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Alternative policies for the liberalization of retail electricity markets in Chile

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ABSTRACT

This article shows that the liberalization of the residential market for electricity in Chile may achieve important welfare gains. We built a model to assess two policy scenarios: partial and full liberalization. Simulations of the model provide equilibrium prices, the distribution toll, and welfare estimations on factual and counterfactual scenarios. Our policy recommendation is to partially liberalize the residential market for electricity. That is, to allow the entrance into this market but regulate both the incumbent's tariffs for residential customers and the distribution toll. Full liberalization, in which only the distribution toll is regulated, produces a lower increase in welfare.

1. Introduction

The restructuring process of electricity industries in most countries recognizes the condition of a natural monopoly in transmission and distribution markets, while generation and retail (supply) markets are considered capable of being developed in competition. In this context, the open access to both transmission and distribution networks plays a crucial role in changes made to the architecture of the industry. Thus, competition between the incumbents and new firms entering the newly liberalized markets depends largely on the rules for access to electricity networks. This issue is of particular interest in developing countries like Chile, where the regulator has timidly advanced in the liberalization of retail electricity markets, in particular the residential one. Currently, the electricity regulation in Chile grants the monopoly activity to distribution companies in the residential market, having liberalized the entrance into the retail market for large consumers.[2]

The Chilean government is planning to introduce more competition in the electricity industry, and new policies could encompass the liberalization of the retail residential market. This paper contributes to the discussion on the scope of this kind of policy.[3] To this end, we propose a methodology to set efficient tariffs to residential consumers and the distribution toll to rivals of the distribution company. We assume that the monopoly in distribution is vertically integrated, so that it also operates as a retailer

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[2] The rationale of this policy is that generating companies may compete with the distribution company to supply energy to large customers located inside the distribution concession area. That is, all customers whose maximum demand in a year exceed two MW must buy its electricity in a free market. The Electricity Act also allows to any consumer whose peak demand is above 500 KW but below 2 MW to enter into the market voluntarily. We call "residential market" the currently regulated market although some of these consumers might be small business. See Raineri (2006) or Arellano (2007) for a detailed description of the electricity industry design and regulation in Chile.

[3] See magazine Electricidad September 5, 2016 http://www.revistaei.cl/2016/09/05/la-propuesta-del-gobierno-para-liberalizar-el-mercado-electrico/(visited September 18, 2016). This proposal is not new, but the government recently launched an initiative named "The Future of the Electricity Distribution". This initiative indicates that in this opportunity the regulator is finally willing to end the lack of competition in the distribution segment of the eletricity sector.

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in all markets for electricity. The liberalization policy fosters competition by allowing to a fringe of competitive firms entering the residential market for electricity and, also, by setting an efficient distribution toll that, precisely, helps to such an entry.

There are many countries where retail electricity markets have been liberalized. For instance, UK and Wales since the 80s and all European Union countries since 2005 have free entry into these markets. All deregulatory reforms give rise to benefits and also involve challenges, like creating the institutions to prevent the abuse of monopolistic power in most electricity markets. Green (1996), Green and McDaniel (1998), Newbery (2006), Newbery and Pollit (1997), and Domah and Pollit (2001) assess the UK experience on this regard. Newbery (2000) examines the international experience on restructuring utilities. Joskow (2000), Joskow and Tirole (2006), Littlechild (2002, 2006, and 2009), and Sioshansi and Pfaffenberger (2006) analyze the international evidence focusing on the advantages of having competition on retailing. Most of the literature finds that retailing improves the sale of energy and power according to the needs of customers, improves the provision of complementary products, provides different payment conditions, transfers the benefits of buying electricity in the spot market, and develops a reputation on the quality and information on the operation of the electricity industry as a whole. This evidence also shows that industrial and large residential customers are those that have mostly made use of product differentiation, whereas smaller residential customers have remained subject to the distributor's supply without modifying their consumption habits. In some sense, this evidence indicates that substitution in retailing, and so competition, is far for being perfect.

In contrast, some authors are skeptical regarding the liberalization of retail electricity markets, in particular the residential one. These authors argue that the design of markets, institutions, and the regulatory process on a newly liberalized market, whose technical features are very different to other sectors, such as electricity generation, are complex (Joskow, 2000, 2008; Hogan, 2002). In addition, there are entry barriers to new providers and switching costs to consumers, the latter due to behavioral constraints that encumber the development of a competitive retailing (Defeuilley, 2009). Others authors have expressed distributional concerns on the liberalization of retailing in Chile (Reveco, 2013) and United Kingdom (CMA, 2016). Finally, as in any network industry, vertical integration of the distributor as owner of the network and also as a provider in retailing, produces benefits in terms of higher productive efficiency and concerns in terms of risk of sabotage, access discrimination, and other abuse of dominance issues (Saavedra, 2001; Mandy and Sappington, 2007; Bustos and Galetovic, 2009; Galetovic and Sanhueza, 2009). We do not address any of these potential problems of the liberalization policies that we assess in this article, but they should be taken into account in the case of being implemented in practice.

Among all aspects that we should keep in mind regarding the design of a liberalization policy in retail electricity markets, the setting of an efficient distribution toll to the network is particularly crucial. If this price is too high, the result will be a barrier to entry, reducing the competition and thus harming consumers in the long run. If the distribution toll is too low, the distribution company may have financial sustainability problems, putting at risk future investments and expansions of the services to consumers, thus also harming consumers in the long run. Previous works have estimated the importance of setting efficient access price to electricity distribution, most of them for Europe (Grønli et al., 1999; Filippini and Wild, 2001; Chernyshova, 2001; Strbac, 2002; Sánchez-Macías and Calero, 2003; De Oliviera - de Jesús et al., 2005; Bazán, 2013). In the case of Chile, de la Cruz (2004), Raineri and Giaconi (2005), Escobar (2009), and Palacios (2012) analyze alternatives for either transmission or distribution tolls considering competition in electricity retail sales. Rámila and Rudnik (2010) and Galetovic and Muñoz (2011) assess other aspects of the necessary liberalization of retail electricity markets in Chile.

Regarding efficient tariffs for electricity, they are clearly related to the regulated efficient distribution toll. If the access to the electricity network increases according to an efficient rule, then regulated tariffs should be reduced in order to maintain the financial constraint of the distribution company. The opposite case is also true. Thus, thanks to this countervailing power, a liberalization policy could induce efficient entry at a minimum cost assuring allocative efficiency in the industry.

This article goes beyond the only estimation of efficient prices. Its main goal is to assess the welfare impacts of liberalizing the distribution segment of the electricity industry in Chile. Since our model that not provide analytical solutions to prices, quantities, and consumers as well as firm's surpluses, we use numerical solutions to compare the welfare impacts of the two liberalization policies considered on this work. It is important to mention that to maintain the model tractable, it does not provide details on electrical industry features. In this context, our model may lose some precision regarding the numerical solutions of the endogenous variables, but we are sure that our results are fairly general since the simplicity of the model may affect both factual and counterfactual scenarios.

By using data from 2009 to 2016 for the main electricity distribution company in Chile, Chilectra (currently, ENEL) that serves more than six million people, this paper finds that both alternative policies for the liberalization of retail electricity markets are welfare improving. Then, on the one hand, when liberalization is partial, that is, when the incumbent's tariff in this market remains regulated, the residential consumer surplus increases in average between 36% and 144% and the large consumers surplus shrinks in less than 1%. This result in an increase ranging from 26% to 77% in total welfare, being higher as the competition becomes stronger. On the other hand, under full liberalization all consumers are also better off, but the impacts on residential consumers and welfare are smaller than under partial liberalization. In fact, when comparing full with partial liberalization, the latter generates higher surplus on residential consumers (4%–11%) and in total welfare (2%–5%), but large consumers would prefer full liberalization. Consequently, as a policy implication, the government should implement a partial deregulation of the residential electricity market in Chile.

We conclude that partial liberalization is better than full liberalization because under the former scenario we assume that a benevolent regulator maximizes total welfare with respect to the distributor's residential tariff and the distribution toll, subject to the budget constraint of this firm; whereas under full liberalization total welfare is not maximized because the regulator has only one instrument (the distribution toll) to fulfill the budget constraint of the distribution company. Nonetheless, it is interesting to notice that welfare effects of these alternative policies are statistically equal at a 95% of confidence level. Then, why should we prefer partial liberalization? Two explanations are not in the model but they are simple to understand. The first one is practical economic policy: full liberalization relies on the feasibility that the incumbent directly subsidizes the entrance of rivals in both retailing markets, which is difficult to implement and subject to an enormous rent seeking behavior. The second reason is that our model assumes no friction in the regulatory process, so having less instruments to curve the market power of the distribution company under full liberalization do not produce any important depart from optimal regulation. Contrary to this, if we assume an increasing welfare loss in the case that a regulatory instrument is set beyond the optimal value, we should expect a higher welfare loss under full

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liberalization, as compared to the case of partial liberalization.

This paper is structured as follows. Section 2 develops the model and delivers the first-order conditions for prices, quantities, and the efficient distribution tolls in both retail electricity markets. The model is calibrated for its different scenarios in Section 3. Section 4 presents the main results per year, in particular those related to residential prices of the distribution company, the regulated distribution toll, and the change in total welfare. Section 5 presents the same results, but restricted to only the average per year simulations, providing an interval of confidence for each variable at a 95% of confidence level. Finally, Section 6 concludes.

2. The basic model

Assume two markets for retail electricity: residential (r) and large (l) customers. Electricity suppliers are in both markets. These retailer firms are the incumbent (the same integrated distribution company or firm 1) and a new entrant or firm 2 (that represents a fringe of competitive entrants). As in Armstrong et al. (1996), each supplier offers a service that is an imperfect substitute of the other supplier's, therefore the demands of all consumers come from quadratic utility functions $u(q_0^x, q_1^x, q_2^x)$ for $x = \{r,l\}$. That is, for each market x:

$$u(q_0^x, q_1^x, q_2^x) = a_1^x \cdot q_1^x + a_2^x \cdot q_2^x - \frac{b^x}{2}\left[(q_1^x)^2 + (q_2^x)^2 - 2 \cdot d^x \cdot q_1^x \cdot q_2^x\right] + q_0$$

where q_0 is a numeraire for all other goods and, without loss of generality, it has a price of one, and $(a_i^x, b^x) > 0$ and $d^x \in (0,1)$, for $i = \{1,2\}$ and $x = \{r,l\}$. It must be true that $b^x > d^x$ and $a_i^x \cdot b^x > a_j^x \cdot d^x$.

$$Max_{a,p_1^r}\ V\left(p_1^r, p_1^l, p_2^l\right) + (a - c_a) \cdot q_2^l\left(p_1^l, p_2^l\right) + (p_1^r - c) \cdot \left[q_1^r(p_1^r) + q_1^l(p_1^r)\right] - K$$
$$s \cdot t \cdot \quad (a - c_a) \cdot q_2^l\left(p_1^l, p_2^l\right) + (p_1^r - c) \cdot \left[q_1^r(p_1^r) + q_1^l(p_1^r)\right] = K \ \ and\ \ p_2^l = a + c^l$$

After maximizing each $u(q_0^x, q_1^x, q_2^x)$ subject to its respective budget constraint, we obtain the inverse demand functions for both firms and goods. Then, directs demands of residential consumers are:

$$q_1^r = A_1^r - B^r \cdot (p_1^r + \sigma^r \cdot p_2^r) \tag{1}$$

$$q_2^r = A_2^r - B^r \cdot (p_2^r + \sigma^r \cdot p_1^r) \tag{2}$$

Similarly, large consumer demands are:

$$q_1^l = A_1^l - B^l \cdot \left(p_1^l + \sigma^l \cdot p_2^l\right) \tag{3}$$

$$q_2^l = A_2^l - B^l \cdot \left(p_2^l + \sigma^l \cdot p_1^l\right) \tag{4}$$

where $A_i^x = \frac{a_i^x \cdot b^x - a_j^x \cdot d^x}{\Delta}$, $B^x = \frac{b^x}{\Delta}$, $\sigma^x = B^x \cdot \frac{d^x}{\Delta} \in (0,1)$, and $\Delta = (b^x)^2 - (d^x)^2$ for $i = \{1,2\}$ and $x = \{r,l\}$.

These demands yield the net aggregate consumer surplus of electricity. Let us name it as $V(p_1^r, p_2^r, p_1^l, p_2^l)$.

The incumbent distribution company has a marginal cost of c for delivering electricity to consumers, which corresponds to the electricity cost of the incumbent plus administrative, maintenance, and operating costs of the network. When providing access into the network to a rival in any retailing market, the distribution company has the direct cost of extra investments and operating costs, c_a, to keep the power of the network. In addition, there are sunk costs of K for the distribution network, which is the amount of sunken investments in this network that are not paid by any other mechanism.[4] There is no any other cost of the network in this model.

Let $\boldsymbol{a}$ be the access price or distribution toll. Thus, free entry into both the residential market and the market for large consumers yields to the following free entry conditions:

$$p_2^r = a + c^r \tag{5}$$

$$p_2^l = a + c^l \tag{6}$$

where c^r and c^l are the marginal costs of the new entrant for supplying electricity to residential and large customers; that is, the cost of the electricity plus some specific administrative costs.

2.1. Current situation: a myopic regulatory process

Currently, the regulator sets both the tariff to residential users, p_1^r, and the distribution tolls for generating companies that uses the network for providing electricity to large customers, a. Electricity prices to large customers of both incumbent and newcomer, p_1^l and p_2^l, are freely chosen by the interaction of both firms. Nonetheless, the regulatory process is myopic, in the sense that it is mandatory to the regulator to consider that the distribution company charges the same regulated tariff into the unregulated market of large consumers. On this regard, a rational but forced-to-be-myopic benevolent regulator maximizes the following objective function:

The first term of the objective function corresponds to the net consumer surplus, the second term corresponds to the distributor surplus for providing access to its distribution network to a rival into the market for large consumers, and the third term corresponds to the distributor surplus for supplying electricity to both residential and large customers, respectively.

