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Storage and Competition in gas market*

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Abstract

In order to analyze competition in gas markets, an intermediate activity of storage is included in a classical model of vertical relations. In that case, firms can inject or withdraw strategically natural gas resource. The access to the storage facility can deteriore the welfare since it incites the vertically integrated firms (production and distribution) to withdraw strategically. This incentive is reduced by vertical integration between storage and distribution. Thus it improves the social welfare.

JEL Classification: L10, L50, Q40

Keywords: Storage, vertical integration, foreclosure.

I. Introduction

In the member States of European Union, competition has been introduced in the gas sector in 1998. Five years later, many reports underline the difficulties to achieve a complete deregulation in this sector. Anti-competitive behaviors are frequently observed, specially concerning transportation activity which is ensured by the so-called historical firm. In the upstream part of the gas chain, similar anti-competitive behaviors can occur. Natural gas resource is an essential factor into the supplier's production process. Thereby, the strategic vertical integration of oil and gas companies that supply gas directly to final consumers could slow down the deregulation process in European gas market (see for example Baranes *et al.* (2003)).

In the intermediate market, the activity of storage has an influence on the deregulation process in energy markets. In this way, the European Commission underlines the necessity of Third Party Access to Natural Gas Storage (TPAS) in order to stimulate competition and to promote entry into deregulated markets by new actors[1]. Some questions must be cleared, in this context: will the access of storage be regulated or negotiated? What is the most relevant criterion which allows to attribute limited capacities of storage facilities under TPAS system? Will some particular and new functions devoted to storage be developed in European gas markets? Will the total capacity of facilities must be opened or will one part of this capacity must be reserved for some public service missions ?

The aim of this article is to analyze the issue of storage when oil and gas companies on upstream market compete with suppliers on downstream market.

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[1] November 25th 2004, the Ministers of members States responsible for the Energy sector have signed an agreement which stipulates that storage facilities will be opened to competitors in 2004.

In the theoretical literature, storage is a facility which contributes to the matching of gas supply and gas demand at a seasonal and daily level. In addition, storage is analyzed in the framework of oligopolistic competition. Kirman and Sobel (1974) and Philps and Richard (1989) analyze the role of storage in the intertemporal price discrimination framework. The strategic role of storage was initially studied by Saloner (1987) and Pal (1991). Storage plays a strategic role if it modifies the decisions of rival firms for the future periods. In that case, storage is viewed as a mean of achieving a strategic advance production plan (see Saloner (1987) and Pal (1991)). Poddar, Sasaki (2002) study the incentives for the firm to store in a simultaneous game.

This theoretical literature focuses only on storage of an output. However, in vertically organized industries (e.g. industries of networks), inputs can also be stored. In this framework, possibility of storage can modify the strategic decisions of the firms on upstream and downstream markets. Reciprocally, the vertical structure of the industry (integration or unbundling) could influence also the decisions concerning the storage of the input.

Literature on vertical relationships is already well developed. Gaudet and Van Long (1996) present an extension of Salinger (1988). In this paper, they allow the vertically integrated firms to make strategic purchase of intermediate good. In that case, the integrated firms have the possibility to buy intermediate goods, as well as downstream firms do. When the integrated firm makes a negative supply (strategic demand), there is a positive effect on the intermediate price because the firm is price maker on the upstream market. This strategy of the integrated firm (strategic purchases) allows the firm to strategically adjust the price on the intermediate market. In that case, the firm has the possibility to increase the cost of its competitors on downstream market (raising rival's costs).

In our model, we adopt the framework developed by Gaudet and Van Long (1996), in order to focus on the strategic aspects of storage in gas sector. Indeed, access to storage (viewed as an essential facility) allows the firms to use it in a strategic way. Our model focuses on cases where access to storage facilities allows rival firms to adjust strategically the gas price on downstream market. We have such a situation when the competitive suppliers are integrated with an upstream oil and gas company. For the industrial structures studied here, we show that TPAS allows the vertically integrated firm (active on both upstream and downstream markets) to strategically rise the intermediate market price in order to increase the cost of the downstream independent firm. In these cases, it seems better from the point of view of welfare to alleviate this strategical behavior by means of the vertical integration of storage operator (when access to storage is opened).

