Mandatory electricity contracts as competitive device

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Abstract

Long-term contracts have been often advocated as an effective remedy against market power in the electricity industry, but when contract demand by risk-averse retailers facing increasing competition is considered, an inefficient level of bilateral agreements will emerge in equilibrium. We argue that contracts markets alone are not well suited to prevent the insurgence of anticompetitive practices and have to be complemented by active behavioural prescriptions or/and interventions. Among the pro-competitive regulation practices, we study the contractual obligation measures. Building on Green (2003a), we examine whether and under what conditions such measures would retrieve marginal cost pricing in the spot market, under alternative regulatory scenarios. We discuss in particular the trade-off between the pro-competitive and the crowding-out effects of the contractual obligation and drive several policy implications.

Keywords: electricity markets, retail competition, regulation.

JEL code numbers: C72, L13, L94.

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1 Introduction

Liberalization of energy markets brought transformations into the organization and functioning of that industry around the world. Regulated vertically integrated monopolies have left room to new institutional frameworks in which natural monopolies (transmission and distribution) and potentially competitive markets (generation, wholesale and retail supply) coexist. To introduce competition and to guarantee coordination between separated segments of the industry, wholesale market operations have been widely organized as compulsory uniform first price auctions (hereafter spot markets).

However, latest international events draw attention to a number of unsatisfactory aspects of the ongoing liberalization processes, especially with respect to a pure spot market mechanism, and highlighted the debate on the role of regulation to prevent excessive prices (Bushnell, 2003; Newbery, 2002; Wolak, 2004; EC Commission first, second and third benchmarking reports, 2001 and 2003). Power markets have demonstrated to be intrinsically vulnerable to the exercise of market power. Economic theory and empirical evidence suggest that in addition to highly concentrated market structures, industry-specific factors (such that low price responsiveness on the demand-side, cyclicality and seasonality, lack of storability and non convexity of supply) and inappropriate market design rules exacerbate the ability of suppliers to exploit their "pivotal positions" (Wolak and Patrick, 1997; Borenstein and Buschnell, 2000; Wolak, 2000b; Wilson, 2002). Spot markets have proved to be prone to the strategic price manipulation or capacity withholding by traders (Le Coq, 2002; Crampes and Creti, 2003; Green, 2004)\(^1\). Albeit academic debate on the performance of uniform price auctions (spot markets) versus pay-as-bid format type of auction (voluntary bilateral trading)\(^2\) is still subject to dispute (Fabra, von der Fehr, and Harbord, 2004), excessive reliance on spot markets and limitation to long-term contracting as been further indicated as one main factor explaining deregulation reforms’ failure (Joskow, 2003).

The degree of confidence on market mechanisms to prevent anti-competitive practices has, thus, been put under question. This issue is central as retailing markets are progressively open to competition and policy goals are shifting to strengthen provisions regarding consumer protection. Policy makers have adopted the view that conditions for effective and undistorted competition in power markets must be fostered by the application of so called "pro-competitive" regulation which is not limited to the abolition of monopoly regulation or the introduction of structural remedies. Rather, active behavioral measures have the aim to promote the accomplishment of welfare-improving

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\(^1\) Generators engage in "economic withholding" when they do not offer output at a market price high enough to cover its cost but wait until the price is above the cost of generating output. "Physical withholding" implies that generators do not produce at any price.

\(^2\) Long term bilateral transactions may involved future physical delivery of energy or financial compensation underlying energy exchanges. In this latter case a spot market might be the used to realize the physical exchange. We will refer to a mixed trading system as the combination of a market for contract (voluntary trade) supplemented by a spot power exchange.
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outcomes through the application of same form of control or monitoring of prices or by affecting firms ability to influence strategically market conditions (DOE, 2000; Newbery, 2002; Bushnell, 2003). However, it is important to notice that when selecting a remedy, regulators should be aware of the impact on firms incentives to compete of every regulatory scheme not to trigger further unnecessary distortions (Viscusi, Vernon and Harrington, 2001).

In this vein, the promotion of voluntary bilateral contracting has been judged a flexible tool to mitigate market power\(^3\). The theoretical argument behind the effectiveness of bilateral long-term contracting in constraining suppliers anticompetitive strategic behavior is due to Allaz and Vila (1993; hereafter A-V). Engaging in forward sales represent a strategic pre-commitment to larger levels of output. The emergence of competitive market for contracts alters firms incentives to compete and enhances efficiency. Under specific conditions, marginal cost-pricing would emerge as an equilibrium in the spot market.

A vast successive literature addressed interest on the competitive implications driven by the interaction between forward and spot markets in the deregulated electricity industries. Evidences show that A-V findings are very sensitive to modelling assumptions; indeed, when changes in the setting are introduces, controversial conclusions might emerges (e.g. von der Fehr and Harbord, 1992; Powell, 1993; Newbery, 1998 and 2002; Green, 1999; Wolak, 2000a; Joskow, 2003). According to Green (2003a) when demand for contracts arises from risk-averse retailers facing increasing competition, to little bilateral agreements will be signed at equilibrium. Spot prices will be far above competitive levels. This allows him to conclude that the mere implementation of a market for contracts is not well suited to prevent the exercise of market power. A monopolistic retailer regulated by yardstick competition makes the consumers better off than a liberalized retail market.

Nevertheless, as the full opening to competition is a key point in the electricity market reforms worldwide, regulating monopolistic incumbent retailers does not appear to be an appropriate solution. This is way we draw attention on alternative pro-competitive policies that can be implemented to reduce the incentive and ability of firms to exercise market power. Joskow and Tirole (2004) refer to those kind of interventions as non-market mechanisms imposed on the emerging competitive wholesale and retail electricity markets and pointed out that ”much of the economic analysis of the behavior and performance of wholesale and retail markets has either ignored these non-market mechanisms or failed to consider them in a comprehensive fashion”. Our work differs from the existing literature, mainly interested in the analysis of the competitive mechanisms underlying forward-spot market interaction, since its purpose is to contribute to this emerging debate.

We explicitly screen country-specific contractual regimes that have been adopted or debated as a tool to promote the diffusion of long term contracting. The main objective is to examine

\(^3\)An emblematic case of this aproach is represented by the electricity market reform in England and Wales. In 2001, the compulsory pool has been abolished in favour to a new set of trading rules that promote a mixed trading system (New Electricity Trading Agreements; OFGEM 1999).
whether and under what conditions a contractual obligation is an effective instrument to restore a competitive equilibrium in the spot market i.e. recoup the efficiency-enhancing effect of forward contracting. This suggests us to introduce into Green’s framework different regulatory scenarios in order to mirror country-specific solutions reflecting contractual requirements imposed on generators (upstream measure), on retailers (downstream measure) or on either operators (vertical measure).

There are two effects at stake: on one side, we expect that imposing a contractual obligation will increase total contracting, mimicking the pro-competitive effect explained by A-V; on the other, as in our model mandatory contracts are strategic substitutes for private ones, a crowding-out effect emerges.

Although the inspiration of the work refers to practical experiences, the model is of interest in its own as it investigates the impact of one "light behavioral" measure on the incentives for producers and retailers to further privately contract forward. Given that we introduce a constraint on the strategic set of actions available to market participants, our main point of interest is to identify an optimal measure, for each regulatory environment, that maximizes the consumers’ welfare objective subject to the generators breakeven constraint. We are able to rank Nash solutions and to select, across regulatory environment, the one that promotes the most liquid forward market.

From a policy perspective, we found that mandatory contracts imposed vertically on both generators and retailers do not solve the inefficient contracting problem pointed out by Green. Instead, contractual obligations imposed only on generators (upstream measures) or on retailers (downstream measures) do constitute effective tools. However, this kind of optimal behavioral regulation proves to be too pervasive if applied on generators; the regulator faces a tradeoff between alleviating market power and affecting negatively the development of an active and voluntary-based forward market. At optimum, the asymmetric downstream measure has the advantage to better control for the crowding-out effect and, thus, appears to be a rather more flexible tool compatible with minimum contractual requirements, also in the spirit of "security of supply" objectives. It is furthermore interesting to notice that the application of downstream measures solves the inefficiency mainly due to risk-aversion pointed out by the previous literature, as it contributes to increase demand-side responsiveness.

As suggested above, those findings are of particular interest as they provide a theoretical ground to the empirical evidences of an increasing attention to light hand regulatory mechanisms applied to the retailing markets.

The work proceeds as follow. Next section arguments the ideas behind the pro-competitive regulation practices and illustrate the country-specific implementation experiences of «contract remedies» to market power. Section 3 presents the literature related to our work, whereas Section 4 is devoted to model setting. Sections 5 explores the introduction of a long-term contracting obligation and shows how the equilibrium in the spot market is affected. The optimal policy, i.e. the level of mandatory contracts that maximize the consumer’s welfare, is discussed in Section 6.
Nash solutions are ranked at optimum to allow comparisons across different regulatory scenarios (Section 7). Some policy recommendations conclude our paper (Section 8). Main proofs are presented in the appendix.

2 Pro-competitive policies

In order to introduce competition in the electricity industry, deregulation efforts have mainly been focused on the abolition of exclusive rights in the generation and supply of electricity. The elimination of any legal restrictions would have created competitive playing fields and fostered the emergence of more competitive structures. Economic regulation (price, quantity, quality and entry/exit control) was eventually limited to «natural monopoly» segments as the assessment of non discriminatory access rules for transmission networks. To emulate the coordination, and favour complementarities, among newly liberalized but technically and economically interrelated activities, mandatory spot markets have been commonly set into operation. As in the vertically integrated paradigm, this market design grants a centralized dispatch of energy. From an economic viewpoint, under the merit order mechanism a single marginal price prevails in equilibrium.

Outside those very general guidelines, restructuring paths have varied considerably across countries. However, regardless of the form of the liberalization architecture implemented, a foremost issue within the industry has been the exercise of market power. The most traditional remedy to deal with market power is to rely on a competitive market structure and a strict enforcement of antitrust laws prohibiting anti-competitive behaviors. Indeed, antitrust legislation has a confined degree of applicability as it can only pursue ex post dominant firm(s) engaging in abusive conducts. By definition, a market strategy constitute an infringement of the antitrust law if a firm holding a "significant market power" use his competitive advantage to exploit consumers or to restrict, distort or prevent competition - creating barrier to entry and/or excluding rivals. Electricity markets have proved to be intrinsically vulnerable to market power exploitation. Those failures have been exacerbated not only by deficiencies in market structures but also in the rules set to govern market operations and by peculiar characteristics of demand and supply in the electricity sector, as we already argued. This is why it has been claimed that public authorities cannot just be reliant on market processes and antitrust law to deal with this issue (see for instance Report on Market Power, U.S. Department of Energy, 2000).

4For example, the EU Directive 96/92/EC on the internal market of electricity, displayed only minimum common requirements, leaving to each Member State the choice among various provisions and options to implement market opening. Specifically, access regimes could have been governed by either a regulated third party access or an a negotiated basis. The new Directive ___ overcame this framework ___


6Traditionally, for durable goods industries, the market power test indicate a "competitive harm" when the firm
In addition, as retailing markets opened to competition, demand will be furthermore characterized by consumers with strong preferences for stable final prices as they have been exposed, under regulated regimes, to constant retail rates,\textsuperscript{7} with contractual adjustments eventually made on annual bases. Therefore, public policy goals are progressively been focused to strengthen provisions regarding public service obligations, consumer protection and security of electricity supply.\textsuperscript{8}

In this vein, it has been suggested that regulation does not have to be confined to natural monopoly activities «for potentially competitive elements still need regulatory oversight to ensure that markets are not manipulated nor market power abused (Newbery, 2002)». Moreover, «regulation may be favoured if market designer is unable to establish a sufficiently competitive market so that prices are vastly in excess of the marginal cost» (Wolak, 2004). The problem being to prevent the insurgence of strategic behaviors leading to inefficient outcomes (that is withholding of generation capacity and unexpectedly high wholesale prices), attention can be restricted to measures that discipline generators incentives to manipulate quantities or prices in the supply markets. However, an important lesson derived from wholesale market failures is that regulatory mechanisms that worked in the former vertically-integrated monopoly regimes are inappropriate for competitive wholesale market regimes (Patrick and Wolak, 1997). Indeed, market designer must recognize the impact of regulatory mechanisms on supplier behavior, that is to design public interventions which are compatible with the individual rationality and the participation constraints.

