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Competition in schedules with cursed traders ☆

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ABSTRACT

We study a market with sellers that compete in supply functions, face an elastic demand, and have imperfect cost information. In our model, sellers neglect some informational content of the price. In order to capture this feature, we use the cursed expectations equilibrium concept. In the linear-quadratic-normal framework, this paper presents conditions under which the unique equilibrium in linear supply functions exists and derives some comparative statics results. Compared to markets with fully rational sellers, we find that market power and the expected price-cost margin are lower; the price reaction to private information can be higher due to imperfect competition and demand elasticity; expected profits can be greater; and expected total surplus can also increase if the efficiency gains from reduced market power outweigh the losses from cursedness.

1. Introduction

In several important markets, such as for wholesale electricity or emission permits, sellers compete in schedules, that is, they specify a quantity to be supplied for any price realization.[1] Many of these markets are characterized by strategic traders and information frictions, such as private information and uncertainty with both common and private components.[2] The canonical literature has found that the interaction of private information with positively correlated costs (interdependent costs) generates excessive market power that leads to consequences detrimental to welfare (Vives, 2011). This literature assumes that traders are fully rational, and consequently, that when costs are interdependent, traders will realize that a high price conveys the information that the rivals' average signal is high, and therefore, that their own costs must be high. However, there is abundant empirical evidence that market participants partially neglect the correlation between costs, meaning that market participants are unable to extract the relevant

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[1] For applications related to wholesale electricity markets, see for example, Ausubel et al. (2014); for emission permits to Lopomo et al. (2011) and Khezr and MacKenzie (2018).

[2] In electricity markets, sellers do not fully know their costs, but have private cost information due to plant availability when there is a day-ahead market organized as a pool where traders submit hourly or daily supply schedules.

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information from the market price.[3] The objective of this paper is to study the implications of strategic traders that (partially) fail to extract the information from the price in markets with competition in schedules. Our contribution is to show that due to sellers' naivety, in markets characterized by imperfect competition and aggregate demand elasticity, several of the previously known findings regarding total surplus, profits, and market statistics can be overturned under certain market conditions.

We examine a model of a market with a finite number of sellers that compete in schedules to supply an elastic demand for a divisible good. Sellers have incomplete information about an element of their costs and receive private signals. Costs may be positively correlated among sellers because they have a common component due to events that systematically affect them all. Market participants are strategic because they take into account the impact of their quantity supplied on the price (also known as price impact). We use a quadratic profit function with normally distributed random variables, allowing us to characterize symmetric linear equilibria. This simple setup allows us to study more complex information structure interdependence with a finite number of sellers. Our model is based on the literature that theoretically analyzes markets with competition in schedules, such as Grossman (1981), Hart (1985), Klemperer and Meyer (1989), Kyle (1989) and Vives (2011). In relation to these, we introduce sellers that may not be fully rational because they do not fully extract the relevant information about other sellers' private information from the market price. In order to model this feature, we use the equilibrium concept of cursed expectations equilibrium (hereafter CEE), based on Eyster and Rabin (2005) and Eyster et al. (2019), that combines payoff maximization with cursed expectations and market clearing. This approach encompasses traders with different degrees of rationality: fully cursed sellers do not extract any information from the market price; partially cursed sellers infer some information; and fully rational sellers correctly and fully infer all the relevant information from the market price. For tractability purposes, we assume that sellers are symmetric in private signal precision, cost functions and degree of cursedness.

We find that a symmetric linear CEE exists even in the case of common costs with noisy signals. This contrasts with the results of Vives (2011) that argues that, with common costs, the equilibrium (with fully rational sellers) collapses. In contrast, cursed sellers do not fully understand that the price reveals the common value, and they put more weight on their private signal than rational sellers would do. This implies that, with cursed sellers, the price contains some information about cost parameters. Hence, the Grossman and Stiglitz (1980) paradox does not work in our setup. Furthermore, the CEE is privately revealing, meaning that, a seller's private signal and the price are sufficient statistics for the joint information in the market. We also find that the equilibrium supply function is not a convex combination of the fully rational and fully cursed equilibrium supply function. This fact drives many the results that follow.

Our results show how the degree of cursedness affects the equilibrium supply function parameters: with cursed sellers, supply functions are more responsive to private signals and prices compared to the equilibrium with fully rational sellers. Due to imperfect competition, sellers have price impact, which is defined as a seller's ability to influence the market price by supplying an additional unit of the good. It can be measured by the slope of a trader's inverse residual demand, and is an indicator of unilateral market power. Interestingly, we find that price impact decreases with the degree of cursedness. Hence, market power is lower in markets with cursed traders than with fully rational ones. This result has important implications for how cursedness affects market statistics and total surplus. We then examine the effects of cursedness on market competitiveness. We show that a higher degree of cursedness implies a lower expected equilibrium price and higher expected quantities supplied. This leads to a lower expected price-cost margin. Taken together, these results imply that the market is more competitive with cursed sellers, and this differs from the results of Vives (2011) with fully rational sellers.

In terms of market statistics, we focus on price volatility and the price reaction to the average signal. In our model, we find that studying the effects of cursedness on price volatility is equivalent to studying the effects of cursedness on the weight of the average signal on the equilibrium price. Our results show that the market price under-reacts to the average signal, meaning that the weight of the average signal on the equilibrium price is higher under perfect competition and full rationality than under our setting. This under-reaction is driven by strategic behavior or cursedness (or both).

One of our central results is to show that increasing cursedness has two effects on the price reaction to the average signal: the inference effect and strategic effect. The inference effect is due to the fact that cursed market participants fail to fully infer information from prices. Due to this, increasing the degree of cursedness makes the equilibrium price under-react more to private signals with cursed sellers compared to fully rational ones. This is because cursed sellers' private signals receive a smaller weight in other sellers' conditional expectations leading to a lower price reaction to the average signal compared to fully rational sellers. In contrast, the strategic effect arises from imperfect competition, indicating that sellers have price impact. Due to this, we find that increasing the degree of cursedness raises the price reaction to the average signal. Intuitively, price impact decreases with cursedness, which makes sellers act more aggressively on their private information, which results in a higher dependence of prices on private signals. Hence, both effects move in opposite directions. The strategic effect dominates when private signals are very precise and costs are highly correlated. When private signals are precise, then sellers rely more on private information and less on the price. Hence, a change in cursedness has little impact on the way sellers predict their random costs, indicating that in this case the inference effect is of little relevance. In addition, in scenarios with highly correlated costs, sellers have significant market power, and the strategic effect becomes noteworthy. In these cases, the price reaction to the average signal and price volatility increase with cursedness. This finding contrasts with the results of Eyster et al. (2019) that find the price always under-reacts to private signals with cursed sellers. This difference arises because in our model we consider imperfect competition and an elastic aggregate demand, while Eyster et al. (2019)

[3] This is related to the winner's curse as explained in detail in Section 2, which reviews the empirical evidence.

have perfect competition and the equivalent of an inelastic aggregate demand. Consequently, our results suggest the market structure is a critical component for understanding the effects of behavioral biases on market outcomes.

Our main contribution is to analyze how total surplus varies with cursedness. We find that in the equilibrium allocation there are inefficiencies due to both traders' strategic behavior and due to their lack of sophistication. An increase in cursedness diminishes the inefficiency due to strategic behavior since the market is more competitive. However, an increase in cursedness raises the inefficiency due to the fact that sellers do not optimally extract the information from the market price. Hence, total surplus increases with cursedness when the increase in efficiency due to sellers' reduction in market power outweights the decrease in efficiency due to sellers' suboptimal inference from the market price. This occurs in markets where the inference from the price is not important to estimate the sellers' own costs (which occurs when sellers' costs are not very correlated) and sellers' inference mistakes are small. In this case, our contribution is to show that total surplus can be higher in markets with cursed sellers than in markets with fully rational sellers such as the one considered by Vives (2011).

Furthermore, one might think that the potential increase in total surplus with the degree of cursedness is due to an increase in consumer surplus. However, this is not always the case. In this paper, we show the counterintuitive result that, in some market conditions, the expected profits of cursed sellers may be higher than those of fully rational sellers: that is, expected profits can be over the supply function equilibrium level with fully rational sellers. We illustrate this point for a perfectly inelastic demand, and show that this result occurs when the aggregate quantity is not high and cursed sellers can better align the quantity sold to the profit per unit than fully rational sellers can: cursed sellers supply a high quantity when their profit per unit is high, and vice versa. This is a novel mechanism which complements the literature that finds that the expected profits of boundedly rational traders can be higher than those of fully rational traders but for different reasons.[4]

This paper is organized as follows. Section 2 presents the related literature; Section 3 describes the model, and Section 4 derives the market equilibrium with cursed traders. In Section 5, we examine the impact of cursedness on a variety of market indicators, and in Section 6 we analyze expected total surplus and profits. Section 7 concludes. Proofs can be found in the paper's Appendix, and additional results in the Online Appendix.

2. Related literature

In this paper, we consider that sellers are boundedly rational since they underestimate the relationship between the actions and the private information of the other sellers. The motivational example for this deviation from full rationality is the winner's curse in common value auctions with private information. There is ample experimental evidence on winner's curse in single-unit auctions with common or interdependent values, as discussed by Thaler (1988) and in the survey by Kagel and Levin (2002). For multi-unit actions, see Kagel and Levin (2001), and for evidence in the field, see Harrison and List (2008).[5] There is also further evidence of correlation neglect in other settings, such as bilateral negotiations (Samuelson and Bazerman, 1985), social learning (Weizsäcker, 2010), zero-sum bilateral trade (Carrillo and Palfrey, 2011), voting (Esponda and Vespa, 2014), and in financial markets (Ngangoué and Weizsäcker, 2021).

In the context of supply function competition with private information about costs, Bayona et al. (2020) design an experiment based on Vives (2011). The experiment has two treatments: uncorrelated costs and positively correlated costs. Participants have the role of sellers facing an inelastic demand and submit supply functions. The tested hypothesis is that the interaction of positive cost correlation with private information (interdependent costs) generates market power exceeding that associated with uncorrelated costs. The authors find that when costs are uncorrelated, behavior is close to the theoretical prediction in the Bayes Nash equilibrium with fully rational agents. However, with interdependent costs, market power is not higher than in markets with uncorrelated costs, thus providing evidence against the main hypothesis.[6] This finding points towards a behavioral explanation of the results, and suggests that subjects do not sufficiently extract the information from the price when costs are interdependent.[7] This experimental finding is the main motivation of the current paper.