We focus on strategic effects related to the TPAS when one of the downstream market competitors is integrated with an upstream oil and gas company. More precisely, we study two different industrial structures: separated TPAS (S) and integrated TPAS (I). The industrial structure S represents the situation in which access to storage facility is allowed to the integrated firm (i.e. TPAS) in order to inject or to withdraw gas. In that case, the activity of storage is independent. The structure I represents a situation of TPAS in which the activity of storage is vertically integrated with a downstream supplier.

Section 2 presents the model. Section 3 studies the case of the industrial structure S in which the activity of storage is independent. Section 4 analyzes the effect of an integration of storage with a supplier (I). Finally, section 5 gives some further results with a linear demand function and the last section is devoted to conclusions.

II. The model

In our framework, the industrial structure of the gas market distinguishes three vertically organized markets: the upstream gas production, the downstream gas distribution and an intermediate level, which is the storage activity. We consider that production and distribution markets are duopolies while the storage activity is insured by a monopoly. This configuration is supposed to be a good approximation of the competition on the whole gas chain, implying further the use of a storage capacity which can be considered as an essential facility. On the other hand, we suppose that the gas routing from the upstream to downstream level requires that non integrated firms use the gas storage facility and consequently support an access cost.[2]

In our model, gas production is devoted to two firms (oil and gas companies) indexed by $j = 1, 2$. The selling price of that production is denoted by k, and is determined by competition in quantities among those firms. The upstream producer j's profit can be written as[3]:

$$\pi_j^u\left(y_j, y_{-j}\right) = \left(k\left(Y\right) - C_j^u\right) y_j$$

where $Y = y_1 + y_2$ and $k\left(Y\right)$ is the inverse demand function on the intermediate market. The produced quantity y_j by an oil and gas firm j that is integrated with downstream suppliers is corresponding to a net supply (that is the production level less the quantity necessary for supplying the downstream demand). If that net supply is negative, it represents a demand for gas on the intermediate market. For every unity produced, a cost C_j^u is borne. This cost can be divided in two parts: a (unit and marginal) cost of production γ and an access charge to the storage facility. Without any loss of generality, we normalize this marginal cost of production γ to zero. So when the net supply is negative, C_j^u the cost of production of the firm is just equal to the storage withdrawal price noted a then $C_j^u = -a$. In the case of a positive net supply, this cost can be reduced to $C_j^u = i$ where i is the storage injection price.

The natural downstream gas market supply is insured by 2 firms indexed by $h = 1, 2$ and we assume again Cournot competition among them. The inverse demand function on the downstream market is denoted by $P(Q)$. We assume normal demand[4] for the product, that is $P'(Q) < 0$. A (downstream) supplier h profit is then written:

$$\pi_h^d\left(q_h, q_{-h}\right) = P\left(Q\right) q_h - \left(k + a\right) q_h$$

with $Q = q_1 + q_2$.

Finally we assume that a single firm is in charge of the storage activity and we denote c the marginal cost of storage. In the case of a Third Party Access to Storage Facilities (TPAS), the storage firm's profit is:

$$\pi_s = \left(a - c\right) S + \left(i - c\right) I$$

where S is the gas amount withdrew from the stock. It corresponds to the final market demand to which are added the possible demands of the upstream producers (negative net supply), that is $S = q_1 + q_2 - \sum_{j \in J^s} y_j$, where $J^s = \{j \mid y_j < 0\}$. The variable I represents the injected gas amount and it is just equal to the upstream market supplies (positive net supply), that is $I = \sum_{j \in J^I} y_j$, where $J^i = \{j \mid y_j \geq 0\}$. From now, we normalize to zero, the marginal cost of storage that is $c = 0$ [5].

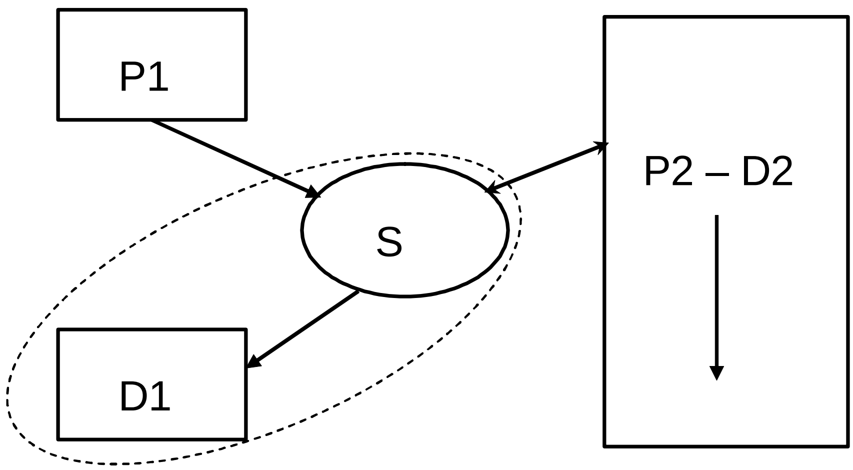
In the following sections, we study more precisely the case where an entirely integrated firm (precisely integration of $h = 2$ and $j = 2$) competes with an independent supplier ($h = 1$) on the final market. The following figure illustrates this structure:

[2] Access to the storage facility is not necessary for an enterely integrated supplier ; it is the case for example when the gas can be directly transported by liquified natural gas carriers.

[3] The superior index u indicates an upstream oil and gas firm. Identically, the superior index d indicates a downstream supplying firm.

[4] We also assume that it is not too convex, in the sense where the function $\Gamma\left(Q\right) = 2P\left(Q\right) + P'\left(Q\right) Q$ is non increasing w.r.t. $Q \geq 0$. In other words, the slope of the inverse demand function is greater than $-(n+1)$, where n is the number of active firms. Here $n + 1 = 3$. This assumption is standard in oligopoly theory and guarantees existence and uniqueness of the Cournot-Nash equilibrium (see for example X. Vives 2000).

[5] This simplification is harmless here because the storage activity is not envisioned within its dynamic dimension. This implies the permanent balance between the entering and outgoing flows within the stock.



As in Gaudet and Van Long (1996), we consider in this model that the issue of the upstream supply in entirely solved by the variable y_2. The integrated firm's profit[6] may be written as:

$$\Pi_2(q_2, q_1, y_2, y_1) = P(Q)\, q_2 + (k - C_2^u)\, y_2$$

Thereafter, we consider a situation where firms engage in competition à la Cournot on the upstream market and on the intermediate market, that is a bilateral oligopoly framework. More exactly, we study a two-stage game: in a first stage, the oil and gas companies determine their strategies of production and in a second stage the downstream suppliers compete on the final market. We look for the subgame perfect Nash equilibria.

III. Competition and independent storage

In this section, we consider a vertical structure (S) in which the integrated firm (firm 2) has an open access to the storage facility and thus can inject or withdraw some gas. In addition, the activity of storage is independent.

On the downstream market, the Cournot equilibrium[7] (q_1^s, q_2^s) must verify:

$$q_1^s = \arg\max_{q_1 \geq 0} \pi_1^d(q_1, q_2^s) \quad \text{and} \quad q_2^s = \arg\max_{q_2 \geq 0} \Pi_2(q_2, q_1^s, y_2, y_1)$$

This equilibrium couple is then implicitly defined by the necessary first order conditions:

$$P(Q^s) - (k + a) + P'(Q^s)\, q_1^s = 0 \quad \text{and} \quad P(Q^s) + P'(Q^s)\, q_2^s = 0$$

with $Q^s = q_1^s + q_2^s$, where Q^s is the equilibrium supply level put on the final market. By assumption, this variable is a part of S, the amount withdrew from the gas inventory. These conditions can be rewritten using the well known Lerner rules:

$$\frac{P(Q^s) - (k + a)}{P(Q^s)} = \frac{s_1^s}{\eta(Q^s)} \quad \text{and} \quad 1 = \frac{s_2^s}{\eta(Q^s)} \tag{1}$$

where $\eta(\cdot)$ is the price elasticity of demand. We recognize here the traditional relation between the Lerner index, the price elasticity of demand and the active firms' market share s_h.

[6] The cost of the access to storage is booked only once (because the gas resource is internally supplied). It corresponds to the injection price i if the net supply is positive or to the withdrawal price a in the negative case.

[7] We only focus here on interior equilibria.

Lemma 1 The market share of the integrated firm is greater than that of the independent downstream firm, i.e. $s_1^n < s_2^n$.

This result stems directly from Lerner rules expressed above. From this market share ranking, we can say the vertical integration allows the firm $j = 2$ to by-pass the storage facility and to get a competitive advantage.