It is important to mention that this myopic regulatory process implies that the regulator do not consider expected actual profits of the distribution company in the large consumers market when setting both the distribution toll and the regulated tariff. Hence, upon considering the quadratic specification of consumer surpluses, the first order conditions of the regulator's problem yield the following two equations:

$$a = c_a + (p_1^r - c) \cdot \left[\frac{p_2^l}{p_1^r} \cdot \frac{\eta_1^r}{\eta_2^l}\right] \tag{7}$$

[4] There are several different tariffs in electricity distribution. The most important is the one that pays the energy consumption. In practice, other tariffs consider the payment for capacity or power, and a fixed charge for electricity consumption.

$$(a-c_a)\cdot q_2^l\left(p_1^l, a+c^l\right)+(p_1^r-c)\cdot\left[q_1^r(p_1^r)+q_1^l(p_1^r, a+c^r)\right]=K \quad (8)$$

where η_i^x corresponds to the own price elasticity of firm i in market x, for $i = \{1,2\}$ and $x = \{r,l\}$.[5]

Two important issues should be notice from these equations. First, the efficient distribution toll is not exactly the same as in Laffont and Tirole (1994), Armstrong, et al. (1996), and Armstrong and Vickers (1998) because our model considers a multi-product regulated electricity network. However, Eq. (7) has the same structure of its predecessors: the efficient access to the distribution network must consider the direct cost of providing such access plus an opportunity cost. Secondly, the price that the incumbent charges in the market for large consumers, $p_2^l = a + c^l$, also affects to p_1^r and a. Since firm 1 knows how the regulator is setting these tariffs, it solves the following problem:

$$\begin{aligned} &Max_{p_1^l}\ (a-c_a)\cdot q_2^l\left(p_1^l, a+c^l\right)+(p_1^r-c)\cdot q_1^r(p_1^r)+\left(p_1^l-c\right)\cdot q_1^l\left(p_1^l\right)-K \\ &s\cdot t\cdot \quad a=c_a+(p_1^r-c)\cdot\frac{p_2^l}{p_1^r}\cdot\frac{\eta_1^r}{\eta_2^l}\ \text{and}\ (a-c_a)\cdot q_2^l\left(p_1^l, a+c^l\right)+(p_1^r-c)\cdot q_1^r(p_1^r)=K \end{aligned}$$

The first order condition of this problem yields:

$$p_1^l=\frac{A_1^l+c\cdot B^l}{2\cdot B^l}+\sigma^l\cdot\frac{2\cdot a+c^l-c_a}{2} \quad (9)$$

Eqs. (1), (3), (4) and (6) to (9) provide the seven endogenous variables of this factual scenario. Since these simulations consider a myopic regulatory process, which is not the case in both counterfactual scenarios, we must simulate an efficient factual scenario. This new factual assumes a sequentially rational regulator that takes into account, during the tariff setting process, actual rents that the incumbent obtains in the large consumer market. By doing so, we may correctly compare the welfare effects of our two counterfactuals: partial and full liberalization scenarios.

2.2. The optimized factual scenario

In order to get right comparisons between the liberalization scenarios and a factual one, we run a new scenario in that the regulator incorporates in tariffs estimations all distribution company's rents. Hence, we assume that the regulator is not forced-to-be-myopic by the regulatory process, so that it knows the incumbent's behavior on the large customers market. In other words, this regulator knows that: i) the incumbent may obtain profits in the market for large consumers and ii) the incumbent will set p_1^l according to Eq. (9). Therefore, a sequentially rational and benevolent regulator, who cares about the self-financing of the regulated firm, maximizes the following objective function:

$$\begin{aligned} &Max_{a,p_1^r}\ V\left(p_1^r, p_1^l, p_2^l\right)+(a-c_a)\cdot q_2^l\left(p_1^l, p_2^l\right)+(p_1^r-c)\cdot q_1^r(p_1^r)+\left(p_1^l-c\right)\cdot q_1^l\left(p_1^l\right)-K \\ &s\cdot t\cdot \quad (a-c_a)\cdot q_2^l\left(p_1^l, p_2^l\right)+(p_1^r-c)\cdot q_1^r(p_1^r)+\left(p_1^l-c\right)\cdot q_1^l\left(p_1^l\right)=K \\ &\qquad p_2^l=a+c^l\ \text{and}\ p_1^l=\frac{A_1^l+c\cdot B^l}{2\cdot B^l}+\sigma^l\cdot\frac{2\cdot a+c^l-c_a}{2} \end{aligned}$$

The fourth term of the objective function is newer. It corresponds to the actual distributor's rents for supplying electricity to large customers. As well as in the previous scenario, the first order conditions yield the equations that determine a and p_1^r. As before, Eq. (9) determines $p_1^l(a)$.

$$a=c_a+(p_1^r-c)\cdot\frac{p_2^l}{p_1^r}\cdot\frac{\eta_1^r}{\eta_2^l}\cdot\left[\frac{1+\sigma^l\cdot\frac{q_1^l}{q_2^l}}{1-(\sigma^l)^2}\right] \quad (10)$$

$$\begin{aligned}&(a-c_a)\cdot q_2^l\left(p_1^l(a), a+c^l\right)+(p_1^r-c)\cdot q_1^r(p_1^r) \\ &\quad+\left(p_1^l(a)-c\right)\cdot q_1^l\left(p_1^l(a)\right)=K\end{aligned} \quad (11)$$

Eqs. (1), (3), (4), (6), and (9) to (11) provide the seven endogenous variables of this optimized factual scenario.

It is easy to observe, by comparing (7) and (10), that there are two opposed effects on the difference between the optimal distribution toll in both scenarios. At a first glance, it seems that the only difference between them is the term in the square bracket of (10), which is strictly above one for any $\sigma^l \in (0,1)$. Thus, if we suppose that all endogenous prices are equals in both scenarios, then necessarily the efficient distribution toll must be higher under a regulation that incorporates in the analysis the actual profits that the incumbent obtains in the market for large consumers. However,

[5] Proofs of all results are available upon request. Notice that our inputs for the calibration process are the demands' parameters are A_i^x, B^x and σ^x for $i = \{1,2\}$ and $x = \{r,l\}$. Precisely, the elasticities help us to recover such parameters. Therefore, equation (7) is equal to $a=c_a+(p_1^r-c)\cdot\frac{q_2^l}{q_1^r}\cdot\frac{B^r}{B^l}$.

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since the efficient regulatory process precisely takes into account these profits, the regulator should reduce p_1^r. This, in turn, reduces the optimal distribution toll because of the smaller opportunity cost of the incumbent. Therefore, we can say nothing about which of these two effects dominate. Whether the regulated price and the distribution toll are either higher or smaller under the optimized scenario is a matter of empirical evidence.

2.3. A first counterfactual: partial liberalization

We assume in this scenario that the regulator allows entry into the residential market for electricity. As a consequence, a fringe of competitive firms enters this market, all of them represented by firm 2. Because of the free entry condition, this new firm charges a price $p_2^r = a + c^r$. As in the previous scenario, we solve the model backward; that it, first we solve the incumbent's problem taken as given p_1^r and a. Secondly, we solve the regulator's problem considering the optimal choice of the incumbent in the market for large consumers: $p_1^l(p_1^r, a)$. Therefore, the benevolent regulator knows that the incumbent maximizes its profits with respect to p_1^l, which yields to Eq. (9). Then, the regulator solves:

$$Max_{a,p_1^r} \quad V\left(p_1^r, p_1^r, p_1^l, p_2^l\right) + (a - c_a)\cdot q_2^r(p_1^r, p_2^r) + (p_1^r - c)\cdot q_1^r(p_1^r)$$
$$+(a - c_a)\cdot q_2^l\left(p_1^l, p_2^l\right) + \left(p_1^l - c\right)\cdot q_1^l\left(p_1^l\right) - K$$
$$s\cdot t\cdot \quad (a - c_a)\cdot\left[q_2^r(p_1^r, p_2^r) + q_2^l\left(p_1^l, p_2^l\right)\right] + (p_1^r - c)\cdot q_1^r(p_1^r) + \left(p_1^l - c\right)\cdot q_1^l\left(p_1^l\right) = K$$
$$p_2^r = a + c^r,\ p_2^l = a + c^l \text{ and } p_1^l = \frac{A_1^l + c\cdot B^l}{2\cdot B^l} + \sigma^l\cdot\frac{2\cdot a + c^l - c_a}{2}$$

After some math, both a and p_1^r solve Eqs. (12) and (13), whereas (9) provides $p_1^l(a)\cdot$

$$a = c_a + (p_1^r - c)\cdot\frac{p_2^l}{p_1^r}\cdot\frac{\eta_1^r}{\eta_2^l}\cdot\left[\frac{\left\{1 + \sigma^l\cdot\frac{q_1^l}{q_2^l}\right\} + \left\{\frac{q_2^r}{q_2^l} + \sigma^r\cdot\frac{q_1^r}{q_2^l}\right\}}{\left\{1 - (\sigma^l)^2\right\} + \left\{\frac{\eta_2^r}{\eta_2^l}\cdot\frac{q_2^r}{q_2^l}\cdot\frac{p_2^l}{p_2^r}\left[1 - \sigma^r\cdot\left(\frac{q_2^r}{q_1^r} + \frac{q_2^l}{q_1^r} + \sigma^r\cdot\frac{q_1^l}{q_1^r}\right)\right]\right\}}\right] \tag{12}$$

$$(a - c_a)\cdot\left[q_2^r(p_1^r, a + c^r) + q_2^l\left(p_1^l(a), a + c^r\right)\right] +$$
$$(p_1^r - c)\cdot q_1^r(p_1^r, a + c^r) + \left(p_1^l(a) - c\right)\cdot q_1^l\left(p_1^l(a), a + c^l\right) = K \tag{13}$$

However, since these equations are expressed in terms of other endogenous variables, the nine Eqs. (1) to (6), (9), (12) and (13) provide the endogenous variables of this optimized factual scenario.

It is easy to notice that the only difference between Eqs. (10) and (12) are inside the square bracket of them. Eq. (12) shows two new positive terms in its square bracket, one in the numerator and the other in the denominator. Thus, it is impossible to figure it out whether the optimal distribution toll under partial liberalization is higher or smaller than that under its factual scenario. Therefore, any correct comparison among equilibrium variables in each scenario is, again, a matter of empirical evidence.

2.4. A second counterfactual: full liberalization of the industry

In the full liberalization scenario both retail electricity markets are freely determined by the strategic interaction between the distribution company (firm 1) and the entrant (firm 2). As a consequence, the only variable that remains regulated is the distribution toll that the incumbent must charge to its rival in both retail markets for using this network. Then, under this scenario the incumbent knows that the entrant's prices are determined by free entry conditions. Thus, the incumbent solves:

$$Max_{p_1^r, p_1^l} \quad (a - c_a)\cdot\left[q_2^r(p_1^r, a + c^r) + q_2^l\left(p_1^l, a + c^l\right)\right] +$$
$$(p_1^r - c)\cdot q_1^r(p_1^r, a + c^r) + \left(p_1^l - c\right)\cdot q_1^l\left(p_1^l, a + c^l\right) - K$$

The first order conditions of this problem yield:

$$p_1^r = \frac{A_1^r + c\cdot B^r}{2\cdot B^r} + \sigma^r\cdot\frac{2\cdot a + c^r - c_a}{2} \tag{14}$$

and $p_1^l = \frac{A_1^l + c\cdot B^l}{2\cdot B^l} + \sigma^l\cdot\frac{2\cdot a + c^l - c_a}{2}$ (9) as before.

Accordingly, a rational benevolent regulator should set the efficient distribution toll, a, by maximizing total welfare subject to the participation constraint of the distribution company. However, this problem does not have enough degrees of freedom, so that the regulator sets the distribution toll to make active the participation constraint of the distribution company. Then, it solves:

$$(a - c_a)\cdot\left[q_2^r(p_1^r(a), a + c^r) + q_2^l\left(p_1^l(a), a + c^l\right)\right] +$$
$$(p_1^r(a) - c)\cdot q_1^r(p_1^r(a), a + c^r) + \left(p_1^l(a) - c\right)\cdot q_1^l\left(p_1^l(a), a + c^l\right) = K$$

Notice that after some math, this expression may be reduced to:

$$a = c_a + \frac{K}{q_2^r + q_2^l} - \left[\frac{(p_1^r - c) \cdot q_1^r}{q_2^r + q_2^l} + \frac{\left(p_1^l - c\right) \cdot q_1^l}{q_2^r + q_2^l} \right] \quad (15)$$

Eqs. (1) to (6), (9), (14) and (15) provide the nine endogenous variables of this full liberalization scenario.

Eq. (15) tells us that the opportunity cost in the distribution toll is equal to the average annual value of recovering the assets of the distributor that are not recovered by the average operating margins of this company. We should notice that the concept of “average” is as if all fix costs were allocated to the entrant, then we must reduce to such estimation the net rents of the incumbent by each unit of production of the entrant.

Definitively, it is not possible to compare (15) with (10). Therefore, any effect on the distribution toll produced by full liberalization of the retail electricity sector must be assessed by numerical simulations. However, we can reasonable conjecture the result that should be. Since the price of the incumbent in the residential market for electricity, p_1^r , may increase because it is now freely set by the distributor, as retailer in this market, then by Eq. (15) we must observe a reduction on the efficient distribution toll on this scenario of full liberalization.

The final impact of full liberalization on both consumers and social welfare are not clear. Only a calibration on the factual model and the posterior simulation on both counterfactuals will tell us about the final welfare effects of liberalizing retail electricity markets in Chile.

3. Data and calibration process

We calibrate the model using data from the distribution company that serves to Santiago, the main city of Chile. Chilectra is the distribution company that has the monopoly right to provide electricity to residential customers on a geographic concession area of this city, supplying electricity to more than six million people.[6] This firm also provides electricity to large customers, mainly industrial firms, but in this market Chilectra compete with several generating companies. In such a case, the incumbent's rivals must pay a distribution toll for using the incumbent's distribution network. This toll is also sets by the regulator. Contrary to the strict regulation on the residential market, all final prices in the market for large consumers are freely chosen by firms.

We observe that all endogenous variables in Eqs. (1)–(15) are determined by demand and cost parameters: $(A_i^x, B^x, \sigma^x, c, c_a, c^x, K)$, for $i = \{1,2\}$ and $x = \{r,l\}$. To obtain A_i^x and B^x we proceed in two steps. In the first step we use the own price elasticity of demands in both the residential and the market for large consumers to obtain initial values of these demand parameters. Accordingly, we proceed as we explain in the next paragraphs.