The theoretical literature on bounded rationality has proposed several ways to represent observed behavior that departs from Bayes Nash equilibrium predictions. One of these approaches is the cursed equilibrium concept of Eyster and Rabin (2005), which assumes that each player correctly infers the distribution of other players' actions but underestimates the correlation between those actions and the private information of the other players. That is, cursed players do not fully consider the logic of other players' strategic behavior, and it is a form of naivety or lack of strategic sophistication. In a financial market setting, Eyster et al. (2019) adapt the cursed equilibrium to the cursed expectations equilibrium, here after CEE, which posits the idea that when traders submit their schedules, they do not fully invert the market price to uncover the information that it contains. Our paper uses the CEE to analyze

[4] See, for example, De Long et al. (1990) and Blume and Easley (1992) for traders that take a disproportionate amount of risk; Kyle and Wang (1997), and Benos (1998) for overconfident traders; or Hirshleifer (2015) for traders that induce self-validating feedback into fundamentals.

[5] In our setting, the analogy with respect to the winner's curse in single-unit auctions applies with respect to adverse selection, but not necessarily with respect to market power. Our results are more in line with the notion of the generalized winner's curse of Ausubel et al. (2014), which suggests that "winning" a larger quantity is worse news than "winning" a lower quantity.

[6] Further empirical evidence of deviations from equilibrium behavior in supply function competition games, which can be explained by boundedly rational players, can be found in the field of electricity markets (Hortaçsu and Puller, 2008), and in the laboratory experiments of Bolle et al. (2013) and Brandts et al. (2014).

[7] Notice that there could be alternative explanations of these experimental results, such as overconfidence (as in Daniel et al., 2001), or dismissiveness, that is, traders underestimate the precision of rivals' private signals (as in Banerjee, 2011). Future experiments could help identify which of these alternative explanations applies by eliciting traders' beliefs about their own private signals and those of their rivals.

a framework of supply function competition with private information. The CEE equilibrium concept is related to the notion of rational expectations equilibrium (REE) first suggested by Muth (1961), which is based on the idea of Hayek (1945) that the market price aggregates dispersed information in the market. The REE model has been further developed to accommodate asymmetric information (Radner, 1979; Grossman, 1981), and imperfect competition Kyle (1989). Alongside, the study of competition in supply functions under uncertainty but with symmetric information was developed by Klemperer and Meyer (1989); extended by Vives (2011) to incorporate asymmetric information; and advanced by Rostek and Weretka (2012) and Rostek and Weretka (2015) to study the effects of market size. These models have been extensively used in a variety of applications.

Underinference from the price is also related to the analogy-based expectation equilibrium and the behavioral equilibrium (Esponda, 2008).[8] The concept of analogy-based expectations was introduced by Jehiel (2005) for extensive form games, and was later adapted to static Bayesian games by Jehiel and Koessler (2008). In both settings, players partition contingencies into analogy classes and perceive endogenous variables of interest as a function of this analogy partition. Miettinen (2009) has established the equivalence between the partially cursed and analogy-based expectation equilibrium. Another alternative is the behavioral equilibrium (Esponda, 2008), in which naïve players correctly recognize the average quality of the supplied product, but fail to take into account the effect that increasing bids has on selection. As the buyer learns from experience that the quality of the product is low, the buyer adjusts the price offer downward, leading to an even worse selection of products and perpetuating the misguided learning.[9]

A different approach is taken by Mondria et al. (2022) that study a two period model, where traders first select their level of sophistication in interpreting asset prices, and then they trade in a financial market. The authors argue that, since interpreting financial prices is costly, noise is added when interpreting the information contained in the price. Increasing sophistication improves investors' ability to interpret market data, but acquiring sophistication is costly. This paper shows that costly interpretation of price information can explain some financial market anomalies, such as price momentum (future returns depend positively on the current price), excessive return volatility, and excessive trading volume. In contrast, we consider that the degree of cursedness is not rationally chosen since this is a behavioral bias inherent to market participants due to their limited capacity to process information.

3. Model

The structure of the model follows from Vives (2011). We consider a market with $N > 1$ symmetric suppliers that sell a homogeneous divisible good.[10] Seller i has a quadratic cost function for supplying x_i units of the good

$$C(x_i;\theta_i) = \theta_i x_i + \frac{\lambda}{2} x_i^2,$$

where θ_i is a random parameter and $\lambda > 0$ is an adjustment cost or transaction cost that determines convexity of a seller's cost function.[11] We assume that $\theta_i \sim N(\mu, \sigma_\theta^2)$, and that $cov(\theta_i, \theta_j) = \rho\sigma_\theta^2$, for $j \neq i$, such that the correlation coefficient $\rho \in [0,1]$ since non-negative correlation is more relevant in applications.[12] This framework encompasses common costs if $\rho = 1$, private costs if $\rho = 0$, and interdependent costs if $0 < \rho < 1$.[13] The aggregate inverse demand function is linear and satisfies: $P(Q) = \alpha - \beta Q$, where Q denotes the quantity demanded of the good and α and β are positive parameters, with $\alpha > \mu$.[14]

For tractability purposes, we have chosen a particular signal structure where the conditional expectations of the random cost parameters are linear in the signals. Prior to trading, each seller receives a private signal, s_i, about the random cost parameter θ_i, such that $s_i = \theta_i + \varepsilon_i$, where $\varepsilon_i \sim N(0, \sigma_\varepsilon^2)$. We assume that error terms in the private signals are correlated neither with themselves nor with the random cost parameters, i.e., $cov(\varepsilon_i, \varepsilon_j) = 0$ for all $i \neq j$, and $cov(\varepsilon_i, \theta_j) = 0$ for all i and j. Denote the vector of all sellers' signals by $s = (s_1, s_2, ..., s_N)$, the average signal of all sellers by $\overline{s} \equiv \frac{\sum_{j=1}^N s_j}{N}$, and the average signal of seller i's rivals by $\overline{s}_{-i} \equiv \frac{\sum_{j\neq i} s_j}{N-1}$. According to Gaussian distribution theory,

$$\mathbb{E}\left[\theta_i | s_i, \overline{s}_{-i}\right] = \mu + \Xi\left(s_i - \mu\right) + \Psi\left(\overline{s}_{-i} - \mu\right) \text{ and} \tag{1}$$

$$\mathbb{E}\left[\theta_i | s_i\right] = \mu + \Lambda_0\left(s_i - \mu\right), \tag{2}$$

where $\Xi = \frac{\left((1-\rho)(1+\rho(N-1))\sigma_\theta^2+\sigma_\varepsilon^2\right)\sigma_\theta^2}{\left((1-\rho)\sigma_\theta^2+\sigma_\varepsilon^2\right)\left((1+\rho(N-1))\sigma_\theta^2+\sigma_\varepsilon^2\right)}$, $\Psi = \frac{\rho\sigma_\theta^2\sigma_\varepsilon^2(N-1)}{\left((1-\rho)\sigma_\theta^2+\sigma_\varepsilon^2\right)\left((1+\rho(N-1))\sigma_\theta^2+\sigma_\varepsilon^2\right)}$, and

[8] For a review of these models, see Eyster (2019).

[9] There is a complimentary non-equilibrium approach where players have limited strategic thinking capacities, the level-k model (Nagel, 1995), and the literature that follows.

[10] We can reinterpret our model in terms of demand schedule competition. The applications of this model are related to financial markets, such as central bank liquidity or Treasury auctions. For further literature, see Vives (2010a) and Ewerhart et al. (2010).

[11] Adjustment costs could arise due to a deviation from a target. In energy markets, this target could be related to production capacity as in Amigues et al. (2015). Transaction costs due to trading are common in several market settings as in Dávila and Parlatore (2021).

[12] For a review, see for example Hortaçsu and Perrigne (2021) that argues that positive dependence of values is the relevant case in interdependent values auctions.

[13] In the auction literature, these are often referred to common values, private values and interdependent values, respectively, since market participants are buyers instead of sellers.

[14] For a review of the micro-foundations of this type of demand refer to Choné and Linnemer (2020).

$$\Lambda_0 = \frac{\sigma_\theta^2}{\sigma_\theta^2 + \sigma_\varepsilon^2}. \tag{3}$$

Notice that a seller finds the private signals of other sellers useful for estimating the own cost whenever costs are interdependent ($\rho \neq 0$) or when the seller's own private signal is not perfectly accurate ($\sigma_\varepsilon^2 \neq 0$).

The timing of the game is as follows. At $t = 0$, the random cost parameters $\{\theta_i\}_{i=1,\dots,N}$ are drawn, but not observed. At $t = 1$, each player observes the own private signal and submits a supply function. At $t = 2$, the market clears: supply schedules are aggregated and crossed with the demand to obtain a uniform market price, which determines the quantity sold by each seller. Finally, profits are collected.

Taking the timing of the game into account, we define a seller's strategy.

Definition 1 *(Seller's strategies)*. A strategy for seller i, denoted by X_i, is a mapping from the signal space to the space of supply functions. Thus, $X_i(\cdot; s_i)$ denotes a supply function for seller i corresponding to a particular realization of the private signal s_i.