Practical concerns and the above theoretical view have driven policy makers with the desire to implement more effective regulatory reforms better suited to influence firms’ market conducts and achieve specific outcomes. This has meant to put an emphasis on the application of so called ex ante pro-competitive regulation in the form of alternative "light hands" tools to traditional

\textsuperscript{7}In EU Member States all customers will be free to choose their downstream retailer by July 2007 (see Directive 2003/54/EC of the European Parliament and of the Council of 26 June 2003 concerning common rules for the internal market in electricity and repealing Directive 96/92/EC, published in Official Journal L 176 , 15/07/2003 P. 0037 – 0056)

\textsuperscript{8}To ensure the security of supply, that is avoid supply scarcity and market failure, the EU Commission foresee the possibility that "Member States oblige suppliers to enter into long-term contracts with generators". Long-term obligations are explicitly indicated as one of the regulatory options available to Member State to promote generation adequacy, as well as the implementation of tenders for the construction of additional plants or the application of different capacity mechanisms on players on the market to maintain reserves. It is observed, however, that one main disadvantage of “long-term” contract is associated with the possibility for eligible customers to switch to suppliers with less expensive contracts. See the Note of the DG Energy & Transport on Directives 2003/54/EC and 2003/55/EC and on the Internal Market in Electricity and Natural Gas "Measures to secure Electricity Supply", January 16, 2004.
economic regulation or remedies that affect directly market structure. The drawback is that micro-
regulation of prices or interventions to achieve specific market outcomes, specifically with respect
to spot markets, might have, in same cases, a direct aim to restore control over wholesale prices\(^9\).

### 2.1 Spot market regulation

For the reasons indicated above, policy makers are interested to insulate downstream markets from
excessive wholesale prices fluctuations and to overcome short term supply scarcity. To deal with
such an issues, regulators have in some cases substituted away market forces to achieve specific
wholesale market outcomes. This is particularly true in the case of supply markets where electricity
transactions are governed by spot mechanisms. To discipline the determination of wholesale prices,
almost every centralized spot markets have experienced the application of some form of transitory
or permanent price or quantity controls, as for instance price caps (Bushnell and Borenstein, 2000).
Clearly the objective is to limit the variance of wholesale spot prices and prevent buyers’ financial
exposition. However, price-caps implicitly determine the scarcity value of the energy and therefore
might provide short-term protection but hinder long-term market efficiency. Price volatility itself
might be desirable when it transmit the "right" signal to agents about market conditions.

Another means to alleviate market inefficiencies due to market power manipulations is to rely
on a more price elastic demand-side. To enhance price responsiveness, end-use consumers should
be confronted with real-time prices. This can be achieved, on one hand, by fostering the participation
of demand in the spot markets or/and the promotion of the installation and usage of time day
metering technologies. Interventions might also be focused to promote product substitutability,
that is encouraging intra-fuel competition, self-generation of electricity or the subscription of inter-
ruptible contracts. However, those latter tools are mainly addressed to energy intensive consumers
(as large industrial buyers). Furthermore, a large amount of uncertainty still remains on their
usage and the impact of such a policies on consumers behavior.

### 2.2 Contract market regulation

A far most interesting regulatory instrument is represented by "contractual remedies". Long-term
contracts might take the form of financial or physical agreements, on energy flows or capacity,
and, therefore, accomplish several goals spanning from risk-hedging against spot price volatility,
to provision for ensuring generation adequacy. It is interesting to notice that this implies a large
flexibility on the usage of such an instrument. Indeed, physical agreements are likely to be applied
either to secure the supply of electricity, to maintain reserve margins, to promote entry of retailers
and/or generators or to mitigate market power. In this respect, long-term agreements might be

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\(^9\)This approach has been attributed to FERC when dealing the Californian electricity crisis given that among its
duties it is required to adopt actions whenever wholesale prices are not “just and reasonable”, with an attempt to
drive them to meet this parameter.
seen as alternative tools to replicate vertical integrated structures or else to implement "light hand" capacity release programs.

Mandatory contract regimes take generally the form of energy or capacity obligation on generators. In practice, a generator(s), commonly holding significant market shares, is(are) entail to devote to downstream suppliers or to rivals a share of the energy produced or of the available generating capacity. "Vesting contracts" or "contract cover" are examples of agreements that grant energy supply to retailers for a fixed price or quantity (Wilson, 2002; Wolak, 2003). Programs of capacity release might take the form of "virtual power plants" auctions\(^\text{10}\). Rivals are therefore able to acquire, under market conditions and on a long-term basis, the right to dispose of a share of generating capacity. This measure represent a furthermore flexible instrument to alleviate excessive degree of concentration and to allow rivals to acquire a comparable competitive size\(^\text{11}\). Finally, "reliability must run" plants constitute example of capacity requirements to lessen transmission congestions or to secure balancing or reserve margins. Those are plants holding a monopoly power in a local area, that are put under the responsibility of a system operator and run under long-term contracts with the remuneration based on audit costs (Bushnell and Wolak, 1999; Borenstein and Bushnell, 2000). Beside the above mentioned goals, it is worth mentioning that contractual obligations oblige by law generator to release part of the energy at disposal. Therefore, putting a constraint on the generator’s strategic variable choice, they provide incentives to limit strategic curtailing of output.

Another interesting aspect related to contractual regimes is the way pricing/quantity conditions as set. Contractual conditions might simply be imposed by regulators (as in the vesting contracts), or they can be assessed by standardized auctions mechanisms, as in the "virtual capacity actions" in which dominant suppliers are required to sell energy to rivals, finally regulators might only require undertaking to enter into minimum quantity long-term agreements letting the market forces to assess the price.

An indirect way to foster the use of long-term contacts is by implementing a (more or less) standardized market for contracts. Electricity exchanges conducted on the basis of private bilateral agreements represent an alternative organizational architecture for the operation and dispatch of

\(^{10}\)The European Commission condition the approval of EDF acquisition of a joint control over the German electricity utility EnBW to a capacity reallease program (M.1853, OJ L 059, 28/02/2002). The requirement tooked the form of "virtual power plants” and "power purchase agreements”. The former representing rights to nominate electricity output for delivery on the following day on the high voltage grid at a pre-defined price. There are peak-load and base-load capacity rights. The latter representing a a block of power based on the output from co-generation plants from which EDF has the obligation to purchase power at regulated tariffs under power purchase contracts.

\(^{11}\)For instance, Wolak and Patrick (1997) advocated that: “There are already [in England and Wales] many independent power producers serving the market, so that simply increasing the number of competitors is not the solution [to abusive conducts]. Given the current number of firms in the market and the market rules, what is important to limiting market power is reducing the size of the largest firm relative to all the others".
energy. At one extreme markets can be run centrally through the setting up of a compulsory spot market; on the other, bilateral contracting is referred as a decentralized trading frameworks commonly designed in conjunction with a residual spot market. The solution applied in each country would depend upon market and structural conditions as it stems from a trade-off between the need for a tight coordination of the activities and the possibility to rely greatly on market forces (Wilson, 2002).

Decentralized trading systems are not incompatible with the application of some form of regulation that is of mandatory long-term contractual regimes.

2.2.1 Country-specific practices

The operation of mandatory contractual regimes is not new. Theoretical and empirical evidence of the implementation of this kind of "light hand" behavioral regulation are given for several countries: among others, Helm and Powell (1992), Powell (1993), Newbery (1998), Green (1999) and Wolfram (1998 and 1999), bring insights on the impact of the British electricity reform on competition; Wolak (2000a) and Wilson (2002) focus on the Australian restructuring experience. Other contributions have been given for Brazil, see for example Coutinho and Rossi de Oliveira (2002) and Wolak (2003).

Although country-specific designs explain the motivation for the introduction of contractual obligations, all above mentioned regulatory experiences have common characteristics. Liberalization processes were at their early stages, that is, tight oligopoly structures were still prevailing as a model of upstream competition and a significant share of consumers continued to be served under regulated tariffs. In such frameworks, mandatory regimes required incumbent generators to enter into temporary long-term agreements with distributors. Vesting contracts were ment to provide distributors with a sufficient quantity of energy to cover non-eligible (captive) consumers for their electricity needs at stable wholesale prices. Prices of contracts were, indeed, commonly subject to regulation or regulatory approval. Even though generally set at “fairly generous levels”, compared to prices that would emerge in the spot market, the literature provides evidence that such agreements favoured, indeed, low levels of wholesale spot prices during the period they were into force. Such measures can be understood as a way to ensure a control over wholesale spot prices. As noted "if one is concerned about market power, effective price-regulation can be imposed by forcing a large enough quantity of hedge contracts [at a fixed quantity and price] on the newly privatized generators” (Wolak, 2000a). Beside a market power mitigation concerns, the application long-term contract in England and Wales is explained by a cost-sharing motivation. Newly liberalized generators were, indeed, required to use extensively national coal to generate

\[12\] Despite the difficulties of getting precise estimated, it is suggested that “85% is a conservative lower boundary on the percent of final demand covered by long-term contracts for all of these market [England and Wales, Australia and Nordic Countries, albeit this area experience a decentralized trading system]” (Wolak, 2003).
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electricity. Pricing conditions set in the vesting contracts allowed them to recover high input costs. In Australia an hedging motive prevailed given that captive consumers represented a major fraction of the national demand for electricity. In Brazil the primary objective was to encourage the development of a forward market and to entail the appearance of stand-alone dealers.

The regulatory experience in the State of Alberta stand for a failure of the public intervention. It is nonetheless useful to notice that the anticompetitive impact of a vast usage of hedging contracts was not due to the instrument itself but by the implementation of a contractual regime in a market structure characterized by vertically related undertakings. That is, the subscription of hedging contracts among dominant generators and their downstream affiliated allowed spot price manipulations discouraging new entry at the retailing level. Spot prices represented a transfer price within the same company group (Wilson, 2002).

A very much similar case is given by the New Zealand electricity industry. During 2001, New Zealand registered an unexpected rise in retail prices. A key feature of the industry structure was to be highly vertically integrated with a large volume of energy already internally hedged. Stand-alone retailers were not able to cover their sales efficiently and thus to promote competition at a retailing level. To reduce barriers to entry, policy makers put under scrutiny a compulsory hedging regime. The underling idea was that “the entire industry would be more competitive if it were possible to induce generators to offer [asymmetrically] sufficient volumes of hedges at efficient prices [i.e. at minimum, the amount of production that was not required for downstream affiliates]” (Small 2002). To provide a competitive allocation of those contracts, it was further suggested to implement anonymous tender administered by an independent third party. It is only, in 2004, with the entering into force of the new electricity law, that the national regulator has been given powers to establish and promote hedge markets. Specifically, under the new law regulator can "require generators to offer by tender a minimum volume of contracts [and] require buyers of electricity from the wholesale market to maintain minimum levels of hedge and contract cover with electricity generators”.

In Italy, the stating up of a spot market, in the first trimester of 2004, reshaped the organization of the national electricity wholesale exchange system. Recent data show that spot trade accounted, during 2004, roughly for 30% of electricity exchanges. The rest is handled by private bilateral agreements (import included) or by public tenders of so called “non conventional energy”. The national wholesale supply structure is still dominated by the ex state-owned monopolist. Full opening of the retailing market being not yet implemented, captive consumers constituted half of the energy national demand. An independent operator (single buyer) is responsible for the supply of electricity to non-eligible market. In this framework, to overcome the concern about the exercise

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13 Another peculiar characteristic of New Zealand industry is the high dependence on hydro-generating plants that exacerbate the problem of price volatility due to seasonal and weather condition constraints.

14 Conversely a decentralized bilateral negotiation would not have been suitable to achieve the purpose of a compulsory hedging regime, i.e. to curtail generators’ market power.
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of potential market power, in the newly spot market, the national regulator intended to require each generator with a relevant market shares (above 20%) to subscribe legally binding financial and physical long-term contracts with the single buyer. Quantities and maximum prices would have been set by the public authority. In addition, temporary price-caps and market performances indexes would have been defined to control for spike prices and provide a series of quick tools to monitor spot market performances. The proposition encountered a strong opposition. The main objection was that the application of an asymmetric contractual obligations would have introduced a discrimination among generators. Indeed, only generators with relevant market shares would have been able to secure, with long-term "contracts cover", a quota of their own generation capacity at more than fair regulated prices. To fulfill the objective of controlling for market power abuses and meanwhile provide a risk hedge to captive consumers, a contractual obligation on the downstream-side has been introduced.\footnote{Delibera AEEG n. 21/04 published in the official journal GU n. 66, 19 march 2004.} The so-called single buyer was required to promote annual or infra-annual public descending price auctions for the subscription of physical and financial long-term contracts. The auctions process end up with a total amount of energy bought under forward contracts of slightly less that 40 TWh (with a maximum of energy cover by contract of 17% in November and December 2004). It is interesting to notice that, to convey the dominant generator to participate to those auctions, the regulator introduce a price condition. The initial tender purchasing prices was set higher of about 2% of the so-called PUN, that is national regulated "wholesale" energy price. Until the enter into force of the single buyer, the PUN was meant to remunerate generators for the energy sold to distributors for non eligible consumers electricity needs. Based on former monopolist generating cost, it was recognized to be quite remunerative. Finally, the dominant operator subscribed contracts with the single buyer for 70%-75% of the total amount of energy supplied through those auctions.

