# Power Generation and the Business Cycle: The Impact of Delaying Investment

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July 2013

**Abstract**

This article presents the hypothesis that exogenous shocks in the electricity market can affect the business cycle of the Chilean economy in the short and medium terms. The shocks are identified as the delays in power-generation investment that have characterized the sector in recent years. The delays are due to political decisions and the process of attaining environmental approvals by state agencies. A comparison of different scenarios reveals that after eight years, the country would lose the equivalent of one year of GDP growth, with a consequent reduction in private investment, domestic consumption, and job creation. This result highlights the importance of environmental and energy policy in reducing business cycle fluctuations.

Keywords: Business Cycle, Electric Energy, Bayesian Econometrics, DSGE models.

JEL: E17, E27, E37, L94

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We thank Felipe Pinto for superb research assistant.

The development of new electricity power plants in Chile has been subject to significant delays and even cancellations in recent years, due to factors exogenous to the projects themselves. These factors are generally political in nature and have generated substantial obstacles in the project approval process. In particular, the time required to obtain environmental approvals by state agencies has almost doubled, on average, in the last ten years.[2]

These delays have caused electricity prices to rise. The resulting dynamic has created a new type of negative supply shock for the Chilean economy, similar to past episodes of oil price shocks. In this paper, we show how the delays in the construction of power plants are connected to the business cycle, through changes in the price of electricity.

The literature connecting the business cycle with fluctuations in the price of energy is mainly focused on exogenous changes in oil prices. Since the early work of Rasche and Tatom (1980) and Hamilton (1983), the empirical literature has identified significant macroeconomic impacts from oil prices in the short and medium terms.[3] According to Kilian (2007), there are four reasons why the oil price has monopolized the attention of economists: first, oil prices have undergone strong and sustained increases and decreases; second, the demand for oil is relatively inelastic; third, changes in oil prices are exogenous (that is, they have external origins) and occur in the presence of significant imperfections in labor markets characterized by sticky wages;[4] and fourth, energy price hikes often occur in combination with major economic disruptions, such as recessions, unemployment, and high inflation. Much less attention has been given to analyzing the impact on the business cycle of fluctuations in the prices of natural gas and coal.[5] Ultimately, fluctuations in the price of electricity and their impact on the business

2 See Fuentes (2013).

3 See, for instance, Barro (1984), Mork (1989), Kahn and Hampton (1990), Huntington (1998), Brown and Yucel (1995, 1999, 2002), Hamilton (2003, 2010, 2012), Dickman and Holloway (2004), Guo and Kliesen (2005), Sill (2007), Krey, Martinsen, and Wagner (2007), Kilian (2008), Oladosu (2009). For the case of Chile, see Álvarez, García and García (2008). Studies that connect energy prices and economic growth in the long-term include Stern (1993), Gardner and Joutz, (1996), Asafu-Adjaye (2000), van Zon and Yetkiner (2003), Jiménez-Rodríguez and Sánchez (2005), and Berk and Yetkiner (2013).

4 On exogenous origins, see Huntington (2005) and Henry and Stokes (2006); on labor market imperfections, see Davis and Haltiwanger (2001) and Blanchard and Galí (2007).

5 Uri and Boyd (1997), Henry and Stokes (2006), Lysenko and Vinhas (2007), Oberndorfer (2009), Luzt and Meyer (2009), Choi, Bakshi, and Haab (2010), Yang, Xuan, and Jackson (2012).

cycle have only been explained by changes in the price of inputs to produce this energy (namely, oil, natural gas, and coal), and not by direct changes in the electricity sector.[6]

This paper shows that delays of the construction of new electricity power plants in Chile have caused increases in electricity prices, which in turn have had a significant effect at the macroeconomic level. By simulating different scenarios from 2007 to 2019, we estimate that the cumulative impact of the delays on GDP growth will be around 6% between 2012 and 2019, with the consequent negative effect on private investment, domestic consumption, and employment.

We propose a direct methodology for addressing this issue. The methodology has two parts: the modeling of electricity price scenarios and the estimation of the macroeconomic impacts. The electricity prices for different scenarios are simulated using a stochastic dual dynamic programming (SDDP) model, which has been widely applied for forecasting electricity market prices. The different electricity price scenarios are then introduced into a dynamic stochastic general equilibrium (DSGE) model, which is the standard methodology for analyzing the business cycle. The contribution of electricity is incorporated explicitly in the DSGE model, which is estimated using Bayesian techniques.

The paper is organized as follows. Section 1 presents the methodology used to estimate electricity prices under different scenarios (delays versus no delays) and to analyze their impact on the business cycle. Section 2 describes the calibration and estimation of the DSGE model. Section 3 then discusses the macroeconomic impact of delays in the construction of new power plants on the business cycle, as identified by the estimated DSGE model. Finally, section 4 presents the main conclusions of the study.

## 1. Modeling the Price of Electricity

This section describes the SDDP model used to estimate the electricity price under different scenarios. We then present the DSGE model and apply it to the energy sector.