Our framework allows deviations from traders' full rationality since we consider that sellers might have difficulties in understanding the relationship between the actions and the private information of the other sellers. In our setup, this causes that sellers might (partially) neglect information contained in the price. We follow the modeling approach of Eyster and Rabin (2005) and Eyster et al. (2019) that define the cursed equilibrium and the cursed expectations equilibrium, respectively.[15] Sellers' *degree of cursedness* is represented by parameter χ, which is common knowledge, and $\chi \in [0, 1]$. Next, we formally define the CEE, which combines profit maximization with cursed expectations and market clearing.[16]

Definition 2 *(Cursed expectations equilibrium)*. Given a degree of cursedness χ, a strategy profile $\{X_i^*\}_{i=1,\dots,N}$ is a Cursed Expectations Equilibrium, hereafter a CEE, if and only if, for each seller i, $i = 1, \dots, N$, and each realization of his or her private signal s_i, the supply function $X_i^*(\cdot; s_i)$ maximizes the expected payoff, i.e., $X_i^*(\cdot; s_i)$ is the solution of the following optimization problem:

$$\max_{X_i(\cdot;s_i)} \mathbb{E}\left[p(s)\, X_i(\cdot; s_i) - \left((1-\chi)\mathbb{E}\left[\theta_i \,|s_i, p(s)\right] + \chi \mathbb{E}\left[\theta_i | s_i\right]\right) X_i(\cdot; s_i) - \frac{\lambda}{2}\left(X_i(\cdot; s_i)\right)^2 \Big| s_i \right],$$

where $p(s)$ denotes the price that satisfies $p(s) = P\left(\sum_{j \neq i} X_j^*(p(s); s_j) + X_i(p(s); s_i)\right)$, with other suppliers' functions taken as given.

Note that depending on sellers' degree of cursedness, we can distinguish the following cases: if $\chi = 0$, then sellers are fully rational and they use both the private signal and the price to form correct conditional expectations about their random cost parameters; if $\chi = 1$, then sellers are fully cursed since they completely ignore the informational content of the price when forming their expectations about their random cost parameters; and if $\chi \in (0, 1)$, then sellers are partially cursed and extract some (but not all) information from the price.

Given a CEE, $\{X_i^*\}_{i=1,\dots,N}$, the equilibrium price, denoted by p^*, is the price that satisfies market clearing.[17] Thus, for each realization of the vector of sellers' private signals, $s = (s_1, \cdots, s_N)$, it holds that

$$p^* = P\left(\sum_{j=1}^{N} X_j^*(p^*; s_j)\right).$$

Given our tractability assumptions (quadratic profit function and normally distributed random variables), which are common in these classes of models, we focus on symmetric linear CEE (for short, equilibria), in which strategies are linear and identical among sellers. Thus, in equilibrium, supply functions can be written as

$$X^*(p; s_i) = b^* - a^* s_i + c^* p \text{ for } i = 1, \dots, N, \tag{4}$$

where b^*, a^*, and c^* are constants.

Unless otherwise stated, for the rest of the analysis we assume that $(1-\chi)\rho\sigma_\varepsilon^2 \neq 0$, i.e., suppliers are not fully cursed, random cost parameters are correlated and private signals are not perfectly informative.

[15] In Eyster et al. (2019) traders have CARA utility functions and a trader's objective function is the geometric mean of the rational expected utility and the fully cursed expected utility. In contrast, in our framework sellers have quadratic utility functions and, as in Eyster and Rabin (2005), we use the arithmetic average.

[16] In the Online Appendix, Section I, we illustrate the equivalence of the Bayes Nash Equilibrium to the CEE.

[17] Hereafter, for simplicity, we will omit the explicit dependence of the price on the vector of signals.

4. Equilibrium in a market with cursed sellers

4.1. Equilibrium derivation

The procedure for characterizing the equilibrium in an imperfect competition setup follows from the approach outlined in Kyle (1989) and Klemperer and Meyer (1989).[18] The equilibrium is derived by adopting the perspective of an individual seller who optimizes against his or her residual demand. This process involves four distinct steps. The first step is to postulate linear strategies (with undetermined coefficients) for the rivals of a given seller, say seller i, and then use these strategies along with the market clearing condition to derive the residual inverse demand faced by this seller. The second step solves seller i's optimization problem. The third step is to derive posterior beliefs about θ_i for seller i, given the realization of the equilibrium price and the seller's private signal. Finally, the fourth step is to identify the coefficients of the optimal strategies to derive a system of equations for the postulated coefficients. Solving this system allows us to characterize the equilibrium, which is stated in Proposition 1. Details of the four steps can be found in the proof of Proposition 1 in the Appendix.

First step. Given that seller i's rivals use strategy $X(p; s_j) = b - as_j + cp$, $j \neq i$, the market clearing condition implies that seller i encounters the following inverse residual demand:

$$p = \alpha - \beta \sum_{j \neq i} X(p; s_j) - \beta x_i,$$

which is equivalent to

$$p = I_i - dx_i, \tag{5}$$

where

$$I_i = d\left(\frac{\alpha}{\beta} - (N-1)\left(b - a\bar{s}_{-i}\right)\right) \text{ and} \tag{6}$$

$$d = \frac{\beta}{1 + \beta(N-1)c}. \tag{7}$$

The interpretation of the inverse residual demand faced by seller i allows us to disentangle the influence of this seller on the market price from the ability of this seller to learn from the price. The intercept of the inverse residual demand faced by seller i, I_i, contains all the information provided by the price to this seller about the signals of other sellers.[19]

The slope of the inverse residual demand curve faced by a seller, d, captures the seller's perceived price impact. It measures how much the seller believes that he or she can change the market price by supplying an additional unit of the good. In equilibrium, a trader's perceived price impact coincides with the actual one.[20] Price impact serves as a natural measure of unilateral market power in imperfectly competitive markets (Wolak, 2003).[21] Notice that in a competitive setup, price impact would be zero.

Second step. This part is devoted to solving seller i's optimization problem, which can be addressed through pointwise optimization: for each realization of the competitors' signals, seller i maximizes against the corresponding inverse residual demand. We find that the solution to this optimization problem can be written as

$$x_i = \frac{p - (1-\chi)\mathbb{E}\left[\theta_i | s_i, p\right] - \chi \mathbb{E}\left[\theta_i | s_i\right]}{d + \lambda}. \tag{8}$$

This expression shows that the price serves a dual role: as a scarcity index and as a conveyor of information. An increase in the price has a direct positive effect on the quantity supplied by seller i, but it also indicates that the random cost parameter of this seller is higher. A high price conveys information to seller i that rivals' private signals are high, and hence, that their own random cost parameter is high because of the positive correlation between random cost parameters.

Third step. Given the affine information structure in our setup, in the Appendix we show that the first conditional expectations of θ_i included in (8) can be written as

$$\mathbb{E}\left[\theta_i | s_i, p\right] = \mu + \Lambda_s\left(s_i - \mu\right) + \Lambda_p\left(p - \mathbb{E}[p]\right), \tag{9}$$

[18] For reviews on this procedure refer to Vives (2010b) and Rostek and Yoon (2023).

[19] We find that rivals' private signals affect more the intercept of the inverse residual demand faced by a seller (and, therefore, the seller's capacity to learn from the price) when price impact is higher or rivals' supply functions react more to their private signals. This follows from (6) since $\frac{\partial I_i}{\partial \bar{s}_{-i}} = (N-1)da$.

[20] This coincidence is also found in Kyle (1989), Rostek and Weretka (2015) and Anthropelos and Kardaras (2024), among others. In contrast, the coincidence between perceived price impact and price impact is not found in models where traders have differing beliefs about the strategies of other players, as in Zhou (2022).

[21] The term price impact has been extensively used in the literature following from Kyle (1989) and often known as "Kyle's λ". Examples of papers that use the term price impact term are Rostek and Weretka (2015), Andreyanov and Sadzik (2021), Manzano and Vives (2021), Bergemann et al. (2021), Kaufmann et al. (2024); in the electricity markets Vives (2011), Prete et al. (2019), Peura and Bunn (2021), Narajewski and Ziel (2022); in the financial economics Rostek and Yoon (2021), Zhou (2022); and in the industrial organization Bimpikis et al. (2019).

where the inference coefficients hold

$$\Lambda_s = \frac{(1-\rho)\sigma_\theta^2}{(1-\rho)\sigma_\theta^2 + \sigma_\varepsilon^2} \text{ and } \Lambda_p = \frac{M}{(1-\chi)(1+M)} \frac{d+\lambda+N\beta}{N\beta}, \tag{10}$$

which are identical across sellers, and

$$M = \frac{(1-\chi)\rho N \sigma_\varepsilon^2}{\left(1-\rho+\chi\frac{\rho\sigma_\varepsilon^2}{\sigma_\theta^2+\sigma_\varepsilon^2}\right)\left((1+\rho(N-1))\sigma_\theta^2+\sigma_\varepsilon^2\right)}, \tag{11}$$

which requires that $1-\rho+\chi\frac{\rho\sigma_\varepsilon^2}{\sigma_\theta^2+\sigma_\varepsilon^2} \neq 0$ for M to be well-defined. We can interpret M as an index of adverse selection: the higher the value of M, the more important is the role of the price as a conveyor of information. This increased informational role makes sellers more reluctant to sell the good. We also observe that M decreases with the degree of cursedness. Notice that, if the index of adverse selection is zero, then sellers do not extract information from prices when inferring their random cost parameters.

Fourth step. The equilibrium supply function coefficients (i.e., b^*, a^*, and c^*) can be identified as the solution of the following system of equations:

$$a = \frac{(1-\chi)\Lambda_s + \chi\Lambda_0}{d+\lambda}, \tag{12}$$

$$b = -\frac{(1-\chi)\left(1-\Lambda_s\right)+\chi\left(1-\Lambda_0\right)}{d+\lambda}\mu + \frac{(1-\chi)\Lambda_p}{d+\lambda}\left(\frac{(d+\lambda)\alpha+N\beta\mu}{d+\lambda+N\beta}\right), \text{ and} \tag{13}$$

$$c = \frac{1-(1-\chi)\Lambda_p}{d+\lambda}. \tag{14}$$

Then, we characterize the equilibrium price impact, d^*, as a function of exogenous variables:

$$d^* = \frac{\beta N(M-N+2) - \lambda(M+N) + \sqrt{\beta^2 N^2 (M-(N-2))^2 + \lambda^2 (N+M)^2 + 2\beta\lambda N(N+M)^2}}{2(N+M)}, \tag{15}$$

which depends on cursedness only through the index of adverse selection, M, and can be shown to satisfy $0 < d^* < \beta N$. We summarize these results in the following proposition.