On a broader view, the development of a forward market has been suggested to be a key conditions in the design and implementation of restructuring reforms to foster competitive wholesale electricity markets in Latin American Countries. One argument is based on the fact that the "magnitude and distribution across suppliers of financial forward contracts to supply electricity to load-serving entities" represents one of the primary mechanisms for increasing the elasticity of the residual demand curve and, thus, reduce the generators’ incentive to exercise unilateral market power. As recognized, since rules have affected market outcomes, to deal with an efficient allocation of forward contracting it appears to be appropriate to "set up periodic anonymous auctions”. Moreover, if firms are equal in size it is recommended to allocate forward contract commitments equally across them to maximize the competitive benefits. If one firm owned twice the capacity of other firms, then it should have roughly twice the forward contract commitments that the other suppliers have (see Wolak, 2003 for a complete report).
3 Related literature

In the last decades, two lines of research offer a rationale explanation for the existence of markets for contracts, and, specifically, of markets for long-term financial agreements.

The first approach gives evidence of the welfare properties of long-term agreements in allocating resources and risk (see Anderson, 1984 for a review). Indeed, financial contracts operate as an insurance device. As parties agree on a fixed price of a good/asset to be paid over a fixed period of time in the future, this minimizes the variance of the profits realized on spot sales and the exposure to more volatile “real-time” markets. Most of the results related to this literature are driven in a framework of perfect competition and simultaneous forward and spot decisions16.

One alternative approach focuses on the strategic motive for trading forward. Allaz (1992) and Allaz and Vila (1993, hereafter A-V) originally show that the emergence of a competitive market for contracts alters operators incentives to produce. Specifically, risk neutral producers engage in forward transactions to pre-commit to higher levels of output to be delivered in a second period in the spot market. Long-term contracting represent a strategic variable yielding a new dimension of price competition into the quantity-game.

The commitment mechanism goes as follow. In a two period forward/spot game, producers with Cournot conjectures knows that increasing output would affect negatively rival’s market position as quantities are strategic substitute (Bulow, Geneakoplos and Klemperer, 1985). As marginal revenues depend on the forward positions previously agreed, none of the competitors is affected by the price elasticity effect due to a production increase. This means that each of them find it profitable to expand sales in order to gain a first mover advantage. Therefore, if only one producer has the chance to sell forward, he can do so profitably, but if all producer start selling forward contracts, they are worse off while consumers are better off than would be the case if the forward market did not exist. This is the “prisoners’ dilemma” type of effect. From the social welfare point of view, the tension between private and collective interests is resolved in favour of an improvement of market efficiency, as no generator succeeds in acquiring a Stackelberg position. As the number of forward transactions approaches infinity the equilibrium converge to the competitive outcome, i.e. inter-temporal trading enhances existing competition among duopolists. Those findings are, however, very sensitive to the setting assumptions: i) sequential nature of the trading process; ii) nature of players’ interaction (producers are modelled as non-cooperative players with static Cournot strategies); iii) no uncertainty on the spot demand and risk-neutrality of forward buyers.

Departing from A-V, a vast, but fragmented, theoretical and empirical literature has contributed to investigate the electricity market dynamics and the impact of long-term contracting on spot market strategic decisions (for a state-of-art, see for example, Martini, Pellegrini and Ballardi, 16 In this literature, long term transactions are generally assumed to be undergone with standardized contracts and transparent prices.
2002). Among those contributions, some have policy implications suggesting that the introduction of a market for contracts might not lead, by itself, to a competitive outcome in electricity spot markets. For instance, Powell (1993) and lately Green (2003a), demonstrate that when demand for contract spans from risk-averse distributors or competing retailers, an equilibrium with partial contracting is likely to emerge. Others, put emphasis on modelling spot market interactions under different framework assumptions. Newbery (1995 and 1998) extends the Supply Function Equilibrium (SFE) approach of the spot market in order to include a contract market or to analyze conditions to contestable entry. Green (1999) found that under SFE and Cournot conjectures a risk neutral generator sells no contracts unless by trading on the contract market it can affect its competitors’ strategy. More recently the focus is on dynamic issues. In particular, taking inspiration from Gul (1987) and Ausubel and Deneckere (1987), some ongoing works attempt to show that A-V conclusions might be reversed. When multiple periods interaction in the spot market is introduced collusive outcomes might be sustain or entry deterred (among others Le Coq 2004).

Empirical studies analyze the static impact of long-term contracting positions on generators’ spot market pricing behavior and offer evidences of the mitigation role of contracts in some of the newly re-structured electricity markets (Helm and Powell, 1992; Wolfram, 1998 and 1999; Wolak, 2000a; Sweeting, 2001).

Retail competition and forward contracts For the purpose of our study we will specifically refer to Green (2003a). This study belongs to a series of theoretical and empirical works in progress with the aim to assess whether the reform of the England and Wales trading system, entered into force in 2001 (New Electricity Trading Arrangements), is likely to be an effective remedy to pursue the declare objective of reducing electricity prices in the country (Green, 1999b; Green, 2003b; Evans and Green, 2003). More precisely, in Green (2003a), the author endogenizes the demand-side contracting behavior to investigate whether the possibility of trading in advance will lead to competitive outcomes. For this purpose, there is no distinction between financial contracts (forward contracts) and bilateral contracts (physical). The analysis is driven by comparing the equilibrium outcomes into two opposite retailing regimes. Reflecting structural changes due to the transition to a fully liberalized industry, one regime encompasses regulated distributors with duty to serve local captive consumers under fixed tariffs; while in the opposite scenario, an incumbent faces competitive pressure by potential new entrants. The combination of the depicted models of

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17 Other lines of research have brought attention to the computational...
18 Within the SFE model, agents do not compete in quantities (as in the Cournot and Stackelberg settings) or in prices (as in Bertrand and Price-leadership models) but set supply functions, that is a set of profit maximizing points in correspondence to each residual demand realization.
19 Relating to the England and Wales electricity industry, Helm and Powell (1992) regress pool prices on demand using dummy variables that represent contracting events. The significance (in the statistical sense) of these variables indicated a strong effect of the level of contracting on the pool price.

Wolfram (1998 and 1999) _____.
electricity retailing with a Cournot model of competition in the wholesale markets, allows Green to infer that risk-aversion and increasing retail competition constraint wholesale buyer’s willingness to enter into long-term relationships. The pro-competitive enhancing impact of a the implementation of a market for contracts is therefore weak. Estimates of the size of this effect on the equilibrium level of spot prices are provided.

The impact of spot/forward interaction on buyers was originally explored by Powell (1993). He first applied to A-V setting a risk-averse demand for contracts spanning from non strategic distributors with a mean-variance utility over their profits. Powell’s motivation was to bring attention on the renegotiation process that would emerge between generators and distributors at the expiration of the so called “vesting contracts”. Specifically, he was mainly concerned with the operation of a contract market when generators are imperfectly competitive and risk neutrality on the demand-side is dropped. A two stage spot/forward market sequential game is developed: in the first stage generators offer forward contract competing in prices, regulated distributors choose the amount of long-term contracts to hedge their final sales, in the second stage generators set quantities in the spot market. On the demand side, as pointed out by A-V, when risk-aversion is introduced strategic motives interact with hedging justifications. Indeed, the degree of hedging increase with risk-aversion (or demand uncertainty), but also the margin between forward and spot price. Conversely, by modelling assumptions, the lower the expected spot price the higher the amount of energy covered. Risk-averse distributors have, therefore, an extra benefit of hedging as it reduces generator’s incentives to withhold quantities and to raise spot prices (mitigation power effect). However, Powell’s main conclusion is that the nature of the upstream competition affect the willingness of distributors to enter into long-term transactions. Specifically, when generators cooperate the equilibrium is characterized by partial contracting and a positive forward-spot price premium. This means that when forward trade is allowed, generators can use the contract market to commit to given levels of output.

The Powell’s approach is extended by Green, whose contribution shares the same common features in the structure of the game, but differs in the investigation goals. Green models the supply-side as a two stage quantity game, but differ from the previous settings as he adds a third stage to examine long-term contractual behavior on the demand-side. As for the supply side, two Cournot producers compete in quantities firstly in a market for contracts and in the second period in the spot market. Long-term conditions are agreed under uncertainty, as spot demand depend upon stochastic variables unknown at that time. The conjectural variations approach is applied to encompass the polar cases of quantity and price competition, allowing comparisons with the earliest theoretical works, precisely A-V and Powell. The equilibrium level of contracts offered in the market is derived solving the game by backward induction.

The two generators, indexed $i$ and $j$, have constant marginal cost equal to $c$. In the spot market, there is quantity competition, with generators choosing $q_i$. In that market, the demand is $p =$
\( A - b(q_i + q_j) \). The intercept \( A \) is stochastic, (we assume it normally distributed with a mean equal to \( A^* \), and a variance \( \sigma_A^2 \)), but at the time where spot market competition occurs, its value is known. Each producer chooses his forward position \( x_i \) to maximize the overall profit function, given the revenue in the spot market and the contract market. Spot market profits are given by 
\[
\pi_i = (A - b(q_i + q_j)) (q_i - x_i) + f x_i - c q_i.
\]
Neglecting the conjectural variation coefficient for ease of explanation, the supply of contracts is given by the following symmetric reaction functions:
\[ x_i = \frac{A^e - c - b x_j + 9 (f - p^e)}{4 b - 9 \frac{\partial}{\partial x_i} (f - p^e)}. \quad (1) \]
\[ x_j = \frac{A^e - c - b x_i + 9 (f - p^e)}{4 b - 9 \frac{\partial}{\partial x_j} (f - p^e)}. \]

The equilibrium level of long-term contracts depend upon the margin between the forward price and the expected spot price, so called expected forward price premium. This in turn is defined endogenously by the solution of the profit maximization problem on the demand-side.

Wholesale buyers, in either the regulated regime as well as in the competitive retailing market, have the option to take long-term or spot positions. However, the demand for contracts is affected by the functional form of the profit function which in turn reflect the peculiarity of the downstream retailing regime under study. By assumption, the demand-side is a non strategic player with a mean-variance utility over the profits. This implies that the choice between long-term and spot positions is resolved to minimize the profit variance.

Profit functions differ under the two retailing regimes, so will do the equilibrium level of contracts demanded.

In the regulated regime, the mean-variance utility function takes the following form:
\[
U = E(\pi) - 1/2 \lambda \sigma^2(\pi) = (p^e - f)(x - (1 - a)V) - 1/2 \lambda \sigma^2(x - (1 - a)V)^2
\]
where \( V \) is the amount of energy sold to final consumers, \( a \) the average proportion of energy bought in the spot market, \( \sigma^2 \) the spot price variance.

In the competitive retailing regime, price competition reflect the prevailing spot price as, by hypothesis, new-entrants compete downstream purchasing energy in the spot market. Therefore, the mean-variance utility function takes is:
\[
U = \frac{V^2}{4h} - x(f - p^e) - 1/2 \lambda \sigma^2
\]
where \( h \) represent a measure of the switching costs. The higher is \( h \) the higher the competitive pressure, indeed, the higher the proportion of final demand that is lost by the incumbent if he offers a retailing price grater than the expected spot price \( p^e \) (entrant’s competing price).
If there are \( n \) identical regulated incumbents, the market inverse demand for contracts, in terms of the margin between the forward price and the expected spot price, is:

\[
f - p^e = (1 - a) V \lambda \sigma^2 - (x_i + x_j) \frac{\lambda \sigma^2}{n},
\]

whereas in for the retailing competitive scenario is:

\[
f - p^e = -(x_i + x_j) \frac{\lambda \sigma^2}{n}.
\]

In both cases,

\[
\frac{\partial}{\partial x_i} (f - p^e) = \frac{\partial}{\partial x_j} (f - p^e) = -\frac{\lambda \sigma^2}{n}.
\]

The way competitive pressure is modelled matters. Conversely to previous theoretical results, when \( f = p^e \) competitive retailers would not buy long-term contracts (4)\(^{20}\). Rather, positive hedging will emerge only when the forward price is strictly lower than the expected spot price\(^{21}\).