Let η^x be the own price elasticity in market x, for $x = \{r,l\}$. For both factual scenarios we have only one firm in the residential market, so in such cases since $A_1^r = q_1^r + B^r \cdot p_1^r$ then by the definition of the own price elasticity:

$$A_1^r = q_1^r \cdot (1 + \eta^r).$$

However, in both counterfactual scenarios we must take into account the effect of the rival's price on each firm's maximum residential demand for electricity. That is, for the incumbent's parameter we have $A_1^r = q_1^r + B^r \cdot (p_1^r - \sigma^r \cdot p_2^r)$ that yields:

$$A_1^r = q_1^r \cdot \left(1 + \eta^r \cdot \left(1 - \sigma^r \cdot \frac{p_2^r}{p_1^r}\right)\right)$$

In other words, the incumbent's demand shrinks with the entrance of a new competitor. By the same argument, this parameter for the entrant in both counterfactual scenarios is equal to:

$$A_2^r = q_2^r \cdot \left(1 + \eta^r \cdot \left(1 - \sigma^r \cdot \frac{p_1^r}{p_2^r}\right)\right)$$

In the case of the large consumers market, since there is free entry in all scenarios, we have:

$$A_1^l = q_1^l \cdot \left(1 + \eta^l \cdot \left(1 - \sigma^l \cdot \frac{p_2^l}{p_1^l}\right)\right) \quad \text{and}$$

$$A_2^l = q_2^l \cdot \left(1 + \eta^l \cdot \left(1 - \sigma^l \cdot \frac{p_1^l}{p_2^l}\right)\right)$$

Finally, B^r and B^l are the change in the demand of each firm upon the change in its own price, in each retail market. By simplicity, we assume that these effects are identical by firm, but they may differ by market. So, for each market x, for $x = \{r,l\}$, after adding the demand for each firm we obtain the total demand, say $q^x = [A_1^x + A_2^x] - B^x \cdot [p_1^x + p_2^x] \cdot (1 - \sigma^x)$. It is easy to observe that $\frac{\partial q^x}{\partial p_i^x} = -B^x \cdot (1 - \sigma^x), \quad \text{for } i = \left\{1,2\right\}$. Moreover, by definition of the market elasticity demand we have $\eta^x = \frac{\partial q_i^x}{\partial p_i^x} \cdot \frac{p_i^x}{q_i^x}$. Therefore, [7]

$$B^x = \frac{\eta^x}{(1 - \sigma^x)} \cdot \frac{q_i^x}{p_i^x}, \quad \text{for } x = r, l$$

These parameters, B^r and B^l, are calibrated from the own price elasticities in both the residential and large consumers markets, the current prices, traded quantities in such markets, and the diversion ratio σ^x. The latter is unknown to the researcher, so that we will assume a grid from 0.5 to 0.8 for such a parameter. We justify this interval because, on the one hand, substitution between the incumbent and its rivals' energy and power services should be high because of the commodity nature of such goods, but on the other hand some degree of switching costs is very common in network industries. Nonetheless, we report in the Appendix simulations for a wider range of the diversion ratio.

After choosing initial values for A_i^x and B^x, for $x = \{r,l\}$ and $i = \{1,2\}$, in a second step we compute new values for p_i^x and q_i^x that, in turn, produce new values for all demand parameters. We iterate this process until total production per market converges to the values observed in the data.

With the definitive cost and demand parameters, initial prices and traded quantities, and for a given diversion ratio, we compute the respective equations for each scenario. By doing so, we obtain new values for endogenous variables. If the difference between each new endogenous variable and the previous one is more than a millionth, we continue the same procedure. We stop iterating if all endogenous variables change in less than that threshold.

To calibrate our model, we use information from 2009 to 2016 reported by the regulator, National Energy Commission (CNE).

[6] The regulatory setting process fixes different prices for different consumption patterns every other four years. For each pattern, there are variable and fix tariffs. Fix tariffs mainly pay power and some additional fixed costs, whereas variable tariffs pay the demand for energy. Which is important to our calibration is that almost all residential customers do not pay the demand for power, being their payments mostly related to their energy consumption.

[7] Notice that $-\frac{\partial q_i^x}{\partial p_i^x} = B^x \cdot (1 - \sigma^x) > B^x$. In other words, the absolute value of the slope of the total demand for x, $B^x \cdot (1 - \sigma^x)$, is lower than the absolute value of the slope of each firm's demand in the same market, B^x.

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Table 1
Starting values of endogenous variables, for all scenarios.

Parameter	Year	Initial Value
$p_1^r = p_1^l$	All	75 Ch$/KWh (134 US$/MWh)
a	All	10 Ch$/KWh (18 US$/MWh)
$q_1^r = q_2^r$ per year in both counterfactual scenarios. Twice for firm 1 in both factual scenarios (in MWh)	2009	4.498.797
	2010	4.722.566
	2011	4.967.510
	2012	5.074.189
	2013	5.616.087
	2014	5.800.124
	2015	6.075.422
	2016	6.284.235
$q_1^l = q_2^l$ per year in all scenarios (in MWh)	2009	2.326.521
	2010	2.296.585
	2011	2.360.361
	2012	2.313.583
	2013	2.240.194
	2014	2.052.941
	2015	1.896.581
	2016	1.975.480

Note: The average exchange rate between 2009 and 2016 is 560 Ch$ per US$.
Source: Own estimations based on data from CNE.

Table 2
Demands' parameters for all scenarios, for 2016 and $\sigma = 0.8$.

Parameter	Factual Scenarios (Current and Optimized)	Counterfactual Scenarios (Partial and Full Liberalization)
A^r	17.470.173.300	8.735.086.650
B^r	65.356.044	32.678.022
A^l	2.889.294.029	2.889.294.029
B^l	12.494.244	12.494.244

Source: Own estimations based on Table 1.

Table 1 provides the values of firm 1's prices, the distribution toll, and initial traded quantities to feed the model.

Regarding the elasticities on retail electricity markets in Chile, Agostini et al. (2012) provides the most recent estimation of the residential demand for electricity in Chile. These authors use information from the 2006 National Socio-Economic Survey (CASEN), the only one that has information of electricity consumption at a housing level. These authors estimate this elasticity in $\eta^r = 0.39$. Their estimation is quite similar to that on Benavente et al. (2005) who uses a panel of the electricity consumption for all distribution companies operating in Chile.

We take the elasticity of the large customers demand from Gómez-Lobo (2009). This author uses a panel data from the National Industry Survey (ENIA) from the years 1996–2005. We use this author's long run estimation of the demand for electricity for Chilectra in Santiago, being equal to 0.48.

We obtain the demand parameters by following the procedure explained in the beginning of this section, the data provided in Table 1, and the market elasticities from Agostini et al. (2012) and Gómez-Lobo (2009). For simplicity, we assume symmetry between the retailer firms, so that $A_1^x = A_2^x \equiv A^x$, for $x = \{r, l\}$ and we also assume that $\sigma^r = \sigma^l \equiv \sigma$. Since demand parameters change with each diversion ratio, whose values ranges from 0.5 to 0.80 in a step of 0.05 (7 different values), and that the residential demand parameters changes in counterfactual scenarios, then we have 42 vectors of different demand parameters per year that, in turn, makes a total of 294 vectors of these parameters. Table 2 provides these parameters for 2016 and $\sigma = 0.8$. All other demand parameters used in our simulations are available upon request.

Cost data to feed the model comes from two tariff setting processes of Chilectra, for periods 2008–12 and 2016–20. Since these processes provide different cost parameters for the first year of each period, we assume that there exists a geometric progression for each parameter, obtaining with this procedure cost parameters for each year of the simulation. The values of all cost parameters are obtained directly from the estimation of the Added Value of Distribution (AVD). The AVD represents the payment made to the distributor for the annuity of its investments, plus its annual operating costs, maintenance and administrative expenses, and billing and customer service expenses. In terms of the regulatory scheme followed in Chile, the AVD exactly pays all costs of a hypothetical efficient firm, forcing to the actual distributor to reduce costs to obtain extra profits. In this sense, the results of our simulations are valid to the hypothetical situation of the regulated efficient firm.

Therefore, according to our model we proceed as follows. The variable c corresponds to the total variable cost of the distribution company for each KWh of consumption. It has two main components. The first one is the cost of the electricity to the distribution company, which includes generation and transmission prices. The second component of c are those administrative costs associated with the direct provision of electricity to final customers, such as the provision of net metering, the billing process, among other miscellaneous costs of customer services.

Regarding the estimated cost of each item, since we are interested in the residential market and in order to keep the calibration tractable, we assume that all customers pay a linear tariff being equal to the total operating cost divided per the total energy that the distribution company supplies to its customers. This estimated average cost ranges from 60.0 to 62.8 Ch$ per KWh (107–112 US$ per MWh), being the lower value in 2013 and the higher value in 2012. Thus, this average cost considers the price that the distribution company pay for energy, transmission costs, and also the cost of power in a variable basis, plus all administrative costs of the firm.

The fix cost K corresponds to the annuity of the net recovering of the distribution company's assets, such as plants, property, and buildings. Such assets are the result of fix investments in high and low voltage transmission network, plus important fix investments associated to the distribution system. We take the value of K as the 10% of the total value of the net recovering of the network (VRN), an average estimation of the total assets that the efficient regulated firm needs to operate. The sources of the data are the 2008–12 and 2016–20 regulatory tariff processes, provide by the CNE. Again, we

Table 3
Calibrated cost parameters.

Parameter	2009	2010	2011	2012	2013	2014	2015	2016
$c = c^r = c^l$	62.61	62.39	61.56	62.75	59.97	61.15	61.40	61.28
	(111,7)	(111,3)	(109,8)	(112,0)	(107,0)	(109,1)	(109,6)	(109,3)
c_a	6.99	6.62	6.30	5.82	5.68	5.21	4.82	4.46
	(12,5)	(11,8)	(11,2)	(10,4)	(10,1)	(9,3)	(8,6)	(8,0)
K	54,757.8	57,856.3	61,130.2	64,589.4	68,244.3	72,106.0	76,186.2	80,497.3
	(97,7)	(103,2)	(109,1)	(115,2)	(121,7)	(128,7)	(135,9)	(143,6)

Note: Variable costs are in Ch$ per KWh (US$ per MWh in parenthesis); K is in million Ch$ (millions US$ in parenthesis).
Source: Own estimations based on data from CNE.

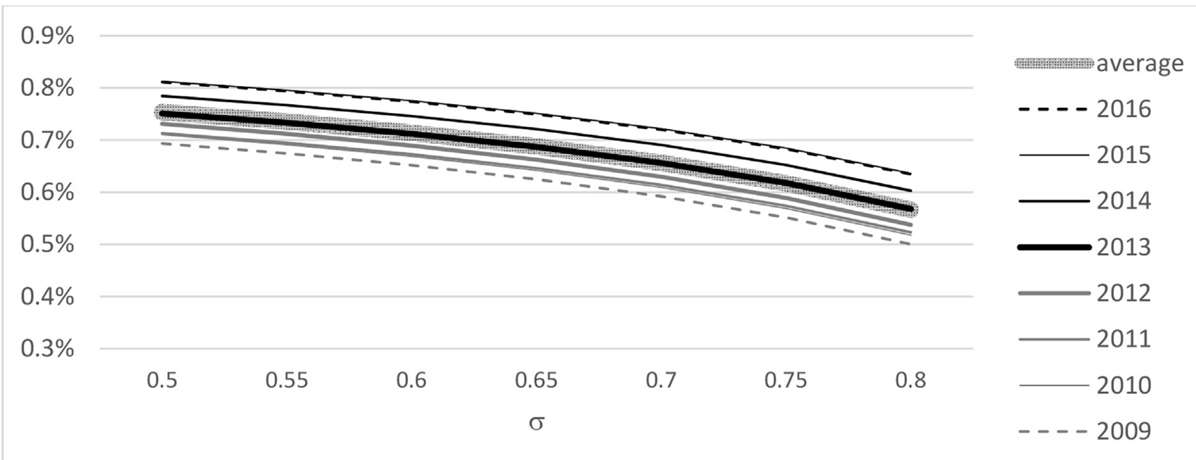

Fig. 1. Welfare comparisons between current and optimized scenarios.
Source: Own estimations based on tables in the Appendix.

assume that the VRN grows from 2008 to 2016 at a geometric rate. Thus, we estimate an annual K ranging from 51,825 to 80,497 million Ch$ (approximately from 98 to 129 million US$), being the lowest value in 2009 and the highest value in 2016.

The direct cost of providing access to a rival into the distribution network, c_a, corresponds to the distribution company payments for power according to the number of hours that the system is in peak. We assume that because rivals increase the use of the system, then we estimate this direct cost for using the network as the total ADV (in KW per month) divided by the number of hours of use (NHU). As before, we take as true the values of ADV and NHU reported in both the 2008–12 and the 2016–20 regulatory processes of Chilectra, and then we assume that each variable grows from 2008 to 2016 at a geometric rate. However, we must subtract the average K from the previous calculus because it corresponds to fixed costs that are already paid in tariffs. Then $c_a = \frac{ADV}{NHU} - \frac{K}{q_1^r + q_1^l}$, being estimated from 4.5 to 7 Ch$ per KWh (approximately from 9 to 12 US$ per MWh). The lowest value of c_a is in 2016 and the highest in 2009.

Finally, we must have an estimation of the average cost for the entrant in both the residential and the market for large consumers, respectively c^r and c^g. Since we do not have further estimation of these variables, and keeping in mind the assumption of symmetry between the incumbent and the entrant in each market, we assume that both are equal to c, the variable cost of the distribution company.

Table 3 summarizes these cost estimations, which are valid for all scenarios.

4. Simulations per year and main results

In the case of the two factual models, we must solve seven equations: three demands, one free entry condition, and three equations that comes from the respective incumbent and regulator's problems. The solutions to these seven equations provide the equilibrium values for seven endogenous variables: $p_1^r, p_1^l, p_2^l, a, q_1^r, q_1^l, q_2^l$ for each of these factual scenarios. There are, in addition, two other variables (p_2^r, p_2^l) that we must estimate in each counterfactual scenario. Since the diversion ratio is unknown to the researcher, we outperform each simulation for values that ranges from 0.5 to 0.8, as explained in the previous section.

We address the robustness of our estimations by applying random and independent shocks of 10% to each calibrated parameter. Therefore, at the end, we use the average of the estimated endogenous variables resulting from 1,000 runs with such shocks. It allows us to build an interval of confidence at the level of 95% around this average estimation.[8] We use software Matlab to run our simulations.

We show our main results, per year, in this section. All tables in the Appendix present the average of 1,000 runs for each endogenous variable in each scenario, per year. Two main results emerge from these tables. The first result is that solving the myopic regulatory setting tariff process in Chile is not really important because it produces welfare gains to society that goes from 0.58% to 0.75% in average, being more important as the service of the incumbent and the entrant are less substitutes. The most important effect of optimizing the regulatory process is in 2015, with an increase in total welfare of 0.82%. Fig. 1 depicts such finding.