Proposition 1 *(Equilibrium characterization). There exists a unique symmetric linear CEE. In equilibrium, the supply function for seller i is given by* $X^*(p;s_i) = \frac{p-(1-\chi)\mathbb{E}\left[\theta_i|s_i,p\right]-\chi\mathbb{E}\left[\theta_i|s_i\right]}{d^*+\lambda}$*, where the equilibrium value of price impact,* d^**, is given by equation (15), which depends on the index of adverse selection given by (11). The coefficients of the equilibrium supply functions* a^**,* b^**, and* c^* *are obtained by substituting* d^* *into expressions (12), (13), and (14), respectively.*

4.2. Interpretation of the equilibrium

It emerges from Proposition 1 that the equilibrium supply function of seller i is *not* a convex combination of the fully rational equilibrium supply function ($\chi = 0$) and the fully cursed equilibrium supply function ($\chi = 1$) because price impact depends on cursedness through the index of adverse selection. This leads to interesting results for market indicators, total surplus and profits.

In terms of information revelation, the equilibrium price is a linear function of the average signal $\bar{s}$. Therefore, we note that (s_i, p) and $(s_i, \bar{s})$ are informationally equivalent and they are sufficient statistics for the joint information in the market $(s_1, ..., s_N)$ for estimating θ_i. This means that the equilibrium is privately revealing. This result has also been shown by Vives (2011), following from the work of Allen (1981).

The expression of the optimal supply function for a seller given in Proposition 1 implies that the slope of the supply function, c^*, varies with the weight of the price in $\mathbb{E}\left[\theta_i|s_i,p\right]$, denoted by Λ_p. We find that the larger Λ_p is, the lower is the responsiveness of the supply to the price. To understand this result, note that, ceteris paribus, a high price conveys the news that the realization of rivals' private signals are high and, therefore, that the value of θ_i tend to be high, due to the positive correlation between θ_i and rivals' private signals. Consequently, if the price is more informative about θ_i (larger is Λ_p), then the reduction in the quantity supplied by a seller due to an increase in p is larger. For cursed sellers, the variation of the equilibrium supply function's slope with the weight of the price in $\mathbb{E}\left[\theta_i|s_i,p\right]$ is smaller than in markets with fully rational sellers of Vives (2011).[22]

The existence of the equilibrium in Proposition 1 requires that $1-\rho+\chi\frac{\rho\sigma_\varepsilon^2}{\sigma_\theta^2+\sigma_\varepsilon^2} \neq 0$, and this is assumed for the rest of the paper. If sellers are fully rational ($\chi = 0$) or private signals are perfectly informative ($\sigma_\varepsilon^2 = 0$), then the previous condition is satisfied provided that $\rho < 1$ (with perfect positive correlation the equilibrium breaks down). Otherwise, with cursed sellers and noisy private signals,

[22] The analysis of how the slope of the supply function for a seller varies with the slope of rivals' supply functions can be found in Online Appendix, part II, Lemma A.1.

the CEE exists even if $\rho = 1$. This contrasts with the results of Vives (2011) that argues that in the common cost case, the equilibrium (with fully rational sellers) collapses. This means that with fully rational sellers, a fully revealing rational expectations equilibrium is not implementable and there is no linear equilibrium. This is because if the price reveals the common cost, then no seller has an incentive to put any weight on the private signal. But if sellers put no weight on their signals, then the price cannot contain any information about the costs parameters. In contrast, we show that cursed sellers do not fully understand that the price reveals the common value, and they put more weight on their private signal than rational sellers would do. This implies that, with cursed sellers, the price contains some information about cost parameters. Hence, the Grossman and Stiglitz (1980) paradox does not work in our model.

4.3. Equilibrium in special cases of the model

The next four remarks analyze the equilibrium in special cases of the model, which are either used for the rest of the paper (Remarks 1 and 2) or are of interest given the extant literature (Remarks 3 and 4). In all these special cases, the equilibrium supply function coefficients are found by substituting the equilibrium value of price impact, d^*, stated in the remarks into equations (12), (13), and (14).

Remark 1. In a perfectly competitive market, there exists a unique CEE where $d^* = 0$.

Remark 2. If the demand is perfectly inelastic, then there exists a unique CEE if $M - N + 2 < 0$. In such a case, $d^* = \frac{\lambda(M+1)}{N-2-M}$, and the equilibrium supply function coefficients are given by substituting d^* into the relevant equations and taking the limits as $\beta \to \infty$ and $\frac{\alpha}{\beta} \to Q$.

Remark 3. If sellers were fully cursed, or random parameters were uncorrelated, or private signals were perfectly informative, i.e., $(1-\chi)\,\rho\sigma_\varepsilon^2 = 0$, then suppliers do not learn from prices, and the index of adverse selection M is null. In such cases, expression (8) becomes $X^*(p; s_i) = \frac{p - \mathbb{E}[\theta_i | s_i]}{d^* + \lambda}$, $i = 1, \ldots, N$, and $d^* = \frac{-\beta(N-2) - \lambda + \sqrt{\beta^2(N-2)^2 + \lambda^2 + 2\beta\lambda N}}{2}$.

Remark 4. If $\lambda = 0$, then the equilibrium exists provided that $M - N + 2 > 0$, with $d^* = \frac{\beta N(M-N+2)}{M+N}$.

4.4. Implications of the equilibrium for prices and quantities

The next corollary derives the equilibrium price, the average quantity sold, and the quantity supplied by a seller.

Corollary 1 *(Equilibrium price and quantity). In equilibrium, the following results hold:*

(*i*) *The equilibrium price satisfies*

$$p^* = \mathbb{E}\left[p^*\right] + A^*\left(\bar{s} - \mu\right), \tag{16}$$

where its expectation is given by

$$\mathbb{E}\left[p^*\right] = \alpha - N\beta\left(\frac{\alpha - \mu}{d^* + \lambda + N\beta}\right), \tag{17}$$

and the weight of the average signal on the equilibrium price is given by

$$A^* = \frac{\frac{\sigma_\theta^2}{\sigma_\theta^2 + \sigma_\varepsilon^2} + (1-\chi)\frac{\rho\sigma_\theta^2\sigma_\varepsilon^2(N-1)}{\left(\sigma_\theta^2 + \sigma_\varepsilon^2\right)\left((1+\rho(N-1))\sigma_\theta^2 + \sigma_\varepsilon^2\right)}}{\frac{d^*+\lambda}{N\beta} + 1}. \tag{18}$$

(*ii*) *The average quantity sold to the market satisfies*

$$\bar{x}^* = \frac{\alpha - \mu}{d^* + \lambda + N\beta} - \frac{A^*}{N\beta}\left(\bar{s} - \mu\right), \tag{19}$$

and the equilibrium quantity supplied by seller i is given by

$$x_i^* = \bar{x}^* + a^*\left(\bar{s} - s_i\right), \tag{20}$$

with their expected values given by

$$\mathbb{E}\left[x_i^*\right] = \mathbb{E}\left[\bar{x}^*\right] = \frac{\alpha - \mu}{d^* + \lambda + N\beta}. \tag{21}$$

We find that the expected equilibrium price and the expected equilibrium quantity depend on cursedness solely through price impact. However, the equilibrium price and the equilibrium average quantity sold to the market depend on cursedness not only through price impact but also through A^*, the weight of the average signal on the equilibrium price. Furthermore, we find that the equilibrium quantity supplied by seller i is the sum of the average quantity and an idiosyncratic term. This idiosyncratic term vanishes when all the sellers receive the same realization of private signals, whereas it is positive (negative) for those sellers with lower (higher) private signals.

We finish this section with a remark that reminds the reader of the dependence of certain variables on the degree of cursedness.

Remark 5. In the sections that follow, it is important to bear in mind that all equilibrium values of the variables that are marked with an asterisk such as a^*, b^*, c^*, d^*, p^*, A^*, $\overline{x}^*$, x_i^*, and also the index of adverse selection, M, depend on sellers' degree of cursedness, χ.

5. Cursedness and market indicators

Using the equilibrium derived in Section 4, in Sub-section 5.1 we analyze how cursedness affect the equilibrium coefficients, price impact and other measures of competitiveness. In Sub-section 5.2, we explore how cursedness affects price volatility and the price reaction to private signals. In Sub-section 5.3, we examine the impact of cursedness on the variance of the quantity supplied by each seller.[23]

5.1. Supply function coefficients and competitiveness

Initially, we examine the impact of cursedness on the equilibrium coefficients and, in particular, price impact.[24]

Proposition 2 *(Cursedness, supply function coefficients, and price impact). In equilibrium, an increase in the degree of cursedness:*

(*i*) *makes sellers' supply functions more responsive to private signals and prices (higher a^* and higher c^*, respectively), and decreases the fixed part of the supply function (lower b^*).*
(*ii*) *decreases price impact (lower d^*).*

Increasing cursedness raises sellers' responsiveness to prices (higher c^*), thus making cursed sellers' supply functions flatter compared to when sellers are fully rational. This is because a cursed seller, by partially ignoring the informational content of the price, does not fully extract the bad news associated with a high price. Because of this, cursed sellers do not moderate their offers as much as rational sellers do, implying that their supply functions are flatter (higher c^*) than those of fully rational sellers. Notice that when the index of adverse selection is very high, i.e., $M > \frac{N\beta}{\beta+\lambda}$, then supply functions are downward sloping. Downward sloping supply functions have also been found in Vives (2011), and in Holmberg and Willems (2015) but due to a different mechanism.[25]

In Proposition 2(ii) we show that price impact is lower for cursed sellers compared to fully rational sellers, indicating that cursed sellers have lower market power. This is due to the inverse relationship between price impact and sellers' supply function responsiveness to prices (c^*), as shown in equation (7), and the fact that c^* increases with cursedness. Thus, we can conclude that cursedness decreases price impact. This finding is crucial for understanding the rest of our results, as price impact influences price volatility, reactions to the average signal, total surplus, and profits.

With respect to the sellers' supply functions responsiveness to private signals (a^*), we find that cursed sellers rely more on private information compared to fully rational traders. This is because cursed sellers assign a higher weight to their private signal when forming conditional expectations about their random cost parameter. Additionally, cursedness reduces price impact, which further enhances sellers' responsiveness to private signals. Consequently, a higher degree of cursedness leads to a greater responsiveness of the supply functions to private signals.

