SIMULATING THE ECONOMIC IMPACT OF THE REPLACEMENT OF COAL THERMAL POWER PLANTS WITH SOLAR AND WIND ENERGY IN CHILE

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Overview

Chile has experienced a strong increase in participation in non-conventional renewable energies (NCRE) in the last two decades. NCRE reached a penetration of close to 40% in 2022, mainly associated with solar (24%) and wind (13%) plants. However, the country's decarbonization goals demonstrate the intention to promote NCRE further. For example, there is a plan for the early shutdown of coal-fired thermoelectric plants, which focused on some plants between 2019 and 2026 (19% of the installed capacity) and the closure of the remaining plants by 2040 without a specific schedule. On the other hand, the Ministry of Energy has proposed that if the country does not reach a minimum of 70% renewable energy by 2050 with high solar and wind energy participation, price mechanisms, corrective bidding, and regulations must be applied. In this context, the present study uses an intersectoral model that allows to define exogenously the changes in the production of the solar, wind, and thermoelectric sectors, and also the investment required in solar and wind plants to replace the generation of coal-fired thermoelectric plants completely. The results obtained from the model and complementary information allow us to identify the economic impacts of this climate policy in Chile.

Methods

2.1 Data

According to the Association of Generators of Chile, investment projects in renewable energy that are in environmental processing total 12,880 MW of installed capacity, with a total investment of USD 17,976 million. Consequently, there is ample scope to replace the production of coal-fired thermoelectric plants (4,478 MW) with new solar and wind energy projects. On the other hand, the investment scenario simulations are based on a study by the National Energy Commission that establishes the total cost of each technology in Chile. However, investment must be disaggregated into imported and domestic inputs at the sector level to apply an input-output approach. For the above, complementary data is used from a study on the investment costs for solar and wind plants with battery systems for energy storage obtained from the National Energy Commission. Finally, the investment requirements were scaled considering the generation capacity of these plants concerning the capacity required to replace all coal-fired thermoelectric energy.

2.2 Mixed input-output model

This study aims to analyze the substitution of thermoelectric energy for NCRE, which requires evaluating shocks on the production vector. The mixed input-output model with partially exogenous production is described by Miller & Blair (2021). This model assumes that k sectors have endogenous production value ($\boldsymbol{x}^{en}$) and exogenous final demand ($\boldsymbol{f}^{ex}$), which in this study correspond to the thermoelectric, solar and wind sectors. The rest of the $n-k$ sectors have exogenous production value ($\boldsymbol{x}^{ex}$) and endogenous final demand ($\boldsymbol{f}^{en}$). On the other hand, the technical coefficient matrix $\boldsymbol{A}$ can be partitioned into four submatrices. $\boldsymbol{A}^{(\boldsymbol{k},\boldsymbol{k})}$ denotes the submatrix of the first k rows and k columns of matrix $\boldsymbol{A}$, $\boldsymbol{A}^{(\boldsymbol{k},-(\boldsymbol{n}.-\boldsymbol{k}))}$ denotes the submatrix of the first k rows and the last $(n-k)$ columns of the matrix $\boldsymbol{A}$, $\boldsymbol{A}^{(-(\boldsymbol{n}.-\boldsymbol{k}),\boldsymbol{k})}$ denotes the submatrix of the first $(n-k)$ rows and the last k columns of the matrix $\boldsymbol{A}$, and $\boldsymbol{A}^{(-(\boldsymbol{n}.-\boldsymbol{k}),-(\boldsymbol{n}-\boldsymbol{k}))}$ denotes the submatrix of the last $(n-k)$ rows and the last $(n-k)$ columns of the matrix $\boldsymbol{A}$. Furthermore, $\boldsymbol{I}$ and $\boldsymbol{0}$ are the identity and null matrices of the dimension required in each case. By applying properties of inverse matrices and partitioned matrices it can be shown that the solution of the model can be represented by:

$$\begin{bmatrix}\boldsymbol{x}^{en}\\ \boldsymbol{f}^{en}\end{bmatrix}=\begin{bmatrix}(\boldsymbol{I}-\boldsymbol{A}^{(\boldsymbol{k},\boldsymbol{k})})^{-1} & (\boldsymbol{I}-\boldsymbol{A}^{(\boldsymbol{k},\boldsymbol{k})})^{-1}\boldsymbol{A}^{(\boldsymbol{k},-(\boldsymbol{n}-\boldsymbol{k}))}\\ -\boldsymbol{A}^{(-(\boldsymbol{n}-\boldsymbol{k}),\boldsymbol{k})}(\boldsymbol{I}-\boldsymbol{A}^{(\boldsymbol{k},\boldsymbol{k})})^{-1} & \left(\boldsymbol{I}-\boldsymbol{A}^{(-(\boldsymbol{n}-\boldsymbol{k}),-(\boldsymbol{n}-\boldsymbol{k}))}\right)-\boldsymbol{A}^{(-(\boldsymbol{n}-\boldsymbol{k}),\boldsymbol{k})}(\boldsymbol{I}-\boldsymbol{A}^{(\boldsymbol{k},\boldsymbol{k})})^{-1}\boldsymbol{A}^{(\boldsymbol{k},-(\boldsymbol{n}-\boldsymbol{k}))}\end{bmatrix}\begin{bmatrix}\boldsymbol{f}^{ex}\\ \boldsymbol{x}^{ex}\end{bmatrix}$$

