0.616 | 0.881 | 1.203 |
| Fishing | 178.2 | -44.943 | -58.865 | -72.425 | -42.955 | -55.653 | -67.624 | -41.656 | -53.661 | -64.841 |
| Food industry | 147.0 | 0.126 | 0.303 | 0.690 | 0.104 | 0.191 | 0.329 | 0.071 | 0.094 | 0.104 |
| Textile industry | 42.4 | 1.034 | 1.713 | 2.973 | 0.897 | 1.390 | 2.138 | 0.795 | 1.182 | 1.708 |
| Wood industry | 119.4 | 0.814 | 1.363 | 2.378 | 1.004 | 1.619 | 2.594 | 1.171 | 1.852 | 2.861 |
| Cellulose industry | 107.9 | 0.623 | 1.021 | 1.737 | 0.772 | 1.229 | 1.943 | 0.907 | 1.421 | 2.177 |
| Petrochemical industry | 415.2 | 0.758 | 1.270 | 2.223 | 0.810 | 1.319 | 2.134 | 0.842 | 1.351 | 2.112 |
| Non-metallic mineral industry | 35.8 | 1.046 | 1.776 | 3.158 | 0.853 | 1.367 | 2.172 | 0.730 | 1.127 | 1.688 |
| Basic metal industry | 141.1 | 1.138 | 1.975 | 3.596 | 0.938 | 1.606 | 2.728 | 0.793 | 1.357 | 2.244 |
| Electricity/gas/water | 110.8 | 1.034 | 1.878 | 3.557 | 0.975 | 1.636 | 2.732 | 0.907 | 1.453 | 2.276 |
| Construction | 41.9 | 0.370 | 0.412 | 0.339 | 0.169 | 0.048 | -0.296 | 0.048 | -0.150 | -0.590 |
| Commerce | 34.2 | -0.140 | -0.210 | -0.319 | -0.269 | -0.424 | -0.675 | -0.345 | -0.541 | -0.851 |
| Financial services | 34.5 | 0.116 | 0.275 | 0.620 | -0.055 | -0.020 | 0.061 | -0.157 | -0.192 | -0.226 |
| Services | 35.2 | 0.954 | 1.667 | 3.013 | 0.716 | 1.145 | 1.807 | 0.548 | 0.816 | 1.174 |

*Source:* prepared by the author.

[a] Millions of pesos.

TABLE 9

### Bío Bío region: volume of exports to the rest of the world

| Activity | Baseline scenario[a] | Low elasticities *(percentages)* | | | Medium elasticities *(percentages)* | | | High elasticities *(percentages)* | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Fish 30 | Fish 40 | Fish 50 | Fish 30 | Fish 40 | Fish 50 | Fish 30 | Fish 40 | Fish 50 |
| Agriculture and forestry | 33.5 | 0.577 | 1.059 | 2.038 | 0.600 | 0.932 | 1.427 | 0.615 | 0.880 | 1.202 |
| Fishing | 3.7 | -44.952 | -58.861 | -72.422 | -42.972 | -55.657 | -67.616 | -41.662 | -53.658 | -64.847 |
| Mining | 2.3 | 2.418 | 4.188 | 7.599 | 2.372 | 3.881 | 6.425 | 2.284 | 3.707 | 5.862 |
| Food industry | 329.7 | 0.126 | 0.303 | 0.690 | 0.104 | 0.190 | 0.329 | 0.072 | 0.095 | 0.105 |
| Textile industry | 20.0 | 1.038 | 1.717 | 2.979 | 0.898 | 1.392 | 2.140 | 0.793 | 1.182 | 1.706 |
| Wood industry | 656.4 | 0.813 | 1.363 | 2.379 | 1.004 | 1.619 | 2.594 | 1.171 | 1.851 | 2.861 |
| Cellulose industry | 491.2 | 0.622 | 1.021 | 1.737 | 0.772 | 1.229 | 1.943 | 0.907 | 1.421 | 2.176 |
| Petrochemical industry | 267.6 | 0.758 | 1.270 | 2.223 | 0.810 | 1.319 | 2.134 | 0.843 | 1.351 | 2.113 |
| Non-metallic mineral industry | 11.2 | 1.041 | 1.776 | 3.158 | 0.852 | 1.372 | 2.179 | 0.726 | 1.130 | 1.694 |
| Basic metal industry | 9.6 | 1.141 | 1.968 | 3.591 | 0.932 | 1.602 | 2.722 | 0.796 | 1.361 | 2.241 |
| Metal-mechanic industry | 40.1 | 1.158 | 1.867 | 3.137 | 0.973 | 1.462 | 2.161 | 0.841 | 1.205 | 1.665 |
| Other industry | 4.7 | -0.530 | -0.361 | 0.361 | -0.742 | -0.742 | -0.467 | -0.849 | -0.934 | -0.870 |
| Transport | 9.4 | 0.638 | 1.053 | 1.808 | 0.437 | 0.660 | 0.990 | 0.309 | 0.448 | 0.618 |
| Communications | 4.1 | 0.758 | 1.222 | 2.103 | 0.514 | 0.783 | 1.149 | 0.367 | 0.514 | 0.660 |

*Source:* prepared by the author.

[a] Millions of pesos.

can be explained by the fact that relative interregional prices have not been altered in the modelling (even though it is possible to simulate different prices with the proposed model).

Imports from the rest of the country in all production sectors decline, mainly because of lower incomes. The largest percentage decline is seen in basic metal; other industry; wood; non-metallic mining; services; electricity, gas and water; textiles; chemicals; communications; and metal-mechanics. Imports from the rest of the world decline in all economic sectors except the fishing sector, although the base volume is so small that the sector's initial trade pattern remains unaffected. Differences in the percentage changes between imports from the rest of the country and the rest of the world are fairly small between the two regions, and this is owed, as in the case of exports, to the fact that relative interregional prices have been left unaltered in the modelling (see tables 10 and 11).

