A strategic perspective on competition between pipeline gas and LNG

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Abstract

Global gas markets feature two types of suppliers: piped gas and LNG exporters. Pipelines have a high degree of “asset specificity”: once built, they are physically bound to a particular route. LNG is transported by tanker, with a choice of export markets. Put simply: LNG is mobile, pipelines are not. This paper uses game-theoretic modelling to show how its commitment to serving a single market confers a strategic advantage on piped gas. By “overinvesting” in its own market, a pipeline exporter can induce LNG rivals to shift sales to their other markets. The model helps understand competition between Russian piped gas and Qatari LNG. It shows how Russia’s dependence on Europe can be good news for gas buyers, why these nonetheless strongly benefit from diversifying into LNG imports, and how the Herfindahl index of imports can mismeasure “supply security”. The paper also discusses Russia’s evolving gas export strategy.

Keywords: Global gas markets, strategic competition, security of supply, diversification strategy

JEL codes: F12 (International Trade with Imperfect Competition), L13 (Oligopoly), L95 (Gas & Pipelines)

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1 Introduction

Competition in the international natural gas industry features two types of suppliers: traditional sellers of gas that is transported by pipeline, such as Russia/Gazprom, and exporters of seaborne liquefied natural gas (LNG), notably Qatar. With the expansion of international trade over the last decade, pipeline gas and LNG now increasingly compete head-to-head, notably in Europe. Yet they are also fundamentally different. Gas pipelines are large infrastructure investments with a very high degree of “asset specificity”: once built, they are physically bound to a particular route, with no alternative use (Williamson, 1985; Makholm, 2012). They are also observable to market participants and largely irreversible, giving them substantial commitment value in business strategy (Ghemawat, 1991). LNG, by contrast, is super-cooled and then transported by tanker, which gives exporters a choice of markets for any given cargo. Put simply: LNG is mobile, pipelines are not. The objective of this paper is use the toolkit of game theory to understand the implications of this asymmetry for competition in global gas markets.

Natural gas is of significant commercial and public-policy interest. It provides close to 25% of worldwide primary energy consumption, being widely used in power generation, residential heating and as a feedstock for industrial production. Following the 2015 COP-21 Paris climate conference, many policy analysts also see an important role for gas in the transition to a low-carbon economy (e.g., IEA, 2017)—notably given that it has half the CO$_2$-emissions intensity of coal.

International trade in natural gas is divided into three main regional markets—Europe, Asia and North America (Stern, 2012)—and is around 70% by pipeline and 30% as LNG.$^1$ The majority of European gas imports come via pipelines from Russia while LNG has played an important role especially for the UK and parts of Southern Europe. By contrast, many Asian gas importers lack pipeline connections; LNG makes up 100% of Japanese and South Korean imports, and Japan is the world’s largest LNG importer. With the rise of hydraulic fracturing, the US has become the world’s largest gas producer—but it has until recently been disconnected from international trade due to a lack of LNG export infrastructure (Joskow, 2013).

On the export side, Qatar is the world’s largest LNG supplier with a global market share of almost 35%; it has supplied close to 50% of European LNG and has also been the largest player in Asia.$^2$ Other large multimarket LNG exporters that serve both Europe and Asia include Nigeria and Trinidad & Tobago; future US LNG exports will be in a strategically similar position. The world’s largest supplier of pipeline gas is Gazprom,$^1$

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$^1$The data in this discussion are taken from BP (2016).

$^2$This paper follows the literature in treating countries as players; there is often a close association with a company, e.g., Russia (Gazprom), Norway (Statoil), Algeria (Sonatrach), Qatar (Qatargas).
which controls 75% of Russian production, with a legal monopoly over exports of piped gas. The “balance of power” between Russia and Qatari LNG has played a central role over the last 10 years (Stern and Rogers, 2014).

This paper presents a simple game-theoretic model that captures these essential features of competition in global gas. The model has two markets $A$ and $B$ and two strategic suppliers: an LNG exporter serves both markets $A$ and $B$ while a pipeline supplier sells only to market $B$. It is a two-stage game of capacity investments followed by quantity competition, where the LNG exporter chooses how to deploy its installed global capacity across the two markets in the 2\textsuperscript{nd} stage. The discussion focuses mostly on the rivalry between Russian piped gas (Gazprom) and Qatari LNG in Europe (market $B$)—where Qatar also serves Asia (market $A$).\footnote{Russia also has a small presence in LNG, currently at less than 5% of its total gas sales. This LNG is based out of different gas fields than its pipeline sales to Europe, so in effect represents a different player to the main one considered in this paper. See Section 5 for further discussion.}

The analysis begins by showing how its commitment to serving a single market confers a strategic advantage on a pipeline supplier. It recognizes that its LNG rival has an alternative use for its capacity in market $A$—and can therefore be induced in the 2\textsuperscript{nd} stage to cede market share of the common market $B$. As this raises its return on investment, the pipeline supplier aggressively “overinvests” in capacity. By contrast, the pipeline player itself has no such outside option because its investment is specific to market $B$. This strategic effect raises the market share and profits of pipeline gas—at the expense of LNG. The paper demonstrates how this effect can be quantitatively significant, and argues that it is robust across different model specifications.

The analysis shows how Russia’s dependence on Europe can benefit local gas buyers: its strategic overinvestment raises the intensity of competition, leading to higher production and a lower gas price.\footnote{Gazprom assumes a role similar to that of a classic Stackelberg leader (see, e.g., Tirole (1988, Section 8.2))—even though the timing of the model has \textit{simultaneous} choices of capacities and outputs; the model does not examine issues of entry deterrence and pre-emptive investment.} For the same reason, the widely-used Herfindahl index may give a misleading picture of “security of supply”: in some cases, higher import concentration is good news for buyers.\footnote{There are many different definitions of “security of supply”. A reasonably representative one is “the availability of sufficient supplies at affordable prices” (Yergin, 2006). While this definition is also imprecise, note that it has similarities with the standard definition of consumer surplus in economics.} The model can also explain why gas-importing countries nonetheless like to diversify into LNG—and how Lithuania’s first LNG import terminal yielded a larger-than-expected price concession from Gazprom.