This stems from two reasons: on one hand, from equation 3 forward contracts directly increase retailers’ profit variance; on the other, increasing downstream rivalry puts constrains on the possibility to pass costs on final consumers. Reluctancy to fully cover retailing sales with long-term agreements arise from the threat of new entry impinged by a lower expected spot price.

Results are different in the regulated regime. Green shows that each regulated incumbent wants to cover the same proportion of its sales with contracts as the rest of the industry, since this minimizes the variance of its profits. Therefore, for a null forward-spot price margin, optimal demand for contracts would be an average proportion of each distributor’s captive market’s needs (see equation 5). Regulated retailers have an extra-benefit, similar to the one explained by Powell\(^{22}\).

Hedging motives interact with strategic ones (mitigation device). The larger the share of finals sales covered by contracts the lower the impact on profit’s variance of further forward positions. However, since risk-aversion reduce the elasticity of contracts demand, imperfectly competitive generators have incentives to increase forward prices. This explains why, in equilibrium, for a sufficiently large degree of risk-aversion as regulated distributors hedge more that competing retailers, the forward price is likely to be larger in the former regime, whereas the expected spot price smaller.

The decentralized equilibrium is found by plugging the demand of contract into the reaction functions. This gives a system with 2 equations and 2 unknowns. In particular, for the retail competition regime, on which we focus, the system reads as follows:

\(^{20}\)Either A-V and Powell show that when \( f = p^e \) a full hedging equilibrium would emerges.

\(^{21}\)In A-V demand comes from risk-neutral speculators. Since by assumption there is no uncertainty and the supply markets are perfectly competitive, a forward price lower that the perfectly anticipated spot price is not an equilibrium. A negative forward expected premium correspond to arbitrage opportunities that will be exercised by speculators. In equilibrium the forward price will equal the expected spot price, speculators will have zero profits, and therefore there will be full hedging.

\(^{22}\)This extra-benefit steams from the fact that in the inverse demand for contracts, as modelled by Powell, the expected spot price is a (negative) function of the amount of energy hedged in the market.
\[ \beta x_i + \alpha x_j = A^e - c \]
\[ \alpha x_i + \beta x_j = A^e - c \]

where \( \alpha = b + 9 \frac{\lambda \sigma^2}{\alpha} < \beta = 4b + 18 \frac{\lambda \sigma^2}{\alpha} \). The Nash equilibrium contract supply is:
\[ x_i^* = x_j^* = \frac{A^e - c}{\alpha + \beta} \]

The quantities produced depends on the contract market equilibrium:
\[ q_i^* = \frac{A^e - c - b(x_j^* + 2x_i^*)}{3b} \]
\[ q_i^* = \frac{A^e - c - b(x_i^* + 2x_j^*)}{3b} \]

but still the expected spot prices is larger than marginal costs:
\[ p^e = c + \frac{(A^e - c) (\alpha + \beta - 2b)}{3(\alpha + \beta)}. \]

as \((\alpha + \beta - 2b) = 5b + 27 \frac{\lambda \sigma^2}{\alpha} > 0\)

Green provides numerical simulations to support his findings. To corroborate the spot pricing increase effect, due to a gradual opening of competition, Green calibrate the model selecting parameter values for risk-aversion and the variance of spot demand on the ground of energy market data for England and Wales along the 1990’s. Results appears to be very sensitive to the value of the conjectural variation parameter and, to a less extent, on the level of risk-aversion.\(^{23}\)

In contrast to the previous literature, and in particular to Powell for whom imperfectly competitive supply markets entail partial contracting,\(^{24}\) Green found that non competitive pricing might emerge irrespective of the nature of the upstream competition (Cournot or Bertrand conjectures) i.e. marginal cost pricing might not be an equilibrium even when producers do not explicitly collude. The resulting inefficient outcomes are the consequence of given structural and economical characteristics of the downstream market. Explicitly, it is the inclusion of an inelastic demand for contracts that offset A-V pre-commitment mechanism. In term of social welfare, as risk-aversion and increasing competition lowers the elasticity of demand, the regulated regime is likely to yield a more appealing solution. Newbery goes further, pointing out that “competently regulated domestic franchise may be preferable to a fully liberalized supply market” (Newbery, 2004).

---

\(^{23}\)Indeed, when price volatility has a high value (i.e. the coefficient of risk-aversion is given by \( \sigma^2 = 34.9 \)) and generators are modelled with Bertrand conjectural variations, the competitive regime show lower levels of forward contracts sold and wholesale prices up to 19% more compare to the regulated franchise regime. However, for lower values of price volatility (\( \sigma^2 = 5.76 \)), the competitive regime would only leads to a moderate prices increases, less than 5%. Equivalent results are obtained when the conjectural variations parameter is assumed to be close to zero (Cournot conjectures), whatever the degree of uncertainty (or risk-aversion).

\(^{24}\)Recall that in Powell, the expected forward price premium represents a strategic variable at generator’s disposal. If generators collude in the supply markets that spot price will be higher than marginal cost, the forward price will be above the expected spot price and hedging will be partial.
4 Mandatory contractual regimes

Our model builds on Green (2003a), with two main simplifications in the setup. First, as the full opening to competition is a key point of the electricity market reform, we focus on the behavior of competitive retailers. Second, we neglect the conjectural variation. This is because, in Green the conjectural variation approach has proved useful to compare the sensitivity of the equilibrium outcomes to the degree of competition in the different segment of the industry. Whereas we model Cournot competition between two generators, as our objective is to show how the inefficient contracting raised in the previous literature can be solved by means of a pro-competitive regulatory intervention. Thus, we introduce the notion of contract obligation, that is we assume that the regulator or the competition agency mandates a quota of long term contracts. This is the main innovation of our work.

The contractual obligation measure can be implemented in several ways, as the pioneeristic experiences of applying this kind of “light-hand” regulation in the electricity markets have also shown. The measure can be horizontal, that is it can be imposed on generators (upstream measure) or retailers (downstream measure), or vertical, when it concerns simultaneously both producers and distributors. In each of these three cases, the regulator or the competition authority has then to decide whether it is most convenient to oblige only one market player or all of them to sign long-term contracts. We will refer to this latter case to as the symmetric measure; on the contrary, if only one generator or retailer is concerned, the measure will be asymmetric.

For example, in the case of an upstream asymmetric measure, one of the two generators, let say generator $i$, is obliged to sign a share of long-term contracts, whose amount is defined by the regulator. The contractual obligation measure is denoted $M = \delta x_i$. The remaining share of contracts (that is $(1-\delta)x_i$) is strategically chosen by the generator $i$ for hedging purposes. Both private and mandatory contracts are sold at the prevailing forward market price $f$.

We will denote the portfolio of contracts of generator $i$ as $X^{fa}_i(M) = M + (1-\delta)x^{fa}_i(M)$.

In more general terms, if the measure is asymmetric, at the decentralized equilibrium, the total portfolio of forward contracts will be:

$$X^{fa}(M) = X^{fa}_i(M) + x^{fa}_j(M) = M + (1-\delta)x^{fa}_i(M) + x^{fa}_j(M),$$

where the $fa$ stands for forward in the asymmetric case. The superscript $fa$ will be equal to $s$, if the measure is imposed to one generator, $d$, if it concerns one retailer, or $v$, if the contractual obligation links one generator to one retailer.

On the contrary, if the measure is equally extended to all the generators (or retailers), the forward contracts are as follows:

$$X^{fs}(M) = 2X^{fs}_i(M) = 2(M + (1-\delta)x^{fs}_i(M))$$

where $fs$ means forward symmetric, and depending on the implementation scenario, $fs$ will be
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denoted ss (measure imposed to all generators), ds (to all retailers), vs (to all market players).

The contractual obligation reintroduces the pro-competitive effect of forward sales as explained by A-V by overcoming the insufficient incentive of oligopolistic generators to engage in long-term relationships. However, as the measure enters as a weighted share of total contracting, it can discourage generators or retailers to subscribe further bilateral agreements in a typical Cournot setting. Therefore, the effectiveness of the obligation results from the trade-off between those pro-competitive and crowding-out effects.

The first step in understanding the impact of the contractual obligation on firms’ strategies is to combine the different implementation possibilities, which give six different Nash games, detailed in Sections 4.1 and 4.2. Stability, positivity and ranking of the solutions obtained for each scenario are detailed in Appendix A. The second step, the most important from the policy perspective, is to target the measure in order to achieve a competitive spot market. This will be discussed in Section 5.

4.1 The horizontal measure

4.1.1 Upstream contractual obligation

Asymmetric case We will first analyze the case of an asymmetric obligation on generator $i$. This implementation scenario corresponds for instance to the mandatory contractual regimes that have been applied in different earliest deregulated industries. More precisely, the concrete application of an asymmetric measure has been indicated as an efficient regulatory tool when supplying companies differs in size, as discussed in Section 2.2.1. To control for possible market power abuses in the newly Italian spot market, the national regulator suggested to require supplying companies, possessing a significant market share, to enter into long-term physical and financial agreements with the single buyer.

The model goes as follow. In the forward market, the producers sell an amount of contract equal to, respectively, $X_i = M + (1 - \delta) x_i^s$ and $x_j^s = x_j$, at price $f$. Each generators maximize its profits, given the revenue in the spot market and the contract market. Profit are asymmetric, given the contract obligation:

\[
\pi_i = (A - b(q_i + q_j)) (q_i - M - (1 - \delta) x_i^s) + f (M + (1 - \delta) x_i^s) - c q_i \quad (10)
\]

\[
\pi_j = (A - b(q_i + q_j)) (q_j - x_j^s) + f x_j^s - c q_j \quad (11)
\]

Differentiating the equations (10) and (11), we obtain a system of reaction functions:

\[
q_i = \frac{A - c - bq_j + bX_i^s}{2b} \quad (12)
\]

\[
q_j = \frac{A - c - bq_i + bx_j^s}{2b} \quad (13)
\]
The solution of the system gives the generators’ output and the spot price as a function of forward sales:

\[ q_i = \frac{A - c - b(x_i^s + 2X_i^s)}{3b} \quad (14) \]
\[ q_j = \frac{A - c - b(x_j^s + 2X_j^s)}{3b} \quad (15) \]
\[ p = c + \frac{A - c - b(X_i^s + x_i^s)}{3} \quad (16) \]

where \( X_i^s = M + (1 - \delta) x_i^s \). These results differ with respect to those of Green (2003a) as price and quantities depends on the whole portfolio of firm \( i \)'s contracts.

At the stage of forward market competition, firms do not know the value of \( A \), which implies that also the quantity produced and the price are random. Their profits are:

\[ \pi_i = \frac{A^e - c - b(x_i^s + x_i^e)}{3} \left( A^e - c - bx_i^s + 2bX_i^s \right) + (f - p^f)X_i^s + \frac{\sigma_A^2}{(9b)^2} \]
\[ \pi_j = \frac{A^e - c - b(x_j^s + x_j^e)}{3} \left( A^e - c - bx_j^s + 2bX_j^s \right) + (f - p^f)x_j^s + \frac{\sigma_A^2}{(9b)^2} \]

where \( X_i^s = M + (1 - \delta) x_i^s \).