Since the Chilean electric system consists of numerous hydropower plants with reservoirs, the electricity price model must take into account not only the existing water supply, but also the

6 On input price fluctuations, see Mohammadi (2009) and He et al. (2010).

future conditions of this resource for a given level of electricity generation and transmission.[7] To solve this problem, we use a stochastic dual dynamic programming (SDDP) model to define the optimal management strategy of reservoirs considering the probabilistic nature of the flow rates for each hydropower plant. The SDDP model determines the opportunity cost of water stored in each reservoir to calculate the short-run marginal costs of the electric system. Future electricity prices are then estimated based on the simulated marginal costs of the SDDP model.[8]

The SDDP model also allows us to formulate different price scenarios depending on how many power plants are operating in the electric system at any given time. We define the following scenarios: the super-optimal scenario, which assumes that the electrical system operated without delays from 2007 to 2019; the optimal scenario, which assumes that the system operates without delays from now on, that is, from 2012 to 2019; and the baseline scenario, which assumes that the current trend in delays continues through 2019. The baseline scenario is considered to be the most likely.

We use these scenarios to make two comparisons. First, we look at the difference between the super-optimal scenario and the baseline scenario. This comparison allows us to measure, in terms of the price differential, the impact of the delays that occurred from 2007 to 2012 and their effect in the coming years. This is thus a measure of what the country has already lost, or what could have been if the delays had not occurred. Second, we compare the optimal scenario and the baseline scenario to measure, in terms of the price differential, the effect of eliminating the delays from now on. By holding the 2007–2012 period constant, we attain a measure of what the country will lose in the future, given the past delays. Table 1 presents the results on electricity prices in each scenario.

**Insert Table 1**

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7 The results of the simulations correspond to the Chile's Central Interconnected System, which produces around 75% of the electricity demanded in the country. For details on the simulations and the assumptions used the SDDP model, see Agurto et al. (2013)

8 The historical information used in the macroeconomic model corresponds to the average market price of free customers; this information was calculated by the National Energy Commission of Chile (CNE) through 2009. In 2010, we estimate the value by subtracting the effect of electricity distribution contracts from the average market price calculated by the CNE.

## 2. The Main Features of the Macroeconomic Model[9]

Figure 1 illustrates the general structure of the DSGE model used in this study. The sectors included in the macroeconomic model can be classified as follows: households, which make decisions on consumption and labor supply; firms, which define the production of intermediate goods (by combining labor, capital, imported inputs, and oil), investment goods, and commodity goods; private banks, which offer credit for the production of capital goods; a central bank, which sets the interest rate; the government, which determines public spending; and an external sector, which chooses imports (intermediate inputs and oil), capital flows (foreign debt), and exports (intermediate goods and commodities).

**Insert Figure 1**

The DSGE model must consider a set of assumptions about the functioning of the economy in order for it to serve as both a complete model for the analysis and an empirically valid model for the estimation (Galí, 2008). Specifically, it assumes that wages and prices are sticky in the short term (Calvo, 1983). With this assumption, production is determined by aggregate demand, so monetary policy can affect economic activity and then control the inflation rate.

In addition to nominal price and wage rigidities, the model assumes adjustment costs that produce lags in the trajectories of the variables after a shock hits the economy, as is standard in this type of model. For example, because the decision to change investment plans carries adjustment costs, an increase in the interest rate will not immediately reduce private investment. Similarly, the model assumes lags in the decisions to use different types of inputs (capital, labor, energy, and imported inputs).

The model also assumes imperfections in the capital market, an issue that has become more pertinent since the international financial crisis of 2008–10. First, the model assumes credit restrictions for a group of households (hand-to-mouth consumers); second, it assumes an elastic supply of external funds (country risk premium); and third, it assumes that private banks can restrict private credit depending on current and expected conditions of the business cycle (Gertler and Karadi, 2009).

9 For details on the assumptions and equations of the DSGE model, see Agurto et al. (2013). In general terms, the DSGE model used in this study is very similar to the models propose by Christiano, Eichenbaum, and Evans (2005), Galí, López-Salido, and Vallés (2007), and Smets and Wouters (2003, 2007).

The external sector in the model is determined by four key elements: external activity, international commodity prices, domestic economic activity, and the real exchange rate. An increase in external activity produces an increase in the demand for Chilean exports of intermediate goods. Similarly, an increase in domestic activity generates an increase in the demand for foreign inputs, and an increase in commodity prices causes the country's income to rise. In all of these effects, the real exchange rate plays a crucial role. The model assumes that the exchange rate is determined only partially by the interest rate differential between Chile and the rest of the world. Thus, fluctuations in the exchange rate have significant effects on the demand for imported inputs, revenues from the commodity exports in dollars (copper is Chile's main export), and the demand for imported oil.

The central bank is modeled through a simple monetary policy rule, where the bank sets the interest rate in line with the inflation rate, the output gap, and the real exchange rate. Finally, government spending is modeled by a fixed rule based on structural tax revenues, that is, income from copper exports (the government has an important share in this industry) and taxes. For the sake of simplicity, the model assumes that taxes are lump sum, but this assumption does not have a significant effect on the simulations performed in this study.

### a. The Energy Sector.

We diverge from the standard DSGE methodology in two ways.[10] First, we introduce electrical energy as a basic input in the production of intermediate goods.[11] Second, we restrict the model parameters such that an increase in the price of electricity causes a contraction in employment in the short term. As explained below, this last consideration is crucial for obtaining correct estimations.