\textbf{Contribution to the literature.} This paper complements the existing literature on natural gas markets, which is dominated by large-scale numerical Cournot-style models (e.g., Egging, Gabriel, Holz and Zhuang, 2008; Holz, von Hirschhausen and Kemfert, 2008; Yergin, 2006).
Chyong and Hobbs, 2014; Growitsch, Hecking and Panke, 2014). It is well-established in this literature that the global gas market is not perfectly competitive; market power is an important driver of prices and trade flows.\(^6\) Such large-scale models are well-suited to policy analysis via numerical simulation of scenarios in terms of gas demand, investment volumes, etc. However, their complexity means that it can be difficult to understand what is driving the numbers. This paper instead emphasizes the microeconomic intuition and strategic interaction between key producers.

Another important difference is that large-scale gas models are typically solved as “open loop” equilibria, in which capacity and production decisions are, in effect, made simultaneously; the analysis here derives a “closed loop” equilibrium in which players’ capacity choices have an impact on subsequent play.\(^7\) This distinction means that the strategic issues studied in this paper are absent from the prior literature.

This paper also relates to the industrial-organization literature on multimarket oligopoly, e.g., Bulow, Geneakoplos and Klemperer (1985); Cooper (1989); Shelegia (2012); Arie, Markovich and Sela (2017). The model here builds on the work of Shelegia (2012); key differences are that: (i) firms here are heterogeneous in terms of production and investment costs (piped gas vs LNG), and (ii) demand conditions vary across markets (Asia vs Europe). Both of these features are central to the global-gas application presented here.

A number of considerations are beyond the scope of the present analysis. Similar to most large-scale gas models, it does not incorporate the details of long-term contracts between buyers and sellers (see, e.g., Brito and Hartley (2007) and Hartley (2015)) and does not feature intertemporal constraints on resource extraction à la Hotelling (or gas storage). The paper also does not address issues arising from the 2014–16 crash in commodity markets.

The paper is organized as follows. Section 2 sets up the model, and Section 3 solves for its equilibrium. Section 4 presents the main results on the strategic advantage of pipeline gas over LNG and its implications. Section 5 discusses Russia’s evolving gas export strategy in light of the model, with a focus on how a future “pivot to Asia” may undermine Gazprom’s strategic position in Europe. Section 6 offers concluding remarks. Proofs of the formal results are in the Appendix.

\(^6\)Ritz (2014) shows that LNG exporter market power can explain observed global gas prices and trade patterns, combined with limited access to the LNG tanker market (which makes it difficult for third-party traders to arbitrage prices between different regions). Li, Joyeux and Ripple (2014) also find that the world gas market is not integrated but do estimate integration between European and Asian markets. Part of the reason is likely that their dataset ends in May 2011—and therefore contains almost no after-effects of the Fukushima Daiichi nuclear accident of March 2011.

\(^7\)In the business strategy literature, Hawk, Pacheco-de-Almeida and Yeung (2013) empirically examine entry strategies into the then-emerging LNG market over the period from 1996 to 2007 and also emphasize the commitment role of capacity investments in business practice.
2 The model

An LNG supplier, denoted as player 1, sells to both markets A and B, with outputs denoted by \(x_1, y_1\). A pipeline exporter, player 2, supplies solely to market B, with sales of \(y_2\). Market A features a linear inverse demand curve \(p^A(x_1) = a - bx_1\), with parameters \(a, b > 0\). Market B has linear demand \(p^B(y_1, y_2) = \alpha - \beta(y_1 + y_2)\), where \(\alpha, \beta > 0\).

The game has two stages. In the first stage, players simultaneously invest in production capacities, \(K_1\) and \(K_2\), respectively at unit costs of capacity \(r_1\) and \(r_2\). In the second stage, players simultaneously decide how much output to sell into markets A and B, at unit costs of production \(c^A_1, c^B_1 \geq 0\) for player 1 and \(c^B_2 \geq 0\) for player 2 (including transportation costs), subject to their installed capacities. Choices are observable to players and there is no discounting. Players maximize their respective profits and the equilibrium concept is subgame-perfect Nash equilibrium. Necessary conditions for an interior solution are \(p^A(0) = a > r_1 + c^A_1\) in market A, \(p^B(0) = \alpha > r_j + c^B_j\) as well as \(\phi_j > \frac{1}{2}\phi_i\), where \(\phi_j \equiv (\alpha - r_j - c^B_j) > 0\) is an index of the profitability of player \(j = 1, 2\), \(i \neq j\), in the common market B. Assume that, in equilibrium, (i) both players sell positive amounts to their respective markets, and (ii) each player’s total sales are at its capacity constraint.\(^8\)

This model is a simplified representation of the global gas market. The two players can be thought of as Qatar (LNG) and Russia/Gazprom (piped gas) as the main strategic producers. Market A is Asia—notably Japan and South Korea—served by LNG, while market B is Europe, served both by LNG and pipeline. Importantly, the model allows for pipeline gas and LNG to have different cost structures, and for demand conditions to vary across regional markets. The assumption of binding capacity constraints seems reasonable for this industry (in which any operational capacity is typically fully used); for example, global LNG export capacity utilization rates have consistently been 80–90%, with Qatar’s liquefaction utilization reported as 100% (IGU, 2013).\(^9\)

3 Solving the model

Define players’ revenue functions across the two markets, \(R^A_1(x_1) = p^A x_1\) and \(R^B_1(y_1, y_2) = p^B y_1, R^B_2(y_1, y_2) = p^B y_2\) as well as the corresponding marginal revenues \(MR^A_1(x_1) = p^A - bx_1\) and \(MR^B_1(y_1, y_2) = p^B - \beta y_1, MR^B_2(y_1, y_2) = p^B - \beta y_2\).

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\(^8\) The assumption that producers are capacity-constrained simplifies the analysis considerably. In effect, it reduces the “dimensionality” of the problem from five choice variables—that is, two capacity choices \((K_1, K_2)\) plus three output choices \((x_1, y_1, y_2)\)—to three.

\(^9\) By contrast, the global LNG import capacity utilization rate has been low and stable at around 40% since 2000; there are almost no countries in which these constraints are close to binding, and even Japan’s utilization has only been around 50% (IGU, 2013).
**Stage 2: Output decisions.** Consider players’ output choices in Stage 2, given Stage-1 investments. By assumption, producers are capacity-constrained, so LNG player 1’s sales satisfy \( x_1 + y_1 = K_1 \) while \( y_2 = K_2 \) for pipeline player 2.