Generators choose strategically their supply of contracts, hence for firm \( i \):

\[ \frac{\partial \pi_i}{\partial x_i^s} = \frac{2(1 - \delta) A^e - c - b(X_i^s + x_i^e)}{9} - (1 - \delta) \frac{A^e - c - bx_i^s + 2bX_i^s}{9} + (1 - \delta)(f - p^f) + (M + (1 - \delta) x_i^s) \frac{\partial}{\partial x_i^s} (f - p^f) = 0, \]

whereas for firm \( j \), we have:

\[ \frac{\partial \pi_j}{\partial x_j^s} = 2 \frac{A^e - c - b(X_j^s + x_j^e)}{9} - \frac{A^e - c - bx_j^s + 2bX_j^s}{9} + (f - p^f) + x_j^s \frac{\partial}{\partial x_j^s} (f - p^f) = 0. \]

Solving the system of equations given by the derivatives of the profit functions, we obtain the supply of contracts:

\[ x_i^s = \frac{A^e - c - bx_i^s + 9(f - p^f)}{4b(1 - \delta) - 9 \frac{\partial}{\partial x_i^s} (f - p^f)} - \frac{M}{1 - \delta} \]
\[ x_j^s = \frac{A^e - c - b(1 - \delta)x_j^s + 9(f - p^f) - bM}{4b - 9 \frac{\partial}{\partial x_j^s} (f - p^f)} \]

Combining the competitive retail demand (equations 5 and 6) with the above contract supply, the system of reaction function reads as follows:

\[ x_i^s = \frac{A^e - c - b(1 - \delta)x_i^s^* + \frac{M}{4b(1 - \delta) + 9 \frac{\partial}{\partial x_i^s} (f - p^f)}}{4b(1 - \delta) + 18 \frac{\partial}{\partial x_i^s} (f - p^f)} \quad (19) \]
\[ x_j^s = \frac{A^e - c - x_j^s^*(1 - \delta) + \frac{M}{4b + 18 \frac{\partial}{\partial x_j^s} (f - p^f)}}{4b + 18 \frac{\partial}{\partial x_j^s} (f - p^f)} \quad (20) \]
or, with a more synthetic writing:

\[
\begin{align*}
\beta^s x_i^* + \alpha x_j^* &= A^e - c - m_i^e M \\
\alpha^s x_i^* + \beta x_j^* &= A^e - c - m_j^e M.
\end{align*}
\]

where:

\[
\beta^s = 4b(1 - \delta) + 18\frac{\lambda x^2}{b}, \quad \alpha^s = b(1 - \delta) + 9\frac{\lambda x^2}{b}, \quad m_i^e = 4b + \frac{9\lambda x^2}{1 - \delta}, \quad m_j^e = b.
\]

\[
\beta^s > \alpha^s, \quad m_i^e > m_j^e
\]

\[
\beta > \beta^s, \quad \alpha > \alpha^s,
\]

The reaction functions 21 and 22 show the trade-off between the pro-competitive and the crowding-out effects of the measure. On one side, with respect to the situation described by Green, the sensitivity of firm \( i \) to firm \( j \) in terms of forward sales increases \((\frac{\beta}{\alpha} < \frac{\beta^s}{\alpha^s})\): the larger the share of public contract \( \delta \), the steeper the reaction function. Firm \( i \) has thus the incentive to be more aggressive in the contract market, relying on the mandatory contract as source of revenue.

On the other, this incentive is restrained by the quantitative effect of \( M \): too much contracting would lower spot market price. The picture is different for firm \( j \): its sensitivity to the strategic variable of the rival decreases \((\frac{\beta}{\beta^s} < \frac{\beta^s}{\beta^s})\), as it knows that firm \( i \) is obliged to sign the mandatory contracts; moreover, the quantitative or Cournot effect also discourages it from contracting. The crowding-out effect of the contractual obligation forces the reaction functions to shift inwards, but the sensitivity of firm \( i \)'s to \( M \) (that is \( \frac{m_i^e}{\alpha^s} \)) is in any case larger than that for firm \( j \) (i.e. \( \frac{m_j^e}{\beta^s} \)).

We solve the system given by equations (21) and (22) to calculate the Nash equilibrium in the contract market:

\[
\begin{align*}
x_i^{**} &= \frac{(\beta - \alpha)(A^e - c) - M(m_i^e\beta - m_j^e\alpha)}{(\beta^s\beta - \alpha^s\alpha)}.
\end{align*}
\]

\[
\begin{align*}
x_j^{**} &= \frac{(\beta^s - \alpha^s)(A^e - c) - M(m_i^e\beta^s - m_j^e\alpha^s)}{(\beta^s\beta - \alpha^s\alpha)}.
\end{align*}
\]

Notice that (see Corollary 1 in the Appendix A) \( x_j^{**} \) is always positive; therefore \( M < (A^e - c) \frac{\beta - \alpha}{m_i^e\beta - m_j^e\alpha} = M^* \) is the necessary and sufficient condition that guarantees \( x_i^{**} > 0 \). This is the consequence of the larger crowding out effect on \( i \).

The solutions are asymmetric, but it is not necessarily the case that the equilibrium contracts sold by \( i \) are larger that those supplied by \( j \), as the pro-competitive effect only plays on firm \( i \).

In the Appendix A we show that in the range of positive solutions, there exists a threshold value of \( M = M_i^e \) such that if and only if \( M < M_i^e \), \( x_i^{**} > x_j^{**} \). Simple calculations show that this effect is similar to introducing a marginal production cost advantage to firm \( i \) in Green setup. If appropriately targeted, a contractual obligation could make generator \( i \) more aggressive in the contract market, as it has an efficiency gain. In the context where one firm possesses a dominant share of the generation capacity, the pro-competitive effect of the asymmetric measure is that it
can induce the large generator to increase its contract cover and output, succeeding in spot market price reduction. This shows the potential benefit of a behavioral regulation, as an alternative to structural remedies.

**Symmetric case** If the measure is imposed on both the producers, that is \( X_i^{ss} = M + (1 - \delta) x_i^{ss} \) and \( X_j^{ss} = M + (1 - \delta) x_j^{ss} \), reaction functions become symmetric:

\[
x_i^{ss} = \frac{A^e - c - bx_i^{ss} + 9(f - p^e)}{4b(1 - \delta) - 9 \frac{\partial}{\partial x_i} (f - p^e)} - \frac{M}{1 - \delta},
\]

\[
x_j^{ss} = \frac{A^e - c - bx_j^{ss} + 9(f - p^e)}{4b(1 - \delta) - 9 \frac{\partial}{\partial x_j} (f - p^e)} - \frac{M}{1 - \delta}.
\]

Integrating in the above system the retail competition behavior (equations 5 and 6), Nash equilibrium in contracting solves:

\[
\begin{align*}
\beta^{ss} x_i + \alpha^{ss} x_j &= A^e - c - m^{ss} M, \quad (24) \\
\alpha^{ss} x_i + \beta^{ss} x_j &= A^e - c - m^{ss} M. \quad (25)
\end{align*}
\]

where:

\[
\beta^{ss} = 4b(1 - \delta) + 18 \frac{\lambda \sigma^2}{n}, \quad \alpha^{ss} = b(1 - \delta) + 9 \frac{\lambda \sigma^2}{n}, \quad m^{ss} = 5b + \frac{9 \lambda \sigma^2}{(1 - \delta)m} = m_i^s + m_j^s.
\]

In the system given by equations (24) and (25) all the coefficient in the matrix of \( x_i^{ss} \) and \( x_j^{ss} \) are now affected by the measure; moreover, the coefficient that multiply \( M \) is the sum of those that enter in the reaction functions (21) and (22), as imposing a contractual obligation to both firms is simply a linear combination of the asymmetric measure. The pro-competitive effect compensates each other: the slope of firm \( j \)'s reaction function is as steeper as the slope of firm \( i \)'s reaction function is flatter; the crowding-out effect is the same for both firms, and stronger than in the asymmetric case. Therefore at the Nash equilibrium both firms sign the same amount of private contracts:

\[
x_i^{sss} = x_j^{sss} = \frac{A^e - c - m^{ss} M}{\alpha^{ss} + \beta^{ss}}.
\]

To have positive contracts, \( M \) must lie below a given threshold \( M < (A^e - c) / m^{ss} = M^{ss} \), see corollary A.1 in the Appendix A).

### 4.1.2 Downstream contractual obligation

**Asymmetric case** Assume now that there is only one retailer that is obliged to sign a mandatory share of long term contract. This is for instance the case for the single buyer in the Italian electricity system, as explained in Section 2.2.1.
The measure will entail a change in the demand of contracts, since now:

\[ f - p^e = -(X_d^i + x_d^j) \frac{\lambda \sigma^2}{n} = -(M + (1 - \delta) x_d^i + x_d^j) \frac{\lambda \sigma^2}{n}. \]  

(26)

\[
\frac{\partial}{\partial x_d^j}(f - p^e) = -\frac{\lambda \sigma^2}{n}, \]

\[
\frac{\partial}{\partial x_d^i}(f - p^e) = -(1 - \delta)\frac{\lambda \sigma^2}{n}.
\]

Retailers positive private contracting realizes when \( f < p^e - M \frac{\lambda \sigma^2}{n} \), hence with a forward price even smaller that the expected spot price (5), as it was in the Green’s model. This further reduction in the contract price is similar to the "extra-benefit" effect, explained by Powell, that has a clear incentive of mitigating market power. Moreover, the sensitivity of retailer \( i \) to the forward-spot margin is larger than the one of the competitors.

Replacing the set of equations (26) into the generators’ reaction functions given by the Green’s equations (1), we obtain:

\[
\beta^d x_d^d + \alpha x_d^j = A^e - c - m^d M. \]

\[
\alpha^d x_d^i + \beta x_d^j = A^e - c - m^d M.
\]

(27)

where:

\[
\beta^d = 4b + 18(1 - \delta) \frac{\lambda \sigma^2}{n} > \alpha^d = b + 9(1 - \delta) \frac{\lambda \sigma^2}{n}, \quad m^d = 9 \frac{\lambda \sigma^2}{n}.
\]

\[
\beta - \alpha > \beta^d - \alpha^d.
\]

The pro-competitive effects at stake have the same nature as those discussed in the asymmetric upstream measure, as in the system 27, only the coefficients for \( x_d^i \) change. However, now the measure modifies the slope of the firms’ reaction functions by smoothing the impact of the retailers’ risk aversion. The crowding-out effect has the same intensity for both firms. At equilibrium firm \( i \) is more aggressive, regardless of \( M \) (see corollary A.1), therefore the asymmetric downstream measure can be seen as an attractive alternative to the regulation of an incumbent retailer proposed by Green. Equilibrium contracts are:

\[
x_d^* = \frac{(\beta - \alpha) (A^e - c) - m^d M}{\beta^d \beta - \alpha^d \alpha}.
\]

\[
x_d^* = \frac{(\beta^d - \alpha^d) (A^e - c) - m^d M}{\beta^d \beta - \alpha^d \alpha}.
\]

Positivity of the solutions depends on \( M \) (\( M < (A^e - c) / m^d = M^d \)).

**Symmetric case**

If all retailers sign a share of mandatory long term contracts (as for instance suggested in the New Zealand energy law or as a measure to ensure security of supply or to fulfil universal service
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and public service obligations), downstream competition is modified as follows:

\[ f - p^e = -(2M + (1 - \delta)(x^d_{i} + x^d_{j})) \frac{\lambda \sigma^2}{n} \] (28)

\[ \frac{\partial}{\partial x^d_{i}} (f - p^e) = \frac{\partial}{\partial x^d_{j}} (f - p^e) = -(1 - \delta) \lambda \sigma^2 n. \]

The forward-spot market differential required by retailers to sign non-mandatory contract is now \( f - p^e < -2M \frac{\lambda \sigma^2}{n} \), implying a further reduction.

The pro-competitive effects of a symmetric downstream measure are qualitatively the same as in the upstream case: the reactions’ functions slope of firm \( i \) decreases and that of firm \( j \) increases (the two effect being symmetric); the crowding-out effect is the same, but stronger, for both generators.

Replacing equations (28) into the reaction functions (1) gives:

\[ \beta^{ds} x^d_{i} + \alpha^{ds} x^d_{j} = A - c - m^{ds}M. \]
\[ \alpha^{ds} x^d_{i} + \beta^{ds} x^d_{j} = A - c - m^{ds}M. \]

where:

\[ \beta^{ds} = 4b + 18(1 - \delta) \frac{\lambda \sigma^2}{n} = \beta^d > \alpha^{ds} = b + 9(1 - \delta) \frac{\lambda \sigma^2}{n} = \alpha^d, \quad m^{ds} = 18 \frac{\lambda \sigma^2}{n} = 2m^d. \]

At equilibrium:

\[ x^*_i = x^*_j = \frac{A - c - m^{ds}M}{\alpha^{ds} + \beta^{ds}}. \]

Positivity of the solutions requires \( M < (A^c - c)/m^{ds} = M^{ds} \) (see corollary A.1 in the appendix).

4.2 The vertical measure

An alternative implementation scenario is represented by imposing the contractual obligation to one retailer and one generator, if the measure is asymmetric, or to generalize this practice to all the market participants. Such an hypothesis reflects the experiences the vertical integrated structures as experienced in Alberta or New Zealand.

If retailer and generator \( i \) are linked through long-term contracts, the contract offer of \( i \) is given by (19), while the retailers behave as specified by the set of equations (26). Finally the Nash equilibrium solves the following system:

\[ (1 - \delta)\beta x^v_{i} + \alpha x^v_{j} = A^c - c - \beta M. \]
\[ (1 - \delta)\alpha x^v_{i} + \beta x^v_{j} = A^c - c - \alpha M. \]

which can be rewritten as

\[ \beta [M + (1 - \delta)x^v_{i}] + \alpha x^v_{j} = A^c - c. \] (29)
\[ \alpha [M + (1 - \delta)x^v_{i}] + \beta x^v_{j} = A^c - c. \]
implying the equilibrium contracts:

\[ x_i^{w} = \frac{A^e - c - M(\beta + \alpha)}{(1 - \delta)(\beta + \alpha)} \]
\[ x_j^{w} = \frac{A^e - c}{\beta + \alpha} \]

Notice that generator \( j \) sells as many contracts as in the Green’s model; \( x_i^{w} \) is positive if and only if \( M < \frac{(A^e - c)}{\beta + \alpha} = M^v \). Similarly to the case of the asymmetric obligation imposed on one generator, in the Appendix A we show that there exists a threshold value of \( M = M_i^v \) such that if and only if \( M < M_i^v \), \( x_i^{w} > x_j^{w} \).