TABLE 10

### Bío Bío region: volume of imports from the rest of the country

| Activity | Baseline scenario[a] | Low elasticities *(percentages)* | | | Medium elasticities *(percentages)* | | | High elasticities *(percentages)* | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Fish 30 | Fish 40 | Fish 50 | Fish 30 | Fish 40 | Fish 50 | Fish 30 | Fish 40 | Fish 50 |
| Agriculture and forestry | 40.8 | -0.786 | -1.834 | -4.110 | -0.814 | -1.689 | -3.293 | -0.832 | -1.624 | -2.971 |
| Mining | 455.6 | -0.384 | -0.537 | -0.738 | -0.345 | -0.463 | -0.602 | -0.319 | -0.418 | -0.529 |
| Food industry | 185.8 | -0.892 | -2.090 | -4.695 | -0.974 | -2.059 | -4.072 | -1.042 | -2.079 | -3.865 |
| Textile industry | 103.5 | -1.796 | -3.149 | -5.699 | -1.772 | -2.972 | -4.942 | -1.761 | -2.889 | -4.623 |
| Wood industry | 20.9 | -2.420 | -3.783 | -6.089 | -2.479 | -3.781 | -5.739 | -2.538 | -3.822 | -5.651 |
| Cellulose industry | 41.9 | -1.779 | -2.668 | -4.084 | -1.833 | -2.712 | -3.978 | -1.881 | -2.766 | -3.985 |
| Petrochemical industry | 279.8 | -2.163 | -3.295 | -5.141 | -2.146 | -3.204 | -4.743 | -2.136 | -3.155 | -4.568 |
| Non-metallic mineral industry | 11.5 | -2.215 | -3.753 | -6.594 | -2.112 | -3.451 | -5.598 | -2.052 | -3.278 | -5.139 |
| Basic metal industry | 23.4 | -3.166 | -4.765 | -7.333 | -3.052 | -4.518 | -6.625 | -2.975 | -4.365 | -6.263 |
| Metal-mechanic industry | 427.6 | -1.586 | -2.816 | -5.172 | -1.583 | -2.691 | -4.534 | -1.584 | -2.629 | -4.263 |
| Other industry | 17.8 | -3.342 | -4.875 | -7.200 | -3.173 | -4.543 | -6.402 | -3.072 | -4.358 | -6.020 |
| Electricity/gas/water | 3.3 | -1.595 | -3.037 | -6.012 | -1.628 | -2.918 | -5.190 | -1.629 | -2.859 | -4.857 |
| Commerce | 114.7 | -1.514 | -2.432 | -4.039 | -1.462 | -2.285 | -3.556 | -1.436 | -2.213 | -3.352 |
| Transport | 179.9 | -1.906 | -3.209 | -5.574 | -1.786 | -2.895 | -4.652 | -1.712 | -2.720 | -4.225 |
| Communications | 48.0 | -1.809 | -3.160 | -5.707 | -1.747 | -2.921 | -4.847 | -1.718 | -2.805 | -4.481 |
| Financial services | 159.4 | -1.887 | -3.010 | -4.948 | -1.791 | -2.778 | -4.284 | -1.734 | -2.650 | -3.973 |
| Services | 18.3 | -1.858 | -3.443 | -6.537 | -1.793 | -3.165 | -5.478 | -1.761 | -3.024 | -5.019 |
| Public administration | 3.1 | -0.353 | -0.962 | -2.342 | -0.481 | -1.123 | -2.278 | -0.610 | -1.219 | -2.342 |

*Source:* prepared by the author.

[a] Millions of pesos.

TABLE 11

### Bío Bío region: volume of imports from the rest of the world

| Activity | Baseline scenario[a] | Low elasticities *(percentages)* | | | Medium elasticities *(percentages)* | | | High elasticities *(percentages)* | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Fish 30 | Fish 40 | Fish 50 | Fish 30 | Fish 40 | Fish 50 | Fish 30 | Fish 40 | Fish 50 |
| Agriculture and forestry | 19.5 | -0.790 | -1.836 | -4.112 | -0.816 | -1.689 | -3.295 | -0.832 | -1.628 | -2.974 |
| Mining | 2.8 | -0.353 | -0.529 | -0.705 | -0.318 | -0.459 | -0.600 | 20.683 | 36.053 | 61.101 |
| Fishing | 1.1 | 24.383 | 46.584 | 92.315 | 22.106 | 39.753 | 70.778 | -0.318 | -0.388 | -0.529 |
| Food industry | 15.6 | -0.888 | -2.089 | -4.694 | -0.972 | -2.059 | -4.073 | -1.043 | -2.080 | -3.865 |
| Textile industry | 29.0 | -1.796 | -3.148 | -5.699 | -1.773 | -2.973 | -4.942 | -1.759 | -2.887 | -4.622 |
| Wood industry | 8.1 | -2.416 | -3.777 | -6.082 | -2.467 | -3.780 | -5.731 | -2.529 | -3.819 | -5.648 |
| Cellulose industry | 8.1 | -1.776 | -2.676 | -4.082 | -1.826 | -2.715 | -3.973 | -1.889 | -2.777 | -3.987 |
| Petrochemical industry | 49.1 | -2.162 | -3.294 | -5.141 | -2.146 | -3.205 | -4.744 | -2.136 | -3.154 | -4.567 |
| Non-metallic mineral industry | 8.5 | -2.220 | -3.754 | -6.600 | -2.115 | -3.461 | -5.611 | -2.056 | -3.285 | -5.141 |
| Basic metal industry | 46.6 | -3.165 | -4.766 | -7.334 | -3.054 | -4.518 | -6.623 | -2.975 | -4.362 | -6.260 |
| Metal-mechanic industry | 131.8 | -1.586 | -2.816 | -5.172 | -1.582 | -2.691 | -4.534 | -1.584 | -2.629 | -4.263 |
| Other industry | 5.7 | -3.341 | -4.873 | -7.205 | -3.167 | -4.542 | -6.404 | -3.080 | -4.368 | -6.022 |
| Electricity/gas/water | 5.1 | -1.570 | -3.042 | -6.024 | -1.631 | -2.927 | -5.206 | -1.652 | -2.871 | -4.856 |
| Commerce | 147.6 | -1.514 | -2.433 | -4.039 | -1.461 | -2.284 | -3.555 | -1.435 | -2.213 | -3.351 |
| Transport | 4.5 | -1.910 | -3.221 | -5.575 | -1.798 | -2.908 | -4.661 | -1.731 | -2.729 | -4.238 |
| Communications | 11.4 | -1.815 | -3.165 | -5.707 | -1.745 | -2.920 | -4.840 | -1.719 | -2.806 | -4.481 |

*Source:* prepared by the author.

