Renewable energy expansion in the Chilean power market: A Linking Bottom-up approach with Dynamic CGE modelling

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Contents:

1. Motivation and objective

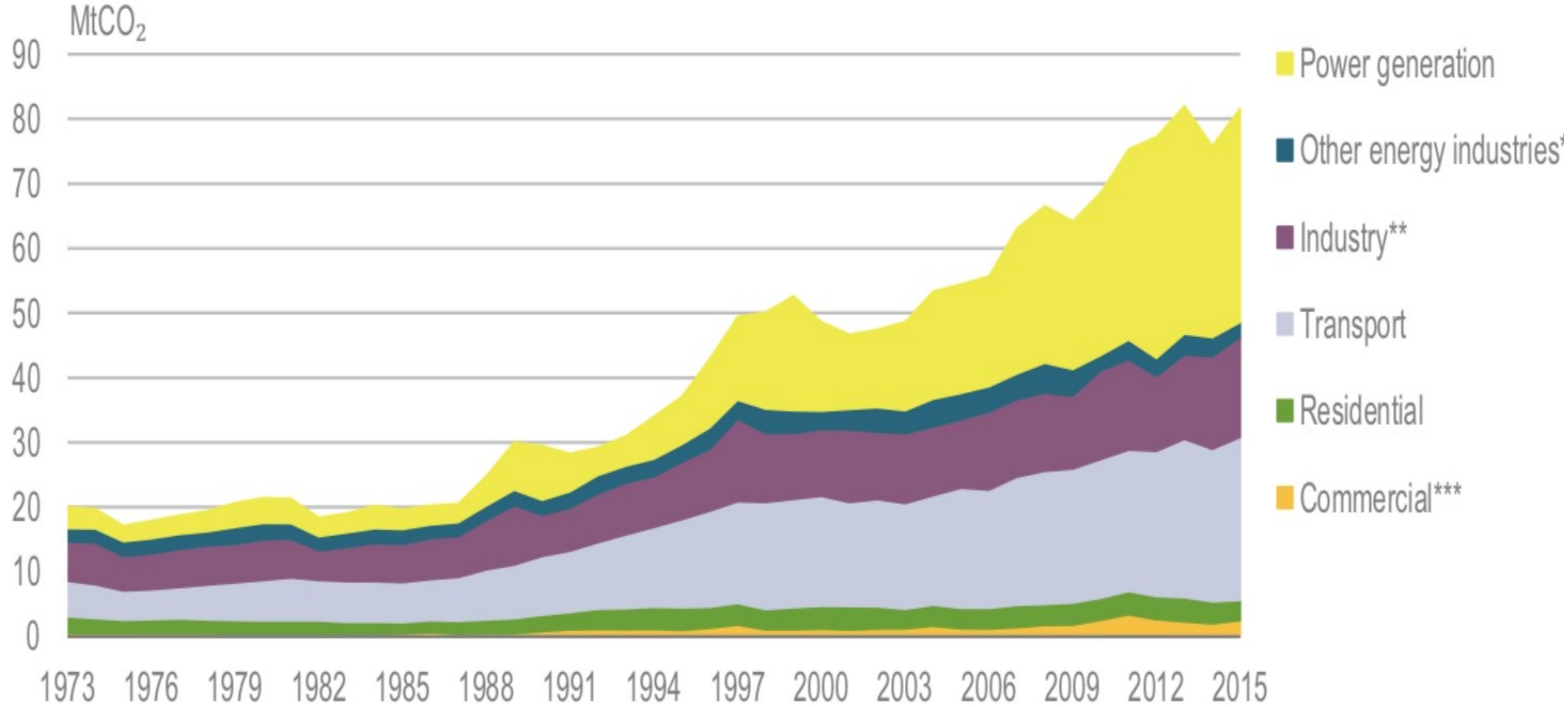
Chile’s NDC

- **First,** it committed to unconditionally achieve a 30% reduction of GHG emissions-intensity of GDP compared to 2007 by 2030 to reach a value of 0.71 tCO2e/million CLP$ 2011 (subject to economic growth).

- **Second,** a further NDC proposal was to reduce GHG emissions-intensity of GDP by 35% - 45% in comparison with the levels in 2007 by 2030, conditional on international financial contributions in the form of grants.