[8] All endogenous variables resulted to be normally distributed, except the distribution toll. Therefore, we build this confidence interval around the average value of each endogenous variable by adding (subtracting) 1.96 times its estimated standard error.

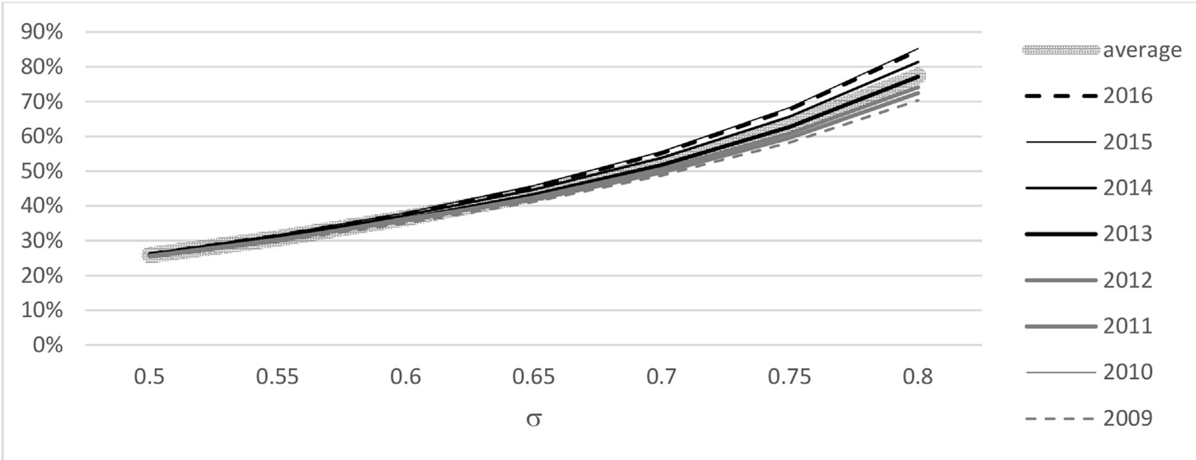

Fig. 2. Welfare comparisons between optimized and partial liberalization scenarios.
Source: Own estimations based on tables in the Appendix.

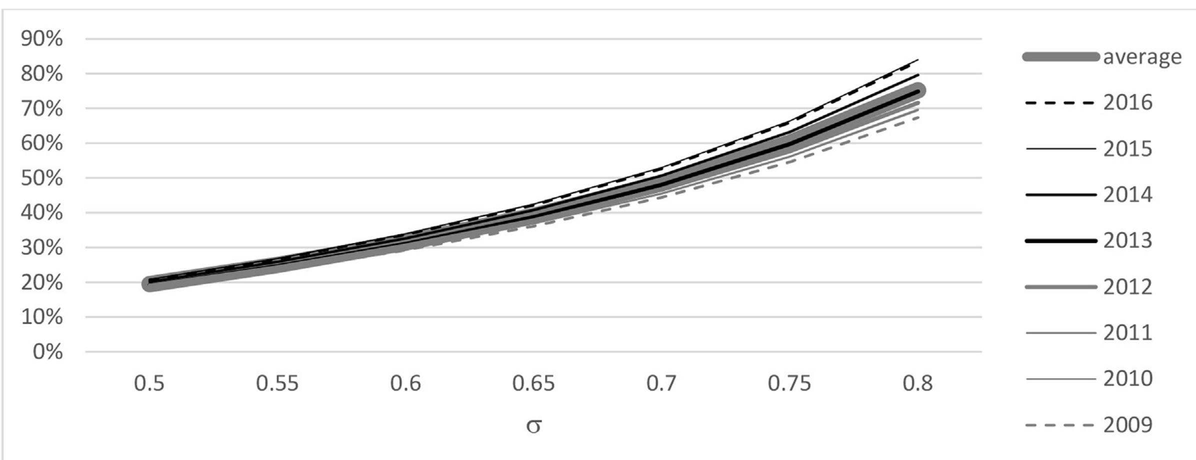

Fig. 3. Welfare comparisons between optimized and full liberalization scenarios.
Source: Own estimations based on tables in the Appendix.

The second result that comes from each year's simulations is that there is a huge increase in welfare thanks to the liberalization of retail electricity markets, being higher as the competition in each market increases (higher diversion ratio). This result is in general more important under partial liberalization than under full liberalization of the residential electricity market, as it is observed in Figs. 2 and 3. From both figures, we observe that the increase in total welfare, after performing a partial liberalization of the residential market, goes from 26% to 77% in average; whereas the same effect after full liberalization of this market is below the previous one, for any diversion ratio, ranging from 19% to 75% in average. Full liberalization of this market only performs similarly to partial liberalization for higher values of the diversion ratio, for instance when it takes the value of 0.9 and only for 2016, which is reported in the Appendix.

Finally, to get an idea of how close are all simulated results around their average, we show in Fig. 4 simulated values for the regulated price (firm 1's equilibrium price) and the distribution toll, for all scenarios. This figure contains, for each variable, its average and the highest and lowest estimations. We observe that extreme values for firm 1's simulated residential price depart from the average in less than 3%, whereas extreme values for the simulated distribution toll depart from their average in less than 20%. In terms of absolute values of these variables, for both factual scenarios, we observe that they seem reasonable and according to prices observed in practice. Both results allow us to trust on calibrated parameters that are behind of these simulations.

Regarding an analysis on these simulations, we can see that in both counterfactual scenarios the distribution toll and the residential price of the distribution company have an inverse relationship. That is, in the case of partial liberalization, the regulator fixes both tariffs in such a way that giving more rents to the regulated firm with one price (e.g., a higher residential tariff) immediately cuts such rents by fixing a lower price in the other variable (e.g., a lower distribution toll). In the case of full liberalization, since the distribution toll is the only regulatory instrument, the regulator curves distributor's high rents by fixing a negative distribution toll.

We may conclude that the simulated values are robust to different configurations of demand and cost parameters of the model. This conclusion will be even clearer in the next section, where we analyze our results using the average simulation of each

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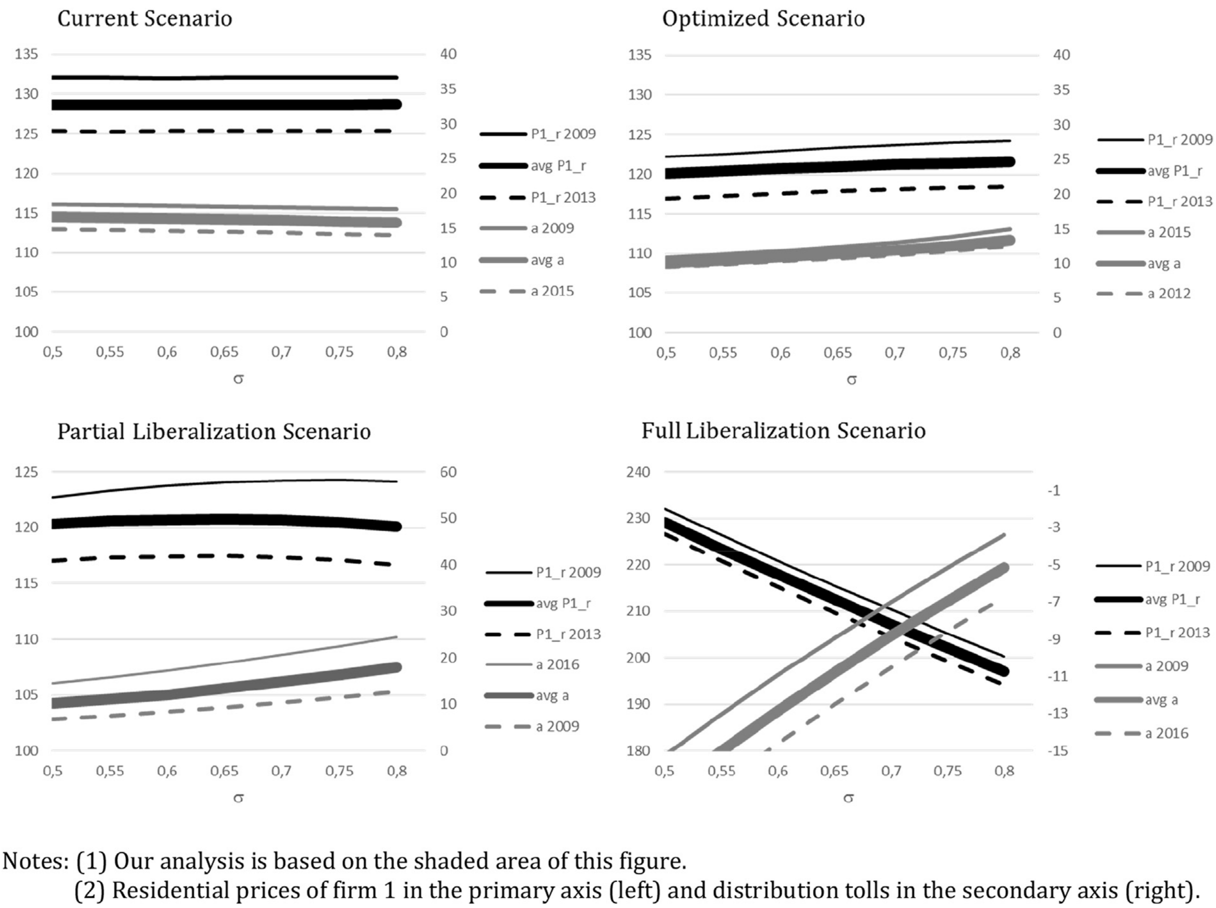

Fig. 4. Price to Residential Consumers and Distribution Toll, per year.
Notes: (1) Our analysis is based on the shaded area of this figure.
(2) Residential prices of firm 1 in the primary axis (left) and distribution tolls in the secondary axis (right).
Source: Own estimations based on tables in the Appendix.

Table 4
Prices and distribution toll under the current scenario, in US$ per MWh.

σ^x	a			p_1^r			p_1^l			p_2^l		
	lower	avg	upper	lower	Avg	Upper	lower	Avg	Upper	lower	Avg	upper
0.5	17.9	**16.6**	15.2	136.4	**128.6**	120.9	246.8	**229.9**	213.0	134.0	**126.5**	119.1
0.55	17.8	**16.5**	15.1	136.8	**128.6**	120.5	242.3	**226.2**	210.1	134.1	**126.4**	118.7
0.6	17.6	**16.3**	15.1	136.6	**128.6**	120.7	238.2	**222.5**	206.8	133.9	**126.3**	118.7
0.65	17.5	**16.2**	14.9	136.5	**128.6**	120.8	233.0	**218.8**	204.6	133.9	**126.2**	118.5
0.7	17.4	**16.1**	14.8	136.5	**128.7**	120.8	229.0	**215.0**	201.1	133.8	**126.1**	118.4
0.75	17.3	**16.0**	14.7	136.5	**128.7**	120.8	224.9	**211.2**	197.5	133.6	**125.9**	118.3
0.8	17.1	**15.8**	14.6	137.2	**128.7**	120.1	220.7	**207.4**	194.2	133.2	**125.8**	118.4

Source: Own estimations based on tables in the Appendix.

variable with the respective interval of confidence.

5. Average simulations and robustness

As we mention in the first paragraph of the previous section, we run the model 1,000 times for each combination of scenario - diversion ratio - year in order to get robust estimations. In each run, we apply a random and independent shock of 10% to each demand and cost parameter of the model. Thus, in this section we work with the average per year simulated values, and their respective interval at a 95% of confidence level. The standard deviation of each endogenous variable, for the average estimated value per year, is also reported in the Appendix.

5.1. Simulation results under the current situation

Table 4 shows the values of endogenous prices and distribution toll for this scenario.

As we may expect, both the distribution toll and the tariff in the residential consumer market are not statistically sensitive to changes in the intensity of competition in the large consumers market for electricity, so it is the price that firm 2 charges in this market. Only the price that the distribution company freely charges in the large consumers market is sensitive to the degree of

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Table 5
Prices and distribution toll under the optimized scenario, in US$ per MWh.

σ^x	a			p_1^r			p_1^l			p_2^l		
	lower	Avg	upper	lower	Avg	Upper	lower	Avg	upper	lower	Avg	upper
0.5	11.3	**10.1**	9.0	128.1	**120.1**	112.2	238.0	**226.7**	215.4	126.9	**120.1**	113.4
0.55	12.0	**10.5**	9.0	128.2	**120.4**	112.7	233.3	**223.0**	212.6	128.4	**120.5**	112.6
0.6	13.1	**10.9**	8.8	128.3	**120.7**	113.1	229.5	**219.3**	209.0	131.0	**120.9**	110.9
0.65	13.7	**11.4**	9.1	128.6	**121.0**	113.4	225.2	**215.6**	206.1	130.9	**121.4**	111.9
0.7	14.3	**11.9**	9.6	128.7	**121.2**	113.7	221.3	**212.1**	202.9	130.9	**121.9**	113.0
0.75	15.2	**12.6**	9.9	129.0	**121.4**	113.8	218.2	**208.7**	199.2	131.8	**122.6**	113.3
0.8	16.1	**13.3**	10.6	129.2	**121.6**	113.9	214.8	**205.5**	196.1	131.9	**123.3**	114.8

Source: Own estimations based on tables in the Appendix.

Table 6
Welfare changes from the current to the optimized factual scenarios.

σ^l	Δ Consumer's Surpluses			ΔTotal Welfare
	Residential	Large Consumers	Total	
0.5	6.0%	2.9%	5.1%	**0.75%**
0.55	5.8%	2.5%	4.8%	**0.74%**
0.6	5.6%	2.1%	4.5%	**0.71%**
0.65	5.5%	1.8%	4.2%	**0.69%**
0.7	5.3%	1.4%	3.8%	**0.66%**
0.75	5.2%	1.0%	3.4%	**0.62%**
0.8	5.2%	0.6%	3.0%	**0.57%**

Source: Own estimations based on calculations that follows from Tables 4 and 5.

competition, being smaller as competition increases.

Endogenous prices determine production and consumption levels, consumer surpluses, incumbent's profits, and total welfare. It is clear that the more competition in the large consumers market for electricity, indicated by a higher diversion ratio, the higher the consumer surplus in this market. Such an increase in welfare is due to the reduction of the incumbent's price driven by the higher competition in this market.