Specifically, the electricity sector is incorporated into the representative production function of industrial goods and intermediate or semi-finished products of the economy, as described in Agurto et al. (2013).[12] We use a standard Cobb-Douglas production function that includes energy (oil and electricity), as well as capital, labor, and imported inputs:

10 Examples of DSGE models that include energy include Sánchez (2011), Acurio Vasconez et al. (2012), and Gavin, Keen, and Kydland (2013).
11 Acurio Vasconez et al. (2012) and Gavin, Keen, and Kydland (2013) use a similar strategy to introduce energy into a DSGE model. Alternatively, Sánchez (2011) assumes that the use of capital requires energy.
12 These goods generally correspond to sectors such as manufacturing, agriculture, and commerce. We do not include mining production as a separate sector in the model due to the lack of statistical information on private investment in the mining sector.

$$Y_t = A_t L_t^{\alpha_1} \left(\xi_t K_t\right)^{\alpha_2} M_t^{\alpha_3} MOIL_t^{\alpha_4} EE_t^{1-\alpha_1-\alpha_2-\alpha_3-\alpha_4}, \quad (1)$$

where *Y* is output, *A* is the level of technology, *L* is employment, *K* is the capital stock, *M* is imported inputs, *MOIL* is oil, and *EE* is electricity. The parameter α represents the share of each input in the production of the intermediate good. We can then calculate the unit costs of producing one good in the intermediate sector:

$$UC_t = \left(\frac{1}{A_t}\right) W_t^{\alpha_1} \left(\xi_t Z_t\right)^{\alpha_2} \left(SX_t P_t^*\right)^{\alpha_3} \left(SX_t POIL_t\right)^{\alpha_4} PE_t^{1-\alpha_1-\alpha_2-\alpha_3-\alpha_4}, \quad (2)$$

where *UC* is the unit cost of production, *W* is wages, *Z* is the rental price of the capital, *SX* is the nominal exchange rate, *P** is the price of imported inputs in dollars, *POIL* is the international oil price in dollars, and *PE* is the price of electricity in domestic currency. Therefore, a higher energy price on aggregate produces a direct increase in the unit costs of production (*UC*), which is transferred directly to the inflation rate of intermediate goods. This can be seen directly from equation (2): an increase in *PE*, which is dependent on $1-\alpha_1-\alpha_2-\alpha_3-\alpha_4$, affects the *UC*.

The final impact on the economy of a change in the price of energy is more complex, however. It basically depends on three key aspects included in the DSGE model:

(i) The substitution between energy and other production inputs. For example, the Cobb-Douglas production function (equation 1) explicitly assumes that the elasticity of substitution is one. This value is standard in models of business cycle fluctuations, where the main inputs are capital and labor, but it could be controversial if energy is treated as an additional input in the production function. In fact, low elasticities of substitution are expected in the short term.[13] This apparent conflict between the need for a standard production function for the DSGE model and a low elasticity of substitution between inputs in the short term is explained below.

(ii) The degree of labor flexibility. If wages are very rigid, an energy shock will have a significant negative impact on aggregate employment.

(iii) The central bank's response to higher inflation. If an increase in the energy price is inflationary, then the central bank will raise its interest rate, producing a contraction in the economy.

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13 For empirical evidence of a low elasticity of substitution between employment and energy, see Hamermesh (1993).

A priori, higher energy prices are expected to have a stagflationary effect, both because production costs will be higher and because the shock will produce a contraction in GDP and, therefore, in employment. The first of these effects is obtained directly from equation (2), which shows a positive relationship between *UC* and the energy price. Modeling the second effect (namely, the contraction in employment) is more complex. Since the energy price shock makes labor relatively cheaper than electricity, firms could substitute cheap labor for expensive energy. This creates a paradox in the model: employment would rise instead of falling, which is clearly a counterintuitive result.[14] To avoid this result, we reduce the elasticity of substitution between inputs in the short term. Thus, the model gives us the magnitude of the effect of an increase in the price of electricity on employment, but the sign of the change is known in advance: it is negative.

Consistent with the above discussion, if employment can reasonably be expected to fall, then the effect that should prevail in the short term is the fall in the demand for intermediate goods, not the change in real wages. To achieve this result, the model must have two ingredients. First, it must assume that the demand for labor is very inelastic to the real wage, so that an increase in energy prices does not paradoxically benefit employment in the short term. Second, it must further assume that wages are sticky above the equilibrium, which allows for the existence of unemployment. Thus, a contraction of labor demand ultimately produces more unemployment (see figure 2).

**Insert Figure 2**

The demand for inputs is modeled with a flexible functional form:

$$input_J = pmg\_input_J\left(y + a - \theta_j \, real\ price\ of\ input_J\right) + \left(1 - pmg\_input_J\right)input_j. \qquad (3)$$

The demand for input *j*, called $input_J$ and expressed in logarithm terms, still depends positively on the level of activity, $y$, and the level of productivity, $a$, while it depends negatively on the price of the input expressed in real terms, called $real\ price\ of\ input_J$.

However, for the elasticity of substitution to be less than one in the short term, we introduced a parameter, $\theta_j < 1$, to reduce the response of the demand for input *j* to the actual change in the price. In addition, to impose more inertia in the firm's decisions, we added the parameter

14 For empirical evidence that energy shocks cause recession and thus do not increase employment, see Davis and Haltiwanger (2001), Brown and Yucel (2002), and Hamilton (2010).