The remaining question is how player 1 splits its sales across markets: it maximizes profits by equalizing its marginal revenues, net of the short-run costs, across markets with \( MR_1^A(x_1) - c_1^A = MR_1^B(y_1, y_2) - c_1^B \). Since players are capacity-constrained, this can be rewritten as:

\[
MR_1^A(K_1 - y_1) - c_1^A = MR_1^B(y_1, K_2) - c_1^B. \tag{1}
\]

LNG player 1’s choice of output to market \( B \) thus depends on the capacity installed by its rival player 2; this plays a crucial role in what follows. In sum, given capacities \( K = (K_1, K_2) \), outputs are \( x_1(K), y_1(K), y_2(K) = K_2 \).

**Stage 1: Capacity decisions.** Anticipating these output decisions, consider players’ capacity decisions at Stage 1. LNG player 1 chooses its investment to maximize its joint profits from both markets:

\[
\max_{K_1} \left\{ R_1^A(x_1(K)) + R_1^B(y_1(K), y_2(K)) - r_1 K_1 - \left[ c_1^A x_1(K) + c_1^B y_1(K) \right] \right\},
\]

which makes explicit the indirect dependency of its revenues and production costs on both players’ capacity choices. The first-order condition is:

\[
0 = MR_1^A \frac{\partial x_1}{\partial K_1} + MR_1^B \frac{\partial y_1}{\partial K_1} - r_1 - \left( c_1^A \frac{\partial x_1}{\partial K_1} + c_1^B \frac{\partial y_1}{\partial K_1} \right). \tag{2}
\]

Since \( \partial x_1/\partial K_1 + \partial y_1/\partial K_1 = 1 \) (given the binding capacity constraint, total sales rise one-for-one with capacity) and using (1), the LNG capacity investment is such that:

\[
(MR_1^A - c_1^A) = (MR_1^B - c_1^B) = r_1 > 0. \tag{3}
\]

This equates marginal revenue with long-run marginal cost (i.e., production cost plus capacity cost) for each market, \( MR_1^\ell = r_1 + c_1^\ell \) for \( \ell = A, B \). So the outcome in market \( A \) is the monopoly price given marginal cost \( r_1 + c_1^A \); denoting the associated output by \( x_m = \frac{1}{2}(a - r_1 - c_1^A)/b \), it follows that \( x_1 = x_m \) and \( y_1 = K_1 - x_m \).

The pipeline supplier 2 chooses its capacity investment to:

\[
\max_{K_2} \left\{ R_2^B(y_1(K), y_2(K)) - r_2 K_2 - c_2^B y_2(K) \right\}
\]
The first-order condition is:

\[ 0 = MR^B_2 \frac{\partial y_2}{\partial K_2} + \frac{\partial R^B_2}{\partial y_1} \frac{\partial y_1}{\partial K_2} - r_2 - c^B_2 \frac{\partial y_2}{\partial K_2}. \]  \hspace{1cm} (4)

Given linear demand in market \( B \), \( \frac{\partial R^B_2}{\partial y_1} = -\beta y_2 \), and similar to before, \( \frac{\partial y_2}{\partial K_2} = 1 \), and so (4) can also be written as:

\[ MR^B_2 + \beta \left( \frac{\partial y_1}{\partial K_2} \right) y_2 = r_2 + c^B_2. \]  \hspace{1cm} (5)

The “strategic effect” linking markets on the supply-side. The pipeline supplier 2 recognizes that its capacity choice affects the product-market behaviour of player 1 in their common market \( B \), via the “strategic effect” \( \sigma \equiv (\partial y_1 / \partial K_2) \).

**Lemma 1.** The strategic effect that links markets \( A \) and \( B \) satisfies:

\[ \sigma = \left( -\frac{\partial y_1}{\partial K_2} \right) = \frac{1}{2} \left( \frac{\beta}{b + \beta} \right) \in (0, \frac{1}{2}). \]

This expression can be understood as follows. A small increase \( dK_2 > 0 \) lowers player 1’s marginal revenue in market \( B \) by \( dMR^B_1 = (\partial MR^B_1 / \partial y_2)(dK_2) = -\beta (dK_2) < 0 \). (This reflects that competition in market \( B \) is in strategic substitutes (Bulow, Geneakoplos & Klemperer 1985).) By how much does player 1 have to adjust its sales \( y_1 \) to market \( B \) to adjust to restore optimality as per (3)? Cutting \( y_1 \) both raises \( MR^B_1 \) and lowers \( MR^A_1 \); specifically, \( dMR^B_1 = -2\beta(dy_1) > 0 \) and \( dMR^A_1 = 2b(dy_1) < 0 \). This leads to the expression for \( \sigma \in (0, \frac{1}{2}) \) in Lemma 1.

Hence the strategic effect captures how strongly pipeline player 2’s investment can induce LNG player 1 to cut back output in their common market \( B \). This raises its marginal return to installing an additional pipeline capacity in Stage 1. It plays a central role in the results of this paper, and is examined in more detail in the next section.

**Summary of the equilibrium.** Lemma 2 derives the equilibrium values \( (\hat{K}, \hat{x}_1, \hat{y}_1, \hat{y}_2) \), together with a parameter condition which ensures: (i) an interior solution for each choice variable, and (ii) that it is indeed optimal for both players to produce up to installed capacity in Stage 2.

**Lemma 2.** Assume that \( \frac{1}{2}(\phi_1 / \phi_2) > \max \left\{ \frac{1}{2(2-\sigma)}, \left[ 1 - \left( \frac{3-2\sigma}{2\sigma} \right) (r_2 / \phi_2) \right] \right\} \). The equilibrium in players’ capacity investments and production volumes is given by:

\[ \hat{x}_1 = x_m = (a - r_1 - c^A_1) / 2b \]
\[ \hat{y}_1 = [(2 - \sigma) \phi_1 - \phi_2] / \beta (3 - 2\sigma) \]
\[ \hat{K}_1 = \hat{x}_1 + \hat{y}_1 \]
\[ \tilde{K}_2 = \tilde{y}_2 = (2\phi_2 - \phi_1)/\beta(3 - 2\sigma), \]

where the strategic effect is \( \sigma \in (0, \frac{1}{2}) \) given by Lemma 1.