If the obligation is generalized, we combine the set of equations (23) with (28), which gives

\[
\begin{align*}
\beta [M + (1 - \delta)x_i^{w}] + \alpha [M + (1 - \delta)x_j^{w}] &= A^e - c. \\
\alpha [M + (1 - \delta)x_i^{w}] + \beta [M + (1 - \delta)x_j^{w}] &= A^e - c. 
\end{align*}
\]

The Nash solutions are:

\[ x_i^{wis} = x_j^{wis} = x_i^{w}. \]

Positivity requires \( M < \frac{(A^e - c)}{\beta + \alpha} = M^{wis}. \)

Equations (29) and (30) show that the vertical measure is totally internalized not only on those on which it is imposed, but also on the other market participants. Generators obliged to enter into mandatory agreements with retailers just substitute private contracting to exactly compensate the mandatory ones, thus neutralizing the pro-competitive effect of the measure. When the obligation is only imposed to firm \( i \), firm \( j \), knowing that at equilibrium the competitor will contract as the measure were absent, is left with the Green’s outcome. If both generators are vertically integrated through mandatory contracts with retailers, they internalize reciprocally the measure.

It results that locking one or all generator to the retailing sector does not allow to solve forward market inefficiency: at the equilibrium, total contracting is the same as in Green (2003a), both in the asymmetric and the symmetric case:

\[ X^{wis}(M) = X^v(M) = 2\frac{A^e - c}{\beta + \alpha}. \]

5 Optimal policy

In all but the vertical measure cases, the contractual obligation can be targeted to solve the forward market inefficiency by calculating the optimal measure that maximizes the consumer surplus\textsuperscript{25} subject to the generators’ breakeven constraint.

\textsuperscript{25} There are several reasons to be in favour of a consumer welfare objective instead of a more general approach to maximize social welfare. First of all, given that the aim of the regulatory intervention is to mitigate market power, it seems reasonable to pursue allocative efficiency which directly benefit consumers as it implies prices at marginal cost. Anyway, absent any price discrimination among consumers categories, from a policy perspective maximizing
Given the interaction between the spot and the forward markets, at the decentralized equilibrium the expected spot price and quantities will in turn depend on $M$. In fact, we have:

$$q^*_i(M) = \frac{A^e - c - b(x^*_i(M) + 2X^*fa(M))}{3b}.$$  \hspace{1cm} (31)

$$q^*_j(M) = \frac{A^e - c - b(X^*fa_i(M) + 2x^*_jfa(M))}{3b}.$$  \hspace{1cm} (32)

$$p^{*e} = \frac{A^e - c - b(X^*fa_i(M) + x^*_jfa(M))}{3}.$$  \hspace{1cm} (33)

where $X^*fa(M) = M + (1 - \delta)x^*_fa(M)$. The optimal policy solves:

$$\text{Max } CS_M = (A^e - p^{*e}(M))(q^*_i(M) + q^*_j(M))$$

$$= \frac{1}{9} \left(2(A^e - c) + 2b(X^*fa_i(M) + x^*_jfa(M))\right)^2$$

$$\text{s.t. } p^{*e}(M) \geq c$$

where $fa = s, d$.

Given that $x^*_i(M)$, $x^*_j(M)$ are linear functions of $M$, straightforward calculations show that the consumer surplus (see equation 34) is convex in $M$; therefore its maximum is reached at the value of $M$ where the constraint is binding. The amount of the asymmetric contractual obligations such that $p^{*e} = c$ will be denoted by $M_{fa}^{mc}$:

$$M_{fa}^{mc} \equiv \text{Arg}\{p^{*e}(M) = c\}$$

Therefore, by setting in an appropriate way the amount of mandatory contracts, we retrieve the limit A-V’s result obtained by infinitely repeating the contract game.

In the Appendix B we compute the optimal contractual asymmetric obligation:

$$M_{fa}^{mc} = (A^e - c) \frac{b \left((1 - \delta)(\beta - \alpha) + (\beta f^a - \alpha f^a)\right) - (\beta f^a \beta - \alpha f^a \alpha)}{b \left((1 - \delta)(m^a_i \beta - m_j \alpha) + (m^a_j \beta f^a - m_i \alpha f^a)\right) - (\beta f^a \beta - \alpha f^a \alpha)}.$$

where $X^*_fa(M) = M + (1 - \delta)x^*_kfa(M)$, for $k = i, j$. The specific coefficients vary depending whether the measure concerns one generator ($fa = s$) or one retailer only ($fa = d$). In the Appendix B (lemma 7), we also check that $M_{fa}^{mc}$ is positive.

If the measure is applied to all market participants, the consumer surplus is slightly different, consumer welfare give the same results of maximizing total surplus. Moreover, EC competition law appears to give more emphasis on consumer welfare. By the principle of the “primacy” of the community law, EC competition law enforcement prevails on national law and, therefore, on regulation. This offers a further argument for the application of the above mentioned analysis.
but still convex in $M$:

$$\begin{align*}
\text{Max} & \quad CS_M = (A^e - p^{*e}(M))(q_i^e(M) + q_j^e(M)) \\
& = \frac{1}{9} \left( 2(A^e - c) + b(X_i^{*fs}(M) + X_j^{*fs}(M)) \right)^2 \\
\text{s.t.} & \quad p^{*e}(M) \geq c
\end{align*}$$

(35)

where $fs = ss, ds$.

The optimal measure is (cf. lemma 8 in the Appendix B):

$$M_{fs}^{mc} = (A^e - c) \frac{\alpha^{fs} + \beta^{fs} - 2b(1 - \delta)}{2b \left( \alpha^{fs} + \beta^{fs} - m^{fs}(1 - \delta) \right)}.$$  

In both the downstream and the upstream cases, $M_{fs}^{mc}$ is positive (see B).

### 5.1 Marginal cost pricing and private contracting

Marginal cost pricing implies that at equilibrium the total portfolio of contracts is equal to $(A^e - c)/b$, both in the symmetric and the asymmetric cases. The question that now arises is whether the contract level that curb generators' market power leaves room for private contracting; as we know from Section 4 that to guarantees interior Nash solutions, we have to restrict the value of $M$ to limit the crowding-out effect.

We show that:

**Proposition 1** In the case of an horizontal upstream measure, when the obligation is asymmetric, marginal cost pricing crowds out generator $i$ ($M^s < M_{fs}^{mc}$); when the measure is symmetric, there is no private contracting at all.

**Proof.** See Appendix C. □

The negative effect on private contracting is weaker when one generator only is constrained to sign a mandatory share of long-term contracts, as the competitor always engage in forward contracting, regardless the level of $M$. When the measure is symmetric, each generator is sensitive to the level of $M$ and marginal cost pricing would require a too high $M$ to preserve private contracting; thus the implementation of a contractual obligation might end-up, in this case, to be too pervasive.

For horizontal downstream measure, both in the symmetric and asymmetric cases, the following holds:

**Proposition 2** In the case of a downstream measure, positive private contracting by both generators is guaranteed if and only if $b > \frac{9\lambda_2}{n}$. 
Proof. See Appendix D. ■

Therefore, with a downstream measure, whether the market can bear a contractual obligation with positive private contracting depends on structural parameters such as risk aversion and numbers of competitors at the retail level, and demand uncertainty and slope at the spot market level.

Assuming that the variance of the price is $\sigma^2$, which gives $\sigma_A^2 = 9\sigma^2$, and using the data provided by Green ($b = 2/3$, $\lambda = 0.178$, $\sigma^2 = 5.76$ or alternatively $\sigma^2 = 34.9$, $n = 12$), the optimal downstream measure would eliminate private contracting, that is the condition of proposition 2 does not hold. However, when $\sigma^2 = 5.76$, two more retailers will be enough to ensure an active forward market. Clearly, if the variance is larger, an optimal downstream measure that constrains generator to marginal cost pricing would require a very large number of retailers (at least 83) to have positive private contracting\textsuperscript{26}. In this case, but also whenever estimation of structural parameters proves to be difficult, it is preferable to implement an asymmetric upstream measure that ensures private contracting, though at the equilibrium the generator which is not obliged to sign contracts is the only one who freely trades bilateral contracts.

At optimum, it is now possible to rank Nash solutions across different regulatory scenarios and to compare private to mandatory contracting.

**Lemma 1** When $b > \frac{9\lambda\sigma^2}{n}$, marginal cost pricing implies the following ranking:

\[
\begin{align*}
x^*_jmc > x^*_mc > x^*_ds > x^*_jmc \\
x^*_jmc > M^*_mc \\
(1-\delta)x^*_mc > M^*_mc \\
2(1-\delta)x^*_mc > 2M^*_mc \\
(1-\delta)x^*_mc + 2(1-\delta)x^*_mc > x^*_mc \\
M^*_mc < 2M^*_mc < M^*_mc
\end{align*}
\]

**Proof.** See Appendix D. ■

From a policy perspective, it is useful to recognize what kind of distortions might be triggered by the application of each regulatory scheme.

By ranking Nash solutions, we see that in term of individual bilateral trade, when the measure is implemented upstream and asymmetrically, as private contracting is a positive function of $M$, generator $j$ will increase his forward position to the point that $x^*_jmc$ turns out to be the largest amount of private contracts ever signed at the optimum.

With respect to downstream regulation, the asymmetric mandatory obligation enhances a stronger pro-competitive effect on generator $i$ compared to the symmetric case. However, since the optimal measure is such that $p^c = c$, larger forward sales directly benefit firm’s $i$ in terms of

\textsuperscript{26}For example, in 2002, the Italian downstream liberalized market accounted for almost 100 active retailers. This despite the fact that 60% of final sales to eligible consumers were supplied by the first four retailers (see case N. A333 - Enel Trade-Clienti Iidonei, violation of art. 82 of the EC treaty; http://www.agcm.it)
higher market shares but would not act as further mitigation device; this result has to be taken into account whenever generator $i$ is dominant. Nevertheless, as pointed out in section 4, downstream regulation promotes price-responsiveness of the demand side as it smooths retailers risk-aversion. This might be sufficient to put a constraint on generator $i$ strategic incentives to forward price manipulation.

Furthermore, as downstream measures grant both generators participation in the voluntary forward market, it is easy to see that total private contracting is larger in the downstream asymmetric scenario compared to the case of an obligation imposed on all retailers and on the upstream side.

A related result is that total private contracting is predominant with respect to mandatory share in any scenario: hence the crowding-out is controlled for, the pro-competitive effect plays its beneficial role. Clearly by definition of marginal cost pricing, as the total portfolio contracts is equal to $(A^e - c)/b$, the larger private contracts the smaller the needs for mandatory contracts. As a consequence, the downstream asymmetric measure appears to be the less pervasive regulatory intervention.

6 Conclusions

The model proposed here attempted to depict various regulatory scenarios as a useful tool for the implementation of a contractual pro-competitive regulation. For this scope, we have investigated the conditions under which optimal mandatory contractual obligations could mitigate generators market power, when those latter face a demand for contracts from competing risk averse retailers. We show that imposing a contractual obligation produces two opposite effects on generators incentives to further trade privately: a pro-competitive and a crowding out effect.

Results suggests that asymmetric upstream optimal requirements might appear to be a too pervasive regulatory tool for the generator on which it is imposed since it crowds out all his private contracting. However, it proves to have the advantage of weakening the crowding effect for rivals, because imposing a contractual obligation on one generator makes the other keen to always subscribe contracts. This is the pro-competitive effect explained by A-V.

To fully preserve active bilateral trade for both generators, regulators ought to impose contractual obligations on the retailing sector. However, the measure has to be targeted on the overall electricity market performance. We find that binding conditions for the optimal downstream obligations to be compatible with private contracting are determined by the relative magnitude of structural parameters (intensity of downstream competition, retailers’ risk aversion, slope and variance of the spot market demand).