$pmg\_inpu_J \in (0,1)$, which indicates that past input levels affect present production decisions. If the model imposes that $\theta_j = 1$ and $pmg\_input_J = 1$, then the elasticity of substitution is one and there is no inertia in hiring input *j*. In this case, the model returns to a scenario of perfect flexibility in the use of inputs for the intermediate goods firm.

### b. Electricity versus Oil

The other source of energy in the model is oil. This input was introduced into the model in two parts: first, it was included directly in equation (1), as an input in the production of intermediate goods ($MOIL_t$); second, it is one of the inputs in the intermediate goods distribution ($Toil_t$), to capture the fact that before these goods are consumed or invested, they must be transported using oil:[15]

$$Y_t^F = \left(Y_t\right)^{\alpha P} \left(TOIL_t\right)^{1-\alpha P} \quad (4)$$

Unlike electricity, an increase in the oil price has two independent transmission channels that affect the economy. There is a direct negative effect on the production of intermediate goods (the same channel as electricity energy) and an additional negative effect through the increase in transportation costs.

### c. Calibration and Estimation of the Macroeconomic Model

The estimation strategy of the macroeconomic model has two parts. First, we calibrate all the parameters related to the steady state of the model; second, we estimate only the parameters related to the dynamics of the model. The calibration process thus replicates the steady-state or long-run equilibrium of the Chilean economy, represented by some ratio over GDP, such as consumption to GDP, investment to GDP, and government expenditure to GDP.

The calibration process requires accurate values for the parameters of the production function for intermediate goods (equation 1). These parameters represent the shares of each input in the gross production of intermediate goods in the long term. The calibration of these parameters is based on information from the 2008 input-output matrix and oil import data from the Central Bank of Chile. The calibration results are shown in table 2, where the share of

15 An alternative is to introduce this type of energy as an additional consumption good (Gavin, Keen, and Kydland, 2013).

electricity in the gross output of intermediate goods is around 3%.[16] Based on this calibration, the model yields a steady-state or long-run equilibrium that is consistent with the information available for the Chilean economy (see table 3).[17]

**Insert Table 2.**

**Insert Table 3.**

The parameters that define the model dynamics are estimated with Bayesian techniques.[18] Bayesian inference starts with the definition of a prior distribution for the parameters (based on economic theory and previous studies), followed by the maximization of the likelihood function.[19] This econometric technique improves the quality of the parameter estimation, especially if the database is limited or has data quality problems. Such problems can lead to overfitting, resulting in unreasonable values for the parameters. This is especially critical in the case of more traditional econometric techniques (maximum likelihood or method of moments), which maximize the probability of generating the sample without imposing prior restrictions on the parameter values (as in the case of Bayesian econometrics).

We use a quarterly sample covering a very short period (2000:2 to 2011:3) that was characterized by important delays in power plant construction. The data are in growth rates (multiplied by 100), except for interest rates, which are divided by four to be expressed on a quarterly basis.

In general, most of the values are in line with the values found in other studies using Bayesian econometrics for DSGE models (for instance, García and González, 2013; García, Moncado, and González, 2013).[20] Therefore, this section focuses on the parameters associated with the impact of electric energy on the economy (see table 4). We find that the growth rate of electricity prices is very volatile (Err_PEE1 of 7%), although it is much lower than the growth rate of oil prices (Err_OIL of 17%). In addition, our prior is that the growth rate of the

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16 Our calibration of equation (1) is based on the fact that 24% of imported oil is used as a direct input for manufacturing, while the rest is used in the transport sector (CNE, 2009). The parameters of equation (4) were calibrated to replicate the steady state of the Chilean economy.

17 See, for example, Restrepo and Soto (2006).

18 For details, see An and Schorfheide (2007).

19 The priors for the estimated parameters were taken from the traditional literature for macroeconomic models; see Agurto et al. (2013). The subsequent result was obtained using the Metropolis-Hastings algorithm based on a Markov chain with 25,000 replications to build the estimated distribution of the parameters (posterior). In this regard, the algorithm achieves an acceptable convergence after 25,000 replications.

20 All the parameter estimations of the DSGE model are available in Agurto et al. (2013).

electricity price is highly persistent, with an estimation of 0.84 (rho_PEE1).[21] This estimation is consistent with the econometric evidence of traditional time series, which yields a high persistence in the electricity price level.

**Insert Table 4.**

As described in section 1.3 (equation 3), the parameters $pmg\_input_J$ and $\theta_j$ measure the short-term sensitivity of the demand for each input to activity and prices, respectively. Table 4 shows that the coefficients of $pmg\_input_J$ are between 0.3 and 0.6, which confirms the existence of significant adjustment costs in hiring inputs in the short term. In addition, labor demand was inelastic to real wages in the short term (0.05), such that an increase in the energy price reduces employment in both the short and medium terms. This is the result of assuming a very low prior for the parameter $\theta_j$ in labor demand and a narrow standard deviation for this parameter.[22]

With regard to the central bank's response to inflation, the model estimations are similar to other estimations for the Chilean economy and other countries, with a strong response of the interest rate to inflation (rho_inf of 2.47). This parameter is crucial in the analysis, since a negative energy price shock (electricity and/or oil) could have a second-round effect on the economy if the central bank decided to increase the interest rate to reduce the inflation rate.