[a] Millions of pesos.

Given that the region has a fixed exchange rate with the rest of the country (the peso) and a fixed exchange rate with the rest of the world (the peso multiplied by the foreign currency), current account balances with both zones are endogenous. In the baseline scenario, exports to the rest of the world are greater than imports from the rest of the world, the result being a build-up of reserves (although these resources are subsequently transferred to the rest of the country). Exports to the rest of the country are lower than imports from the rest of the country, which means that the region has a negative current account balance.

The simulations show the surplus with the rest of the world and the deficit with the rest of the country becoming larger. The former is due to a small increase in exports and a drastic decline in imports from the rest of the world. The latter is explained by a drastic fall in exports and a smaller drop in imports from the rest of the country (see table 12).

The decline in fishing activity affects the labour market. Because the model assumes perfect labour mobility, the excess supply of labour is reallocated to the remaining production sectors, with activity there increasing, but results in a drop in the price of factors of production to rebalance the factor market. The most pronounced drop in factor income is seen at the more highly skilled levels (see table 13).

Since payment to factors of production flows to the households that possess these factors, we can see that the shock caused by the fishing crisis is progressive, i.e., it affects in greater proportion the families with the greatest income levels, basically because these families have the most skilled labor and capital (see table 14).

The decline in the consumption of the households is proportionally greater in families with greater incomes, which accounts for the somewhat counter-intuitive

TABLE 12

**Bío Bío region: current account balance**

| | Baseline scenario[a] | Low elasticities *(percentages)* | | | Medium elasticities *(percentages)* | | | High elasticities *(percentages)* | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Fish 30 | Fish 40 | Fish 50 | Fish 30 | Fish 40 | Fish 50 | Fish 30 | Fish 40 | Fish 50 |
| Rest of world | 1 444.3 | 1.2 | 2.1 | 3.8 | 1.5 | 2.4 | 3.7 | 1.7 | 2.6 | 3.9 |
| Rest of country | -2 802.8 | 1.4 | 1.3 | 0.4 | 1.3 | 1.2 | 0.6 | 1.2 | 1.2 | 0.6 |

*Source:* prepared by the author.

[a] Millions of pesos.

TABLE 13

**Bío Bío region: factor income**

| | Baseline scenario[a] | Low elasticities *(percentages)* | | | Medium elasticities *(percentages)* | | | High elasticities *(percentages)* | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Fish 30 | Fish 40 | Fish 50 | Fish 30 | Fish 40 | Fish 50 | Fish 30 | Fish 40 | Fish 50 |
| Capital | 3 179.8 | -1.6 | -2.7 | -4.4 | -1.6 | -2.6 | -4.0 | -1.7 | -2.5 | -3.8 |
| Unskilled | 857.3 | -1.2 | -1.9 | -3.2 | -1.0 | -1.6 | -2.4 | -0.8 | -1.4 | -2.1 |
| Semi-skilled | 629.6 | -2.2 | -3.7 | -6.5 | -1.8 | -3.1 | -5.1 | -1.5 | -2.7 | -4.3 |
| Skilled | 572.8 | -2.7 | -4.8 | -8.7 | -2.3 | -4.0 | -6.8 | -2.0 | -3.5 | -5.8 |

*Source:* prepared by the author.

[a] Millions of pesos.

TABLE 14

**Bío Bío region: household income**

| Households | Baseline scenario[a] | Low elasticities *(percentages)* | | | Medium elasticities *(percentages)* | | | High elasticities *(percentages)* | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Fish 30 | Fish 40 | Fish 50 | Fish 30 | Fish 40 | Fish 50 | Fish 30 | Fish 40 | Fish 50 |
| Quintile 1 | 185.2 | -0.5 | -1.3 | -3.4 | -0.4 | -1.2 | -2.7 | -0.5 | -1.2 | -2.5 |
| Quintile 2 | 349.2 | -1.6 | -2.8 | -5.0 | -1.4 | -2.4 | -4.0 | -1.3 | -2.2 | -3.5 |
| Quintile 3 | 462.7 | -2.5 | -4.1 | -7.0 | -2.3 | -3.7 | -5.8 | -2.1 | -3.4 | -5.2 |
| Quintile 4 | 646.3 | -3.0 | -4.9 | -8.4 | -2.8 | -4.5 | -7.1 | -2.7 | -4.2 | -6.5 |
| Quintile 5 | 1 398.1 | -3.1 | -5.3 | -9.1 | -2.9 | -4.7 | -7.6 | -2.8 | -4.4 | -6.9 |

*Source:* prepared by the author.

[a] Millions of pesos.

results of the changes in sectoral activity (see table 7): because the income of families with higher purchasing power falls, so does their consumption in sectors such as construction (real estate), services, commerce and financial services. Although the income of the poorer quintiles also contracts, their consumption of goods and services in these sectors has less of an impact (see table 15).

The macroeconomic effects at the regional level (in constant pesos) reveal a drop in GDP of between 0.8% and 2.0%, depending on the elasticities used and the scale of the shock. Each of the individual components of GDP is lower, except for exports to the rest of the world, owing to the change in the production structure resulting in a greater concentration on the wood and cellulose industry. Private consumption contracts by between 0.6% and 3.5%, investment falls by between 0.8% and 4.5%, government spending without countercyclical and pro-employment policies changes by between 0.1% and -1.5%, the volume of aggregate exports is down by between 1.4% and 2.1%, and imports are between 1.5% and 4.3% lower. The rise in exports to the rest of the world (of between 0.6% and 2.0%) is not enough to offset the decline in exports to the rest of the country (of between 4.3% and 6.7%), and the fall in imports from the rest of the world (of between 1.7% and 4.8%) is even greater than the fall in imports from the rest of the country (of between 1.4% and 4.2%) (see table 16).