Why energy sector in important in Climate Change?

Energy-related CO2 emissions by sector, 1973-2015 in Chile



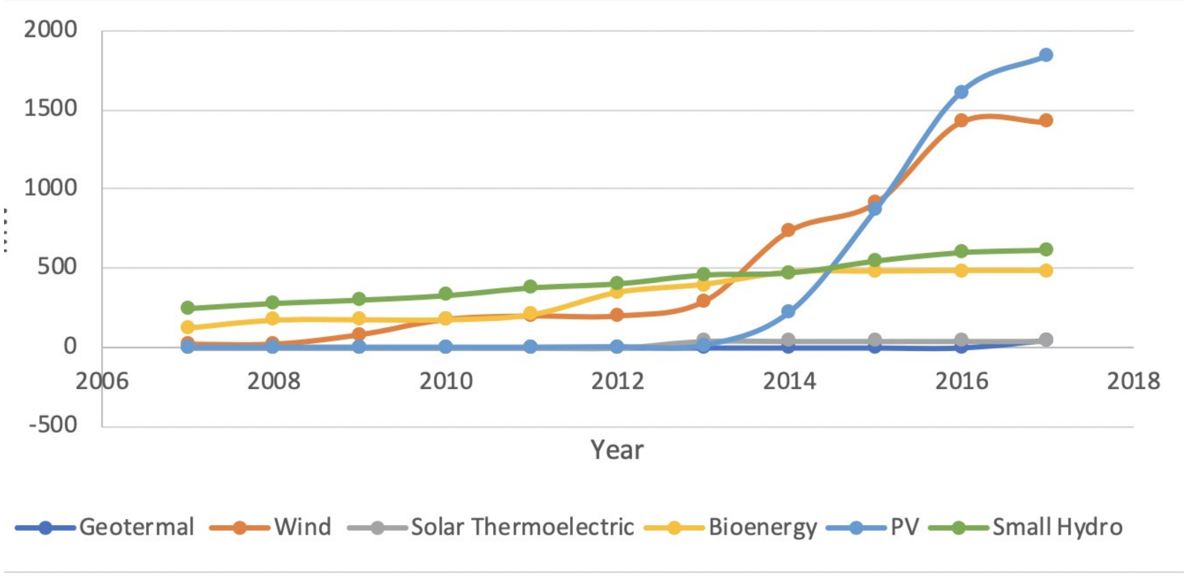
- In the 1980s, hydro-power resources accounted for more than 70% of the total electric system installed capacity in Chile.

  - Milestones in the Chilean electricity system

Structural Change in the Energy Matrix

- The share of RES has more than quadrupled in the last few years, reaching 22% in September of 2019. Considering large hydropower plants over 20 MW, the share of total RES in the Chilean energy mix accounts for around 50%

- The National Energy Policy 2050 set main objectives to increase the share of renewable energy in power generation to 60% by 2035 and to 70% by 2050



Motivation

- Change in Energy Matrix
- INDC’s
- There is little quantitative assessment of dynamic effects of the change in the Matrix
- Need to evaluate economic, social and environmental effects of different scenarios to define specific policies and the INDC

Goal of the paper

In this paper using a link approach with the Dynamic CGE model ECOGEM-Chile, we evaluate different scenarios for the development of the electricity sector in Chile and the expected impacts on its CO_2 emissions and INDC target.

Methodology:

Description of the Chilean CGE model and the data

WHY CGE MODELING?

- Top-down modeling approaches can capture the effects over the whole economy, especially the interactions among sectors.
- Can identify “winners and losers”.
- Allows comprehending the mechanisms that drive the results, favoring the economic analysis of alternatives.