5.2. Simulation results in the optimized factual scenario

Table 5 shows the values of endogenous prices and the distribution toll for the optimized factual scenario. We observe that as competition becomes stronger in the market for large consumers, the incumbent reduces its price in this market, which in turn drives an increase in both optimal distribution toll and regulated tariff in the residential market.

Regarding the difference on prices between both factual scenarios (Tables 4 and 5), we observe a decrease in the distribution toll when the regulatory process incorporates actual rents of the distributor in the large consumers market for electricity. This situation implies a reduction in prices of both firms in the market for large consumers because of the pressure of a stronger entry. Since the participation constraint of the incumbent is active, it forces the regulated tariff in the residential market to be 6% lower under this optimized scenario than under the current scenario.

Regarding welfare comparisons in both factual scenarios, it is clear that being all prices lower under the optimized scenario, consumer surpluses and total welfare increase. Such result is more important as competition becomes less intense. Indeed, Table 6 shows that: i) the residential consumer's surplus grows between 5.2% and 6% in this optimized scenario; ii) the change in the large consumers surplus goes from 0.6% to 2.9%; and iii) total welfare increase between 0.57% and 0.75%.

5.3. Simulation results in the first counterfactual scenario: partial liberalization

Table 7 shows the values of endogenous prices and the distribution toll for partial liberalization; that is, when the regulation allows entry into the retailing of residential electricity.

This table shows several interesting results. First, regarding the level of prices and the distribution toll we observe that the regulator sets the latter below of that under the optimized scenario. The reason is that the regulator is not only concerned to strengthen competition in the market for large consumers, but also it does so regarding the residential electricity market. Thus, the regulator favors the entrance in both markets by setting the distribution toll between its marginal cost and its value on the optimized factual scenario (see Table 6). This result is true for any diversion ratio.

Regarding the incumbent's regulated tariff, the price of the new entrant in the residential market, and equilibrium prices in the large consumers market, we observe that all of them almost similar to those under the optimized factual scenario. Therefore, the large gain for consumers is variety. In fact, welfare changes are very strong thanks to the liberalization policy as we observe in Table 8. All of these changes are explained by important gains in the residential market, precisely the one that has a new firm that defies the distribution company's monopolistic power on retailing.

Table 7
Prices and distribution toll under the partial liberalization scenario, in US$ per MWh.

σ^x	a			p_1^r			p_2^r			p_1^l			p_2^l		
	lower	Avg	upper	lower	Avg	Upper	lower	Avg	upper	Lower	Avg	upper	lower	Avg	upper
0.5	12.2	**10.2**	8.1	125.2	**120.3**	115.5	128.1	**120.2**	112.2	241.9	**226.7**	211.6	128.1	**120.2**	112.2
0.55	13.3	**11.2**	9.1	125.4	**120.6**	115.8	128.9	**121.2**	113.4	237.0	**223.3**	209.6	128.9	**121.2**	113.4
0.6	13.9	**11.9**	10.0	125.4	**120.7**	116.0	129.6	**121.9**	114.2	233.5	**219.9**	206.2	129.6	**121.9**	114.2
0.65	15.5	**13.5**	11.6	126.6	**120.8**	114.9	130.6	**123.5**	116.4	229.7	**217.0**	204.3	130.6	**123.5**	116.4
0.7	16.9	**14.9**	12.9	128.6	**120.7**	112.7	131.6	**124.9**	118.1	226.4	**214.2**	201.9	131.6	**124.9**	118.1
0.75	18.6	**16.4**	14.1	129.8	**120.4**	111.0	133.3	**126.4**	119.4	223.0	**211.5**	200.1	133.3	**126.4**	119.4
0.8	22.9	**18.0**	13.0	130.9	**120.1**	109.2	137.2	**128.0**	118.7	221.7	**209.2**	196.6	137.2	**128.0**	118.7

Source: Own estimations based on tables in the Appendix.

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Table 8
Welfare changes from the optimized to the partial liberalization scenarios.

σ^l	Δ Consumer's Surpluses			Δ Total Welfare
	Residential	Large Consumers	Total	
0.5	35.8%	0.1%	25.8%	25.8%
0.55	43.8%	−0.2%	30.7%	30.7%
0.6	53.8%	−0.3%	36.5%	36.5%
0.65	66.5%	−0.7%	43.4%	43.4%
0.7	83.6%	−0.8%	52.0%	52.0%
0.75	107.7%	−1.0%	63.0%	63.0%
0.8	143.8%	−1.0%	77.4%	77.4%

Source: Own estimations based on calculations that follows from Tables 5 and 7.

Table 10
Welfare changes from the optimized to the full liberalization scenarios.

σ^l	Δ Consumer's Surpluses			Δ Total Welfare
	Residential	Large Consumers	Total	
0.5	22.3%	12.2%	19.5%	19.5%
0.55	31.0%	10.7%	25.0%	25.0%
0.6	41.8%	9.3%	31.4%	31.4%
0.65	55.5%	7.9%	39.1%	39.1%
0.7	73.4%	6.7%	48.5%	48.5%
0.75	98.3%	5.5%	60.1%	60.1%
0.8	135.2%	4.4%	75.2%	75.2%

Source: Own estimations based on calculations that follows from Tables 5 and 9.

5.4. Simulation results in the second counterfactual scenario: full liberalization

As mentioned, full liberalization means that all prices to final consumers are freely chosen by retailers in both markets, but still the regulator has to set the distribution toll such that an efficient newcomer can access the incumbent's distribution network. Table 9 shows the values of endogenous prices and the distribution toll for full liberalization. Under this scenario, the regulator loses its direct instrument to curve the incumbent's market power, which is the price of this firm in the residential electricity market. Hence, the regulator only may fix the distribution toll at the minimum possible level such that it may induce higher entry in both markets and, by doing so, indirectly curve the incumbent's market power in both markets.

Table 9 shows that the optimal regulated distribution toll is negative for any diversion ratio, which means that the regulator mandates the incumbent to directly subsidize the entry in both retail electricity markets. Such a subsidy is higher as competition on these retail markets becomes less intense. The incumbent chooses p_1^r that is from 67% to 90% above that regulated under the optimized factual scenario. However, this not necessarily means a negative consequence on the residential consumer's surplus because the negative distribution toll reduces firm 2's prices and, more importantly, increases the residential consumer surplus by the entrance of a new provider in the market. Regarding the impact of this liberalization on the surplus of large consumers, they are better off with this policy, as compared to their surplus on the optimized scenario, thanks to the reduction in the distribution toll. In fact, prices on this market reduce by 7% in the case of the distributor and 25% in the case of its independent rival.

Table 10 presents welfare changes under this full counterfactual scenario compared to the optimized factual scenario. Full liberalization also produces significant increase in residential consumers welfare, clearly increasing with more competition in both retail markets.

It is important to mention that, contrary to the case of partial liberalization, the policy of full liberalization of retail electricity markets produces distributional concerns resulting from higher equilibrium prices to final consumers in both retail markets. Fig. 5 shows the comparison of the welfare effects of these two alternative policies. It becomes clear that a partial liberalization policy not only generates less inequality problems than under a full liberalization policy, but also the former generates higher surpluses on the residential market and on the electricity consumers as a whole. Only the surplus of large consumers is lower under partial liberalization. As a consequence, total welfare is higher under partial liberalization than under full liberalization. All these results are less important in magnitude as both retail electricity markets become more competitive. Actually, from tables in the Appendix is possible to infer that all differences in welfare impacts between partial and full liberalization tend to zero as the diversion ration goes to one. The reason is simple, perfect regulation always emulates perfect competition, and vice versa.

6. Conclusions

The supply of electricity to residential customers in Chile is provided by a regulated monopoly in each geographic concession area. Each distribution company not only owns the distribution network but also is the only provider of electricity to this important segment of consumers. International evidence strongly indicates that the liberalization of retail electricity markets generates important welfare improvements to society. However, is crucial to any liberalization on this matter to set efficient distribution tolls to incentive competition in retailing markets. Moreover, it is also important to set efficient tariffs to the incumbent that take into account the increase in structure competition of the industry.

We establish a methodology to set both the efficient distribution toll to the electricity distribution network and the incumbent's prices of the residential electricity market, in case that such a price remains regulated. We follow the standard literature that takes into account the strategic interdependence between the incumbent as a supplier of electricity and its potential competitors. By simplicity,

Table 9
Prices and distribution toll under the full liberalization scenario, in US$ per MWh.

σ^x	a			p_1^r			p_2^r			p_1^l			p_2^l		
	lower	avg	upper	lower	Avg	Upper	lower	Avg	upper	lower	Avg	upper	lower	Avg	upper
0.5	−12.7	**−17.3**	−21.9	245.2	**229.1**	213.0	102.0	**92.7**	83.4	227.6	**213.0**	198.4	102.0	**92.7**	83.4
0.55	−11.2	**−15.0**	−18.8	237.8	**223.4**	209.0	103.9	**95.0**	86.0	222.5	**208.9**	195.3	103.9	**95.0**	86.0
0.6	−9.6	**−12.8**	−16.1	228.6	**217.9**	207.1	104.6	**97.1**	89.7	216.1	**205.0**	193.8	104.6	**97.1**	89.7
0.65	−8.1	**−10.8**	−13.5	225.5	**212.5**	199.4	107.8	**99.2**	90.6	213.8	**201.2**	188.6	107.8	**99.2**	90.6
0.7	−6.2	**−8.8**	−11.5	219.0	**207.2**	195.4	110.0	**101.2**	92.3	210.1	**197.6**	185.1	110.0	**101.2**	92.3
0.75	−5.3	**−6.9**	−8.6	213.5	**202.1**	190.7	111.7	**103.0**	94.4	205.9	**194.1**	182.3	111.7	**103.0**	94.4
0.8	−3.7	**−5.1**	−6.6	207.5	**197.1**	186.7	113.1	**104.8**	96.6	202.7	**190.7**	178.6	113.1	**104.8**	96.6

Source: Own estimations based on tables in the Appendix.

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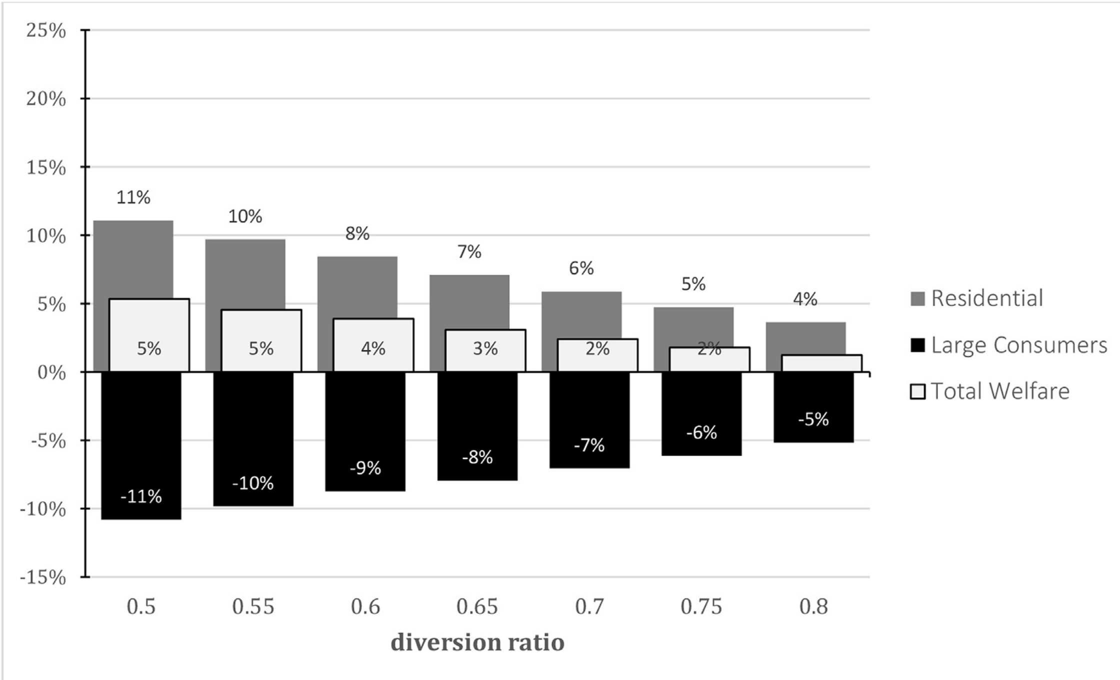

Note: A positive (negative) value indicate a higher surplus under partial (full) liberalization.

Fig. 5. Welfare comparison between partial and full liberalization scenarios.
Note: A positive (negative) value indicate a higher surplus under partial (full) liberalization.
Source: Own estimations based on calculations that follows from Tables 7 and 9.

we assume that there is no strategic behavior from the incumbent aimed to discriminate rivals on these markets.

Table 11 summarizes the total welfare in each scenario. The current scenario corresponds to the situation that shares the main features of the Chilean electricity regulation. The optimized scenario assumes that the regulator sets tariffs taking into account the incumbent's rents in the large consumers market. Thus, we use the optimized scenario as a factual to evaluate the effects of two alternative liberalization policies in retail electricity markets: partial and full liberalization scenarios.

From these simulations, we get the following main results:

- When comparing the effect of changing the current regulatory process to a one that gets rid-off the assumption of perfect competition in the electricity market for large consumers, we observe an increase in the residential consumer's surplus (5%–6%), in the surplus of large consumers (0%–3%), and in total welfare (less than 1%). The regulated distribution company has a strong reduction in its profits, as expected from an efficient regulation. It may become clear from Table 11 that although we observe an increase in total welfare in the optimized scenario, for any diversion ratio considered in simulations, such increase is always statistically insignificant.
- When the residential market for electricity is partially liberalized, that is when the entrance is allowed but the incumbent's tariff in this market remains regulated, there is an important increase in the residential surplus (36%–144%), being higher as the competition becomes stronger. This drives to an increase in total welfare (26%–77%). As we observe from Table 11, such increase in total welfare is statistically significant at a 5% level since both intervals of confidence never overlaps.
- Full liberalization has an important impact on welfare too, but less than the impact of partial liberalization. In fact, when comparing the results under these two alternative policies, partial liberalization generates higher surplus on residential market (4%–11%) and on total welfare (1%–5%), being higher as competition becomes less intense. Only large consumers get a lost from partial liberalization as compared to full liberalization.

Table 11
Total welfare and its interval of confidence for each scenario, in billions of US$.