In addition to simulating the repercussions of the impact on the fishing sector, it is important to evaluate some type of economic policy designed to mitigate the social impact of the jack mackerel crisis. One of the options that have been discussed is to auction fishing quotas to improve efficiency, as this would offset the

TABLE 15

**Bío Bío region: household consumption**

| Households | Baseline scenario[a] | Low elasticities *(percentages)* | | | Medium elasticities *(percentages)* | | | High elasticities *(percentages)* | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Fish 30 | Fish 40 | Fish 50 | Fish 30 | Fish 40 | Fish 50 | Fish 30 | Fish 40 | Fish 50 |
| Quintile 1 | 327.9 | 3.6 | 3.1 | -0.2 | 2.6 | 2.1 | -0.4 | 1.9 | 1.3 | -1.0 |
| Quintile 2 | 450.4 | 1.3 | 0.4 | -2.7 | 0.8 | 0.0 | -2.3 | 0.5 | -0.4 | -2.4 |
| Quintile 3 | 508.4 | -0.8 | -2.3 | -5.7 | -1.0 | -2.3 | -4.9 | -1.1 | -2.4 | -4.6 |
| Quintile 4 | 659.0 | -2.2 | -4.2 | -7.8 | -2.2 | -3.9 | -6.7 | -2.2 | -3.8 | -6.2 |
| Quintile 5 | 1 074.6 | -4.3 | -6.6 | -10.0 | -3.8 | -5.7 | -8.2 | -3.5 | -5.1 | -7.3 |

*Source:* prepared by the author.

[a] Millions of pesos.

TABLE 16

**Bío Bío region: macroregional effects**

| | Baseline scenario[a] | Low elasticities *(percentages)* | | | Medium elasticities *(percentages)* | | | High elasticities *(percentages)* | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Fish 30 | Fish 40 | Fish 50 | Fish 30 | Fish 40 | Fish 50 | Fish 30 | Fish 40 | Fish 50 |
| Absorption | 5 064.3 | -0.5 | -1.4 | -3.2 | -0.7 | -1.5 | -3.0 | -0.8 | -1.5 | -2.9 |
| Consumption | 3 006.9 | -0.6 | -1.6 | -3.5 | -0.7 | -1.6 | -3.1 | -0.8 | -1.6 | -3.0 |
| Investment | 1 076.1 | -0.8 | -2.0 | -4.5 | -1.0 | -2.0 | -4.0 | -1.1 | -2.1 | -3.9 |
| Government consumption | 918.8 | 0.1 | -0.2 | -1.1 | -0.1 | -0.5 | -1.3 | -0.3 | -0.7 | -1.5 |
| Exports | 3 385.6 | -1.8 | -2.1 | -2.0 | -1.6 | -1.8 | -1.8 | -1.4 | -1.6 | -1.6 |
| Imports | -2 573.2 | -1.5 | -2.5 | -4.3 | -1.5 | -2.4 | -3.8 | -1.5 | -2.3 | -3.6 |
| Exports to rest of world | 1 881.6 | 0.6 | 1.0 | 1.8 | 0.8 | 1.2 | 1.9 | 0.9 | 1.4 | 2.0 |
| Exports to rest of country | 1 504.0 | -4.7 | -5.9 | -6.7 | -4.4 | -5.6 | -6.4 | -4.3 | -5.4 | -6.2 |
| Imports from rest of world | -437.3 | -1.7 | -2.8 | -4.8 | -1.7 | -2.7 | -4.3 | -1.7 | -2.7 | -4.1 |
| Imports from rest of country | -2 135.9 | -1.4 | -2.4 | -4.2 | -1.4 | -2.3 | -3.7 | -1.4 | -2.3 | -3.5 |
| Regional GDP | 5 876.7 | -0.8 | -1.3 | -2.0 | -0.8 | -1.3 | -1.9 | -0.8 | -1.2 | -1.8 |

*Source:* prepared by the author.
GDP: gross domestic product.

[a] Millions of pesos.

decline in productivity, while in the case of fishing sector workers, it has been suggested that they should be given occupational training and early retirement. If a short-term approach is taken, early retirement looks like an attractive way of dealing rapidly with the social problem; this economic policy can be modelled as a direct income transfer to fisheries workers. In the REGCGE model, however, it is not possible to allocate this targeted transfer only to workers in the fisheries sector; rather, it has to be included as an average transfer to all households by income quintile. An alternative adopted in the literature is to use a microsimulation methodology to analyse the effects using data disaggregated at the household level.

Specifically, with non-parametric microsimulations (see Ganuza and others, 2005) it is assumed that changes in the demand for labour and the remuneration of the different types of labour generated by the REGCGE model can be passed through to microdata, using a household survey with a random selection of individuals who change economic sector and remuneration as projected by the REGCGE model. Thus, it is possible to determine the disaggregated effects on pay and income, and thence on poverty and income distribution.

Table 17 presents the results of the household inequality and poverty microsimulations under different scenarios. The baseline scenario uses data for the Bío Bío region from the CASEN 2006 survey (this survey year is taken for the sake of consistency with the SAM used). The Fish 30, Fish 40 and Fish 50 scenarios represent the impact on the baseline scenario given the labour market changes generated by the REGCGE model. To avoid presenting too many scenarios, only Fish 30 is considered with low elasticities, Fish 40 with medium elasticities and Fish 50 with high elasticities. Also considered are policy scenarios involving direct transfers to fishery workers in the three poorest quintiles in the form of early retirement with between 20% and 100% of the income they originally received before the impact on the fishing industry.