From this downstream market equilibrium, it is now possible to express intermediate market demand. This inverse demand is given by $k = \left(q_1^n\right)^{-1}(Y)$, the intermediate (upstream) supply being equal to $Y = y_1 + y_2$. The cost of access (injection/withdrawal) C_j^u then depends on the sign of the net supply, y_j.

In the first stage of the game, the Cournot equilibrium[8] is denoted (y_1^s, y_2^s), and determined by the following relations:

$$\frac{k^s - C_1^u}{k^s} = \frac{\sigma_1^s}{\varepsilon(Y^s)} \quad \text{and} \quad \frac{k^s - C_2^u + P'(Q^s)\, q_2^s}{k^s} = \frac{\sigma_2^s}{\varepsilon(Y^s)} \lesseqgtr 0 \tag{2}$$

The independent firm supports only the cost of production C_1^u. By contrast, the integrated firm supports an additionally marginal cost $P'(Q^s)\, q_2^s < 0$. This marginal cost represents for the firm the indirect (strategic) effect $\frac{d\Pi_2^s}{dq_1}\frac{dq_1^s}{dy_2}$ of its upstream strategy on its downstream supply. In this case, the quantity produced by the integrated firm induces two opposite effects on its profit: a direct positive effect on its upstream profit (quantity effect linked to the margin $k - C_2^u$) and a strategic effect on its downstream profit (indirect effect). This last effect shows that an increase of the production of that integrated firm leads to a fall in the intermediate market price. Then this strategic effect benefits to the downstream independent firm: its costs are decreasing and thus it can develop a competitive advantage in the downstream market (relatively to the integrated firm). The decision of producing the amount y_2 precisely incorporates the trade-off between the direct and strategic effects.

The equilibrium on this intermediate market requires a positive trade, so

$$Y^s = q_1^s\left(k\left(Y^s\right)\right) > 0$$

Consequently, we can derive from this last result that both firms cannot inject or withdraw simultaneously in the stock.

Lemma 2 If one of the upstream firms is withdrawing at the equilibrium, it is necessarily the integrated one.

Proof. Assume that the independent upstream firm withdraws so $y_1^s \leq 0$. Relations (2) then imply: $\frac{k^s + a}{k^s} > 1$. But in this case, the independent downstream supplier's market share is negative by definition, a contradiction since $\frac{k^s + a}{k^s} = \frac{\sigma_1^s}{\varepsilon(Y^s)} \leq 0$. ■

Consequently we can see that at the equilibrium, the independent firm injects a certain amount of gas in the stock so $y_1^s > 0$. Then (2) writes now:

$$\frac{k^s - i}{k^s} = \frac{\sigma_1^s}{\varepsilon(Y^s)} > 0 \quad \text{and} \quad \frac{k^s - C_2^u + P'(Q^s)\, q_2^s}{k^s} = \frac{\sigma_2^s}{\varepsilon(Y^s)} \gtreqless 0 \tag{3}$$

The integrated firm's strategy on the intermediate market thus depends very strongly on the shape of the demand function k on this market and more generally on the final market demand. Thus, at this stage of the analysis, we cannot exclude any of the three types of equilibria: those with an injection strategy $(y_j > 0)$ from the integrated firm, those with withdrawal $(y_j < 0)$ or those with foreclosure

[8] We suppose the interior equilibrium does exist that is $\left(q_1^n\right)^{-1}(Y)$ is not too convex.

($y_j = 0$). Then everything depends on the scope of the direct effect with regard to the strategic effect. When the direct effect (respectively the strategic effect) dominates the strategic effect (resp. the direct effect), the integrated firm should rather sell (resp. buy) on the intermediate market and thus inject (resp. withdraw) some gas in the stock. A foreclosure equilibrium, such that $y_2^s = 0$, is selected if

$$\hat{k}^s + a > -P' q_2^s > \hat{k}^s - i$$

IV. Competition and integrated storage

In this section, we suppose that the storage is vertically integrated with the downstream supplier 1. The profit function of the integrated storage writes now

$$\Pi_1 (q_1, q_2) = \pi_1^d + \pi_s = (P(Q) - k - c) q_1 + a\hat{S} + iI$$

where $\hat{S} = -\sum_{j \in J^s} y_j$, with $J^s = \{j | \, y_j < 0\}$.