Equilibrium prices follow as \( \hat{p}^A = p^A(\tilde{x}_1) \) and \( \hat{p}^B = p^B(\tilde{y}_1, \tilde{y}_2) \).

The parameter condition on \( \phi_1/\phi_2 \) is satisfied, for all possible values \( \sigma \in (0, \frac{1}{2}) \), with e.g., (i) symmetric costs, \( c_1^A = c_1^B = c \) and \( r_1 = r_2 = r \), satisfying \( r > \frac{1}{5}(\alpha - c) \), or (ii) sufficiently similar costs in that \( \phi_1/\phi_2 \in (\frac{3}{5}, 2) \) as well as \( r_2 \geq \frac{1}{4}(\alpha - c_2) \). Roughly put, the multimarket LNG player’s cost structure cannot be too inferior and the pipeline’s investment cost not too small; the former ensures an interior solution while the latter means that the pipeline player does not install capacity that is subsequently unused.

4 The strategic advantage of pipeline gas over LNG and its implications

This section develops the main equilibrium results of the paper. The key to them lies in the asymmetry discussed at the outset: LNG is mobile while pipelines are not.

In the model, the pipeline supplier recognizes that its multimarket LNG rival has an alternative use for its capacity in market \( A \)—and can therefore be induced in Stage 2 to cede market share of the common market \( B \). This logic operates in an asymmetric fashion: the pipeline player has no such “outside option” for its capacity because its investment is specific to market \( B \).

That is, the strategic weakness of LNG that arises from its ability to diversify sales across several markets is exploited via the commitment of pipeline gas to serving a single market. This leads to “overinvestment”: the pipeline supplier 2 expands capacity beyond the point where marginal revenue equals long-run marginal cost (so that \( MR^B_2 < r_2 + c_2 \)). The strategic effect \( \sigma \) captures the strength of this single-market commitment.

Letting \( \hat{s}_j = \hat{y}_j/(\hat{y}_1 + \hat{y}_2) \) denote player \( j \)'s equilibrium market share and \( \hat{\Pi}_j^B \) its profits in market \( B \), leads to the main first result:

**Proposition 1.** In equilibrium, in the common market \( B \):
(a) the pipeline player’s \( 2 \)'s market share \( \hat{s}_2 \) and profits \( \hat{\Pi}_2^B \) rise with the strategic effect \( \sigma \), while the LNG player 1’s profits \( \hat{\Pi}_1^B \) fall;
(b) the market price \( \hat{p}^B \) declines with \( \sigma \).

Proposition 1 formalizes the idea that a pipeline supplier has a strategic advantage over a multimarket LNG rival in their common export markets. Its single-market commitment enables aggressive overinvestment which makes the pipeline supplier gain market share and profits over its LNG rival in common markets. Conversely, the additional capacity
investment means that total output in market $B$ rises—so that the market price and local consumers are better off.

The role taken by the pipeline player is similar to that of a textbook Stackelberg leader. The difference is that players’ choices are here made simultaneously rather than sequentially, so the advantage is due to an asymmetry in the market-specificity of technologies rather than the asynchronous timing of moves. In contrast to much of the industrial-organization literature on commitment, neither firm is “the incumbent”.

The degree of competition in market $B$ thus lies between perfect competition and the standard Cournot-Nash solution (for output choices in Stage 2, which is nested by Lemma 2 where $\sigma \equiv 0$). This is consistent with the simulation results of large-scale models of the European gas market, see, e.g., Egging, Gabriel, Holz and Zhuang (2008). The Cournot equilibrium would here arise if two pipeline suppliers, both solely selling to market $B$, were competing against one another.

(Informally, this analysis extends the industrial-organization results of Shelegia (2012, Proposition 3) to settings in which players have heterogeneous cost structures and demand conditions can vary across markets.)

**Implications for understanding competition in European gas markets.** Proposition 1(a) shows how Gazprom’s traditional “dependency” on the European market can be a source of strength—not necessarily a weakness, as is usually claimed in energy-policy discussions. By contrast, the flexibility of LNG to choose between different export markets also creates strategic vulnerability. This provides a different perspective on the widely-discussed role of Qatari LNG as the “swing producer” between Asia and Europe.

Proposition 1(b) then suggests how European gas customers can benefit from Gazprom having a “high” market share (for a given number of players competing in the market). Its strategic overinvestment raises the intensity of competition in the European market; total gas consumption rises and becomes cheaper. The “quasi-Stackelberg” logic means that a high Gazprom market share can go hand-in-hand with lower prices. This suggests that some caution is needed in drawing inferences about consumer welfare from Gazprom’s observed market share, and also that putting a cap on its allowable market share may be a counterproductive policy measure.

In sum, the model suggests that Gazprom enjoys two sources of competitive advantage over Qatar in the European market. First, industry estimates suggest that Gazprom has significantly lower overall unit costs of supplying the European market than Qatar and other LNG suppliers, including US LNG exports (e.g., IEA, 2009: pp. 481–485; OIES, 2016).\(^{10}\) In the model, this leads to a standard efficiency-based advantage in terms of

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\(^{10}\)OIES (2016) cited in “Global Gas Braced for Price War” (*Financial Times*, 3 February 2016)
market share and profits. Second, magnifying the cost argument, it enjoys the strategic advantage identified here.

The same argument also applies more broadly to competition between piped gas and LNG. The reason is that pipeline connections to end-consumer markets are typically preferable, from a cost perspective, for relatively short distances whereas LNG is more economical for long distances (Jensen, 2004). Crudely put, it makes little sense to build a pipeline from the Middle East to Japan; LNG is the only viable option. Thus, for a given consumer market served by both producer types, LNG imports tend to come from further away—with higher transportation costs. Hence pipeline suppliers typically have a cost advantage over LNG rivals.

Implications for “security of supply” analysis and understanding buyer diversification strategies. The analysis also sheds new light on concerns of security of supply and on the diversification strategies pursued by gas buyers. The Herfindahl index of gas-import concentration $H = \sum_{j} s_j^2$ is a standard metric to quantify supply security and to capture how it varies across importing countries (e.g., European Commission 2014). The underlying idea is that supply security is worse when the Herfindahl index is higher—which is associated with the presence of fewer and/or larger suppliers.