σ^x	Current Scenario			Optimized Scenario			Partial Liberalization Scenario			Full Liberalization Scenario		
	lower	avg	Upper	lower	Avg	Upper	Lower	Avg	upper	lower	Avg	upper
0.5	2.82	**2.75**	2.69	2.82	**2.77**	2.73	3.57	**3.49**	3.41	3.64	**3.31**	2.98
0.55	2.89	**2.82**	2.75	2.90	**2.84**	2.78	3.80	**3.71**	3.62	3.88	**3.55**	3.21
0.6	2.98	**2.90**	2.83	3.01	**2.92**	2.84	4.10	**3.99**	3.89	4.14	**3.84**	3.55
0.65	3.11	**3.01**	2.91	3.12	**3.03**	2.94	4.49	**4.34**	4.20	4.58	**4.21**	3.85
0.7	3.28	**3.15**	3.02	3.29	**3.17**	3.06	5.03	**4.82**	4.62	5.12	**4.71**	4.30
0.75	3.54	**3.35**	3.16	3.53	**3.37**	3.21	5.80	**5.49**	5.18	5.85	**5.39**	4.94
0.8	3.93	**3.64**	3.35	3.87	**3.66**	3.45	7.02	**6.50**	5.97	6.92	**6.42**	5.91

Source: Own estimations based on tables in the Appendix.

Again, according to Table 11, the welfare gains for full liberalizing the retail electricity market in Chile, as compared to a situation of optimal regulation without such liberalization, is also statistically significant at a 5% level.

- Despite being a better alternative in terms of the average increase in total welfare, both partial and full liberalization of retail electricity markets in Chile are statistically the same at a 95% of confidence level, for any diversion ratio considered in simulations. This result can be observed in Table 11, on the last two columns on the right. In fact, both intervals of confidence overlap for any diversion ratio.

Prudency is a good advice in terms of public policy. We found that partial liberalization on retail electricity markets in Chile seems to be the best policy recommendation. The reason is that we assume that a benevolent regulator maximizes total welfare with respect to both the distributor's residential tariff and the distribution toll, subject to the budget constraint of this company. Such a maximization procedure is not possible under full liberalization because, under this scenario, the price of the incumbent is no longer a regulatory instrument. Thus, the regulatory process cannot guarantee that equilibrium prices are maximizing the total welfare. However, as mentioned, the difference on welfare impacts between these two counterfactual scenarios becomes lower as competition increases. Actually, such a difference is almost zero when the diversion ratio is 0.9, as it can be observed in the Appendix.

Our findings are preliminaries. Further research on this topic is strongly needed. In particular, it is important to empirically assess all concerns regarding the frictions that reduce entry and exit in retailing electricity markets, the possibility of any abuse of dominance by the distribution network against independent rivals, and problems that may arise from market and institutional design during the liberalization process.

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Appendix

A.1 Simulation results, average of 1000 runs (per scenario, diversion ration, and year)

2009	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Current Scenario	a	18.6	18.5	18.4	18.3	18.2	18.1	18.0	17.8	17.7	17.6	17.4
	p1_r	132.1	132.1	132.1	132.0	132.0	132.0	132.1	132.1	132.1	132.1	132.1
	p1_l	240	236	233	229	225	222	218	214	211	207	203
	p2_l	130	130	130	130	130	130	130	130	129	129	129
	q_r	9.04	9.04	9.04	9.04	9.04	9.04	9.04	9.04	9.04	9.04	9.04
	q_l	3.98	4.04	4.10	4.15	4.21	4.27	4.32	4.38	4.43	4.49	4.54
	CS_r	1.543	1.543	1.543	1.543	1.543	1.543	1.543	1.543	1.543	1.543	1.543
	CS_l	0.675	0.728	0.792	0.868	0.961	1.079	1.234	1.448	1.767	2.293	3.338
	Profits	0.128	0.124	0.119	0.115	0.110	0.106	0.101	0.097	0.092	0.088	0.083
	W	2.346	2.395	2.454	2.526	2.615	2.728	2.879	3.089	3.402	3.924	4.964
2009	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Optimized Scenario	a	9.4	9.7	10.1	10.4	10.8	11.2	11.6	12.1	12.6	13.2	14.1
	p1_r	121	122	122	123	123	123	124	124	124	124	125
	p1_l	236	232	229	225	221	217	214	210	207	203	200
	p2_l	121	121	122	122	122	123	123	124	124	125	126
	q_r	9.32	9.31	9.30	9.29	9.28	9.27	9.26	9.26	9.25	9.24	9.24
	q_l	4.06	4.11	4.17	4.22	4.27	4.32	4.36	4.41	4.46	4.51	4.55
	CS_r	1.658	1.654	1.650	1.646	1.643	1.639	1.636	1.633	1.631	1.629	1.628
	CS_l	0.705	0.758	0.821	0.896	0.989	1.106	1.259	1.472	1.788	2.311	3.353
	Profits	−0.005	−0.005	−0.004	−0.004	−0.004	−0.003	−0.002	−0.001	0.000	0.002	0.005
	W	2.363	2.412	2.471	2.543	2.632	2.745	2.896	3.106	3.419	3.941	4.981
2009	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Partial Liberalization Scenario	a	5.4	6.0	6.7	7.5	8.3	9.3	10.3	11.5	12.8	14.1	15.6
	p1_r	121	122	123	123	124	124	124	124	124	124	123
	p2_r	117	118	118	119	120	121	122	123	124	126	127
	p1_l	235	231	227	223	220	216	213	210	207	204	202
	p2_l	117	118	118	119	120	121	122	123	124	126	127
	q_r	9.30	9.27	9.25	9.22	9.19	9.17	9.14	9.12	9.10	9.07	9.05
	q_l	4.10	4.15	4.19	4.24	4.28	4.33	4.37	4.42	4.46	4.50	4.55
	CS_r	2.078	2.163	2.266	2.394	2.555	2.764	3.045	3.441	4.038	5.036	7.038
	CS_l	0.718	0.771	0.833	0.907	0.998	1.113	1.264	1.475	1.788	2.308	3.346
	Profits	−0.000	0.000	0.000	0.000	0.000	−0.000	0.000	−0.000	−0.000	−0.000	−0.000
	W	2.796	2.934	3.100	3.301	3.553	3.877	4.310	4.916	5.825	7.344	10.384
2009	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
	a	−20.0	−17.6	−15.2	−13.0	−10.9	−8.9	−7.0	−5.2	−3.4	−1.7	−0.1

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(*continued*)

2009	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Full Liberalization Scenario	p1_r	244	238	232	226	221	216	210	205	200	195	191
	p2_r	92	94	96	99	101	103	105	107	108	110	112
	p1_l	224	220	216	212	208	204	201	197	194	191	187
	p2_l	92	94	96	99	101	103	105	107	108	110	112
	q_r	8.29	8.36	8.42	8.49	8.55	8.61	8.67	8.73	8.79	8.84	8.90
	q_l	4.32	4.35	4.38	4.41	4.43	4.46	4.49	4.52	4.54	4.57	4.60
	CS_r	1.792	1.892	2.011	2.153	2.329	2.552	2.847	3.257	3.867	4.879	6.893
	CS_l	0.807	0.856	0.914	0.985	1.073	1.186	1.335	1.544	1.857	2.377	3.416
	Profits	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	W	2.599	2.748	2.925	3.138	3.402	3.738	4.183	4.801	5.724	7.255	10.309

Notes: (1) Prices are in US$ per MWh; quantities are in millions of MWh; surpluses are in billions of US$.
(2) Each value corresponds to the average of 1000 runs.
Source: Own elaboration.

2010	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Current Scenario	a	18.0	17.9	17.8	17.7	17.6	17.5	17.4	17.3	17.1	17.0	16.9
	p1_r	131	131	131	131	131	131	131	131	131	131	131
	p1_l	239	236	232	228	225	221	217	214	210	206	202
	p2_l	129	129	129	129	129	129	129	129	128	128	128
	q_r	9.52	9.52	9.52	9.52	9.52	9.52	9.52	9.52	9.52	9.52	9.52
	q_l	3.94	3.99	4.05	4.11	4.16	4.22	4.27	4.33	4.38	4.44	4.49
	CS_r	1.628	1.629	1.629	1.629	1.629	1.629	1.629	1.628	1.628	1.628	1.628
	CS_l	0.669	0.722	0.785	0.860	0.952	1.068	1.222	1.433	1.748	2.267	3.298
	Profits	0.127	0.122	0.118	0.114	0.109	0.105	0.100	0.096	0.091	0.087	0.082
	W	2.424	2.473	2.531	2.602	2.690	2.802	2.951	3.158	3.467	3.982	5.009
2010	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Optimized Scenario	a	9.4	9.7	10.0	10.4	10.8	11.2	11.6	12.1	12.7	13.4	14.3
	p1_r	121	121	122	122	122	123	123	123	124	124	124
	p1_l	236	232	228	224	221	217	213	210	206	203	200
	p2_l	121	121	121	122	122	122	123	123	124	125	126
	q_r	9.80	9.79	9.78	9.77	9.76	9.75	9.74	9.73	9.73	9.72	9.72
	q_l	4.01	4.06	4.11	4.16	4.21	4.26	4.31	4.36	4.40	4.45	4.50
	CS_r	1.745	1.741	1.737	1.734	1.730	1.727	1.724	1.721	1.719	1.718	1.717
	CS_l	0.697	0.750	0.812	0.886	0.977	1.093	1.244	1.454	1.766	2.282	3.309
	Profits	−0.004	−0.003	−0.003	−0.003	−0.002	−0.001	−0.000	0.001	0.002	0.004	0.007
	W	2.442	2.491	2.549	2.620	2.708	2.820	2.969	3.176	3.485	4.000	5.027
2010	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Partial Liberalization Scenario	a	6.1	6.8	7.5	8.3	9.2	10.2	11.3	12.6	13.9	15.4	16.9
	p1_r	121	121	122	122	123	123	123	123	123	123	122
	p2_r	117	118	119	120	121	122	123	124	125	127	128
	p1_l	234	231	227	223	220	216	213	210	207	205	202
	p2_l	117	118	119	120	121	122	123	124	125	127	128
	q_r	9.77	9.74	9.71	9.68	9.66	9.63	9.60	9.58	9.55	9.52	9.50
	q_l	4.04	4.09	4.14	4.18	4.23	4.27	4.31	4.35	4.40	4.44	4.49
	CS_r	2.183	2.272	2.381	2.515	2.684	2.904	3.199	3.615	4.241	5.289	7.391
	CS_l	0.708	0.760	0.821	0.894	0.983	1.096	1.246	1.453	1.761	2.274	3.298
	Profits	0.000	−0.000	0.000	−0.000	−0.000	0.000	0.000	−0.000	0.000	0.000	−0.000
	W	2.891	3.032	3.202	3.409	3.668	4.000	4.445	5.067	6.002	7.563	10.689
2010	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Full Liberalization Scenario	a	−20.6	−18.2	−15.8	−13.6	−11.5	−9.5	−7.5	−5.7	−3.9	−2.2	−0.6
	p1_r	243	237	231	226	220	215	209	204	199	195	190
	p2_r	91	93	95	98	100	102	104	106	107	109	111
	p1_l	224	219	215	211	207	203	200	196	193	190	187
	p2_l	91	93	95	98	100	102	104	106	107	109	111
	q_r	8.72	8.79	8.86	8.93	8.99	9.05	9.12	9.18	9.23	9.29	9.34
	q_l	4.27	4.30	4.33	4.36	4.38	4.41	4.44	4.46	4.49	4.51	4.54
	CS_r	1.889	1.995	2.119	2.268	2.453	2.688	2.997	3.427	4.068	5.129	7.244
	CS_l	0.800	0.849	0.906	0.976	1.063	1.174	1.322	1.528	1.836	2.350	3.375
	Profits	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	W	2.690	2.843	3.025	3.244	3.516	3.862	4.319	4.955	5.904	7.479	10.620

Notes: (1) Prices are in US$ per MWh; quantities are in millions of MWh; surpluses are in billions of US$.
(2) Each value corresponds to the average of 1000 runs.
Source: Own elaboration.

2011	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Current Scenario	a	17.5	17.4	17.3	17.2	17.1	17.0	16.9	16.7	16.6	16.5	16.3
	p1_r	129	129	129	129	129	129	129	129	129	129	129
	p1_l	238	234	230	227	223	219	216	212	208	204	200
	p2_l	127	127	127	127	127	127	127	127	126	126	126
	q_r	10.07	10.07	10.07	10.07	10.07	10.07	10.07	10.07	10.07	10.07	10.07
	q_l	4.06	4.12	4.18	4.23	4.29	4.34	4.40	4.46	4.51	4.56	4.62
	CS_r	1.733	1.733	1.733	1.733	1.733	1.733	1.733	1.733	1.733	1.733	1.732
	CS_l	0.694	0.748	0.813	0.890	0.985	1.105	1.263	1.480	1.804	2.337	3.398
	Profits	0.132	0.127	0.122	0.118	0.113	0.108	0.104	0.099	0.094	0.089	0.085
	W	2.558	2.608	2.668	2.741	2.831	2.946	3.099	3.312	3.631	4.159	5.215

2011	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Optimized Scenario	a	9.0	9.3	9.7	10.0	10.4	10.8	11.3	11.8	12.4	13.2	14.2
	p1_r	119	119	120	120	120	121	121	121	122	122	122
	p1_l	234	230	227	223	219	215	212	208	205	201	198
	p2_l	119	119	120	120	120	121	121	122	122	123	124
	q_r	10.36	10.35	10.34	10.33	10.32	10.31	10.30	10.30	10.29	10.28	10.28
	q_l	4.14	4.19	4.24	4.29	4.34	4.39	4.44	4.48	4.53	4.58	4.62
	CS_r	1.855	1.851	1.847	1.843	1.840	1.836	1.833	1.830	1.828	1.827	1.826
	CS_l	0.722	0.777	0.840	0.917	1.011	1.129	1.285	1.501	1.821	2.352	3.407
	Profits	−0.003	−0.003	−0.003	−0.002	−0.002	−0.001	0.000	0.001	0.003	0.006	0.009
	W	2.577	2.627	2.687	2.760	2.850	2.965	3.118	3.331	3.650	4.178	5.234

2011	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Partial Liberalization Scenario	a	6.0	6.6	7.4	8.2	6.3	10.2	11.4	12.6	14.0	15.5	17.2
	p1_r	119	120	120	120	120	121	121	121	121	120	120
	p2_r	116	116	117	118	116	120	121	122	124	125	127
	p1_l	233	229	225	222	217	215	212	209	206	203	201
	p2_l	116	116	117	118	116	120	121	122	124	125	127
	q_r	10.31	10.28	10.25	10.22	10.22	10.16	10.13	10.10	10.07	10.03	10.00
	q_l	4.16	4.21	4.26	4.31	4.37	4.39	4.44	4.48	4.52	4.57	4.61
	CS_r	2.314	2.408	2.523	2.664	2.858	3.073	3.383	3.820	4.479	5.581	7.791
	CS_l	0.733	0.786	0.849	0.924	1.027	1.132	1.285	1.497	1.815	2.341	3.394
	Profits	−0.000	0.000	0.000	−0.000	−0.013	0.000	0.000	−0.000	−0.000	0.000	0.000
	W	3.047	3.194	3.371	3.587	3.885	4.204	4.668	5.317	6.293	7.922	11.185

2011	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Full Liberalization Scenario	a	−21.4	−18.9	−16.5	−14.3	−12.1	−10.1	−8.1	−6.3	−4.5	−2.8	−1.1
	p1_r	242	235	230	224	218	213	208	203	198	193	188
	p2_r	88	91	93	96	98	100	102	104	105	107	109
	p1_l	222	218	214	209	206	202	198	195	191	188	185
	p2_l	88	91	93	96	98	100	102	104	105	107	109
	q_r	9.22	9.29	9.36	9.43	9.49	9.56	9.62	9.68	9.74	9.79	9.84
	q_l	4.41	4.44	4.46	4.49	4.52	4.54	4.57	4.59	4.62	4.64	4.67
	CS_r	2.006	2.117	2.248	2.405	2.599	2.846	3.172	3.624	4.298	5.415	7.639
	CS_l	0.830	0.879	0.939	1.010	1.100	1.214	1.366	1.578	1.895	2.423	3.477
	Profits	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	W	2.836	2.996	3.186	3.415	3.699	4.060	4.538	5.202	6.193	7.837	11.116

Notes: (1) Prices are in US$ per MWh; quantities are in millions of MWh; surpluses are in billions of US$.
(2) Each value corresponds to the average of 1000 runs.
Source: Own elaboration.