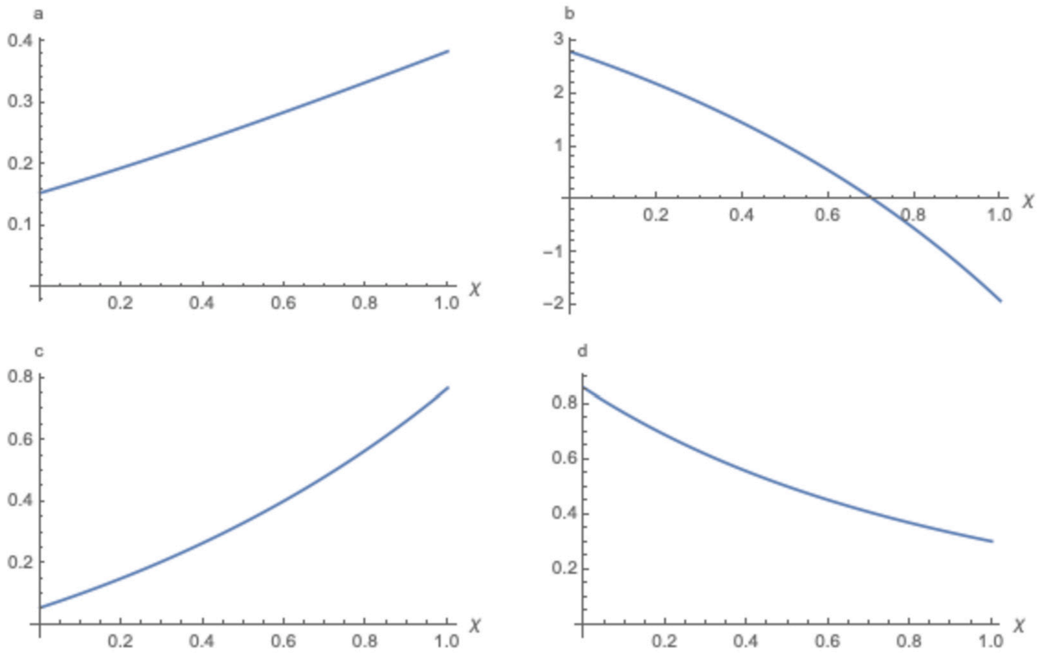
Concerning the relationship between the fixed part of the supply function (b^*) and cursedness, note that it increases with the highest price any buyer is willing to pay (α) and decreases with the mean of the marginal cost's intercept (μ). This implies that as the highest price increases, sellers provide a higher quantity, whereas if sellers expect a higher mean value of the marginal cost's intercept, they supply a lower quantity. In addition, the coefficients multiplying both α and μ decrease with the degree of cursedness. Consequently, we can unambiguously conclude that the fixed part of the supply functions decreases with cursedness.

In Fig. 1, we visually summarize how cursedness affects the equilibrium supply function coefficients and price impact. In Fig. 2, we show how a seller's equilibrium supply function changes with respect to the degree of cursedness.

[23] In the Online Appendix, part IV, we also show that price informativeness does not vary with cursedness (Proposition A.3).

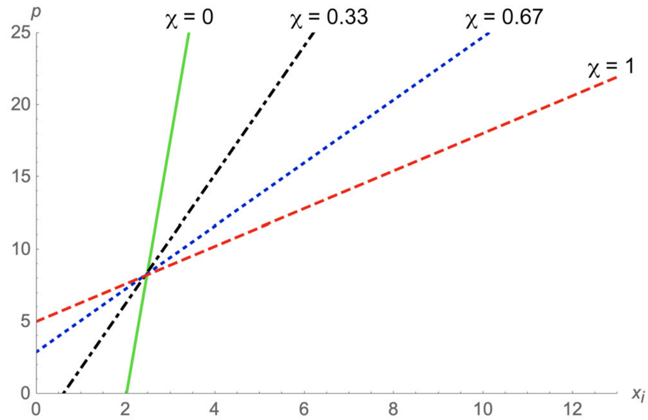
[24] Additional comparative statics results related to how the equilibrium changes when other parameters of the model vary can be found in Proposition A.1 in Online Appendix, part III. The variables analyzed are the correlation among the random cost parameters, ρ, the ratio of the noisiness of the private signal, $\frac{\sigma_\epsilon^2}{\sigma_\theta^2}$, and the slope of the inverse demand function, β.

[25] In Holmberg and Willems (2015) commodity sellers commit to a downward sloping supply function in order to soften competition in the spot market through speculation in derivative contracts.



Parameter values: $N = 4$, $\lambda = 1$, $\rho = 0.6$, $\sigma_\theta^2 = 1$, $\sigma_\varepsilon^2 = 1$, $\alpha = 20$, $\beta = 1$, and $\mu = 5$.

Fig. 1. Equilibrium supply function coefficients and price impact vs. cursedness.



Parameter values: $N = 4$, $\lambda = 1$, $\rho = 0.6$, $\sigma_\theta^2 = 1$, $\sigma_\varepsilon^2 = 1$, $\alpha = 20$, $\beta = 1$, and $s_i = \mu = 5$.

Fig. 2. Equilibrium supply functions for different values of cursedness.

In Corollary 2, we examine the impact of cursedness on market competitiveness. We begin by exploring how cursedness affects the expected quantity supplied by each seller and the expected equilibrium price. Next, we analyze how cursedness influences the expected price-cost margin (i.e., the difference between the market price and a seller's marginal cost, in expected terms).

Corollary 2 *(Cursedness and competitiveness). In equilibrium, an increase in the degree of cursedness:*

(*i*) *increases the expected quantity supplied by each seller and decreases the expected equilibrium price;*
(*ii*) *decreases the expected price-cost margin.*

Intuitively, an increase in cursedness reduces price impact, which induces an increase in the expected quantity supplied by each seller. This, in turn, leads to a decrease in the expected equilibrium price. Furthermore, from the expression of the cost function and equation (8), it can be shown that the expected price-cost margin is equal to

$$\mathbb{E}\left[d^*x_i^*\right] = \frac{d^*(\alpha-\mu)}{d^*+\lambda+N\beta},$$

which shows a positive relationship between the expected-cost margin and price impact. Hence, we expect that the price-cost margin decreases with cursedness, due to the reduction in price impact. Notice that if sellers were price takers, then price impact would be zero, and consequently, the expected price-cost margin would also be null.

Taken together, the results shown in Proposition 2 and Corollary 2 imply that a higher degree of cursedness makes the market more competitive.

5.2. Price volatility and price reaction to the average signal

The analysis of how much information is incorporated into prices has a long tradition in the literature of rational expectations.[26] In addition, Siddiqui et al. (2000) find excess volatility in prices for electricity markets. The subsequent analysis examines under what market conditions cursedness could be a factor that promotes or decreases price volatility.

In our setup, studying the impact of cursedness on the volatility of prices is equivalent to analyzing how cursedness affects the weight of the average signal on the equilibrium price since $var\left[p^*\right]=(A^*)^2 var\left[\overline{s}\right]$. We summarize this finding in the following lemma.

Lemma 1 *(Price volatility and price reaction to the average signal). The effects of increasing cursedness on price volatility are identical to those on the weight of the average signal on the equilibrium price, A^*.*

The analysis of how cursedness affects A^* is important by itself since it allows us to determine whether the equilibrium price under-reacts or over-reacts to the average signal with cursed sellers compared with fully rational sellers. To understand this relationship, we decompose A as follows:

$$A^* = A^O A^{IC} A^{SC}. \tag{22}$$

The first component of price reaction to the average signal, denoted by A^O, corresponds to A^* under perfect competition and full rationality and it is given by $A^O = \frac{\frac{(1+\rho(N-1))\sigma_\theta^2}{(1+\rho(N-1))\sigma_\theta^2+\sigma_\varepsilon^2}}{\frac{\lambda}{N\beta}+1}$. The second component, denoted by A^{IC}, is the inference component. It modifies A^O because in our setup sellers fail to fully infer information from the market price and satisfies $A^{IC} = \left(1-\frac{\chi\rho(N-1)\sigma_\varepsilon^2}{(1+\rho(N-1))\left(\sigma_\theta^2+\sigma_\varepsilon^2\right)}\right) < 1$. The third component, denoted by A^{SC}, is the strategic component. It modifies the product of the first two terms because in our setup we consider strategic behavior and it is equal to $A^{SC} = \frac{\lambda+N\beta}{d^*+\lambda+N\beta} < 1$. This leads to the result stated in Proposition 3(*i*).

The previous decomposition of the price reaction to the average signal suggests that a change in cursedness have two effects on A^*: an inference effect and strategic effect, which have opposite signs, since

$$\frac{\partial A^{IC}}{\partial\chi} < 0 \text{ and } \frac{\partial A^{SC}}{\partial\chi} > 0,$$

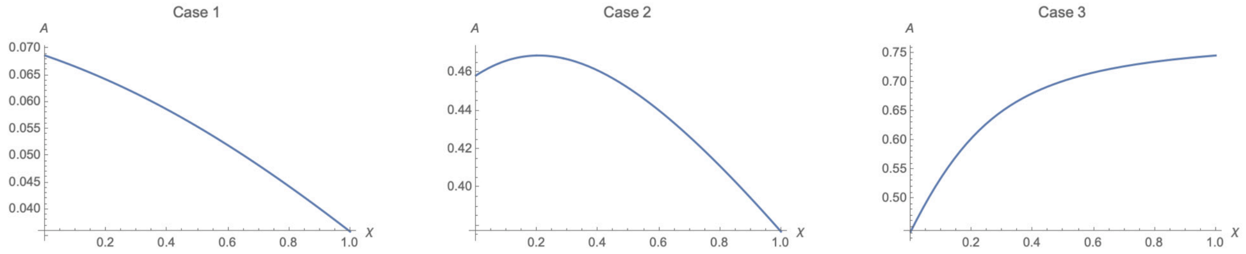
while A^O is independent of cursedness. The fact that the inference effect is negative means that the equilibrium price under-reacts more to private signals with cursed sellers compared to fully rational sellers. The economic intuition is as follows. When sellers are cursed, they insufficiently condition on the market price, meaning that seller i's private signal receives a smaller weight in others' conditional expectations. As a consequence, the weight of seller i's private signal on the price is smaller when sellers are cursed than when sellers are rational. In contrast, the strategic effect is positive because price impact decreases with cursedness, making sellers act more aggressively on their private information, which results in a higher dependence of prices on private signals.