The present modelling shows that, contrary to this conventional wisdom, a higher Herfindahl index of gas-import concentration can be good for consumers. Defining the equilibrium Herfindahl index for market $B$ as $\hat{H} = (\hat{s}_1 + \hat{s}_2)^2$, leads to the following result:

**Proposition 2.** In equilibrium, in the common market $B$, if pipeline player 2 has weakly lower costs than LNG player 1 (that is, $r_2 + c_2^B \leq r_1 + c_1^B$), then the Herfindahl index $\hat{H}$ rises with the strategic effect $\sigma$, while this makes consumers better off (with a lower market price and higher consumption).

Proposition 2 highlights a limitation to the common practice of using Herfindahl concentration indices as an inverse measure of “security of supply” in energy markets. Applied to the European energy policy context, the point is that high or increased levels of country-level or regional Herfindahl import indices—for example, due to Gazprom’s market share—are not necessarily bad news for consumers.

To understand the result, note if the pipeline supplier has lower costs than its LNG rival, then it must have a larger market share. But since a higher strategic effect further raises its market share (i.e., further above 50%)—and so the Herfindahl index of concentration also rises. At the same time, by Proposition 1(b), consumers are better off. Thus it is entirely possible for the Herfindahl index and consumer welfare to move in the same direction. In this sense, a higher Herfindahl index may be good for energy security.
It is useful to contrast this with the standard industrial-economics theory on industry concentration. In Cournot-style models, the Herfindahl index and firms’ average price-cost margins are positively related (see, e.g., Tirole (1988, Section 5.5)). This result applies when varying industry concentration for a given underlying intensity of competition. By contrast, in the present model, the overinvestment logic leads to an endogenous change in the intensity of competition—which in turn is what drives the change in Herfindahl index. Put simply, not only does industry concentration change, also “Cournot becomes more like Stackelberg”. This illustrates how the details of the competitive context are important for properly interpreting market-share measures of supply security.

The model can help also explain why gas-importing countries place significant emphasis on access to LNG supplies. This was evident when Lithuania in late 2014 opened Klaipeda, its first LNG import terminal (in form of a floating storage regasification unit, known as FRSU). This for the first time created direct competition to piped gas from Russia, and reports suggested that it induced a larger-than-expected price concession from Gazprom. In the model, all else equal, an individual gas-importing country is better off with an import mix of one each of pipeline and LNG supply (such that $\sigma > 0$) than it would be with two dedicated pipeline suppliers (which corresponds to $\sigma \equiv 0$).

The LNG exporter creates an additional competitive externality on the pipeline supplier, making it compete more aggressively. This reduces the import price more strongly than if it were competing against another pipeline rival. For example, if all suppliers have identical costs, the price reduction can be up to 50% greater due to the strategic effect. For the same reason, it can also be desirable for a country to diversify into LNG imports even if these have higher costs than pipeline supplies.

**What determines the magnitude of the strategic effect?** Recalling from Lemma 1 that $\sigma = \frac{1}{2} \left[ \beta / (\beta + b) \right] \in (0, \frac{1}{2})$, its strength depends on the ratio $b/\beta$. This is a measure of the relative sizes of markets $A$ and $B$, in form of the ratio of the slopes of their respective demand curves. Larger $\beta$ corresponds to a smaller common market $B$; LNG player 1 then finds it less attractive—and is more easily induced to redirect output away from it, so $\sigma$ is larger. Conversely, with smaller $b$, the price in its other market $A$ drops less in response to higher sales—so this also favours redirection and $\sigma$ is larger. (Hence, the comparative statics on $\sigma$ from Propositions 1–2 can be thought of as being driven by changes in market $A$, leaving everything else in market $B$ unchanged.)

In sum, the strategic effect is larger, making European gas buyers and Gazprom better off, when the Asian LNG market is larger relative to Europe. Intuitively, a more attractive outside option in Asia makes it easier for Gazprom to displace LNG in Europe.

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11 See, e.g., “How Lithuania is Kicking Russia to the Curbs” (Forbes, 18 October 2015).

11
Numerical example. A simple example illustrates these results and shows how the impacts can be quantitatively significant. The numbers here are illustrative but loosely chosen to resemble regional prices and annual sales quantities the early 2010s. During this period, LNG’s choice between serving Europe and Japan/Asia was particularly important.

Qatar is player 1 and Russia/Gazprom is player 2. Qatar faces a (residual) LNG demand curve in Asia of \( p^A = 12\frac{1}{2} - \frac{1}{20}x_1 \), where the units are per mmbtu for price and bcm per annum for quantity. So \( a = \text{US$12.5} \) per mmbtu while \( b = \frac{1}{20} \) converts quantity units into price. Both players face a (residual) demand curve for their exports to Europe of \( p^B = 19\frac{1}{6} - \frac{1}{20}(y_1 + y_2) \), so \( \alpha = 19\frac{1}{6} \) and \( \beta = \frac{1}{20} \). Using Lemma 1, these demand parameters already pin down the value of the strategic effect \( \sigma = \frac{1}{4} \).

Players’ long-run marginal costs are, respectively, \( r_1 + c^A_1 = r_1 + c^B_1 = $7\frac{1}{2} \) mmbtu and \( r_2 + c^B_2 = $5 \) mmbtu. This reflects (i) similar shipping costs for Qatari LNG in serving Asia and Europe (\( c^A_1 \approx c^B_1 \), see Ritz 2014), and (ii) Gazprom’s cost advantage over LNG in Europe. Now recall that \( \phi_j \equiv (\alpha - r_j - c^B_j) > 0 \) and the parameter condition from Lemma 2, \( \frac{1}{2}(\phi_1 / \phi_2) > \max \left\{ \frac{1}{2} (1 - (\frac{2\alpha}{20})) (r_2 / \phi_2) \right\} \); it is easy to check that the first part holds. The second part depends on player 2’s investment cost being “sufficiently high”; it here requires that \( r_2 > $1\frac{2}{3} \) mmbtu—which is equivalent to the short-run marginal cost \( c^B_2 < $3\frac{1}{3} \) mmbtu.

Using Lemma 2, the equilibrium is as follows. Qatar installs \( \hat{K}_1 = 100 \) bcm of capacity, with annual sales split equally between Asia and Europe \( \hat{y}_1 = \hat{y}_2 = 50 \) bcm. Russia’s capacity investment and sales to Europe \( \hat{K}_2 = \hat{y}_2 = 133\frac{1}{3} \) bcm, giving a market share (within this duopoly) of close to \( \hat{s}_2 = 73\% \) and a Herfindahl index of \( \hat{H} = 6033 \). Finally, equilibrium prices here are identical in both markets, with \( \hat{p}^A = \hat{p}^B = $10 \) mmbtu.