COMPUTABLE GENERAL EQUILIBRIUM MODELS (CGE)

- Data Source: structure of a SAM
- Behavioral equations
- Market-clearing conditions
- SOLVING THE MODEL
- Shock simulation

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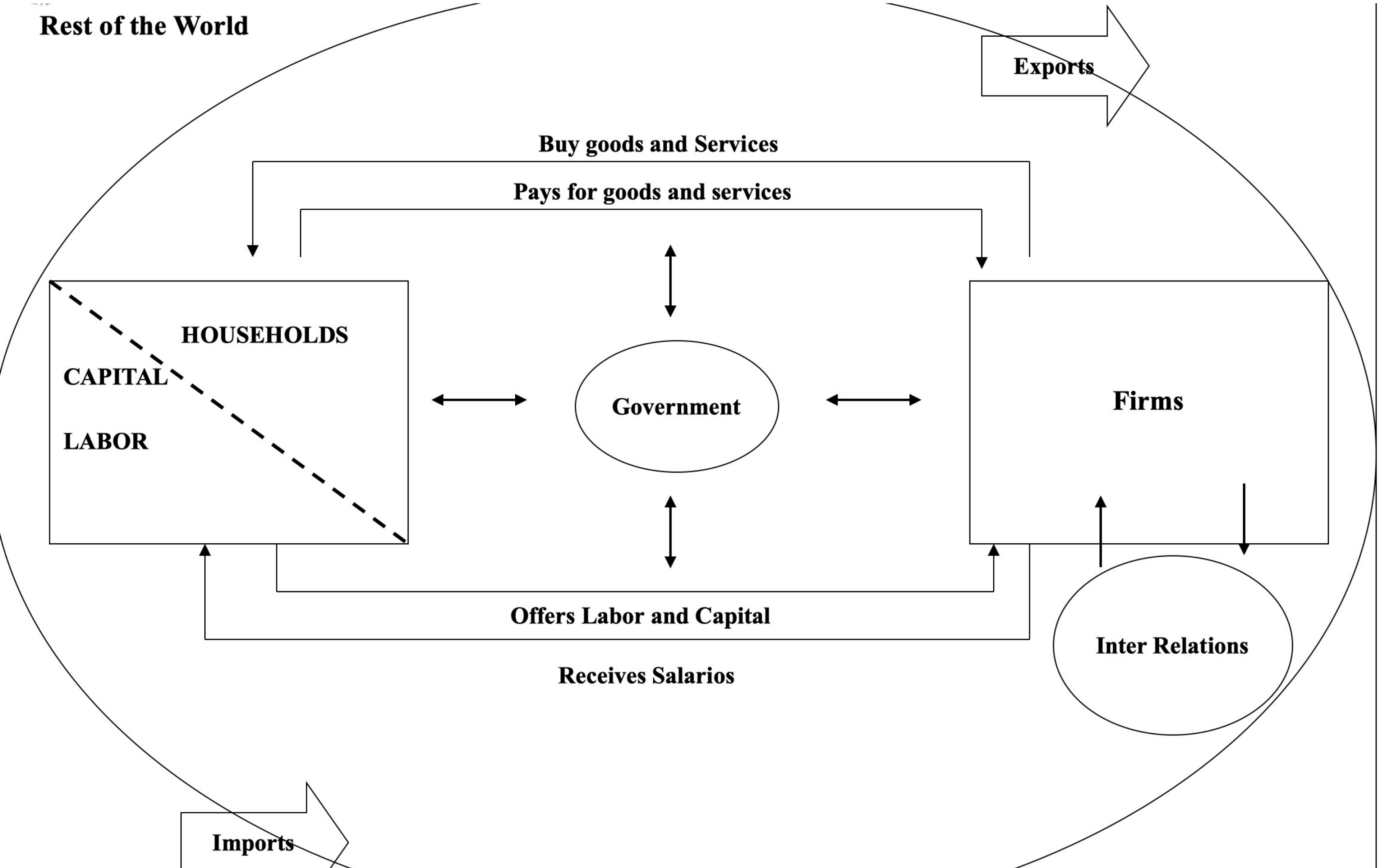

ECOGEM- Chile

Based on OECD GREEN CGE model

Features:

- Production (Min Costs, CES and Leontieff)
- Consumption (Max Utility, ELES)
- Other Final Demands Fixed shares (Investment, Government, Margins, Stocks)
- Foreign sector (Armington Assumption and CET)
- Closure Rules (Walras Law, Savings driven)
- Dynamic Framework

Summary of Characteristics of the ECOGEM model

Characteristics	Description
Sectors and activities	61 sectors: 27 productive sectors, 7 energy generation sectors, 27 services (including water, health, transportation among others)
Occupational categories	12 categories: high-, medium- and low-skill disaggregation by gender (Male/Female) and by place (Urban/Rural)
Household income groups	10 deciles: income groups
Trade partners	35 trade partners: Brazil, USA, China and others and groups of countries or regions (rest of Asia or America and others)
Public finances	Breakdown of taxes and transfers: direct and indirect taxes to businesses, direct taxes on households (income), labor tax, tariffs, VAT and government transfers to households from/to abroad
Pollutions	6 types of pollutants: Chile’s own emission factors have been estimated by sectoral production and final consumption for airborne pollutants.