2.3 Model Calibration

Although the input-output models have a high sectoral disaggregation, the input-output tables at the national level typically do not have a disaggregation of the energy sector. The above implies that thermoelectric, hydroelectric, solar, wind, nuclear, or other generation are grouped in terms of the value of production and purchase of inputs, which is why additional data, assumptions, and efforts are required to disaggregate the different electrical sectors. Fortunately, this study uses input-output tables with high disaggregation of the electricity sector (thermoelectric, hydroelectric, solar, wind, and biomass) developed by Mardones & Brevis (2021).

Results

Table 1 shows the effects on sectoral production. In the first scenario, the change in production is induced by a final demand shock associated with the investment in solar and wind plants. This first scenario shows that investment in solar and wind plants directly stimulates the construction, manufacturing & machinery, and various services sectors due to the installation and assembly of the plants, electrical supplies, and engineering services. In addition, an indirect impact is generated in other sectors caused by productive linkages. It should be noted that the components of solar or wind equipment are not produced in Chile, so imports of this equipment do not directly stimulate economic activity. In the second scenario, the production of the non-electricity sectors is endogenously determined by the shock in the production mix of the electricity generation sectors. In this scenario, the production of coal-fired thermoelectric plants is completely suppressed, so there is a negative indirect effect on the production of some sectors, such as water, gas & recycling; transportation; transmission & distribution of electricity; textile & leather; refined fuels; oil & gas; and financial services. The sectors that increase their production are solar and wind energy, which completely replace the production of coal-fired thermoelectric plants. The above generates an indirect positive impact on the production of some sectors: various services; manufacturing & machinery; construction; mining; metallic & non-metallic mining; wood & cellulose; chemical industry; Agriculture & fishing; forest; and food industry. The net effect on the economy's total production is a slight reduction of 70 million dollars (USD). In the third scenario, the required investment in solar and wind plants is simulated, and production from coal-fired thermoelectric plants is replaced with NCRE. The results show that the impact on production is approximately equal to the sum of the first two scenarios. In addition, there is a net positive impact on the production of the entire economy.

Table 1. Effects on sectoral production in millions of USD

Sector	Investment shocks	Production shocks	Investment and production shocks
Agriculture & fishing	3.4	1.2	4.4
Forestry	4.0	1.0	4.8
Coal	0.0	0.0	0.0
Oil & gas	0.1	-0.4	-0.4
Mining	12.5	30.5	42.9
Food industry	1.9	0.9	2.8
Textile & leather industry	2.2	-12.8	-10.6
Wood & cellulose industry	21.6	5.3	26.9
Refined fuels industry	3.7	-27.0	-23.5
Chemical industry	16.4	3.2	19.7
metallic & non-metallic industry	78.2	11.6	89.7
Manufacturing & machinery industry	165.1	79.0	243.5
Water, gas, & recycling	5.3	-528.7	-525.1
Construction	538.3	64.7	603.0
Commerce & hotels	27.4	1.5	28.6
Transport	21.3	-143.7	-123.1
Financial services	26.1	-0.7	24.7
Various services	101.1	453.6	553.2
Electricity transmission & distribution	19.5	-9.1	9.0
Hydroelectric power	3.8	0.0	0.0
Solar energy	0.4	2,147.0	2,147.0
Wind energy	0.4	1,589.7	1,589.7
Thermoelectric energy	11.0	-3,736.9	-3,736.9
Biomass energy	0.6	0.0	0.0
Total	1,065.0	-70.0	970.5

Conclusions

The results allow us to affirm that NCRE investment shocks stimulate sectoral production, especially economic activity in the construction and manufacturing & machinery industry. In contrast, the replacement of thermoelectric generation by solar and wind sources has heterogeneous effects in the non-electricity sectors, which is explained by the different productive linkages of each energy sector. For example, the shutdown of thermoelectric plants induces a drop in demand for inputs from the transportation, water, gas & recycling, and refined fuels sectors. However, the joint effect of investment and production shocks would increase national production at the agreggated level. Finally, it can be argued that replacing thermoelectric energy with NCRE will strongly contribute to the country's carbon neutrality.

References

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