It is useful to compare the equilibrium with the counterfactual of two pipeline competitors in the Europe market (with identical cost structures, for a clean comparison). As noted above, this yields the standard Cournot-Nash equilibrium (\( \sigma = 0 \)). Russia then installs and sells \( \hat{K}_2 (0) = \hat{y}_2 (0) = 111\frac{1}{5} \) bcm while Qatar’s sales to Europe \( \hat{y}_1 (0) = 61\frac{1}{5} \) bcm, so \( \hat{s}_2 (0) = 65\% \), \( \hat{H} (0) = 5421 \) and the European market price \( \hat{p}^B (0) = $10\frac{5}{3} \) mmbtu.

In sum, the equilibrium with the strategic effect features a Russian market share that is 8 percentage points higher and a Herfindahl index around 600 points higher—as well as a market price that is over 5% lower. This is driven by “overinvestment” in pipeline capacity (at 20% above the Cournot-Nash level), which in turn is driven by the ability of its single-market commitment to gain share from its mobile multimarket LNG rival.

How robust are these results? The above model is deliberately kept simple to help bring out the underlying intuition as clearly as possible—but its results are significantly more general:

First, note that neither of Propositions 1–2 hinge on one of the markets having a
higher price than the other, i.e., the sign or magnitude of the price difference \([\hat{p}^A - \hat{p}^B]\). In this sense, the results from the modelling are robust to whether or not regional prices are higher in Asia than in the European market. Indeed, the numerical example above shows how the effects are significant even with identical regional prices.

Second, the analysis has assumed, for simplicity, that the demand curves in both markets \(A\) and \(B\) are linear. Such linear-demand assumptions are widespread in the gas-markets literature; they are not necessary for any of the present results but do help simplify the exposition. In the common market \(B\), the key feature is that competition is in \textit{strategic substitutes}; this is what generates a positive strategic effect \(\sigma \equiv -\partial y_1/\partial K_2 > 0\) and holds also with many non-linear demand structures. In market \(A\), allowing player 1 to face non-linear demand can strengthen or weaken the strategic effect—but does not overturn its existence.

Third, it is also worth emphasizing that the multimarket LNG player is not acting irrationally by operating in both markets. Its profitability in market \(B\) may be lower than its pipeline rival’s but it can nonetheless be profit-maximizing for both players to self-select respectively into “diversified” and “focused” structures. For LNG player 1, serving both markets \(A\) and \(B\) is more profitable than serving only market \(B\) whenever the profit contribution of \(A\) exceeds the adverse impact on profits from \(B\). Similarly, it may be too expensive (or infeasible) for the pipeline player 2 to make another investment to enter market \(A\), e.g., due to the geographic location of its resource base (i.e., player 2’s cost structure is too high, relative to demand \(p^A(\cdot)\), to allow for profitable entry in market \(A\)).

Fourth, to bring out the results as clearly as possible, this paper considers a model with only two players. Yet this setup does not seem critical for its insights to hold. For instance, if the LNG player faced a competitive fringe of small producers in market \(A\), it would simply act as a residual monopolist. The economic logic of equalizing marginal revenues across markets—and its resulting strategic vulnerability remains. Or, with other pipeline players supplying market \(B\), all would vie to exploit their LNG rivals’ multimarket exposure. More realistic market structures quickly make the model unwieldy but its main insights appear to be generalizable. (In a recent industrial-organization paper, Arie, Markovic and Varela (2017) make progress in this direction in a model that restricts attention to firms having symmetric costs.)

Fifth, the analysis also raises the question of how a multimarket LNG player might mitigate its strategic weakness. For example, it could, already at the investment stage, earmark specific capacity shares to individual markets by signing long-term contracts with local buyers. Then it would no longer have to—or indeed be able to—allocate capacity between markets in Stage 2; in effect, this bundles together the two stages. The
multimarket weakness, and the qualitative insights from above, apply as soon as some installed capacity is flexibly allocated between markets by in Stage 2—not necessarily all capacity, as is formally the case in the model. Such a mix reflects actual industry practice; there are significant flexible volumes that LNG producers allocate between export markets—even if long-term contracts still play an important role.

Finally, a straightforward model extension is to include horizontally and/or vertically differentiated products in the common market $B$. This can reflect the small differences in quality (e.g. due to chemical composition) offered by piped gas and LNG, or that buyers might have a somewhat higher willingness-to-pay for “insurance” LNG supplies. As long as suppliers’ products in market $B$ are not fully differentiated, i.e., they remain substitutes in the eyes of consumers, the qualitative conclusions from Propositions 1 and 2 will remain valid.

5 Observations on Russian gas export strategy

While Russian gas exports have traditionally been dedicated to the European market, it has recently moved towards what has been variously described as a “pivot to Asia”. The model helps shed light on the strategic issues arising from this evolution of its gas-export strategy.

In May 2014, Russia and China reached agreement on the largest contract in the history of the natural gas industry. The “Power of Siberia” deal was reported to involve pipeline gas deliveries worth US$400 billion over a 30-year period commencing in 2018, with China also extending US$25 billion of financing to support the development of Eastern Siberian gasfields and pipeline construction.

At first glance, this eastward diversification of Russian gas exports may appear puzzling in light of the preceding game-theoretic analysis. In particular, it seems to turn...
Russia into a multimarket exporter to both Europe and Asia—and thus expose her to the same strategic vulnerability of LNG exporters. On closer inspection, however, it turns out that this conclusion does not follow. The key point is the Power of Siberia project involves natural gas in Eastern Siberia that was previously “stranded” and will become dedicated to the Chinese market. Hence the above concerns over strategic weakness do not apply. In effect, the existing western-bound pipeline (to Europe) and the new eastern-bound pipeline (to Asia) are different capacities, specific to different gas fields, with no scope for redirection into each other’s markets.