This market structure has similar characteristics to the previous scenario S and the downstream market equilibrium is similar to the equilibrium described by the relation 1. However, the cost of supply of the independent firm 1 is now lower because the access charge is not paid anymore. Thus $k + a$ becomes k. We can show (see the appendix for details) at the downstream market equilibrium it must be the case that $q_1^i > q_1^s$, $q_2^i < q_2^s$ and $Q^i > Q^s$. Hence we can directly state the following proposition:

Proposition 1 *The integration of storage decreases the market share of the vertically integrated oil and gas company (firm 2):* $s_2^i < s_2^s$

The integration of the storage allows the supplier 1 to reduce to zero the cost of access to storage. Consequently, it allows the supplier 1 to restore its position on the downstream market and to improve its market share.

The intermediate demand writes now $k^i = (q_1^i)^{-1}(Y)$ and competition in the intermediate market leads to the following equilibrium rules:

$$\frac{k^i - C_1^u}{k^i} = \frac{\sigma_1^i}{\varepsilon(Y^i)} \text{ and } \frac{k^i - C_2^u + P'(Q^i) q_2^i}{k^i} = \frac{\sigma_2^i}{\varepsilon(Y^i)} \gtrless 0$$

This equilibrium structure is the same as in the previous situation. At the equilibrium, the integrated firm strategy depends on the balance between the direct and strategic effects (discussed above). However, the strategic effect depends on q_2^i that is weaker than q_2^s. *Ceteris paribus*, this effect is now less strong than in the previous situation S. In this case, the integration of storage will reduce the possibility of an equilibrium with a withdrawal behavior (strategic purchase).

V. The linear case

We compare the two industrial structures using a linear demand function in order to illustrate the direct and strategic effects presented in the previous sections. More precisely, we assume that the inverse demand function is given[9] by $P(Q) = 1 - Q$. In that case, we focus on the strategies of an oil and gas company when it is active on downstream and upstream markets: it can strategically buy natural gas on intermediate market in order to raise the cost of the rival firm which is only on the downstream market. This strategy is an equilibrium of the game when the strategic effect dominates the direct effect.

[9] This simplistic formulation is broadly used in the vertical relation literature.

In the industrial structure S, the intermediate market net supply of the integrated oil and gas company may be written as[10]:

$$y_1^s = \frac{5}{24}\left(1 - 2\left(a + i\right)\right) \quad \text{and} \quad y_2^s = -\frac{1}{12}\left(1 - 2\left(a + i\right)\right) \quad \text{if} \quad a < \frac{1}{2} - i$$

When the storage activity is integrated (structure I), the "withdrawal" and "foreclosure" equilibria are the only one possible. More precisely, a "withdrawal" equilibrium emerges for $a < \frac{1}{6} - \frac{i}{3}$. In this case, we obtain:

$$y_1^i = \frac{5}{24}(1 - \frac{6}{5}a - 2i) \text{ and } y_2^i = -\frac{1}{12}\left(1 - 6a - 2i\right)$$

For $a > \frac{1}{6} - \frac{i}{3}$, the "strategic effect" balances with the "direct effect" and the integrated firm chooses strategic foreclosure, $y_2^i = 0$. The supply of the distributor 1 is $y_1^i = \frac{1}{6}\left(1 - 2i\right)$. It is strictly positive if the price of injection is not too high (here $i \leq \frac{1}{2}$).

The integration of the storage with a downstream supplier induces a reduction of the strategic purchases of firm 2 on the intermediate market and it consequently involves a reduction of the allocative distortion. This reduction is all the stronger as access to storage prices (for withdrawal and injection) are high.

Proposition 2 The integration of the storage with a downstream supplier induces an increase of the intermediate market price, $k^i \geq k^s$.

Proof. The prices on the intermediate market are written as $k^s = \frac{5}{16}(1 - 2a + \frac{6}{5}i)$ and $k^i = \frac{5}{16} - \frac{3}{8}\left(a - i\right)$. Straightforwardly, we see here that $k^i = k^s + \frac{1}{4}a$ which yields the result. ■

This result is not surprising anymore because the integration of storage reduces the level of strategic purchases. In fact, this increase in the intermediate price level stems from the demand increase of the distributor 1. As a matter of fact, the distributor 1 increases his demand on the intermediate market because he is more efficient after integration with the storage operator (he internalizes one margin).

Proposition 3 The integration of the storage activity with a downstream supplier improves the welfare (because it lowers the final prices).