Setting out from these results, it can be concluded that poverty increases by between 0.49 and 1.01 percentage points, depending on the depth of the impact the fishing crisis has on productivity, while inequality as measured by the Gini coefficient is unchanged. Early retirement policies would improve poverty and inequality indicators, but only marginally; the greatest impact arises with an early retirement pension of 100%, as a result of this being targeted only on fishery workers from the three poorest quintiles, but again the medium- and long-run effects on the pressures affecting the whole labour market are not reflected in it.

TABLE 17

**Bío Bío region: results of microsimulations**

| Scenario | Poverty *(percentages)* | Gini coefficient for household income |
|---|---|---|
| Baseline | 20.68 | 0.5488 |
| Fish 30 | 21.17 | 0.5488 |
| Fish 30 subsidy of 20% | 21.15 | 0.5487 |
| Fish 30 subsidy of 40% | 21.13 | 0.5486 |
| Fish 30 subsidy of 60% | 21.11 | 0.5486 |
| Fish 30 subsidy of 80% | 21.10 | 0.5485 |
| Fish 30 subsidy of 100% | 21.10 | 0.5485 |
| Fish 40 | 21.38 | 0.5492 |
| Fish 40 subsidy of 20% | 21.36 | 0.5491 |
| Fish 40 subsidy of 40% | 21.35 | 0.5490 |
| Fish 40 subsidy of 60% | 21.32 | 0.5489 |
| Fish 40 subsidy of 80% | 21.31 | 0.5489 |
| Fish 40 subsidy of 100% | 21.31 | 0.5488 |
| Fish 50 | 21.69 | 0.5488 |
| Fish 50 subsidy of 20% | 21.67 | 0.5487 |
| Fish 50 subsidy of 40% | 21.66 | 0.5486 |
| Fish 50 subsidy of 60% | 21.63 | 0.5485 |
| Fish 50 subsidy of 80% | 21.63 | 0.5485 |
| Fish 50 subsidy of 100% | 21.62 | 0.5485 |

*Source:* prepared by the author.

# IV

## Conclusions

A regional computable general equilibrium model is developed. This is called the REGCGE model and is standardized for the data available from regional input-output matrices in Chile. Its purpose is to analyse policies or economic impacts that are particularly relevant when dealing with regional problems. Although this study does not extend the modelling knowledge frontier, it may serve socially useful purposes in a country like Chile where little research has been done on regional problems.

To illustrate its potential and benefits, an application is generated for the Bío Bío region, given the availability of a SAM updated to 2006 using indirect methods. Specifically, it simulates the effects of the scarcity of fish stocks (the so-called jack mackerel crisis), modelling this as declining productivity in the fishing sector.

The study reveals increased specialization of the Bío Bío region production structure in the wood and cellulose industry in the wake of the fishing crisis.

The negative impact is also felt in the labour market, disproportionately affecting the remuneration of more highly skilled labour, so that the incomes of families at higher socio-economic levels are the most affected by the fish stocks crisis. This comes out particularly strongly in the demand for products consumed by these families, such as construction, services, trade and financial services. Other families' consumption is affected, but proportionally less.

This general equilibrium analysis made it possible to identify unforeseen indirect effects. It was even possible to determine that sectors with limited production linkages to the fishing industry would be strongly affected by the drop in incomes in the wealthiest quintiles.

Because of the above, it can be concluded that this regional CGE model has a significant contribution to make as a tool for the analysis of regional economic policies and shocks in Chile.

Lastly, there is an analysis of economic policies designed to moderate the short-term social repercussions of the fishing crisis using the non-parametric microsimulations methodology.

*(Original: Spanish)*

## APPENDIX 1

### regcge model equations

Mathematical representation for a region given that it trades with two major regions, *r*, rest of country and rest of world. A total of *c* goods are marketed in the economy, produced in *a* sectors using *f* production sectors and generating income for *h* families, which also receive transfers from *i* institutions, from other families or from the government, *gov*.

Price equations:

$$PM_c = \sum_{r\in R}\left(\beta^r_{c',c}\cdot PMR_{c,r}{}^{1-\sigma^m_c}\right)^{\frac{1}{1-\sigma^m_c}} + \sum_{c'\in C}\left(PQ_{c'}\cdot icm_{c',c}\right) \qquad (1)$$

$$PE_c = \sum_{r\in R}\left(\alpha^r_{c',c}\cdot PER_{c,r}{}^{1-\sigma^x_c}\right)^{\frac{1}{1-\sigma^x_c}} - \sum_{c'\in C}\left(PQ_{c'}\cdot ice_{c',c}\right) \qquad (2)$$

$$PMR_{c,r} = pwm_{c,r}\cdot\left(1+tm_{c,r}\right)\cdot EXR_r \qquad (3)$$

$$PER_{c,r} = pwe_{c,r}\cdot\left(1-te_{c,r}\right)\cdot EXR_r \qquad (4)$$

$$PDD_c = PDS_c + \sum_{c'\in C}\left(PQ_{c'}\cdot icd_{c',c}\right) \qquad (5)$$

$$PQ_c\cdot\left(1-tq_c\right)\cdot QQ_c = PDD_c\cdot QD_c + PM_c\cdot QM_c \qquad (6)$$

$$PX_c\cdot QX_c = PDS_c\cdot QD_c + PE_c\cdot QE_c \qquad (7)$$

$$PA_a = \sum_{c\in C} PXAC_{a,c}\cdot\theta_{a,c} \qquad (8)$$

$$PINTA_a = \sum_{c\in C} PQ_c\cdot ica_{a,c} \qquad (9)$$

$$PA_a\cdot\left(1-ta_a\right)\cdot QA_a = PVA_a\cdot QVA_a + PINTA_a\cdot QINTA_a \qquad (10)$$

$$CPI = \sum_{c\in C} PQ_c\cdot cwts_c \qquad (11)$$

$$\overline{DPI} = \sum_{c\in C} PDS_c\cdot dwts_c \qquad (12)$$

Production and marketing equations:

$$QA_a = \alpha^a_a\cdot\left(\delta^a_a\cdot QVA_a^{-\rho^a_a} + (1-\delta^a_a)\cdot QINTA_a^{-\rho^a_a}\right)^{-\frac{1}{\rho^a_a}} \qquad (13)$$

$$\frac{QVA_a}{QINTA_a} = \left(\frac{PINTA_a}{PVA_a}\cdot\frac{\delta^a_a}{1-\delta^a_a}\right)^{\frac{1}{1+\rho^a_a}} \qquad (14)$$

$$QVA_a = iva_a\cdot QA_a \qquad (15)$$

$$QINTA_a = inta_a\cdot QA_a \qquad (16)$$

$$QVA_a = \alpha_a^{va} \cdot \left( \sum_{f \in F} \delta_{f,a}^{va} \cdot QF_{f,a}^{-\rho_a^{va}} \right)^{-\frac{1}{\rho_a^{va}}} \tag{17}$$

$$WF_f \cdot \overline{WFDIST}_{f,a} = PVA_{a,} \cdot \left(1 - tva_a\right) \cdot QVA_a \cdot \left( \sum_{f \in F} \delta_{f,a}^{va} \cdot QF_{f,a}^{-\rho_a^{va}} \right)^{-1} \cdot \delta_{f,a}^{va} \cdot QF_{f,a}^{-\rho_a^{va}-1} \cdot \left( \sum_{f' \in F} \delta_{f,a}^{va} \cdot QF_{f,a}^{-\rho_a^{va}} \right)^{-1} \cdot \delta_{f,a}^{va} \cdot QF_{f,a}^{-\rho_a^{va}-1} \tag{18}$$

$$QINT_{c,a} = ica_{c,a} \cdot QINTA_a \tag{19}$$

$$QXAC_{a,c} + \sum_{h \in H} QHA_{a,c,h} = \theta_{c,a} \cdot QA_a \tag{20}$$

$$QX_c = \alpha_c^{ac} \cdot \left( \sum_{a \in A} \delta_{a,c}^{ac} \cdot QXAC_{a,c}^{-\rho_c^{ac}} \right)^{-\frac{1}{\rho_c^{ac}-1}} \tag{21}$$

$$\frac{PXAC_{a,c}}{PX_c} = QX_c \cdot \sum_{a' \in A} \left( \delta_{a',c}^{a,c} \cdot QXAC_{a',c}^{-\rho_c^{a,c}} \right)^{-1} \cdot \delta_{a',c}^{a,c} \cdot QXAC_{a,c}^{-\rho_c^{a,c}-1} \tag{22}$$

$$QX_c = \alpha_c^t \cdot \left( \delta_c^t \cdot QE_c^{\rho_c^t} + (1 - \delta_c^t) \cdot QD_c^{\rho_c^t} \right)^{\frac{1}{\rho_c^t}} \tag{23}$$

$$\frac{QE_c}{QD_c} = \left( \frac{PE_c}{PDS_c} \cdot \frac{1 - \delta_c^t}{\delta_c^t} \right)^{\frac{1}{\rho_c^t - 1}} \tag{24}$$

$$QX_c = QD_c + QE_c \tag{25}$$

$$QQ_c = \alpha_c^q \cdot \left( \delta_c^q \cdot QM_c^{-\rho_c^q} + (1 - \delta_c^q) \cdot QD_c^{-\rho_c^q} \right)^{-\frac{1}{\rho_c^q}} \tag{26}$$

$$\frac{QM_c}{QD_c} = \left( \frac{PDD_c}{PM_c} \cdot \frac{\delta_c^q}{1 - \delta_c^q} \right)^{\frac{1}{1+\rho_c^q}} \tag{27}$$

$$QQ_c = QD_c + QM_c \tag{28}$$

$$QT_c = \sum_{c' \in C'} \left( icm_{c,c'} \cdot QM_{c'} + ice_{c,c'} \cdot QE_{c'} + icd_{c,c'} \cdot QD_{c'} \right) \tag{29}$$

$$QMR_{c,r} = \beta_{c,r'} \cdot \left( PM_{c'} / PMR_{c,r'} \right)^{\sigma_r^m} \cdot QM_{c'} \tag{30}$$

$$QER_{c,r} = \alpha_{c',c}^r \cdot \left( PE_{c'} / PER_{c,r'} \right)^{\sigma_r^x} \cdot QE_{c'} \tag{31}$$

Equations of flows between institutions:

$$YF_f = \sum_{a \in A} WF_f \cdot \overline{WFDIST}_{f,a} \cdot QF_{f,a} \tag{32}$$

$$YIF_{i,f} = shif_{i,f} \cdot \left[ \left(1 - tf_f\right) \cdot YF_f - \sum_{r \in R} trnsfr_{r,f} \cdot EXP_r \right] \tag{33}$$

$$TRII_{i,i'} = shii_{i,i'} \cdot (1 - MPS_{i'}) \cdot (1 - TINS_{i'}) \cdot YI_{i'} \tag{34}$$

$$YI_i = \sum_{f \in F} YIF_{i,f} + \sum_{i' \in INSDNG'} TRII_{i,i'} + trnsfr_{i,gov} \cdot CPI + \sum_{r \in R} trnsfr_{i,r} \cdot EXR_r \tag{35}$$

$$TINS_i = \overline{tins_i} \cdot \left(1 + \overline{TINSADJ} \cdot tins01_i\right) + \overline{DTINS} \cdot tins01_i \tag{36}$$

$$EH_h = \left(1 - \sum_{i \in INSDNG} shii_{i,h}\right) \cdot \left(1 - MPS_h\right) \cdot (1 - TINS_h) \cdot YI_h \tag{37}$$

$$PQ_c \cdot QH_{c,h} = PQ_c \cdot \gamma^m_{c,h} + \beta^m_{c,h} \cdot \left(EH_h - \sum_{c' \in C} PQ_{c'} \cdot \gamma^m_{c',h} - \sum_{a \in A} \sum_{c' \in C} PXAC_{a,c'} \cdot \gamma^h_{a,c',h}\right) \tag{38}$$