Particularly interesting in this regard is that, soon thereafter, in November 2014, it was reported that Russia and China were agreeing on a further major gas deal. This “Altai” project is fundamentally different in that it involves pipeline gas from Western Siberia that has so far been going to European consumers. This led to speculation that Russia could indeed become the new “swing producer” between European and Asian markets, taking over this role from Qatari LNG. The present analysis suggests that, from a strategic viewpoint, this deal should be significantly less attractive to Russia because it risks undermining Gazprom’s position in Europe. Indeed, more recent press reports suggest, for a range of economic and political considerations, this Altai project is no longer being pursued.

The present analysis also points to the possibility that the Power of Siberia project, as a pipeline investment dedicated to the Chinese market, has a strategic incentive to “overinvest” in capacity. This would allow it to gain market share from current (and future) LNG rivals—such as Qatar but also Australian and US LNG export projects—who serve the Chinese market, amongst others. If so, this will intensify competition in the Chinese market, shift market share from LNG to piped gas, and significantly benefit local gas buyers.

It is also worth noting that Russia has, over the last decade has itself been building a presence in LNG—though it remains small at around 5% of total gas exports. This LNG has come from the Sakhalin-2 project, which has been running since 2009, where Gazprom is partnered with Royal Dutch Shell, Mitsui and Mitsubishi. Again, these LNG exports do not come from the same fields that sell pipeline gas to Europe; in effect, they represent different capacity investments. To date, the project has been selling almost exclusively to Japan and South Korea, in part because transport costs to Europe or Latin America are very high. There is also the Yamal LNG project in the Russian Arctic, which involves different players: Novatek, Total, and CNPC. This project shipped its first gas in late 2017—and some observers expect it to double Russia’s share of the global LNG market over the coming years.

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15 See Henderson (2014) for another perspective on the recent gas deals between Russia and China.
More generally, the above analysis demonstrates that diversification of a traditionally pipeline-based exporter into LNG (from the same gas fields) can come at a strategic cost. So it can be rational for a pipeline seller to reject a seemingly profitable diversification opportunity into LNG so as to protect its existing business.

6 Conclusion

This paper has presented a new perspective on international trade in the natural gas industry. Its insights are driven by a fundamental asymmetry: LNG is mobile, pipelines are not. Game-theoretic modelling showed how piped gas enjoys a strategic advantage over LNG rivals, developed implications for the analysis of supply security, and helped shed light on the diversification strategies pursued by gas-importing and gas-exporting countries.

This paper has deliberately focused, quite narrowly, on the strategic advantage enjoyed by a firm committed to serving fewer markets than its rivals. In practice, uncertainty over demand and costs (and rival behaviour) can play a significant role in driving decisions. There may be trade-offs between committing to particular investments and retaining flexibility to adjust decisions further down the road (see, e.g., Ghemawat and del Sol 1998). Multimarket LNG players may be better equipped to deal with, and benefit from, such uncertainty.

The analysis presented here opens other avenues for future research. Over the next 5 years, the US looks set to become a major LNG exporter; the first such project, Cheniere Energy’s US$10 billion export facility at Sabine Pass, Louisiana, began deliveries in 2016—and has already sold cargos to both Europe and Asia. Incorporating this would extend the model to three regions in which the repercussions for competition against Russian piped gas and other LNG exporters could be studied.

The present results may also lend themselves to empirical testing. This includes, for example, the finding that gas buyers are better off, all else equal, with imports from a mix of piped gas and LNG than being supplied only by pipelines. With access to better data on natural gas markets, the literature may in future be able to econometrically test such predictions.

Finally, it would be useful to try to integrate the current strategic perspective on competition—via the commitment role of players’ capacity investments—into the large-scale simulation models that currently dominate the literature on natural gas markets. This may prove challenging from a technical perspective but it could have substantial payoffs in form of a richer picture of competitive dynamics.
References


Appendix

Proof of Lemma 1. Totally differentiating (1) shows that the strategic effect satisfies:

\[ \sigma \equiv \left( -\frac{\partial y_1}{\partial K_2} \right) = \frac{\partial MR^A}{\partial K_2} - \frac{\partial MR^B}{\partial K_2} \left( \frac{\partial^2 M^A}{\partial y_1^2} - \frac{\partial^2 M^B}{\partial y_1^2} \right) = \left[ \frac{\beta}{2\beta + 2b} \right] \in (0, \frac{1}{2}), \]

The final equality uses that \( \partial MR^A/\partial K_2 = 0 \) (player 2’s actions have no direct impact on revenues in market A), \( \partial MR^B/\partial K_2 = \partial MR^B/\partial y_2 = -\beta \), \( \partial MR^A/\partial y_1 = -\partial MR^A/\partial x_1 = -2\beta \), as well as \( \partial MR^B/\partial y_1 = -2b \).

Proof of Lemma 2. Begin by deriving the equilibrium values \( (\hat{K}, \hat{x}_1, \hat{y}_1, \hat{y}_2) \), and then determine parameter conditions which ensure that the equilibrium is indeed valid. By arguments in the main text, \( b_{x_1} = x_m \), and, by assumption, \( \hat{y}_2 = \hat{K}_2 \). The two remaining unknowns \( (y_1, K_2) \) are pinned down as follows. First, by (1), \( MR^B(y_1, K_2) = r_1 + c^B_1 \); using \( y_2 = K_2 \) and \( MR^B(y_1, K_2) = p^B_1 - \beta y_1 = \alpha - \beta(2y_1 + K_2) \), this can also be written as:

\[ y_1 = \frac{(\phi_1 - \beta K_2)}{2\beta}. \]

Second, by (5), \( MR^B_2 + \beta y_2 = r_2 + c^B_2 \), which using \( y_2 = K_2 \) gives:

\[ K_2 = \frac{(\phi_2 - \beta y_1)}{\beta (2 - \sigma)}. \]

Solving these two equations simultaneously yields:

\[ \hat{y}_1 = \frac{(2 - \sigma) \phi_1 - \phi_2}{\beta (3 - 2\sigma)} \text{ and } \hat{K}_2 = \frac{(2\phi_2 - \phi_1)}{\beta (3 - 2\sigma)}; \]

Confirming \( (\hat{K}, \hat{x}_1, \hat{y}_1, \hat{y}_2) \) as a valid equilibrium requires two more steps: (1) determining parameter conditions which ensure interior solutions, \( \hat{x}_1, \hat{y}_1, \hat{K}_2 > 0 \); and (2) verifying that both players indeed find it optimal to fully use their installed capacity in Stage 2, with \( \hat{x}_1 + \hat{y}_1 = \hat{K}_1 \) and \( \hat{y}_2 = \hat{K}_2 \).