## 3. Macroeconomic Results for the Different Scenarios

This study only measured the impact of delaying the construction and entry into operation of power plants, assuming no other shocks occured simultaneously. The results must thus be interpreted alongside the impulse response functions, which show the trajectory of a particular variable over time after an exogenous shock. According to figure 3, an exogenous increase in the electricity price has a significant and contractionary effect, especially on GDP, private investment, consumption, and employment. The shape of the impulse responses is standard for a negative supply shock: a contraction with higher inflation or stagflation (Galí, 2008). However, the reaction of the inflation rate and, therefore, the central bank’s reaction of increasing the monetary policy interest rate are only moderate.

21 The model also imposed a high persistence in the growth rate of oil prices; the estimation was of 0.87 (rho_oil).

22 We checked the complete consistency of the model to different shocks, in particular to changes in the oil price. We assume that the demand for oil for transport has a similar structure to the demand for inputs in the production of intermediate goods, and we find adjustment costs near 0.5 (pmg_TOIL) in the demand for oil for transport. In addition, we again need to assume a low prior for the price elasticity of this demand, in order to obtain a fall in employment when the oil price rises (Theta_TOIL of 0.09).

Conceptually, the macroeconomic model shows the following series of events after a shock in the electricity price hit the economy. The first impact is an increase in the real marginal costs of producing intermediate goods, which increases inflation and reduces output (GDP). Next, the lower production and the low elasticity of labor demand to real wages cause a reduction in employment. The lower employment then affects the consumption of hand-to-mouth agents, that is, those households who cannot smooth their consumption because they do not have access to the credit market (such that their consumption depends on labor income). As a result, aggregate consumption drops. Finally, the more pessimistic expectations about the future of the business cycle also reduce private investment.

**Insert Figure 3.**

Table 5 shows the projections for the period 2012 to 2019 for the three different macroeconomic scenarios (super-optimal, optimal, and baseline). These results, which were constructed directly from the impulse response functions, highlight the significant impact of delaying investment in power plants on the Chilean economy. For the baseline scenario, the table shows the cumulative sum of various negative shocks, which represent the delays that hit the economy over time (see table 1). In contrast, the other two scenarios are associated with the cumulative sum of positive shocks from the absence of delays, that is, new power plants are entering the market at the scheduled time, thereby increasing the supply of electricity and systematically decreasing energy prices in the first period (see table 1).

**Insert Table 5.**

In cumulative terms, after eight years, the country would lose the equivalent of one year of growth because the super-optimal scenario did not materialize (the Chilean economy's potential GDP is around 5%). This result is obtained by comparing the difference between the super-optimal scenario and the baseline scenario, or 4.74% – (–1.41%). Figure 4 graphically illustrates this difference over the years. When we compare the optimal scenario with the baseline scenario, the cumulative loss in GDP is much lower, at only 2.78% in the same period.

**Insert Figure 4.**

As shown in table 5, the economy's loss is concentrated mainly in private investment. In the super-optimal scenario, private investment increases 17.85% compared with the baseline scenario. Under the optimal scenario, the increase in private investment is 8.18% over the baseline scenario.

Employment also records a strong effect. The annual average growth rate between 2000 and 2011 was 2.5%. Under the baseline scenario, the employment growth rate for the period 2012–2019 would be negative, at –1.89%. This contrasts with a cumulative growth rate of 6.42% under the super-optimal scenario. In other words, the economy would lose 8.31% of employment growth under the baseline scenario vis-à-vis the potential growth of super-optimal scenario, or more than three years of growth in employment. The difference between the optimal case and the baseline case is lower, but still significant at 3.71%. Table 5 also projects losses in terms of competitiveness (measured by the real exchange rate) and inflation if the baseline scenario materializes.

The results of table 5 show that the loss for the Chilean economy is irreversible in this decade. This is because the level of private investment, a key variable for future economic growth and job creation, will grow at a modest cumulative growth rate of 4.4% in the optimal scenario compared with a cumulative growth rate of 14% under the super-optimal scenario. Another key variable is consumption, which corresponds to about 60% of GDP and provides a measure of the welfare level in the country. Under the best-case scenario for this decade (the optimal case, consumption could grow at a cumulative rate of just 1.8% , versus 6.6% under the super-optimal scenario.

## 4. Conclusions

The main conclusion of this article is that the delays in the construction and operation of new power plants have had a strong impact on the business cycle of the Chilean economy, mainly through the effects on GDP, investment, consumption, and employment. Delays have had a smaller impact on the real exchange rate and the inflation rate.

Under the counterfactual scenario in which the delays had not occurred from 2007 to 2011 (which we call the super-optimal scenario), the cumulative growth rate for GDP would have been 6.15% higher from 2012 to 2019 than under the baseline scenario. Private investment is the most strongly affected variable, with a cumulative growth rate of 17.85%. This result is significant, considering that potential GDP growth in Chile is approximately 5%.

Under the counterfactual scenario in which the delays do not occur from 2012 onward (which we call the optimal scenario), the cumulative growth rate of GDP would be 2.78% higher than the baseline scenario between 2012 and 2019. This result indicates that the loss for the Chilean economy is irreversible in this decade due to delays in building new power plants.

The study is based on simulations of a stylized model that did not take into account the environmental and health costs of building new power plants. Nevertheless, our results highlight the importance of decisions related to the regulation and planning of the installed capacity of the electric system, as well as environmental and energy policy, in terms of their effect on the business cycle and economic growth.