$$PXAC_{a,c} \cdot QHA_{a,c,h} = PXAC_{a,c} \cdot \gamma^h_{a,c,h} + \beta^h_{a,c,h} \cdot \left(EH_h - \sum_{c' \in C} PQ_{c'} \cdot \gamma^m_{c',h} - \sum_{a \in A} \sum_{c' \in C} PXAC_{a,c'} \cdot \gamma^h_{a,c',h}\right) \tag{39}$$

$$QINV_c = \overline{IADJ} \cdot \overline{qinv}_c \tag{40}$$

$$QG_c = \overline{GADJ} \cdot \overline{qg}_c \tag{41}$$

$$\begin{aligned} YG = {} & \sum_{i \in INSDNG} TINS_i \cdot YI_i + \sum_{f \in F} tf_f \cdot YF_f + \sum_{a \in A} ta_a \cdot PA_a \cdot Q_a + \sum_{a \in A} tva_a \cdot PVA_a \cdot QVA_a + \\ & \sum_{r \in R} \sum_{c \in CM} tm_{c,r} \cdot pwm_{c,r} \cdot QMR_{c,r} \cdot EXR_r + \sum_{r \in R} \sum_{c \in CE} te_{c,r} \cdot pwe_{c,r} \cdot QER_{c,r} \cdot EXR_r + \sum_{c \in C} tq_c \cdot PQ_c \cdot QQ_c + \\ & \sum_{f \in F} {}^{YIF_{gov,f}} + \sum_{r \in R} trnsfr_{gov,r} \cdot EXR_r \end{aligned} \tag{42}$$

$$EG = \sum_{c \in C} PQ_c \cdot QG_c + \sum_{i \in INSDNH} trnsfr_{i,\, gov} \cdot CPI \tag{43}$$

Constraint equations:

$$QFS_f = qfs0_f \cdot \left[\sum_{a \in A} \frac{(WF_f \cdot WFDIST_{f,a} \cdot QF_{f,a}) / (QFS_f \cdot CPI)}{wfcountry0_f / cpicountry0}\right]^{etlas_f} \tag{44}$$

$$\sum_{a \in A} QF_{f,a} = QFS_f \qquad \sum_{a \in A} QF_{f,a} = QFS_f \tag{45}$$

$$QQ_c = \sum_{a \in A} QINT_{c,a} + \sum_{h \in H} QH_{c,h} + QG + QINV_c + qdst_c + QT_c \tag{46}$$

$$\sum_{c \in CM} pwm_{c,r} \cdot QMR_{c,r} + \sum_{f \in F} trnsfr_{r,f} = \sum_{c \in CE} pwe_{c,r} \cdot QER_{c,r} + \sum_{i \in INSD} trnsfr_{i,r} + FSAV_r \tag{47}$$

$$GSAV = YG - EG \tag{48}$$

$$MPS_i = \overline{mps_i} \cdot \left(1 + \overline{MPSADJ} \cdot mps01_i\right) + DMPS \cdot mps01_i \tag{49}$$

$$\sum_{i \in INSDNG} MPS_i (1 - TINS_i) \cdot YI_i + GSAV + \sum_{r \in R} EXR_r \cdot FSAV_r = \sum_{c \in C} PQ_c \cdot QINV_c + \sum_{c \in C} PQ_c \cdot qdst_c + WALRAS \tag{50}$$

$$TABS = \sum_{h\in H}\sum_{c\in C} PQ_c \cdot QH_{c,h} + \sum_{a\in A}\sum_{h\in H}\sum_{c\in C} PXAC_{a,c} \cdot QHA_{a,c,h} + \sum_{c\in C} PQ_c \cdot QG_c + \sum_{c\in C} PQ_c \cdot QINV_c + \sum_{c\in C} PQ_c \cdot qdst_c \tag{51}$$

$$INVSHR \cdot TABS = \sum_{c\in C} PQ_c \cdot QINV_c + \sum_{c\in C} PQ_c \cdot qdst_c \tag{52}$$

$$GOVSHR \cdot TABS = \sum_{c\in C} PQ_c \cdot QG_c \tag{53}$$

Technical note 1: To transform the standard CGE model of Löfgren, Harris and Robinson (2001) into a regional one, changes have been made to equations (1), (2), (3), (4), (33), (35), (42), (47) and (50) and equations (30), (31) and (44) have been included.