At optimum, implementing an asymmetric downstream obligation has the advantage to require a relatively low level of public contracts and thus promote a higher private trade. This intervention proves to be a rather flexible tool compatible for instance with a minimum ”security of supply”
objective. In addition, it goes in the direction to solve the inefficiency highlighted by Green, that is too little demand side responsiveness, by smoothing risk aversion. Clearly, those findings can contribute to address the debate on regulatory efforts to stimulate demand elasticity.

Extensions to this analysis will include targeting an optimal contractual measure on long run marginal cost to take into account investment issues or comparing the relative efficiency of mandatory contract with respect to upstream capacity release programmes.

References


A Properties of the Nash solutions

For ease of calculations, we will study the case of a symmetric measure (Section A.1) with respect to the case of a symmetric one (Section A.2).
A.1 Asymmetric measure

We study the properties of the Nash solutions given by the following system:

\[ \beta f a x_i + \alpha x_j = A^e - c - m_i f a M \]
\[ \alpha f a x_i + \beta x_j = A^e - c - m_j f a M \]

\( f_a = s \) (supply only), \( d \) (demand only), \( v \) (vertical)

Nash solutions can be written as:

\[ x_{i}^{f a} = \frac{(\beta - \alpha)(A^e - c) - M(m_i f a \beta - m_j f a \alpha)}{\beta f a \beta - \alpha f a \alpha} \]
\[ x_{j}^{f a} = \frac{(\beta f a - \alpha f a)(A^e - c) - M(m_i f a \beta f a - m_j f a \alpha f a)}{\beta f a \beta - \alpha f a \alpha} \]

Recall the case-specific coefficients:

\[ \beta^s = 4b(1-\delta) + 18 \frac{\lambda \sigma^2}{n}, \quad \alpha^s = b(1-\delta) + 9 \frac{\lambda \sigma^2}{n}, \quad m_i^s = 4b + 9 \frac{\lambda \sigma^2}{n}, \quad m_j^s = b. \]
\[ \beta^d = 4b + 18(1-\delta) \frac{\lambda \sigma^2}{n}, \quad \alpha^d = b + 9(1-\delta) \frac{\lambda \sigma^2}{n}, \quad m_i^d = m_j^d = 9 \frac{\lambda \sigma^2}{n}. \]
\[ \beta^v = (1-\delta) \beta, \quad \alpha^v = (1-\delta) \alpha, \quad m_i^v = \beta, \quad m_j^v = \alpha. \]
\[ m_i f a \beta - m_j f a \alpha = () \]

**Lemma 2** (Stability) The Nash solutions given by (36) are stable, that is

\[ \left| \frac{\beta f a}{\alpha f a} \right| > \left| \frac{\alpha}{\beta} \right| \]

for \( f_a = s, d, v \).

**Proof.** This is immediate, given that

\[ (\beta^s f a - \alpha^s f a) = 3^{3 \frac{1}{2} \frac{b^2 n^2 (1-\delta) + 2b \lambda^2 \sigma^2 (2-\delta) + 8s^2 \sigma^4}{n^2}} > 0 \]
\[ (\beta^d f a - \alpha^d f a) = 3^{5 \frac{b^2 n^2 + 2b \lambda^2 \sigma^2 (2-\delta) + 8s^2 \sigma^4 (1-\delta)}{n^2}} > 0 \]
\[ (1-\delta) \beta^2 - (1-\delta) \alpha^2 = 3^{3^{b n^2 + 3 \lambda^2 \sigma^2 (5bn + 27 \lambda^2 \sigma^2)}} > 0 \]

**Lemma 3** (Positivity) NSC for interior solutions given by (36) are as follows:

1) if \( \min \left\{ m_i f a \beta - m_j f a \alpha, m_j f a \beta f a - m_i f a \alpha f a \right\} \geq 0, x_i, x_j > 0 \leftrightarrow \)
\[ M < \min \left\{ (A^e - c) m_i f a \beta - m_j f a \alpha, (A^e - c) m_j f a \beta f a - m_i f a \alpha f a \right\} \]
2a) if \( \min \left\{ m_i f a \beta - m_j f a \alpha, m_j f a \beta f a - m_i f a \alpha f a \right\} = m_i f a \beta - m_j f a \alpha < 0, \text{ then } x_i > 0; x_j > 0 \leftrightarrow M < \)
\[ (A^e - c) m_i f a \beta - m_j f a \alpha \]

2b) if \( \min \left\{ m_i f a \beta - m_j f a \alpha, m_j f a \beta f a - m_i f a \alpha f a \right\} = m_j f a \beta f a - m_i f a \alpha f a < 0, \text{ then } x_i > 0; x_j > 0 \leftrightarrow \)
\[ M < (A^e - c) m_i f a \beta - m_j f a \alpha \]
**Proof.** Stability (cf Lemma 2) ensures \((\beta^f a - \alpha^f a) > 0\); straightforward calculations show that \(\beta > \alpha, \beta^f a > \alpha^f a \forall f a = s, d, v\); moreover, by assumption \((A^e - c) > 0\). The positivity of the solutions given by equations (36) solely depends on their denominator. ■

**Corollary 1 Measure on supply:**
\[
\min \{m_i^s \beta - m_i^s \alpha, m_i^s \beta_i - m_i^s \alpha_i\} = m_i^s \beta_i^s - m_i^s \alpha_i^s < 0, \text{ hence } x_i^{ss} > 0 \forall M;
\]
\[m_i^s \beta - m_i^s \alpha > 0, \text{ hence } M < (A^e - c) \frac{\beta - \alpha}{m_i^s \beta - m_i^s \alpha} = M^s \Leftrightarrow x_i^{ss} > 0.\]

**Corollary 2 Measure on demand:**
\[
\min \{m_d^d (\beta - \alpha), m_d^d (\beta_i^d - \alpha_i^d)\} = m_d^d (\beta_i^d - \alpha_i^d) > 0, \text{ hence } M < (A^e - c) \frac{1}{m_d^d} = M_d \Leftrightarrow x_i^{sd}, x_i^{sd} > 0.
\]

**Corollary 3 Vertical measure:**
\[
\min \{m_i^v \beta - m_i^v \alpha, m_i^v \beta_i - m_i^v \alpha_i\} = -m_i^v \alpha_i + m_i^v \beta_i = 0; \ x_j^{sv} > 0 \forall M.
\]
\[M < (A^e - c) \frac{1}{m_i^v} = M^v \Leftrightarrow x_i^{sv} > 0.\]

**Lemma 4 (Ranking of the solutions).** There exists an \(M_i^{fa} = M_i^{fa}(A^e, c, b, \delta, \lambda, \sigma^2, n) > 0\), for \(fa = s, d, v\), such that
\[x_i^{sf a} \geq x_i^{sf a} \iff M \leq M_i^{fa}\]
where \(M_i^{fa} = \frac{(A^e - c)[\beta - \alpha - (\beta^f a - \alpha^f a)]}{(m_i^s \beta - m_i^s \alpha) - (m_i^v \beta - m_i^v \alpha)}.
\]

**Proof.** The calculation of \(M_i^{fa}\) immediately obtains by comparing the Nash solutions given by equations (36). ■

**Corollary 4 Measure on supply:** \(M_i^s < M^s\).

**Proof.** Simple calculations show that
\[
M_i^s - M^s = (A^e - c) \frac{\beta - \alpha - (\beta^s - \alpha^s)}{(m_i^s \beta - m_i^s \alpha) - (m_i^v \beta - m_i^v \alpha)} \ll 0
\]
as, by corollary 1, \(-(m_i^s \beta - m_i^s \alpha) > 0\), and \((m_i^s \beta - m_i^s \alpha) > 0\); then \((m_i^v \beta - m_i^v \alpha) - (m_i^v \beta - m_i^v \alpha) > 0\); 
\[
(\beta - \alpha - (\beta^s - \alpha^s)) \left( m_i^s \beta - m_i^s \alpha \right) - (\beta - \alpha) \left[ (m_i^s \beta - m_i^s \alpha) - (m_i^v \beta - m_i^v \alpha) \right] =
-9 \left(5b^2 n^2 (1 - \delta) + 21b n^2 \lambda^2 (2 - \delta) + 81 \lambda^2 \sigma^4 \right) \frac{bn(1-\delta)+3\lambda \sigma}{n^2(1-\delta)} < 0
\]
We conclude that for \(M < M_i^s, x_i^{ss} > x_i^{sd}^s\), whereas for \(M_i^s < M < M^s, x_i^{ss} > x_i^{sd}^s = 0.\)

**Corollary 5 Measure on demand:** \(M_d = M_i^d \Leftrightarrow x_i^{sd} > x_i^{sd} > 0 \forall M.
\]

**Corollary 6 Vertical measure:** \(M_i^v - M^v < 0\).

**Proof.** \(M_i^v - M^v = -(A^e - c) \frac{1}{m_i^v} < 0\); the proof is similar to that of Corollary 4. ■
A.2 Symmetric measure

We study the properties of the Nash solutions given by the following system

\[ \beta^{fs} x_i + \alpha^{fs} x_j = A^e - c - m^{fs} M \]  
\[ \alpha^{fs} x_i + \beta^{fs} x_j = A^e - c - m^{fs} M \]

where \( fs=ss \) (supply symmetric), \( ds \) (demand symmetric), \( vs \) (vertical symmetric).

The Nash solutions are:

\[ x^{fs}_{i} = x^{fs}_{j} = \left( A^e - c - m^{fs} M \right) \frac{\alpha^{fs}}{\beta^{fs} + \alpha^{fs}} \]  
\[ (38) \]

Recall that the coefficient take specific values, depending on the implementation scenario:

\[ \beta^{ss} = 4b(1 - \delta) + 18 \frac{\lambda \sigma^2}{n}, \quad \alpha^{ss} = b(1 - \delta) + 9 \frac{\lambda \sigma^2}{n}, \quad m^{ss} = 5b + \frac{9\lambda \sigma^2}{(1-2)\lambda n} \]
\[ \beta^{ds} = 4b + 18(1 - \delta) \frac{\lambda \sigma^2}{n}, \quad \alpha^{ds} = b + 9(1 - \delta) \frac{\lambda \sigma^2}{n}, \quad m^{ds} = 18 \frac{\lambda \sigma^2}{n} \]
\[ \beta^{vs} = (1 - \delta) \beta, \quad \alpha^{vs} = (1 - \delta) \alpha, \quad m^{vs} = (5b + 27 \frac{\lambda \sigma^2}{n}) = \alpha + \beta. \]

Lemma 5 The Nash solutions given by (38) are stable, that is

\[ \left| \frac{\beta^{fs}}{\alpha^{fs}} \right| > \left| \frac{\alpha^{fs}}{\beta^{fs}} \right| \]

for \( fs = ss, ds, vs \).

Proof. This is immediate, given that:

\[ (\beta^{ss})^2 - (\alpha^{ss})^2 = 3 \left( 3 \lambda \sigma^2 + 5b(1 - \delta) \right) \frac{27\lambda \sigma^2 + 5bn(1 - \delta)}{n^2} > 0. \]
\[ (\beta^{ds})^2 - (\alpha^{ds})^2 = 3 \left( 5bn + 27 \lambda \sigma^2(1 - \delta) \right) \frac{bn + 3\lambda \sigma^2(1 - \delta)}{n^2} > 0. \]
\[ (1 - \delta)^2 \beta^2 - (1 - \delta)^2 \alpha^2 = 3 \frac{bn + 3\lambda \sigma^2}{n^2} (5bn + 27 \lambda \sigma^2) (1 - \delta)^2 > 0. \]

Lemma 6 There exists an \( M^{fs} = M^{fs} (A^e, c, b, \delta, \lambda, \sigma^2, n) \), for \( s = ss, ds, vs \), such that the Nash solutions given by (38) are positive.

Proof. Given that \( \beta^{fs} + \alpha^{fs} > 0, (A^e - c) > 0 \), the Nash solutions are positive if \( M < \frac{A^e - c}{m^{fs}} \), for \( s = ss, ds, vs \).

B Optimal policy

Lemma 7 It exists a unique \( M^{fa}_{mc} = M^{s}_{mc} (A^e, c, b, \delta, \lambda, \sigma^2, n) > 0 \) such that \( M^{s}_{mc} = \text{Arg} \{ p^c (M^s) = c \} \) for \( fa = s, d \).
Lemma 8: It exists a unique $M_{m ec}^s = \text{Arg} \{ p^e (M^s) = c \}$ gives:

$$M_{m ec}^s = (A^e - c) \frac{b((1-\delta)(\beta - \alpha) + (\beta^s - \alpha^s)) - (\beta^s \beta - \alpha^s \alpha)}{b((1-\delta)(m^s_\beta \beta - m^s_\alpha \alpha) + (m^s_\beta \beta^s - m^s_\alpha \alpha^s) - (\beta^s \beta - \alpha^s \alpha))}.$$ 

Given that the equation $p^e (M^s) - c = 0$ is linear in $M$, $M_{m ec}^s$ is unique.