The fact that the two preceding effects move in opposite directions implies that the total effect of cursedness on A^* is in general ambiguous. In Proposition 3, we show that the sign of the total effect depends on characteristics of the market and on the information structure.

Proposition 3 *(Cursedness and price volatility or price reaction to the average signal). In equilibrium, the following results hold:*

(*i*) *Either strategic behavior or cursedness, or both, lead to a price underreaction to the average signal, that is, $A^O > A^*$.*
(*ii*) *For price volatility and price reaction to the average signal, the following three cases can be distinguished:*
Case 1 [Private signals are not very accurate, i.e., $\frac{\sigma_\varepsilon^2}{\sigma_\theta^2} \geq \overline{E}$]. The price reaction to the average signal and price volatility decrease with cursedness.
Case 2 [The accuracy of private signals is intermediate, i.e., $\underline{E} < \frac{\sigma_\varepsilon^2}{\sigma_\theta^2} < \overline{E}$].
- *If $\rho \leq \widehat{\rho}$, then the price reaction to the average signal and price volatility decrease with cursedness for all χ, and*

[26] See Vives (2010b) for an overview.



Common parameters values: $N = 4$, $\lambda = 1$, $\alpha = 20$, $\beta = 1$, and $\mu = 5$. Case 1 has $\rho = 0.5$, $\sigma_\theta^2 = 1$, $\sigma_\varepsilon^2 = 20$; Case 2 has $\rho = 0.85$, $\sigma_\theta^2 = 1$, $\sigma_\varepsilon^2 = 1$; and Case 3 has $\rho = 1$, $\sigma_\theta^2 = 10$, $\sigma_\varepsilon^2 = 0.01$.

Fig. 3. The weight of the average signal on the equilibrium price and cursedness.

- *if $\rho > \widehat{\rho}$, then there exists a value of χ, denoted by $\widehat{\chi}$, such that the price reaction to the average signal and price volatility decrease with cursedness if and only if $\chi > \widehat{\chi}$.*

Case 3 [Private signals are sufficiently accurate, i.e., $\frac{\sigma_\varepsilon^2}{\sigma_\theta^2} \leq \underline{E}$].

- *If $\rho \leq \widehat{\rho}$, then the price reaction to the average signal and price volatility decrease with cursedness for all χ,*
- *if $\widehat{\rho} < \rho < \widehat{\widehat{\rho}}$, then there exists a value of χ, denoted by $\widehat{\chi}$, such that the price reaction to the average signal and price volatility decrease with cursedness if and only if $\chi > \widehat{\chi}$, and*
- *if $\rho \geq \widehat{\widehat{\rho}}$, then the price reaction to the average signal and price volatility increase with cursedness for all χ.*[27]

We have shown how the response of the equilibrium price on the average signal varies with cursedness in Proposition 3, part (*ii*). When the inference effect dominates, then increasing cursedness decreases the price reaction to the average signal. This occurs when private signals are very imprecise (Case 1), and when private signals are relatively more precise (Cases 2 and 3), but the strategic effect is small. In Case 1, sellers have clear incentives to consider prices when predicting their random costs, and this inference procedure is greatly affected by cursedness. In Cases 2 and 3, the inference effect dominates whenever the strategic effect is small, which occurs when the correlation among the random cost parameter is low or when the degree of cursedness is high enough. In the other parameter configurations the reverse result holds, that is, that the response of the equilibrium price to the average signal increases with cursedness.

In order to develop the intuition for the case when the strategic effect dominates, consider the following example. Suppose that private signals are very precise and that costs are highly correlated. In such a case, the inference effect is of little relevance because sellers, having very precise private information, rely little on the price. Therefore, a change in cursedness has a small impact on the way sellers predict their random costs. In addition, under this parameter configuration, the strategic effect gains more importance than in the other cases because price impact is more relevant (since price impact increases with cost correlation). Consequently, in this scenario, the strategic effect dominates the inference effect. Hence, raising the degree of cursedness increases the price reaction to the average signal.

Our results contrast sharply with those in markets with perfect competition or a perfectly inelastic demand. In these two special cases, price volatility always decreases with cursedness. Under perfect competition, the strategic effect is non-existent since price impact is zero. Similarly, with a perfectly inelastic demand, the strategic effect becomes negligible, leading to the same result. Interestingly, our results suggest that the negative relationship between cursedness and price volatility may not hold in markets with strategic sellers and an elastic demand.

The three cases outlined in Proposition 3 can be illustrated in Fig. 3. Case 1 shows a framework in which private signals are very imprecise. Case 2 illustrates an example of intermediate accuracy of private signals and high correlation among costs. The figure shows that when cursedness is relatively low, the strategic effect dominates, implying that the price reaction to the average signal increases with cursedness. However, if cursedness is high, then the inference effect dominates, and A^* decreases with cursedness. Case 3 shows a market with extremely precise private signals and perfectly correlated costs. In this case, the strategic effect dominates. Hence, the price reaction to the average signal unambiguously increases with cursedness.

As we will see in the following sections, the results of Proposition 3 are critical for understanding the main effects of cursedness on total surplus.

5.3. Variance of the quantity supplied

We next study how cursedness affects the variance of the quantity supplied by each seller, which is an important dimension for studying total surplus and profits. The variance of the quantity supplied by seller i is given by

[27] Details of threshold values can be found in the proof of this proposition included in the Appendix.

$$var[x_i^*] = \frac{(A^*)^2}{(N\beta)^2} \frac{(1+(N-1)\rho)\sigma_\theta^2 + \sigma_\varepsilon^2}{N} + (a^*)^2 \frac{(N-1)\left((1-\rho)\sigma_\theta^2 + \sigma_\varepsilon^2\right)}{N}, \tag{23}$$

following from expressions (19) and (20). Hence, the effect of cursedness on the variance of the quantity supplied by a seller is through two channels. The first channel is through the price reaction to private information (A^*), while the second channel is the supply function's response to the private signal (a^*). From Propositions 2 and 3, we know that increasing cursedness increases a^*, but has an ambiguous effect on A^*. If the price reaction to the average signal increases with cursedness, then the overall effect of cursedness on the variance of the quantity supplied is positive. By contrast, if the price reaction to private information decreases with cursedness and this effect dominates, then the variance of the quantity supplied by a seller decreases with cursedness. The following proposition characterizes how the variance of the quantity supplied varies with cursedness under different market conditions.

Proposition 4 *(Cursedness and the variance of the quantity supplied). Increasing the degree of cursedness increases the variance of the quantity supplied if:*

(*i*) *the accuracy of private signals is intermediate ($\underline{E} < \frac{\sigma_\varepsilon^2}{\sigma_\theta^2} < \overline{E}$), costs are sufficiently correlated ($\rho > \widehat{\rho}$), and the degree of cursedness is sufficiently low ($\chi < \widehat{\chi}$); or*

(*ii*) *the accuracy of private signals is sufficiently high ($\frac{\sigma_\varepsilon^2}{\sigma_\theta^2} \leq \underline{E}$) and: a) costs are highly correlated ($\rho \geq \widehat{\widehat{\rho}}$); or b) cost correlation is intermediate ($\widehat{\rho} < \rho < \widehat{\widehat{\rho}}$) and the degree of cursedness is sufficiently low ($\chi < \widehat{\chi}$).*[28]

However, the variance of the quantity supplied can decrease with cursedness. Necessary conditions for this to occur are that demand is sufficiently elastic or costs are sufficiently convex.

Proposition 4 (*i* and *ii*) shows that in parameter configurations where A^* increases with cursedness (as outlined in Proposition 3), the variance of the quantity supplied by a seller also rises with cursedness. Nevertheless, this proposition also suggests that the reversal result might also hold in our framework. A necessary condition for the variance of the quantity supplied to decrease with cursedness is that, when the degree of cursedness increases, the price reaction to private information decreases substantially. This occurs when the demand is sufficiently elastic (β small enough) or costs are sufficiently convex (λ is high enough), as the strategic component in expression (22) does not vary much with cursedness. Hence, the inference effect of cursedness on A^* dominates, and if it is sufficiently large, then the variance of the quantity supplied decreases with cursedness.

Our results contrast with those of Eyster et al. (2019), which find that the variance of the quantity supplied always increases with cursedness, assuming perfect competition and a perfectly inelastic demand. In order to better understand the differences between our environment and setup of Eyster et al. (2019), in the following corollary we analyze the impact of cursedness on the variance of the quantity supplied by a seller, considering separately the assumptions of perfect competition and perfectly inelastic demand.

Corollary 3 *(Cursedness and the variance of the quantity supplied by a seller with a perfectly inelastic demand or with perfect competition). In equilibrium, increasing the degree of cursedness:*

(*i*) *[Perfectly inelastic demand] increases the variance of the quantity supplied by each seller in markets with strategic sellers;*

(*ii*) *[Perfect competition] decreases the variance of the quantity supplied by each seller provided that the aggregate demand is sufficiently elastic or costs are sufficiently convex.*

The intuition behind these results is as follows. If the aggregate demand is perfectly inelastic, then the average quantity does not vary with cursedness (as $\overline{x}^* = \frac{Q}{N}$). Consequently, the variance of the quantity supplied by each seller depends on cursedness only through the supply functions response to private signals. Hence, the variance of the quantity supplied increases with cursedness (by Proposition 2).

Under perfect competition, the first term in equation (23) always decreases with cursedness, while the second one increases with cursedness. In addition, the importance of the first term is more pronounced as the aggregate demand becomes more elastic, while the second term does not depend on β. Consequently, the variance of the quantity supplied decreases with cursedness whenever the aggregate demand is sufficiently elastic. Similar reasoning could be applied with sufficiently high cost convexity.

To sum up, our analysis shows that the key ingredient in Eyster et al. (2019) to obtain the result that the variance of the quantity supplied always increases with cursedness is a perfectly inelastic demand, rather than perfect competition.

6. Total surplus and profits

In this section, we address the question of how total surplus and profits vary with the degree of cursedness. We first identify both the equilibrium and efficient allocations, and then derive how deadweight loss at the equilibrium allocation is affected by cursedness. Finally, we examine whether expected profits can be higher with cursed sellers than with fully rational sellers.