### APPENDIX 2

## regcge model variables

| | |
|---|---|
| CPI | regional consumer price index |
| DPI | regional producer price index |
| DMPS | change in marginal propensity to save |
| DTINS | change in tax rate |
| EG | total government expenditure |
| $EH_h$ | household consumption expenditure |
| $EXR_r$ | exchange rate in external region *r* (rest of country and rest of world) |
| $FSAV_r$ | external saving in external region *r* |
| GADJ | government demand adjustment factor |
| GOVSHR | ratio of government consumption to absorption |
| GSAV | government saving |
| IADJ | investment scaling factor |
| INVSHR | ratio of investment to absorption |
| $MPS_i$ | marginal propensity to save for non-governmental domestic institutions |
| MPSADJ | scaling factor for saving rate |
| $PA_a$ | activity product price for *a* |
| $PDD_c$ | demand price for commodity *c* produced and sold domestically |
| $PDS_c$ | supply price for commodity *c* produced and sold domestically |
| $PER_{c,r}$ | export price for commodity *c* by destination region (rest of country and rest of world) |
| $PINTA_a$ | aggregate intermediate input price |
| $PMR_{c,r}$ | export price for commodity *c* by region of origin (rest of country and rest of world) |
| $PM_c$ | composite price of imports of commodity *c* |
| $PE_c$ | composite price of exports of commodity *c* |
| $PQ_c$ | composite price of commodity *c* |
| $PVA_a$ | price of value added |
| $PWE_{c,r}$ | price of exports by region of destination (rest of country and rest of world) |
| $PWM_{c,r}$ | price of imports by region of destination (rest of country and rest of world) |
| $PX_c$ | average price of commodity *c* |
| $PXAC_{a,c}$ | price of commodity *c* from activity *a* |
| $QA_a$ | activity level in the region |
| $QD_c$ | quantity of sales in the region |
| $QER_{c,r}$ | quantity of exports to each region of destination (rest of country and rest of world) |
| $QMR_{c,r}$ | quantity of imports from each region of origin (rest of country and rest of world) |
| $QE_c$ | quantity of exports of commodity *c* |
| $QM_c$ | quantity of imports of commodity *c* |
| $QF_{f,a}$ | quantity of factor *f* demanded by activity *a* |
| $QFS_f$ | quantity of factor *f* supplied |
| $QG_c$ | quantity of government consumption |
| $QH_{c,h}$ | quantity of marketed commodity *c* consumed by family *h* |
| $QHA_{a,c,h}$ | quantity of domestic commodity *c* consumed by family *h* |
| $QINT_{c,a}$ | quantity of intermediate demand for commodity *c* from activity *a* |
| $QINTA_a$ | quantity of aggregate intermediate input |
| $QINV_c$ | quantity of investment demand |
| $QQ_c$ | quantity of composite commodity supply |
| $QT_c$ | quantity of transport and marketing demanded by commodity *c* |
| $QVA_a$ | quantity of value added |
| $QX_c$ | aggregated marketed quantity of commodity |
| $QXAC_{a,c}$ | quantity of output of commodity *c* from activity *a* |
| TABS | total absorption |
| $TINS_i$ | direct tax rate on institution *i* |
| TINSADJ | direct tax scaling factor |
| $TRII_{i,i'}$ | transfers to institution *i* from institution *i'* |
| WALRAS | saving-investment imbalance (should be zero in equilibrium) |
| $WF_f$ | wage for factor *f* |
| $WFDIST_{f,a}$ | wage distortion factor in activity *a* |
| $YF_f$ | income of factor *f* |
| YG | government income |
| $YIF_{i,f}$ | income of institution *i* from factor *f* |
| $YI_i$ | income of institution *i* |

Technical note 2: To transform the standard CGE model of Löfgren, Harris and Robinson (2001) into a regional one, the following variables have been introduced: $EXR_r$, $FSAV_r$, $PER_{c,r}$, $PMR_{c,r}$, $PWE_{c,r}$, $PWM_{c,r}$, $QER_{c,r}$, $QMR_{c,r}$.

**APPENDIX 3**

## Aggregate social accounting matrix for the Bío Bío region

*(Base year: 2006)*

| | ACT | PROD | CSTTR | CAP | LAB | HOUSE | GOV | DITAX | ACTAX | VATAX | IMTAX | ROW | ROC | S-I | DSTCK | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ACT | | 12 532.9 | | | | | | | | | | | | | | 12 532.9 |
| PROD | 6 668.1 | | 853.2 | | | 3 019.6 | 911.6 | | | | | 1 881.7 | 1 504.0 | 1 078.6 | 62.5 | 15 979.4 |
| CSTTR | | 853.2 | | | | | | | | | | | | | | 853.2 |
| CAP | 3 191.0 | | | | | | | | | | | | | | | 3 191.0 |
| LAB | 2 083.3 | | | | | | | | | | | | | | | 2 083.3 |
| HOUSE | | | | 755.4 | 2 083.3 | 366.4 | 8.6 | | | | | | | | | 3 213.7 |
| GOV | | | | 264.7 | | | | 112.9 | 101.8 | 488.7 | 13.7 | | | | | 981.7 |
| DITAX | | | | | | 112.9 | | | | | | | | | | 112.9 |
| ACTAX | 101.8 | | | | | | | | | | | | | | | 101.8 |
| VATAX | 488.7 | | | | | | | | | | | | | | | 488.7 |
| IMTAX | | 13.7 | | | | | | | | | | | | | | 13.7 |
| ROW | | 470.1 | | | | | | | | | | | | | | 470.1 |
| ROC | | 2 109.4 | | 2 170.9 | | | | | | | | | | | | 4 280.3 |
| S-I | | | | | | -285.2 | 61.6 | | | | | -1 411.6 | 2 776.3 | | | 1 141.1 |
| DSTCK | | | | | | | | | | | | | | 62.5 | | 62.5 |
| *Total* | *12 532.9* | *15 979.4* | *853.2* | *3 191.0* | *2 083.3* | *3 213.7* | *981.7* | *112.9* | *101.8* | *488.7* | *13.7* | *470.1* | *4 280.3* | *1 141.1* | *62.5* | *45 506.3* |

*Source:* C. Mardones and J. Saavedra, "Matriz de contabilidad social extendida ambientalmente para análisis económico de la Región del Bío Bío", *Revista de análisis económico*, vol. 26, No. 1, 2011.

Nomenclature:
ACT production activity; PROD products; CSTTR transaction cost; CAP capital; LAB labour; HOUSE households; GOV government; DITAX income tax; ACTAX activity tax; VATAX value added tax; IMTAX import tax; ROW rest of world; ROC rest of country; S-I saving-investment balance; DSTCK change in stock.

**APPENDIX 4**

## Calibration of model elasticities

The elasticities used to calibrate the model are taken from the literature. The elasticity between capital and labour is 0.9 (Claro, 2003); the elasticity between value added and the aggregate intermediate input is 0 (Leontief function); the elasticity of spending in the system of demand (LES) is 1.0 and the Frisch parameter is –2.4 (Nganou, 2004); the constant elasticity of transformation (CET) of the function that divides domestic production from exports and the Armington elasticity of domestic production and imports is 1.2 for primary sectors, 0.8 for industry and 0.6 for services (Jung and Thorbecke, 2003); these last values are also used to divide exports and imports between the rest of the country and the rest of the world.

To increase the sensitivity of the results, different values are considered for parameters and elasticities that might generate a substantial impact.

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