$M_{m ec}^s > 0$, as

$$b((1-\delta)(\beta - \alpha) + (\beta^s - \alpha^s)) - (\beta^s \beta - \alpha^s \alpha) = 9 \frac{3b^2 \sigma^2(1-\delta) + 6b \lambda \sigma^2 (2-\delta) - 27 \lambda^2 \hat{\sigma}^4}{n^2} < 0.$$ 

$$(1-\delta)(m^s_\beta \beta - m^s_\alpha \alpha) + (m^s_\beta \beta^s - m^s_\alpha \alpha^s) - (\beta^s \beta - \alpha^s \alpha) = -27 \lambda^2 \frac{2b(1-\delta) + 3 \lambda \sigma^2 (2-\delta)}{n^2} < 0.$$ 

Measure on demand. By equating $p^e (M^s) - c = 0$, we obtain: Uniqueness is proved similarly to the previous case. Positivity of $M_{m ec}^d$

$$M_{m ec}^d = (A^e - c) \frac{b((\beta - \alpha)(1-\delta) + (\beta^d - \alpha^d)) - (\beta^d \beta - \alpha^d \alpha)}{b((1-\delta)(m^d_\beta \beta - m^d_\alpha \alpha) + (m^d_\beta \beta^d - m^d_\alpha \alpha^d) - (\beta^d \beta - \alpha^d \alpha)).}$$ 

Uniqueness is proved similarly to the previous case. Positivity of $M_{m ec}^d$ is also straightforward, as

$$b((\beta - \alpha)(1-\delta) + (\beta^d - \alpha^d)) - (\beta^d \beta - \alpha^d \alpha) = -3b^2 \sigma^2(1+\delta) + 36b \lambda \sigma^2 (1-\delta) + 15 \lambda^2 \sigma^4 (1-\delta) < 0.$$ 

$$(m^d(1-\delta)(\beta - \alpha) + m^d(\beta^d - \alpha^d) - (\beta^d \beta - \alpha^d \alpha)) = -3b^2 \sigma^2 + 12b \lambda \sigma^2 (2-\delta) + 27 \lambda^2 \sigma^4 (1-\delta) < 0.$$ 

Lemma 8: It exists a unique $M_{m ec}^{fs} = M_{m ec}^s (A^e, c, b, \delta, \lambda, \sigma^2, n) > 0$ such that $M_{m ec}^s = \text{Arg} \{ p^e (M^s) = c \}$ for $fs = ss, ds$.

Measure on supply. Similarly to the previous cases, $M_{m ec}^{ss}$ is unique.

$$M_{m ec}^{ss} = (A^e - c) \frac{2b(1-\delta) - (\alpha^{ss} + \beta^{ss})}{2b (m^{ss} (1-\delta) - (\alpha^{ss} + \beta^{ss}))}.$$ 

$M_{m ec}^{ss} > 0$, as

$$2b(1-\delta) - \alpha^{ss} - \beta^{ss} = -\frac{2b(1-\delta) - \alpha^{ss} - \beta^{ss}}{n} < 0.$$ 

$m^{ss} (1-\delta) - (\alpha^{ss} + \beta^{ss}) = -2 \frac{b \lambda \sigma^2 - 9 \lambda \sigma^2 \delta + 6b \delta}{n} < 0.$

Measure on demand. The equation $p^e (M^{ds}) - c = 0$ gives $M_{m ec}^{ds}$.
\[ M_{mc}^{ds} = (A^c - c) \frac{2b(1 - \delta) - (\alpha^{ds} + \beta^{ds})}{2b\left(m^{ds}(1 - \delta) - (\alpha^{ds} + \beta^{ds})\right)}. \]

\[ M_{mc}^{ds} > 0, \text{as} \]

\[ 2b(1 - \delta) - (\alpha^{ds} + \beta^{ds}) = -\frac{bn(3 + 2\delta) + 27\lambda\sigma^2(1 - \delta)}{n} < 0. \]

\[ m^{ds}(1 - \delta) - (\alpha^{ds} + \beta^{ds}) = -5b - 9\frac{\lambda^2}{n}(1 - \delta) < 0. \]

C Proof of Proposition 1

Asymmetric case.

Measure on supply. Partial crowding out: the positivity constraint on \( x_i^{ss} \) is violated (recall that by Lemma 3, \( x_i^{ss} > 0 \forall M \)).

\[ M^s_{mc} - M^s = -(A^c - c) (\beta^s - \alpha^s) \frac{\beta(b - m_i) - b(m_i^g - m_i^f) + \alpha(m_i^g - b)}{b(1 - \delta)(m_i^g - m_i^f) + (m_i^g - m_i^f)(\beta - \alpha^s))} > 0. \]

as \( \beta(b - m_i) - b(m_i^g - m_i^f) + \alpha(m_i^g - b) = -9(6\lambda\sigma^2 + bn) \frac{bn + bn\beta - 3\lambda\sigma^2}{\lambda^2} < 0. \)

Corollary 2 ensures \((\beta^s - \alpha^s) > 0 \) and positivity of \( M^s_{mc} \) (see Appendix B) that

\[ b \left((1 - \delta)(m_i^g - \alpha^s - m_i^f) + (m_i^g - \alpha^s - m_i^f)(\beta - \alpha^s))\right) (m_i^g - m_i^f) < 0. \]

Symmetric case.

Measure on supply. Total crowding out: the positivity constraint (see Lemma 3) is violated.

\[ M^{ss}_{mc} - M^{ss} = (A^c - c) (\alpha^{ss} + \beta^{ss}) \frac{2b - m^{ss}}{bm^{ss}(1 - \delta) - (\alpha^{ss} + \beta^{ss})} > 0. \]

as (see Appendix B) \((m^{ss}(1 - \delta) - (\alpha^{ss} + \beta^{ss})) < 0 \) and \( 2b - m^{ss} = -3\frac{bn(1 - \delta) + 3\lambda\sigma^2}{(1 - \delta)n} < 0. \)

D Proof of Proposition 2

Asymmetric case Positivity of contracting obtains if and only if the optimal measure is compatible with the conditions given by Lemma 3; we check the sign of \( M_{mc}^{d} - M^{d} \).

\[ M_{mc}^{d} - M^{d} = -(m^d - b) \frac{(\beta^d - \alpha^d)}{bm^d(1 - \delta)(\beta - \alpha) + m^d(\beta^d - \alpha^d) - (\beta^d - \alpha^d).} \]

As \( \beta^d - \alpha^d > 0 \) and \((m^d(1 - \delta)(\beta - \alpha) + m^d(\beta^d - \alpha^d) - (\beta^d - \alpha^d)) < 0 \), we have:

\[ M_{mc}^{d} - M^{d} < 0 \iff b > m^d. \]
Symmetric case Similarly to the previous case:

\[
M_{mc}^{ds} - M^{ds} = -\frac{1}{2} (2b - m^{ds}) \frac{\alpha^{ds} + \beta^{ds}}{b m^{ds} (\alpha^{ds} + \beta^{ds} - m^{ds} (1 - \delta))}.
\]

Since \(\alpha^{ds} + \beta^{ds} - m^{ds} (1 - \delta) > 0\) and \(\alpha^{ds} + \beta^{ds} > 0\), the condition on the sign is as follows:

\[
M_{mc}^{ds} - M^{ds} < 0 \iff 2b > m^{ds}.
\]

As \(m^{ds} = 2m^{d}\), we finally have:

\[
M_{mc}^{ds} - M^{ds} < 0 \iff b > m^{d}.
\]

D.1 Proof of Lemma 1

Ranking of private contracting Recall that by Proposition 2 \(bn - 9\sigma^{2}\lambda > 0\) to have positive contracting in the downstream cases. Tardious calculations show that:

1. \(x_{jmc}^{ed} - x_{jmc}^{ids} = \frac{-3(A' - c)(bn - 9\sigma^{2}\lambda - 9\sigma^{2}\lambda\delta)(bn - 9\sigma^{2}\lambda)\sigma^{2}\lambda\delta}{b(5\sigma^{2}\lambda - 9\sigma^{2}\lambda - 5\sigma^{2}\lambda\delta)(12(\sigma^{2}\lambda - 5\sigma^{2}\lambda - 5\sigma^{2}\lambda\delta) - 3(\sigma^{2}\lambda + 3\sigma^{2}\lambda\delta))} < 0\)

2. \(x_{jmc}^{ed} - x_{jmc}^{ids} = \frac{3(n - 9\sigma^{2}\lambda)(A' - c)n\sigma^{2}\lambda\delta}{(9\sigma^{2}\lambda - 9\sigma^{2}\lambda - 5\sigma^{2}\lambda)(12\sigma^{2}\lambda - 24\sigma^{2}\lambda - 5\sigma^{2}\lambda - 2\sigma^{2}\lambda + 2\sigma^{2}\lambda\delta)} > 0\)

Hence \(x_{jmc}^{es} > x_{jmc}^{ids} > x_{jmc}^{ids} > x_{jmc}^{ed}\).

4. \(2(1 - \delta) + m^{ds} - M_{mc}^{ds} = \frac{(A' - c)(bn(2 - (1 - \delta) - b(3 - 2\delta)) - 9\sigma^{2}\lambda(2(1 - \delta) - 3b(1 - \delta)))}{b(5\sigma^{2}\lambda + 9\sigma^{2}\lambda(1 - \delta))} > 0\)

as \(bn > 9\sigma^{2}\lambda\) and \(2(1 - \delta) - b(3 - 2\delta) > 2(1 - \delta) + 3b(1 - \delta)\).

Hence \(2(1 - \delta)x_{jmc}^{ds} > M_{mc}^{ds}\).

5. For ease of calculation, as total contracting must be equal to \(\frac{A' - c}{b}\), we compute \(M_{mc}^{es}\) as follows:

\[
\frac{A' - c}{b} - x_{jmc}^{es} = \frac{(A' - c)(1 - \delta)(bn + 3\sigma^{2}\lambda)}{b(2n(1 - \delta) + 3\sigma^{2}\lambda(2 - \delta))} = M_{mc}^{es}.
\]

Therefore

\[
x_{jmc}^{es} - M_{mc}^{es} = \frac{3(A' - c)\sigma^{2}\lambda\delta}{2b(n(1 - \delta) + 3\sigma^{2}\lambda(2 - \delta))} > 0.
\]

Hence \(x_{jmc}^{es} > M_{mc}^{es}\).
Ranking of the measure

1. We first calculate that $2x^{*d}_{mc}(1 - \delta) - ((1 - \delta)x^{*d}_{i mc} + x^{*d}_{j mc})$:

$$2x^{*d}_{mc}(1 - \delta) - ((1 - \delta)x^{*d}_{i mc} + x^{*d}_{j mc}) =$$

$$\frac{(A' - c)(-3\sigma^2\lambda(1-\delta) - bn)5n\delta}{(9\sigma^2\lambda^2 - 9\sigma^2\lambda - 5bn)(12bn\sigma^2\lambda^2 - 24\sigma^2\lambda - 5bn^2 - 2\sigma^2\lambda^2 - 2\sigma^2\lambda + 2\sigma^2\lambda^2)} < 0$$

Hence $2x^{*d}_{mc}(1 - \delta) < ((1 - \delta)x^{*d}_{i mc} + x^{*d}_{j mc})$. As $2x^{*d}_{mc}(1 - \delta) + 2M^{ds}_{mc} = (1 - \delta)x^{*d}_{i mc} + x^{*d}_{j mc} + M^{d}_{mc} = (A' - c)\frac{b}{5}$, it follows that $2M^{ds}_{mc} > M^{d}_{mc}$.

2. We calculate $2x^{*d}_{mc}(1 - \delta) - x^{*d}_{j mc}$:

$$2x^{*d}_{mc}(1 - \delta) - x^{*d}_{j mc} =$$

$$\frac{(48bn\sigma^2\lambda(1 - \delta) + b^2n^2(1 - \delta) + \sigma^4\lambda^2(135 - 81\delta) + 9bn\sigma^2\lambda\delta^2)}{b(5bn + 9\sigma^2\lambda(1 - \delta))(2bn(1 - \delta) + 3\sigma^2\lambda(2 - \delta))} > 0$$

Hence $2x^{*d}_{mc}(1 - \delta) > x^{*d}_{j mc}$. As total contracting in both cases must be equal to $\frac{(A' - c)}{5}$, it follows that $2M^{ds}_{mc} < M^{d}_{mc}$. 