[28] Ibid.

6.1. Expected total surplus

In accordance with the related literature, such as in Vives (1988) and Angeletos and Pavan (2007), we define an efficient allocation as the solution to a planner's problem that consists of maximizing expected total surplus under the constraint that sellers use decentralized linear production strategies in their private signals and the price (or equivalently $\overline{s}$). Formally, an efficient allocation solves the following optimization program:

$$\max_{\hat{a},\hat{b},\hat{c}} \mathbb{E}\left[TS(x)\right] \quad , \qquad s.t. \quad x_i = \hat{b} - \hat{a}s_i + \hat{c}\overline{s},\ i = 1,\ldots,N$$

where $TS(x)$ denotes the total surplus corresponding to an allocation $x = \left(x_1,\ldots,x_N\right)'$ and is given by $TS(x) = \int_0^X p(Z)dZ - \sum_{i=1}^N C\left(x_i;\theta_i\right)$, with $X = \sum_{i=1}^N x_i$.

For completeness and ease of exposition, we include the following proposition derived by Vives (2011) that characterizes the efficient allocation and provides the expression for the expected deadweight loss at the equilibrium allocation. This loss is defined as the difference between the expected total surplus at the efficient and equilibrium allocations. In the text that follows, the superscript O in a variable indicates that it corresponds to the efficient outcome.

Proposition 5 *(Efficient allocation and expected deadweight loss at the equilibrium allocation).*

(*i*) *The efficient allocation, denoted by x^O, is the equilibrium allocation with fully rational traders that behave as price-takers.*
(*ii*) *The expected deadweight loss at the equilibrium allocation, denoted by $\mathbb{E}\left[DWL^*\right]$, is given by*

$$\mathbb{E}\left[DWL^*\right] = \frac{N(N\beta+\lambda)}{2}\mathbb{E}\left[\left(\overline{x}^O - \overline{x}^*\right)^2\right] + \frac{\lambda}{2}\sum_{j=1}^N \mathbb{E}\left[\left(u_j^O - u_j^*\right)^2\right], \tag{24}$$

with $\overline{x}^O = \frac{\sum_{i=1}^N x_i^O}{N}$, $\overline{x}^* = \frac{\sum_{i=1}^N x_i^*}{N}$, $u_j^O = x_j^O - \overline{x}^O$, and $u_j^* = x_j^* - \overline{x}^*$, $j = 1,\ldots,N$.

Proposition 5(*i*) shows that the efficient allocation corresponds to the allocation of the price-taking equilibrium ($d = 0$) with fully rational sellers ($\chi = 0$). Consequently, in our framework, inefficiencies arise from two main factors: traders' strategic behavior and their failure to fully extract information from the market price. In addition, Proposition 5(*ii*) states that the expected deadweight loss at the equilibrium allocation can be decomposed into two components. The first represents aggregate inefficiency, which occurs because the aggregate quantity produced in the market ($N\overline{x}^*$) is distorted in relation to the efficient outcome ($N\overline{x}^O$), while sellers produce in a cost-minimizing way. The second component shows distributive inefficiency, which is on account of a distortion in the distribution of production for a given average quantity.

With respect to aggregate inefficiency, the first term in equation (24) is proportional to

$$\mathbb{E}\left[\left(\overline{x}^O - \overline{x}^*\right)^2\right] = \left(\mathbb{E}\left[\overline{x}^O - \overline{x}^*\right]\right)^2 + var\left[\overline{x}^O - \overline{x}^*\right] \tag{25}$$
$$= \left(\frac{\alpha-\mu}{\lambda+N\beta} - \frac{\alpha-\mu}{d^*+\lambda+N\beta}\right)^2 + \frac{\left(A^O - A^*\right)^2}{N^2\beta^2} var\left[\overline{s}\right].$$

Therefore, aggregate inefficiency depends on the expected value and the variance of the difference between the average efficient and equilibrium quantities. The next lemma shows how aggregate inefficiency depends on cursedness.

Lemma 2 *(Cursedness and aggregate inefficiency). The following results hold regarding aggregate inefficiency at the equilibrium allocation. Aggregate inefficiency decreases with cursedness if:*

(*a*) *the difference between the highest price that any buyer would pay and the mean of the marginal cost's intercept, $\alpha - \mu$, is high enough; or*
(*b*) *the price reaction to the average signal, A^*, increases with cursedness, which occurs if:*
  (*b*.1) *the accuracy of private signals is intermediate ($\underline{E} < \frac{\sigma_\varepsilon^2}{\sigma_\theta^2} < \overline{E}$), costs are sufficiently correlated ($\rho > \hat{\rho}$), and the degree of cursedness is sufficiently low ($\chi < \hat{\chi}$); or*
  (*b*.2) *the accuracy of private signals is sufficiently high ($\frac{\sigma_\varepsilon^2}{\sigma_\theta^2} \le \underline{E}$) and either: costs are highly correlated ($\rho \ge \hat{\hat{\rho}}$); or cost correlation is intermediate ($\hat{\rho} < \rho < \hat{\hat{\rho}}$) and the degree of cursedness is sufficiently low ($\chi < \hat{\chi}$).*[29]

Otherwise, aggregate inefficiency can increase with cursedness.

[29] Ibid.

To gain intuition about the result of Lemma 2, we analyze how each of the terms in equation (25) depends on cursedness. First, we find that the expected term in (25) increases in price impact, which implies that it decreases with cursedness. This is because strategic sellers moderate their offers more compared to price-taking sellers. This under-production is smaller when the sellers' degree of cursedness is higher (due to the reduction in price impact), and it is larger when $\alpha - \mu$ is high. In other words, cursed sellers under-produce (relative to the efficient quantity) more than fully rational sellers (e.g., Vives, 2011), and this under-production is larger when $\alpha - \mu$ is high. Second, with regards to the variance term in (25), we find that it depends on cursedness through the price reaction to private information, A^*. Given that $A^O > A^*$, we find that this variance decreases (increases) with cursedness whenever A^* increases (decreases) with cursedness. Therefore, cursedness could have opposite effects on the two terms that add up to give aggregate inefficiency. As shown in Lemma 2, the sign of the total effect depends on characteristics of the market and on the information structure. Additionally, Lemma 2 shows that aggregate inefficiency decreases with cursedness under the following conditions: (a) the change in the expected value of the difference between the average and inefficient quantities in (25) dominates, which occurs if $\alpha - \mu$ is large enough (Lemma 2a); or (b) the weight of the average signal on the equilibrium price (A^*) increases with cursedness (Lemma 2b).

With respect to distributive inefficiency, the second term in equation (24) is proportional to

$$\mathbb{E}\left[\left(u_i^O - u_i^*\right)^2\right] = \left(a^O - a^*\right)^2 var\left[\overline{s} - s_i\right], \tag{26}$$

where a^O is the efficient supply function responsiveness to private signals. Hence, distributive inefficiency depends on the difference between the efficient and equilibrium supply function response to private information. The next lemma analyzes how distributive inefficiency varies with cursedness.

Lemma 3 *(Cursedness and distributive inefficiency). The following results hold regarding distributive inefficiency at the equilibrium allocation:*

(*i*) *If $\rho \leq \widehat{\rho}_{DI}$, then distributive inefficiency decreases with cursedness.*
(*ii*) *If $\rho > \widehat{\rho}_{DI}$, then distributive inefficiency decreases with cursedness whenever the degree of cursedness is sufficiently low. Otherwise, distributive inefficiency increases with cursedness.*[30]

The intuition for Lemma 3 is as follows. We can show that the sign of the change in distributive inefficiency due to cursedness is the same as the sign of $\left(a^* - a^O\right)$. For low ρ or low χ, we find that the neglect of information from the price is of little significance because: if ρ is low, the price is not very useful in providing information about the signals of others; if χ is low, sellers do not neglect much information from the price. So, the main cause of the discrepancy between the equilibrium and efficient allocations is due to strategic behavior. Therefore, sellers' equilibrium supply functions under-react to private signals compared to the efficient outcome ($a^O > a^*$). In this case, increasing the degree of cursedness rises sellers' response to private information, which makes a^* closer to the efficient response to private information, a^O. As a result, distributive inefficiency decreases with cursedness. Conversely, if ρ and χ are high, then the neglect of information from the price is very significant, and cursed sellers' equilibrium supply function over-react to private signals compared to the efficient outcome ($a^* > a^O$). Hence, increasing cursedness makes the difference $a^* - a^O$ larger, leading to an increase in distributive inefficiency.

The next proposition combines the previous two lemmas and allows us to examine how the expected deadweight loss at the equilibrium allocation varies with cursedness.[31]

Proposition 6 *(Cursedness and expected deadweight loss). The expected deadweight loss at the equilibrium allocation decreases with cursedness if both aggregate and distributive inefficiency decrease with cursedness. This decrease is guaranteed when:* (i) *the difference between the highest price that any buyer would pay and the mean of the marginal cost's intercept* ($\alpha - \mu$) *is high enough, and* (ii) *either cost correlation or the degree of cursedness is low enough. Otherwise, expected deadweight loss may increase with cursedness.*

Therefore, we find that total surplus increases with cursedness if $\alpha - \mu$ is high enough, and either cost correlation or the degree of cursedness is low enough. In these environments, total surplus is higher in markets with cursed sellers than with fully rational sellers (e.g., Vives, 2011). To further understand how this result depends on the market structure, we analyze in the next corollary how cursedness affects the expected deadweight loss at the equilibrium allocation in both a market with perfectly inelastic demand and a perfectly competitive market.

Corollary 4 *(Cursedness and expected deadweight loss with a perfectly inelastic demand or with perfect competition). Depending on the market conditions, we obtain the following results:*

[30] The details of the threshold values can be found in the proof in the Appendix.

[31] In Proposition A.2 in the III section of the Online Appendix we analyze how aggregate and distributive inefficiency depend on the correlation among costs. We find that aggregate inefficiency increases in ρ, while distributive inefficiency may increase or decrease in ρ. This result was also found by Vives (2011) with fully rational sellers.