2012	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Current Scenario	a	17.0	16.9	16.8	16.7	16.5	16.4	16.3	16.2	16.0	15.9	15.7
	p1_r	130.8	130.8	130.8	130.8	130.8	130.8	130.8	130.8	130.9	130.9	130.9
	p1_l	239	235	232	228	224	221	217	213	209	206	202
	p2_l	129	129	129	129	129	128	128	128	128	128	128
	q_r	10.24	10.24	10.24	10.24	10.24	10.24	10.24	10.24	10.24	10.24	10.23
	q_l	3.98	4.03	4.09	4.14	4.20	4.25	4.31	4.36	4.42	4.47	4.52
	CS_r	1.753	1.753	1.753	1.753	1.753	1.753	1.753	1.753	1.753	1.753	1.753
	CS_l	0.676	0.730	0.793	0.869	0.961	1.079	1.233	1.447	1.763	2.287	3.326
	Profits	0.128	0.124	0.119	0.115	0.110	0.106	0.101	0.097	0.092	0.087	0.083
	W	2.557	2.607	2.665	2.737	2.825	2.938	3.088	3.296	3.608	4.127	5.161

2012	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Optimized Scenario	a	8.9	9.2	9.6	9.9	10.3	10.8	11.3	11.9	12.5	13.4	14.5
	p1_r	121	121	122	122	122	123	123	123	123	123	123
	p1_l	236	232	228	224	221	217	213	210	207	204	201
	p2_l	121	121	122	122	122	123	123	124	124	125	126

(*continued*)

2012	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
	q_r	10.53	10.52	10.51	10.50	10.49	10.48	10.47	10.47	10.46	10.46	10.46
	q_l	4.05	4.10	4.15	4.20	4.25	4.29	4.34	4.39	4.44	4.48	4.53
	CS_r	1.874	1.870	1.867	1.863	1.860	1.857	1.854	1.851	1.850	1.849	1.849
	CS_l	0.703	0.756	0.818	0.893	0.985	1.101	1.253	1.464	1.778	2.297	3.331
	Profits	−0.002	−0.002	−0.002	−0.001	−0.000	0.001	0.002	0.004	0.006	0.008	0.012
	W	2.577	2.626	2.685	2.756	2.844	2.957	3.107	3.316	3.628	4.146	5.180

2012	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Partial Liberalization Scenario	a	6.8	6.0	8.3	9.3	10.3	11.4	12.6	14.0	15.4	17.0	18.7
	p1_r	121	121	122	122	122	122	122	122	122	121	121
	p2_r	119	118	120	121	122	123	125	126	127	129	131
	p1_l	235	230	227	224	220	217	214	211	209	207	205
	p2_l	119	118	120	121	122	123	125	126	127	129	131
	q_r	10.48	10.47	10.42	10.39	10.36	10.34	10.31	10.28	10.25	10.23	10.20
	q_l	4.06	4.13	4.16	4.20	4.25	4.29	4.33	4.38	4.42	4.47	4.52
	CS_r	2.338	2.445	2.551	2.696	2.878	3.114	3.431	3.878	4.551	5.677	7.936
	CS_l	0.710	0.767	0.823	0.895	0.985	1.098	1.248	1.456	1.766	2.282	3.313
	Profits	−0.000	−0.008	0.000	0.000	0.000	0.000	0.000	−0.000	−0.000	0.000	0.000
	W	3.048	3.212	3.374	3.591	3.863	4.212	4.679	5.334	6.317	7.959	11.248

2012	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Full Liberalization Scenario	a	−21.7	−19.2	−16.9	−14.6	−12.5	−10.5	−8.6	−6.7	−4.9	−3.2	−1.6
	p1_r	243	237	231	225	220	214	209	204	199	194	189
	p2_r	90	93	95	97	99	101	103	105	107	109	110
	p1_l	223	219	215	211	207	203	199	196	193	189	186
	p2_l	90	93	95	97	99	101	103	105	107	109	110
	q_r	9.38	9.46	9.53	9.60	9.67	9.74	9.80	9.86	9.93	9.99	10.04
	q_l	4.31	4.34	4.37	4.40	4.42	4.45	4.47	4.50	4.52	4.55	4.58
	CS_r	2.034	2.147	2.280	2.441	2.639	2.891	3.224	3.686	4.374	5.515	7.787
	CS_l	0.809	0.857	0.915	0.986	1.073	1.185	1.334	1.541	1.852	2.370	3.403
	Profits	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	W	2.843	3.004	3.196	3.427	3.712	4.076	4.558	5.227	6.226	7.884	11.190

Notes: (1) Prices are in US$ per MWh; quantities are in millions of MWh; surpluses are in billions of US$.
(2) Each value corresponds to the average of 1000 runs.
Source: Own elaboration.

2013	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Current Scenario	a	16.5	16.4	16.3	16.2	16.1	16.0	15.8	15.7	15.6	15.4	15.3
	p1_r	125.4	125.4	125.4	125.4	125.4	125.4	125.4	125.4	125.4	125.4	125.5
	p1_l	235	231	228	224	220	216	212	208	205	201	197
	p2_l	124	123	123	123	123	123	123	123	123	122	122
	q_r	11.51	11.51	11.51	11.51	11.51	11.51	11.51	11.51	11.51	11.51	11.51
	q_l	3.88	3.93	3.99	4.04	4.09	4.14	4.19	4.24	4.29	4.34	4.39
	CS_r	2.002	2.002	2.002	2.002	2.002	2.002	2.002	2.002	2.002	2.002	2.001
	CS_l	0.669	0.722	0.783	0.857	0.947	1.061	1.211	1.418	1.725	2.232	3.238
	Profits	0.127	0.122	0.118	0.113	0.109	0.104	0.099	0.095	0.090	0.085	0.080
	W	2.798	2.846	2.903	2.972	3.058	3.167	3.312	3.515	3.817	4.319	5.320

2013	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Optimized Scenario	a	9.3	9.6	10.0	10.4	10.8	11.2	11.8	12.4	13.1	14.1	15.4
	p1_r	116	117	117	117	118	118	118	118	118	118	118
	p1_l	232	228	224	221	217	213	209	206	203	200	197
	p2_l	116	117	117	117	118	118	119	119	120	121	122
	q_r	11.80	11.79	11.78	11.77	11.76	11.75	11.75	11.74	11.74	11.73	11.74
	q_l	3.94	3.99	4.04	4.08	4.13	4.17	4.22	4.26	4.31	4.35	4.39
	CS_r	2.128	2.124	2.120	2.117	2.113	2.110	2.108	2.105	2.104	2.103	2.104
	CS_l	0.692	0.744	0.805	0.877	0.966	1.079	1.227	1.431	1.735	2.237	3.238
	Profits	−0.001	−0.001	−0.000	0.000	0.001	0.002	0.004	0.006	0.008	0.011	0.015
	W	2.820	2.868	2.925	2.994	3.080	3.189	3.334	3.536	3.839	4.340	5.342

2013	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Partial Liberalization Scenario	a	8.1	8.9	9.8	10.7	11.8	13.0	14.4	15.9	17.6	19.3	21.2
	p1_r	116	117	117	117	117	117	117	117	117	116	115
	p2_r	115	116	117	118	119	120	121	123	125	126	128
	p1_l	232	228	224	221	217	214	211	209	206	204	202
	p2_l	115	116	117	118	119	120	121	123	125	126	128
	q_r	11.70	11.67	11.63	11.59	11.56	11.52	11.48	11.44	11.40	11.36	11.32

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2013	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
	q_l	3.95	3.99	4.04	4.08	4.12	4.16	4.20	4.24	4.28	4.33	4.37
	CS_r	2.636	2.743	2.872	3.032	3.233	3.494	3.845	4.339	5.083	6.329	8.828
	CS_l	0.696	0.747	0.805	0.876	0.962	1.072	1.216	1.417	1.717	2.215	3.213
	Profits	0.000	0.000	0.000	0.000	−0.000	0.000	−0.000	−0.000	−0.000	0.000	0.000
	W	3.332	3.489	3.677	3.908	4.195	4.566	5.061	5.756	6.800	8.545	12.041
2013	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Full Liberalization Scenario	a	−22.8	−20.3	−17.8	−15.5	−13.3	−11.2	−9.2	−7.3	−5.5	−3.7	−2.0
	p1_r	239	233	227	221	215	210	204	199	194	189	184
	p2_r	84	87	89	91	94	96	98	100	102	103	105
	p1_l	219	215	210	206	202	198	195	191	188	184	181
	p2_l	84	87	89	91	94	96	98	100	102	103	105
	q_r	10.51	10.59	10.67	10.74	10.81	10.87	10.94	11.00	11.05	11.11	11.15
	q_l	4.21	4.24	4.26	4.28	4.31	4.33	4.35	4.38	4.40	4.42	4.44
	CS_r	2.309	2.434	2.582	2.760	2.980	3.259	3.627	4.139	4.900	6.163	8.678
	CS_l	0.801	0.848	0.904	0.972	1.057	1.165	1.309	1.511	1.812	2.312	3.313
	Profits	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	W	3.109	3.282	3.486	3.732	4.036	4.424	4.937	5.649	6.712	8.475	11.991

Notes: (1) Prices are in US$ per MWh; quantities are in millions of MWh; surpluses are in billions of US$.
(2) Each value corresponds to the average of 1000 runs.
Source: Own elaboration.

2014	Σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Current Scenario	a	16.0	15.9	15.8	15.7	15.6	15.4	15.3	15.2	15.0	14.9	14.7
	p1_r	127.1	127.1	127.1	127.1	127.1	127.1	127.1	127.1	127.1	127.1	127.1
	p1_l	236	232	229	225	221	217	214	210	206	202	198
	p2_l	125	125	125	125	125	125	124	124	124	124	124
	q_r	11.83	11.83	11.83	11.83	11.83	11.83	11.83	11.83	11.83	11.83	11.83
	q_l	3.55	3.60	3.65	3.70	3.74	3.79	3.84	3.89	3.93	3.98	4.02
	CS_r	2.048	2.048	2.048	2.048	2.048	2.048	2.048	2.048	2.048	2.047	2.047
	CS_l	0.610	0.658	0.714	0.781	0.864	0.969	1.106	1.296	1.577	2.041	2.964
	Profits	0.116	0.111	0.107	0.103	0.099	0.095	0.091	0.086	0.082	0.078	0.074
	W	2.773	2.817	2.869	2.933	3.011	3.111	3.244	3.430	3.707	4.167	5.084
2014	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Optimized Scenario	a	9.8	10.1	10.5	10.9	11.3	11.8	12.4	13.1	14.0	15.2	16.8
	p1_r	119	119	119	120	120	120	120	120	120	120	120
	p1_l	234	230	226	222	219	215	212	208	205	202	200
	p2_l	119	119	120	120	120	121	122	122	123	124	126
	q_r	12.11	12.10	12.09	12.08	12.07	12.07	12.06	12.05	12.05	12.05	12.06
	q_l	3.60	3.64	3.69	3.73	3.77	3.82	3.86	3.90	3.94	3.98	4.02
	CS_r	2.168	2.164	2.161	2.158	2.155	2.153	2.151	2.149	2.148	2.149	2.151
	CS_l	0.628	0.675	0.731	0.797	0.878	0.981	1.116	1.303	1.581	2.040	2.955
	Profits	0.001	0.001	0.002	0.003	0.004	0.005	0.007	0.009	0.011	0.014	0.019
	W	2.796	2.840	2.892	2.955	3.034	3.134	3.267	3.452	3.729	4.189	5.107
2014	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Partial Liberalization Scenario	a	11.6	11.8	12.4	13.5	14.8	16.2	17.7	19.4	21.2	23.1	25.2
	p1_r	119	119	119	119	119	119	119	119	118	117	117
	p2_r	121	121	121	123	124	125	127	128	130	132	134
	p1_l	234	231	227	224	221	218	215	213	211	209	208
	p2_l	121	121	121	123	124	125	127	128	130	132	134
	q_r	11.97	11.95	11.93	11.89	11.86	11.83	11.79	11.76	11.73	11.69	11.66
	q_l	3.58	3.63	3.67	3.71	3.75	3.79	3.83	3.86	3.90	3.95	3.99
	CS_r	2.670	2.786	2.924	3.089	3.297	3.567	3.929	4.440	5.209	6.496	9.078
	CS_l	0.623	0.670	0.725	0.788	0.867	0.966	1.097	1.280	1.554	2.010	2.923
	Profits	0.006	0.002	0.000	0.000	0.000	0.000	0.000	−0.000	0.000	0.000	0.000
	W	3.293	3.456	3.648	3.877	4.164	4.533	5.027	5.720	6.763	8.506	12.001
2014	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Full Liberalization Scenario	a	−23.1	−20.6	−18.2	−15.9	−13.7	−11.6	−9.6	−7.7	−5.9	−4.1	−2.4
	p1_r	240	234	228	222	216	211	206	201	196	191	186
	p2_r	86	89	91	93	95	98	100	101	103	105	107
	p1_l	220	216	212	208	204	200	196	193	189	186	183
	p2_l	86	89	91	93	95	98	100	101	103	105	107
	q_r	10.82	10.90	10.98	11.05	11.13	11.20	11.27	11.33	11.39	11.45	11.51

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(*continued*)

2014	Σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
	q_l	3.85	3.88	3.90	3.92	3.94	3.96	3.99	4.01	4.03	4.05	4.07
	CS_r	2.367	2.496	2.649	2.832	3.059	3.347	3.727	4.255	5.042	6.346	8.943
	CS_l	0.730	0.773	0.824	0.887	0.964	1.064	1.195	1.380	1.656	2.114	3.031
	Profits	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	W	3.097	3.269	3.473	3.719	4.023	4.411	4.923	5.635	6.697	8.460	11.974

Notes: (1) Prices are in US$ per MWh; quantities are in millions of MWh; surpluses are in billions of US$.
(2) Each value corresponds to the average of 1000 runs.
Source: Own elaboration.