Step 1. For player 2, (9) implies that \( \hat{K}_2 > 0 \) if and only if \( \phi_2 > \frac{1}{2} \phi_1 \) which holds by assumption. For player 1, \( \hat{x}_1 > 0 \) follows from the assumption \( p^A(0) > r_1 + c^A_1 \); moreover, (9) shows that \( \hat{y}_1 > 0 \) if and only if \( \phi_1/\phi_2 > \frac{1}{(2 - \sigma)} \), which is the first part of the parameter condition.

Step 2. In Stage 2, player 1 will find it optimal to fully use all of its installed capacity, such that \( \hat{x}_1 + \hat{y}_1 = \hat{K}_1 \), as long as its marginal revenue at \( (\hat{K}, \hat{x}_1, \hat{y}_1, \hat{y}_2) \) exceeds its production.
cost in each market. This holds since (1) implies that \((MR_1^A - c_1^A) = (MR_1^B - c_1^B) = r_1 > 0\). For player 2, similarly, if \(MR_2^B > c_2^B\) at \((\hat{K}, \tilde{x}_1, \hat{y}_1, \hat{y}_2)\) then \(\hat{y}_2 = \hat{\hat{K}}_2\) is optimal. Recalling \(MR_2^B(\hat{y}_1, \hat{K}_2) = [\alpha - \beta \hat{y}_1 - 2\beta \hat{\hat{K}}_2]\) and using \(\hat{y}_1, \hat{K}_2\) from (9) gives that \(MR_2^B(\hat{y}_1, \hat{K}_2) > c_2^B\) if and only if:

\[
(\alpha - c_2) > \beta \hat{y}_1 + 2\beta \hat{\hat{K}}_2 = \frac{(3\phi_2 - \sigma \phi_1)}{(3 - 2\sigma)}.
\]

Noting that \((\alpha - c_2) \equiv (\phi_2 + r_2)\) and some rearranging gives that this is last condition equivalent to \(\phi_1/\phi_2 > 2 \left[1 - \left(\frac{3-2\sigma}{2\sigma}\right) (r_2/\phi_2)\right]\), which is the second part of the parameter condition.

**Proof of Proposition 1.** For part (a), using \((\hat{y}_1, \hat{y}_2)\) from Lemma 2 gives an expression for player 2’s market share:

\[
\hat{s}_2(\sigma) \equiv \hat{\hat{y}}_2 \hat{\hat{y}}_1 + (2\phi_2 - \phi_1) \quad (10)
\]

It is easy to see that \(\partial \hat{s}_2(\sigma)/\partial \sigma > 0\), as claimed. Player 2’s equilibrium profits \(\hat{\Pi}_2^B = [R_2^B(\hat{y}_1, \hat{y}_2) - (r_2 + c_2^B)\hat{y}_2]\) in market B can be written as:

\[
\hat{\Pi}_2^B(\sigma) = \beta (1 - \sigma)(\hat{y}_2)^2 = \frac{1}{\beta} \frac{(1 - \sigma)(2\phi_2 - \phi_1)^2}{(3 - 2\sigma)^2},
\]

since \(MR_2^B + \beta \sigma y_2 = \hat{p}^B - \beta (1 - \sigma)\hat{y}_2 = r_2 + c_2^B\) by (5), and using \(\hat{y}_2\) from Lemma 2. Differentiation shows that:

\[
\frac{\partial \hat{\Pi}_2^B(\sigma)}{\partial \sigma} = \frac{1}{\beta} \frac{(1 - 2\sigma)}{(3 - 2\sigma)^3} (2\phi_2 - \phi_1)^2 > 0 \quad (12)
\]

which is positive since \(\sigma \in (0, \frac{1}{2})\). Similarly, player 1’s profits \(\hat{\Pi}_1^B = [R_1^B(\hat{y}_1, \hat{y}_2) - (r_1 + c_1^B)\hat{y}_1]\) from market B can be written as:

\[
\hat{\Pi}_1^B(\sigma) = \beta (\hat{y}_1)^2 = \frac{1}{\beta} \frac{[(2 - \sigma) \phi_1 - \phi_2]^2}{(3 - 2\sigma)^2},
\]

since \(MR_1^B = \hat{p}^B - \beta \hat{y}_1 = r_1 + c_1^B\) by (3), and using \(\hat{y}_1\) from Lemma 2. Differentiation shows that:

\[
\frac{\partial \hat{\Pi}_1^B(\sigma)}{\partial \sigma} = \frac{1}{\beta} \frac{2(\phi_1 - 2\phi_2)}{(3 - 2\sigma)^3} [(2 - \sigma) \phi_1 - \phi_2] < 0 \quad (14)
\]

which is negative since \(\phi_1/\phi_2 > \frac{2}{3}\) by assumption. For part (b), using Lemma 1, players’ joint outputs and the price in market B satisfy:

\[
\hat{y}_1 + \hat{y}_2 = \frac{[(1 - \sigma) \phi_1 + \phi_2]}{\beta (3 - 2\sigma)} \quad \text{and} \quad \hat{p}^B = \alpha - \frac{[(1 - \sigma) \phi_1 + \phi_2]}{(3 - 2\sigma)} \quad (15)
\]
so \( \partial \hat{p}^B / \partial \sigma = -(2\phi_2 - \phi_1) / (3 - 2\sigma)^2 < 0 \), as claimed.

**Proof of Proposition 2.** The Herfindahl index, at equilibrium, can be written as
\[
\hat{H}(\sigma) = 1 - 2\hat{s}_2(\sigma)[1 - \hat{s}_2(\sigma)],
\]
so differentiation gives \( \hat{H}'(\sigma) = -\hat{s}_2'(\sigma)[1 - 2\hat{s}_2(\sigma)] \). By assumption, player 2 has lower costs, \( r_2 + c_2^B \leq r_1 + c_1^B \Leftrightarrow \phi_2 \geq \phi_1 \), which, using (10), this implies that \( \hat{s}_2(\sigma) > \frac{1}{2} \). Since \( \hat{s}_2(\sigma) > 0 \) by Proposition 1(a), it then follows that \( \hat{H}'(\sigma) > 0 \) as claimed but Proposition 1(b) applies so also \( \partial \hat{p}^B / \partial \sigma < 0 \).