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## Tables

### Table 1. Electricity Prices Simulated by the SDDP Model

*US$ per MWh*

| year | baseline | optimal | super-optimal |
|---|---|---|---|
| 2012 | 131.8 | 128.3 | 114.6 |
| 2013 | 116.9 | 111.8 | 107.7 |
| 2014 | 124.4 | 113 | 102.1 |
| 2015 | 124.4 | 113 | 102.1 |
| 2016 | 124.4 | 113 | 102.1 |
| 2017 | 124.4 | 113 | 102.1 |
| 2018 | 124.4 | 113 | 102.1 |
| 2019 | 124.4 | 113 | 102.1 |

Source: Authors' calculations.

### Table 2. Share of Inputs in the Gross Production of Intermediate Goods

| Parameters | Shares |
|---|---|
| Labor | 0.39 |
| Capital | 0.35 |
| Electric Energy | 0.03 |
| Oil | 0.02 |
| Imported Inputs | 0.21 |

Source: Authors' calculations, based on data from the Central Bank of Chile

## Table 3. The Steady State of the DSGE model

| Steady State | over GDP |
|---|---|
| consumption | 0.62 |
| investment | 0.22 |
| exports | 0.34 |
| imports | 0.31 |
| government spending | 0.10 |
| foreign debt | 0.34 |
| commodity export (copper) | 0.08 |

Source: Authors' calculations.

## Table 4. Parameters Associated with the Impact of Electric Energy on Economy

| Parameters | Prior | Posterior | Confidence Interval 90% | | Prior Distribution | Standard Deviation Prior |
|---|---|---|---|---|---|---|
| rho_PEE_1 | 0.9 | 0.84 | 0.79 | 0.87 | beta | 0.05 |
| Err_PEE_1 | 7.00 | 8.22 | 7.05 | 9.27 | invg2 | Inf |
| rho_Oil | 0.9 | 0.87 | 0.84 | 0.91 | beta | 0.05 |
| Err_Oil | 14.36 | 17.16 | 15.33 | 18.86 | invg2 | Inf |
| rho_inf | 2 | 2.47 | 2.31 | 2.64 | beta | 0.3 |
| pmg_M | 0.5 | 0.63 | 0.57 | 0.69 | beta | 0.1 |
| pmg_L | 0.5 | 0.27 | 0.20 | 0.33 | beta | 0.1 |
| pmg_K | 0.5 | 0.66 | 0.60 | 0.73 | beta | 0.1 |
| pmg_MOIL | 0.5 | 0.56 | 0.46 | 0.67 | beta | 0.1 |
| pmg_EE | 0.5 | 0.57 | 0.51 | 0.62 | beta | 0.1 |
| theta_TOIL | 0.1 | 0.09 | 0.08 | 0.10 | beta | 0.01 |
| theta_L | 0.05 | 0.05 | 0.04 | 0.05 | beta | 0.01 |
| pmg_TOIL | 0.5 | 0.55 | 0.51 | 0.59 | beta | 0.05 |

Source: Authors' calculations.

## Table 5. Macroeconomic Results

*Percentage change*

| | baseline | super- optimal | optimal | | baseline | super-optimal | optimal |
|---|---|---|---|---|---|---|---|
| 2012 | -0.16 | 0.08 | -0.11 | 2012 | -0.09 | 0.05 | -0.06 |
| 2013 | -0.36 | 0.38 | -0.17 | 2013 | -0.36 | 0.30 | -0.20 |
| 2014 | -0.04 | 0.73 | 0.31 | 2014 | -0.20 | 0.70 | 0.14 |
| 2015 | -0.17 | 0.90 | 0.37 | 2015 | -0.22 | 1.05 | 0.36 |
| 2016 | -0.20 | 0.81 | 0.32 | 2016 | -0.29 | 1.17 | 0.41 |
| 2017 | -0.18 | 0.67 | 0.25 | 2017 | -0.29 | 1.13 | 0.41 |
| 2018 | -0.15 | 0.54 | 0.20 | 2018 | -0.27 | 1.03 | 0.37 |
| 2019 | -0.15 | 0.54 | 0.20 | 2019 | -0.27 | 1.03 | 0.37 |
| Accumulated | -1.41 | 4.74 | 1.38 | Accumulated | -1.98 | 6.62 | 1.81 |

| | Employment | | | | Private Investment | | |
|---|---|---|---|---|---|---|---|
| | baseline | super-optimal | optimal | | baseline | super-optimal | optimal |
| 2012 | -0.03 | 0.02 | -0.02 | 2012 | -0.46 | 0.24 | -0.32 |
| 2013 | -0.31 | 0.21 | -0.20 | 2013 | -1.86 | 1.55 | -1.07 |
| 2014 | -0.35 | 0.63 | -0.05 | 2014 | -0.19 | 3.21 | 1.30 |
| 2015 | -0.17 | 1.07 | 0.40 | 2015 | 0.10 | 3.79 | 2.36 |
| 2016 | -0.24 | 1.26 | 0.51 | 2016 | -0.62 | 2.67 | 1.31 |
| 2017 | -0.28 | 1.15 | 0.45 | 2017 | -0.45 | 1.19 | 0.51 |
| 2018 | -0.26 | 0.96 | 0.36 | 2018 | -0.19 | 0.33 | 0.13 |
| 2019 | -0.26 | 0.96 | 0.36 | 2019 | -0.19 | 0.33 | 0.13 |
| Accumulated | -1.89 | 6.42 | 1.82 | Accumulated | -3.79 | 14.05 | 4.38 |