2015	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Current Scenario	a	16.5	16.4	16.3	16.2	16.1	16.0	15.8	15.7	15.6	14.4	14.2
	p1_r	125.4	125.4	125.4	125.4	125.4	125.4	125.4	125.4	125.4	127.2	127.2
	p1_l	235	231	228	224	220	216	212	208	205	202	198
	p2_l	124	123	123	123	123	123	123	123	123	124	124
	q_r	12.39	12.39	12.39	12.39	12.39	12.39	12.39	12.39	12.39	12.39	12.39
	q_l	3.28	3.33	3.37	3.42	3.46	3.50	3.55	3.59	3.63	3.68	3.72
	CS_r	2.002	2.002	2.002	2.002	2.002	2.002	2.002	2.002	2.002	2.144	2.144
	CS_l	0.669	0.722	0.783	0.857	0.947	1.061	1.211	1.418	1.725	1.886	2.739
	Profits	0.127	0.122	0.118	0.113	0.109	0.104	0.099	0.095	0.090	0.072	0.068
	W	2.798	2.846	2.903	2.972	3.058	3.167	3.312	3.515	3.817	4.102	4.950
2015	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Optimized Scenario	a	9.3	9.6	10.0	10.4	10.8	11.2	11.8	12.4	13.1	16.3	18.3
	p1_r	116	117	117	117	118	118	118	118	118	121	120
	p1_l	232	228	224	221	217	213	209	206	203	204	202
	p2_l	116	117	117	117	118	118	119	119	120	126	128
	q_r	12.65	12.64	12.64	12.63	12.62	12.62	12.61	12.61	12.61	12.61	12.62
	q_l	3.32	3.36	3.40	3.44	3.48	3.52	3.56	3.60	3.63	3.67	3.71
	CS_r	2.128	2.124	2.120	2.117	2.113	2.110	2.108	2.105	2.104	2.246	2.250
	CS_l	0.692	0.744	0.805	0.877	0.966	1.079	1.227	1.431	1.735	1.880	2.724
	Profits	−0.001	−0.001	−0.000	0.000	0.001	0.002	0.004	0.006	0.008	0.017	0.022
	W	2.820	2.868	2.925	2.994	3.080	3.189	3.334	3.536	3.839	4.126	4.974
2015	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Partial Liberalization Scenario	a	12.7	13.7	14.8	16.1	17.5	19.1	20.8	22.6	24.6	26.6	28.7
	p1_r	120	120	120	120	120	120	119	119	118	118	117
	p2_r	122	123	124	126	127	129	130	132	134	136	138
	p1_l	235	232	228	225	223	220	218	216	214	212	211
	p2_l	122	123	124	126	127	129	130	132	134	136	138
	q_r	12.51	12.48	12.44	12.41	12.38	12.35	12.32	12.29	12.26	12.23	12.20
	q_l	3.30	3.34	3.38	3.41	3.45	3.48	3.52	3.55	3.59	3.63	3.68
	CS_r	2.783	2.899	3.039	3.212	3.430	3.713	4.092	4.627	5.432	6.781	9.485
	CS_l	0.572	0.613	0.662	0.720	0.791	0.882	1.003	1.171	1.423	1.843	2.686
	Profits	0.000	0.000	0.000	0.000	−0.000	0.000	−0.000	−0.000	0.000	−0.000	−0.000
	W	3.354	3.512	3.700	3.932	4.221	4.595	5.095	5.798	6.855	8.624	12.171
2015	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Full Liberalization Scenario	a	−23.6	−21.0	−18.6	−16.3	−14.1	−12.0	−10.0	−8.1	−6.2	−4.5	−2.8
	p1_r	240	234	228	222	216	211	206	201	196	191	186
	p2_r	86	89	91	93	95	98	100	101	103	105	107
	p1_l	220	216	212	208	204	200	196	193	189	186	183
	p2_l	86	89	91	93	95	98	100	101	103	105	107
	q_r	11.34	11.42	11.50	11.58	11.66	11.73	11.80	11.87	11.93	12.00	12.05
	q_l	3.56	3.58	3.60	3.62	3.64	3.66	3.68	3.70	3.72	3.74	3.76
	CS_r	2.480	2.615	2.775	2.967	3.204	3.506	3.904	4.457	5.281	6.646	9.366
	CS_l	0.675	0.715	0.762	0.820	0.891	0.983	1.105	1.275	1.530	1.954	2.800
	Profits	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	W	3.155	3.330	3.537	3.786	4.095	4.489	5.009	5.732	6.810	8.600	12.167

Notes: (1) Prices are in US$ per MWh; quantities are in millions of MWh; surpluses are in billions of US$.
(2) Each value corresponds to the average of 1000 runs.
Source: Own elaboration.

2016	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Current Scenario	a	16.0	15.9	15.8	15.7	15.6	15.4	15.3	15.2	15.0	13.8	13.6
	p1_r	127.1	127.1	127.1	127.1	127.1	127.1	127.1	127.1	127.1	126.5	126.5
	p1_l	236	232	229	225	221	217	214	210	206	201	197
	p2_l	125	125	125	125	125	125	124	124	124	123	123
	q_r	12.84	12.84	12.84	12.84	12.84	12.84	12.84	12.84	12.84	12.84	12.84
	q_l	3.43	3.47	3.52	3.56	3.61	3.66	3.70	3.74	3.79	3.83	3.87
	CS_r	2.048	2.048	2.048	2.048	2.048	2.048	2.048	2.048	2.048	2.227	2.226
	CS_l	0.610	0.658	0.714	0.781	0.864	0.969	1.106	1.296	1.577	1.968	2.855
	Profits	0.116	0.111	0.107	0.103	0.099	0.095	0.091	0.086	0.082	0.075	0.071
	W	2.773	2.817	2.869	2.933	3.011	3.111	3.244	3.430	3.707	4.269	5.152
2016	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Optimized Scenario	a	9.8	10.1	10.5	10.9	11.3	11.8	12.4	13.1	14.0	15.9	18.0
	p1_r	119	119	119	120	120	120	120	120	120	120	120
	p1_l	234	230	226	222	219	215	212	208	205	203	201
	p2_l	119	119	120	120	120	121	122	122	123	125	127
	q_r	13.12	13.11	13.10	13.09	13.08	13.08	13.07	13.07	13.07	13.07	13.09
	q_l	3.47	3.51	3.55	3.59	3.63	3.67	3.71	3.75	3.79	3.82	3.86
	CS_r	2.168	2.164	2.161	2.158	2.155	2.153	2.151	2.149	2.148	2.333	2.337
	CS_l	0.628	0.675	0.731	0.797	0.878	0.981	1.116	1.303	1.581	1.960	2.839
	Profits	0.001	0.001	0.002	0.003	0.004	0.005	0.007	0.009	0.011	0.019	0.024
	W	2.796	2.840	2.892	2.955	3.034	3.134	3.267	3.452	3.729	4.293	5.176
2016	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Partial Liberalization Scenario	a	12.3	13.4	14.5	15.8	17.3	18.8	20.6	22.4	24.4	26.5	28.6
	p1_r	119	119	120	119	119	119	119	118	118	117	116
	p2_r	122	123	124	125	127	128	130	132	134	136	138
	p1_l	234	231	228	225	222	220	217	215	214	212	211
	p2_l	122	123	124	125	127	128	130	132	134	136	138
	q_r	12.96	12.92	12.89	12.85	12.82	12.79	12.75	12.72	12.69	12.65	12.62
	q_l	3.45	3.48	3.52	3.56	3.59	3.63	3.66	3.70	3.74	3.79	3.83
	CS_r	2.887	3.007	3.152	3.331	3.556	3.848	4.241	4.793	5.627	7.022	9.819
	CS_l	0.597	0.640	0.691	0.751	0.826	0.921	1.046	1.221	1.483	1.921	2.799
	Profits	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	−0.000	0.000	0.000
	W	3.484	3.647	3.842	4.082	4.382	4.769	5.287	6.014	7.110	8.943	12.618
2016	σ	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Full Liberalization Scenario	a	−24.1	−21.6	−19.1	−16.8	−14.6	−12.5	−10.5	−8.6	−6.7	−5.0	−3.3
	p1_r	239	233	227	221	216	210	205	200	195	190	185
	p2_r	85	88	90	93	95	97	99	101	103	104	106
	p1_l	220	215	211	207	203	199	196	192	189	185	182
	p2_l	85	88	90	93	95	97	99	101	103	104	106
	q_r	11.74	11.83	11.91	11.99	12.07	12.15	12.22	12.29	12.35	12.42	12.47
	q_l	3.72	3.74	3.76	3.78	3.80	3.82	3.84	3.86	3.88	3.90	3.91
	CS_r	2.573	2.713	2.878	3.077	3.323	3.635	4.047	4.619	5.471	6.883	9.697
	CS_l	0.705	0.747	0.796	0.856	0.931	1.026	1.153	1.330	1.596	2.037	2.919
	Profits	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	W	3.278	3.460	3.674	3.933	4.253	4.661	5.200	5.949	7.066	8.920	12.616

Notes: (1) Prices are in US$ per MWh; quantities are in millions of MWh; surpluses are in billions of US$.
(2) Each value corresponds to the average of 1000 runs.
Source: Own elaboration.

A.2 Standard deviations for each average per year simulation

Average per Year	σ	std a	std P1_r	std P2_r	std P1_l	std P2_l	std W
Current Scenario	0,4	0,71	4,08		9,22	3,94	0,03
	0,45	0,72	3,95		8,93	3,88	0,04
	0,5	0,68	3,96		8,62	3,82	0,03
	0,55	0,70	4,16		8,21	3,93	0,03
	0,6	0,65	4,04		8,02	3,88	0,04
	0,65	0,67	4,02		7,24	3,92	0,05
	0,7	0,67	4,02		7,11	3,92	0,07
	0,75	0,66	4,02		6,99	3,92	0,10
	0,8	0,64	4,35		6,76	3,76	0,15
	0,85	0,67	4,16		7,39	3,90	0,30
	0,9	0,62	4,28		6,03	3,72	0,23

Note: Each value is obtained from 1000 runs for each combination of diversion ratio and year.
Source: Own elaboration.

Average per Year	σ	std a	std P1_r	std P2_r	std P1_l	std P2_l	std W
Optimized Scenario	0,4	0,52	4,16		7,60	3,36	0,01
	0,45	0,53	4,17		6,89	3,46	0,02
	0,5	0,57	4,06		5,77	3,45	0,02
	0,55	0,76	3,96		5,28	4,05	0,03
	0,6	1,09	3,87		5,24	5,12	0,04
	0,65	1,16	3,86		4,89	4,83	0,05
	0,7	1,20	3,84		4,70	4,56	0,06
	0,75	1,35	3,88		4,87	4,73	0,08
	0,8	1,38	3,92		4,76	4,36	0,11
	0,85	1,50	3,90		4,68	4,21	0,16
	0,9	1,61	3,95		4,66	4,05	0,26

Note: Each value is obtained from 1000 runs for each combination of diversion ratio and year.
Source: Own elaboration.

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Average per Year	σ	std a	std P1_r	std P2_r	std P1_l	std P2_l	std W
Partial Liberalization Scenario	0,4	1,11	2,86	4,39	8,00	4,77	0,04
	0,45	1,06	2,68	4,60	8,18	4,50	0,04
	0,5	1,04	2,47	4,20	7,74	4,07	0,04
	0,55	1,07	2,43	3,98	6,99	3,97	0,05
	0,6	1,01	2,40	3,89	6,98	3,94	0,05
	0,65	1,00	2,98	4,01	6,46	3,64	0,07
	0,7	1,02	4,06	4,05	6,26	3,45	0,10
	0,75	1,16	4,79	3,83	5,86	3,56	0,16
	0,8	2,53	5,55	4,76	6,40	4,71	0,27
	0,85	5,03	8,15	7,44	9,54	7,20	0,60
	0,9	1,74	4,14	4,11	5,09	3,50	0,51

Note: Each value is obtained from 1000 runs for each combination of diversion ratio and year.
Source: Own elaboration.

Average per Year	σ	std a	std P1_r	std P2_r	std P1_l	std P2_l	std W
Full Liberalization Scenario	0,4	2,97	8,98	4,36	8,41	4,88	0,16
	0,45	2,56	8,27	4,19	7,86	4,69	0,16
	0,5	2,36	8,20	4,14	7,43	4,74	0,17
	0,55	1,96	7,34	4,06	6,95	4,57	0,17
	0,6	1,66	5,46	3,45	5,69	3,80	0,15
	0,65	1,37	6,65	4,11	6,41	4,39	0,19
	0,7	1,36	6,01	3,90	6,37	4,51	0,21
	0,75	0,83	5,84	3,99	6,02	4,41	0,23
	0,8	0,74	5,30	3,88	6,14	4,21	0,26
	0,85	0,67	5,23	3,92	5,46	4,20	0,32
	0,9	0,45	4,70	3,84	5,12	4,23	0,45

Note: Each value is obtained from 1000 runs for each combination of diversion ratio and year.
Source: Own elaboration.

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