One can see as a proof that the increase of the intermediate market price due to the vertical integration of storage activity doesn't increase the final price. Indeed, we have,

$$p^s = \frac{1}{8}\left(7 + 2\left(a + i\right)\right) \quad \text{and} \quad p^i = \frac{1}{16}\left(7 - 2\left(a - i\right)\right)$$

and we can directly state:

$$p^s = p^i + \frac{3}{8}a + \frac{1}{8}i + \frac{7}{16} > p^i$$

This result emerges because the vertical structure is more efficient (less costly) with the integration of the storage. This "efficiency effect" dominates the effect of the intermediate price level on the final price. In this case, increasing intermediate price doesn't involve increasing final price.

[10] Details are simple but fastidious, so we omit them. They are available on the web page: http://www.sceco.univ-montp1.fr/creden/Poudou/Poudou.htm

VI. Conclusion

In this article, we discuss some questions concerning third party access to the storage capacities. In the framework of the industrial structures considered, two main results have been shown:

- first, the storage facilities can be strategically used by the oil and gas companies active on the upstream and downstream markets. Theses integrated firms have incentives to buy natural gas on intermediate market (represented by the activity of storage). In this way, the behavior of oil and gas companies has an impact on the natural gas demand on the intermediate market. In this context, access to storage facilities allows integrated firms to adjust strategically the gas price on downstream market. It allows to raise the cost of the rival firms that buy natural gas in order to supply the downstream market. This "raising rival cost" strategy induces some distortions and reduces the welfare.
- Second, the integration of storage activity with a downstream supplier allows to reduce this distortion and to improve the welfare.

These two results allow us to make an interesting remark on the optimal regulation of gas markets. Considering the strategic behavior of oil and gas companies on the storage activity, it is socially optimal for the regulator to integrate storage and supply activities. Such an integration allows to compensate for this strategic behavior. More precisely, it lowers the cost supported by the non integrated supplier with regard to that of the vertically integrated oil and gas companies. This idea translates the principle of a symmetric regulation: if authorities accept vertical integration of oil and gas companies, they may also accept vertical integration of the storage activity.

Appendix

S and I downstream market equilibria have a similar structure: in the S situation, relations 1 hold and in the I situation, they hold just modifying the firm's 1 marginal cost which is only set to k. So let $q_h(x)$ the downstream production of firm h when x is the firm's 1 cost of production. Using these notations, S and I productions at the firm level can now be denoted $q_h^s = q_h(k+a)$ and $q_h^i = q_h(k)$. Then generically a downstream (Cournot) equilibrium (S or I) is defined by

$$\begin{aligned} P(Q(x)) - x + P'(Q(x))\, q_1(x) &= 0 \\ P(Q(x)) + P'(Q(x))\, q_2(x) &= 0 \end{aligned}$$

where $Q(x) = q_1(x) + q_2(x)$. Differentiating w.r.t. x and omitting arguments Q and x, gives

$$½ \begin{array}{l} [P'(\cdot) + P''(\cdot)\, q_1](dq_1 + dq_2) + P'(\cdot)\, dq_1 = dx > 0 \\ [P'(\cdot) + P''(\cdot)\, q_2](dq_1 + dq_2) + P'(\cdot)\, dq_2 = 0 \end{array}$$

which finally leads to the comparative statics result

$$\begin{aligned} q_1'(x) &= \frac{2P'(Q(x)) + P''(Q(x))\, q_2(x)}{P'(Q(x))\, \Gamma'(Q(x))} < 0 \\ q_2'(x) &= -\frac{P'(Q(x)) + P''(Q(x))\, q_2(x)}{P'(Q(x))\, \Gamma'(Q(x))} > 0 \\ Q'(x) &= \frac{1}{\Gamma'(Q(x))} < 0 \end{aligned}$$

where by definition (see footnote 4) $\Gamma(Q) = 2P(Q) + P'(Q)\, Q$ is a non increasing function of $Q \geq 0$.

Since in the S regime $x = k + a$ but $x = k$ in the I regime, from the comparative statics result above it is straightforward that

$$\begin{aligned} q_1(k+a) &= q_1^s < q_1^i = q_1(k) \\ q_2(k+a) &= q_2^s > q_2^i = q_2(k) \\ Q^s &= Q(k+a) < Q(k) = Q^i \end{aligned}$$

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