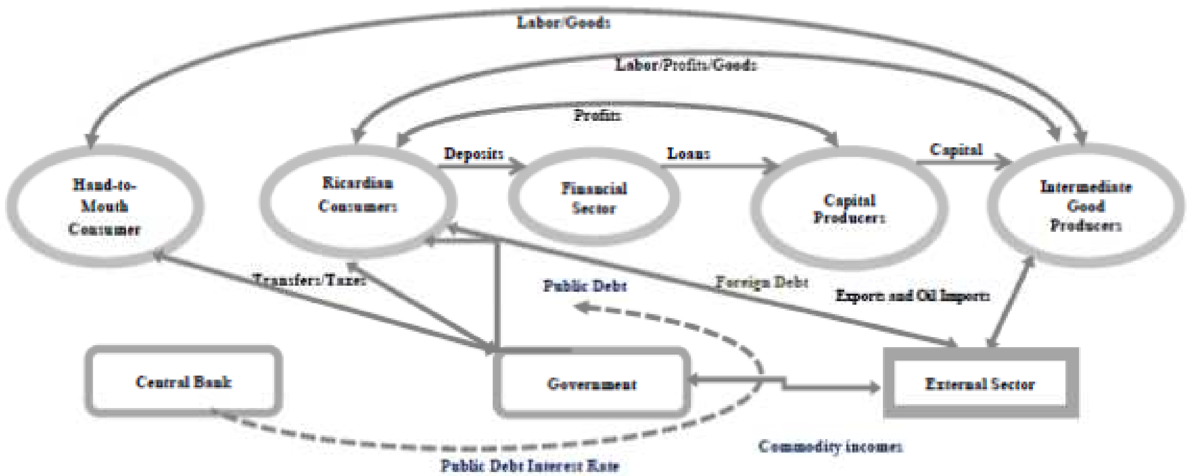
| | Real Exchange Rate | | | | Inflation Rate | | |
|---|---|---|---|---|---|---|---|
| | baseline | super-optimal | optimal | | baseline | super-optimal | optimal |
| 2012 | -0.11 | 0.06 | -0.08 | 2012 | 0.27 | -0.14 | 0.19 |
| 2013 | -0.48 | 0.39 | -0.28 | 2013 | 0.36 | -0.53 | 0.11 |
| 2014 | -0.07 | 0.81 | 0.31 | 2014 | -0.22 | -0.78 | -0.61 |
| 2015 | -0.16 | 1.08 | 0.47 | 2015 | 0.31 | -0.78 | -0.23 |
| 2016 | -0.28 | 1.02 | 0.37 | 2016 | 0.16 | -0.56 | -0.21 |
| 2017 | -0.20 | 0.84 | 0.34 | 2017 | 0.11 | -0.46 | -0.19 |
| 2018 | -0.16 | 0.68 | 0.27 | 2018 | 0.11 | -0.38 | -0.14 |
| 2019 | -0.16 | 0.68 | 0.27 | 2019 | 0.11 | -0.38 | -0.14 |
| Accumulated | -1.62 | 5.68 | 1.69 | Accumulated | 1.23 | -3.94 | -1.21 |

Source: Authors' calculations.

a. The cumulative results are calculated as $\left(\left(\prod_{i=2012}^{2019}(1+x_i/100)\right)-1\right)*100$.