The Data

Data and Parameters

- 2013 I/O Matrix for Chile
- Updating of SAM to 2013
- Elasticicities (Beghin et. al.) and own estimations
- Emission Coefficients estimated by the research team for Chile.

Methodology:

Simulation scenarios from bottom-up modeling iUAI EARTH CENTER UNIVERSIDAD ADOLFO IBÁÑEZ

WHY Bottom-up engineering modeling?

- Bottom-up-based simulation and optimization models are more popular within energy analysis and planning fields
- These models include detailed analyses of energy technologies with both technical and economic parameters.
- Therefore, resources, technologies and users can easily be modeled with the desired scope and detail.

Energy Scenarios from Engineering Model

FACTORS	SCENARIO A	SCENARIO B	SCENARIO C	SCENARIO D	SCENARIO E
Social Disposition	+Cost, CCS	Free	+Cost, CCS	+Cost	+Cost
Energy Demand	Low	high	medium	low	high
Technological change in batteries	High	low	medium	medium	high
Environemtal externalities cost	current	high	current	current	high
Investment costs of renewable technologies	low	low	medium	high	low
Price of fossil fuels	medium	high	low	low	high

The shares of the generation technologies per scenario for 2025 and 2030 years

	Scenario A		Scenario C		Scenario D	
	2025	2030	2025	2030	2025	2030
Solar[7]	6.3%	8.3%	8.7%	14.1%	8.8%	10.8%
Biomass	3.8%	5.0%	4.0%	3.7%	4.0%	3.9%
Wind	3.4%	4.5%	12.5%	11.1%	12.7%	11.8%
Coal	29.6%	38.7%	37.2%	33.3%	37.2%	35.7%
Nat. Gas	1.7%	2.2%	2.6%	6.4%	1.7%	4.5%
Diesel	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hydro[8]	30.7%	40.1%	34.0%	30.5%	34.6%	32.5%

Methodology:

Incorporating bottom-up results in CGE modeling

Why Linking?

CGE modeling does not adequately incorporate expert projections of RE penetration. Structural change.

Bottom-up models describe technologies in detail, are recent, and prospective and come usually as mathematical programming. Best suited for policies referring technology changes.

Soft linking gives more control to the end user, as opposed to hard linking or integration.

Softlinking is practical transparent and allows learning.

Linking scheme of the ECOGEM-Chile/CGE and a bottom-up engineering model.

Changes in the Model: linking with the energy sector

Opening the Energy Sector in the SAM

TECHNOLOGIES

ELECTRICITY GENERATION

- Natural Gas
- Coal
- Biomass
- Water
- Wind
- Solar
- Oil derivatives

PRODUCTION

Parameter of energy demand (base scenario or BAU)	$\text{andx}_{tec,t}^{\text{bau}} = \frac{\text{ND}_{tec,t}}{\text{XP}_{tec,t}}$ $\text{akel}_{tec,t}^{\text{bau}} = \frac{\text{KEL}_{tec,t}}{\text{XP}_{tec,t}}$
New parameter of energy demand (energy scenario)	$\text{andx}_{tec,t}^{\text{esc}} = \frac{\text{ND}_{tec,t}}{\text{XP}_{tec,t}} + \Delta\text{gen}_{\text{tec,t}}^{\text{esc}}$ $\text{akel}_{tec,t}^{\text{esc}} = \frac{\text{KEL}_{tec,t}}{\text{XP}_{tec,t}} + \Delta\text{gen}_{\text{tec,t}}^{\text{esc}}$

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RESULTS

CO2 EMISSIONS PER SCENARIO

EMISSIONS INTENSITY PER SCENARIO

GDP PER SCENARIO

The change of electricity prices, 2013 - 2030.

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