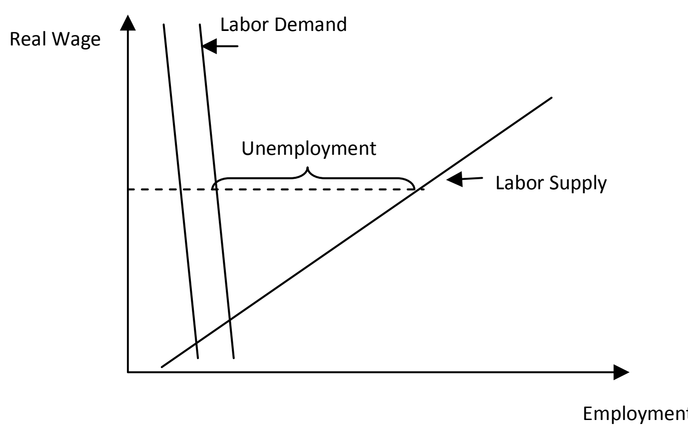
**Figures**

## Figure 1. The DSGE Model



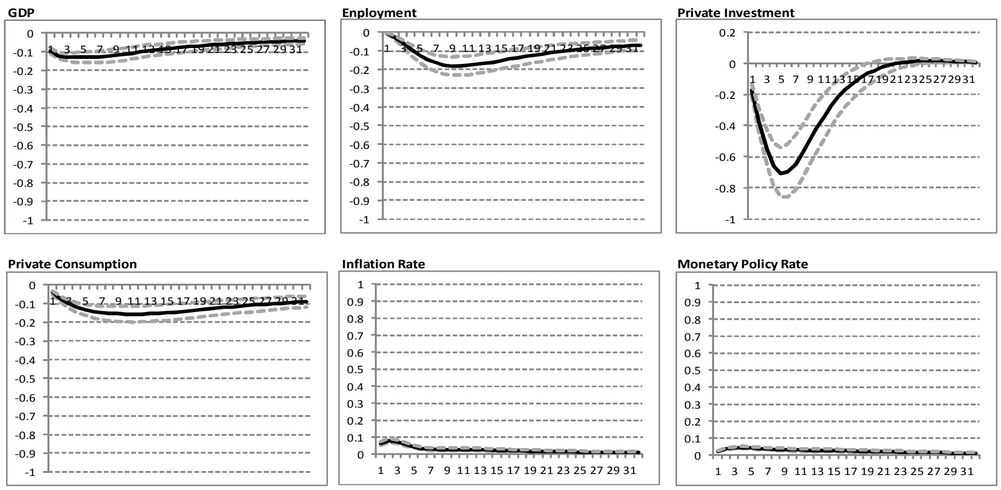

Source: Garcia, Moncado, and González (2013).

## Figure 2. The Labor Market in the DSGE Model




Source: Agurto et al. (2013).

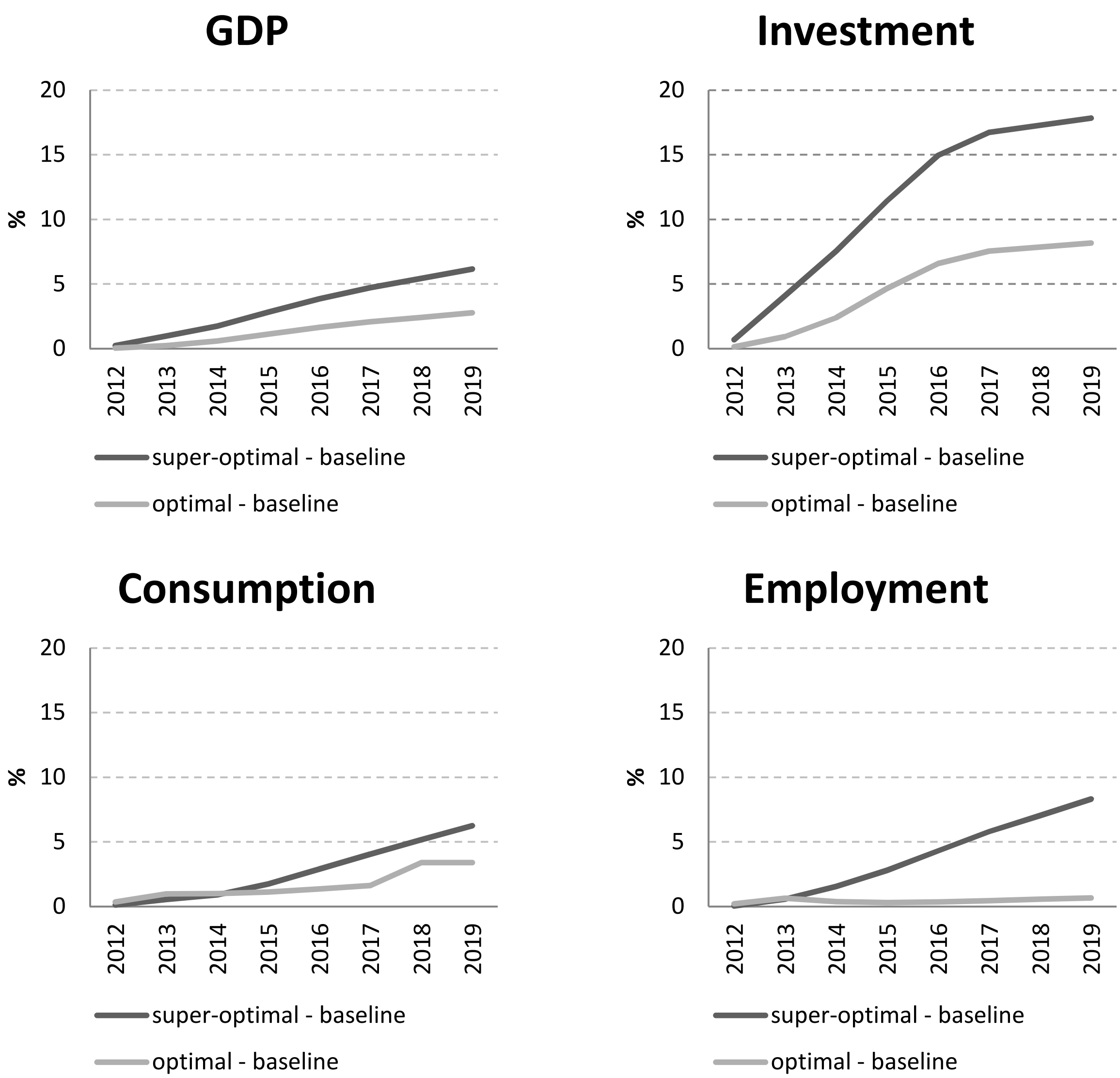
**Figure 3. Impulse Response Functions of a One-Standard-Devation Shock to Electricity Prices[a]**




Source: Author’s calculations.

a. Time is measured in quarters (on the x axis).

**Figure 4: Cumulative Percentage Change in Macroeconomic Variables between Scenarios: 2012–2019**




Source: Authors' calculations.