(*i*) [*Perfectly inelastic demand*]. *The expected deadweight loss at the equilibrium allocation decreases with cursedness if* $\rho \leq \frac{\sigma_\theta^2+\sigma_\varepsilon^2}{\sigma_\theta^2+(N-1)\sigma_\varepsilon^2}$, *or if* $\rho > \frac{\sigma_\theta^2+\sigma_\varepsilon^2}{\sigma_\theta^2+(N-1)\sigma_\varepsilon^2}$ *and* χ *is low enough. Otherwise, it increases with cursedness.*

(*ii*) [*Perfect competition*]. *The expected deadweight loss at the equilibrium allocation increases with cursedness.*

We find that in the case of a perfectly inelastic demand, only distributive inefficiency matters since there is no aggregate inefficiency at the equilibrium allocation. Thus, we can conclude that if ρ or χ is low enough, then the expected deadweight loss at the equilibrium allocation decreases with cursedness. Otherwise, it increases with cursedness.

In perfectly competitive markets, the expected deadweight loss at the equilibrium allocation increases with cursedness since both aggregate and distributive inefficiencies rise with cursedness. Note that in this case, there is no strategic behavior, so the only discrepancy between the equilibrium and efficient allocations is due to cursedness.

To summarize, the inefficiencies in our market stem from two key factors: sellers' strategic behavior and their inability to fully extract information from the market price. An increase in cursedness diminishes the inefficiency due to strategic behavior since cursed sellers have lower market power than fully rational sellers. However, a higher degree of cursedness amplifies the inefficiency related to sellers' failure to fully extract information from the market price. Consequently, cursedness increases total surplus when the increase in efficiency due to sellers' reduction in market power outweighs the decrease in efficiency due to sellers' suboptimal inference from the market price. This arises when $\alpha - \mu$ is sufficiently high and when the inference errors made by cursed sellers are not very significant (either because the sellers' costs are weakly correlated or because the sellers' degree of cursedness is low).

6.2. Expected profits

One could think that when expected total surplus increases with cursedness is due to the fact that consumers are better off in a market with cursed sellers. However, we show below that we can obtain the counterintuitive result that sellers' expected profits can increase with cursedness. To illustrate this result, we focus on the case of a perfectly inelastic demand. Expected profits for seller i, denoted by $\mathbb{E}[\pi_i^*]$, hold

$$\mathbb{E}[\pi_i^*] = \underbrace{\mathbb{E}\left[p^* - \theta_i - \frac{\lambda}{2}x_i^*\right]\mathbb{E}\left[x_i^*\right]}_{\text{Expected price effect}} + \underbrace{cov\left[p^* - \theta_i - \frac{\lambda}{2}x_i^*, x_i^*\right]}_{\text{Covariance effect}}, \tag{27}$$

where $x_i^* = \frac{Q}{N} + a^*\left(\overline{s} - s_i\right)$ and $p^* = \mu + \frac{(d^*+\lambda)Q}{N} + A^*\left(\overline{s} - \mu\right)$, with Q denoting the aggregate quantity demanded. From expression (27), we can see that there are two effects on expected profits due to a change in cursedness. The first is the expected price effect: increasing the degree of cursedness decreases the expected price and does not vary the expected quantity supplied by a seller (since $\mathbb{E}\left[x_i^*\right] = \frac{Q}{N}$). Because of this, price-cost margins decrease with cursedness. However, expected profits do not necessarily decrease with cursedness because of the covariance effect, which refers to the change in the covariance between the profit per unit and the quantity supplied as a result of shifting the degree of cursedness. As we will show below, the covariance effect increases with cursedness, which can potentially lead to higher profits for cursed sellers than for fully rational sellers, as we will show in Proposition 7.

Using the expressions of the equilibrium quantity and price, it follows that

$$cov\left[p^* - \theta_i - \frac{\lambda}{2}x_i^*, x_i^*\right] = a^* cov\left[\theta_i, \theta_i - \overline{\theta}\right] - \frac{\lambda}{2}var\left[x_i^*\right],$$

which indicates that, in general, the covariance effect has an ambiguous sign because both $a^* cov\left[\theta_i, \theta_i - \overline{\theta}\right]$ and $var\left[x_i^*\right]$ increase with cursedness (by Proposition 2 and Corollary 3(*i*)). However, when all sellers have the same cost ($\rho = 1$) the covariance effect is unequivocally negative. Note that in this case the covariance effect reduces to $-\frac{\lambda}{2}var\left[x_i^*\right]$, as $cov\left[\theta_i, \theta_i - \overline{\theta}\right] = 0$. By contrast, when ρ is small enough or χ is small enough and $\rho < 1$, Proposition 7 suggests that the opposite result holds. This indicates that, although increasing cursedness raises the variance of the quantity supplied, this effect is dominated by the increase in the first term of the covariance $\left(a^* cov\left[\theta_i, \theta_i - \overline{\theta}\right]\right)$.

Proposition 7 *(Cursedness and expected profits). Suppose that the demand is perfectly inelastic. Then, it holds that if the aggregate quantity demanded is high enough, then sellers' expected profits decrease with cursedness. In contrast, if the quantity demanded is low enough, three possible cases arise:*

(*i*) *When the correlation among costs is low enough, expected profits increase with cursedness;*

(*ii*) *when the correlation among costs is large enough* (but $\rho < 1$)*, sellers' expected profits increase (decrease) with cursedness for low (large) values of the degree of cursedness; and*

(*iii*) *when costs are common among sellers* ($\rho = 1$)*, sellers' expected profits decrease for all degrees of cursedness.*

These results show that, in the model with a perfectly inelastic demand, cursed sellers can earn higher expected profits than fully rational sellers. That is, cursed sellers' profits can be over and above those that correspond to the supply function equilibrium level (e.g., Vives, 2011). This occurs when the aggregate quantity demanded is small and either the cost correlation is low or the cost correlation is high (except for common costs) and the degree of cursedness is low. In these scenarios, cursed sellers can better align the quantity sold to the profit per unit, i.e., sellers supply a high (small) quantity when the profit per unit is high (low). This is a new mechanism that has not been discussed before in the existing literature.

7. Concluding remarks

Market participants do not always fully understand the information conveyed by market prices. Our paper examines the presence of boundedly rational sellers that (partially) neglect the informational content of the price in a market with competition in supply functions and incomplete information. We use the cursed expectations equilibrium concept to analyze this setting. We study the impact of cursed sellers on market quality statistics, such as the expected market price, market competitiveness, price volatility, variance of the quantity supplied, and total surplus.

Market participants' cursedness increases competitiveness, leading to a lower expected price-cost margin and reduced price impact, although this does not necessarily result in lower expected profits.[32] Additionally, prices may overreact to the average signal, and price volatility could be higher if private signals are sufficiently accurate and the cost correlation is high enough. All these predictions are made in comparison to markets comprised of fully rational traders, as described by Vives (2011). Thus, our results generate new empirical predictions that can be tested either in an experimental setting or with field data.

Our results can also be connected to policy issues related to markets such as wholesale electricity or emissions permits. First, our analysis suggests that cursedness is not necessarily detrimental from a total surplus perspective. This occurs if the reduction in market power is sufficiently large to compensate the increase in inefficiency due to bounded rationality. Hence, policymakers should take into account the interaction between traders' behavioral biases and the market structure. In terms of market structure, our contribution shows that imperfect competition and demand elasticity are the critical components that policymakers should consider. Second, our policy implications are related to sellers' profits. On the one hand, in market settings where sellers' equilibrium profits increase with cursedness (and are higher than in a market with fully rational sellers), policymakers may want to determine whether this is due to cursedness or collusion. To answer this question, our results would point out that checking profits alone is not enough, and policymakers should also look at equilibrium prices. If profits are high while prices are low, the increase in profits is likely due to cursedness. Conversely, if both profits and prices are high, it indicates that high profits may result from collusion. On the other hand, in market settings where firms' profits decrease due to cursedness, a Friedman (1953)-like argument would suggest that such firms would not survive. Thus, if cursedness negatively impacts sellers' profits, firms have an incentive to "educate" themselves.[33] Therefore, in such a setting, cursed sellers have an incentive to hire a consultancy to help them extract information embedded in the market price, although the impact of the consultancy on consumer surplus or total surplus remains unclear. If these surpluses were to decrease, a policymaker might consider addressing firms' behavioral biases, although in practice, this seems unlikely.[34]

Going forward, we could extend our model of strategic behavior and imperfect information with boundedly rational traders in several ways. One extension could focus on markets comprised of sellers that are asymmetric in various dimensions, such as the degree of cursedness. Another interesting addition would be to consider other relevant behavioral biases, such as overconfidence and dismissiveness, and analyze how the predictions of this paper might change. Finally, future work could also examine a dynamic game where firms could learn from their behavioral biases over time.

CRediT authorship contribution statement

Anna Bayona: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Carolina Manzano:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization.

Declaration of competing interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

Appendix A

Proof of Proposition 1. In what follows, we develop parts of the second, third, and fourth steps of the equilibrium derivation stated at the beginning of Section 4.1.

[32] In Section 6.2, we have shown that a lower expected price cost margin does not necessarily imply lower expected profits due to the covariance effect.

[33] There is a remote analogy to the "unshrouding" concept used by Gabaix and Laibson (2006), Heidhues et al. (2016) and Heidhues et al. (2017), where firms set a transparent price and an additional add-on price. Boundedly rational consumers ignore add-on prices unless at least one firm "unshrouds" (educates or reveals) the add-on price. In our setting, it is the firms (and not consumers) that are boundedly rational. For a discussion of firms' behavioral biases see Armstrong and Huck (2010).

[34] For discussions on whether competition authorities should take firm's behavioral biases and non-profit maximizing objectives into account, see Van den Bergh (2013), Stucke (2014), and Fletcher (2024). Generally, these papers point towards the idea that competition authorities should focus on consumers' behavioral biases and firms' responses to these, but there is less support and consensus for interventions tackling supply-side behavioral biases.

Second step. Next, we adopt the approach of Klemperer and Meyer (1989) and Kyle (1989), which shows that seller i's optimization problem can be solved through pointwise optimization. For each realization of the competitor's signal, s_{-i}, seller i maximizes against the corresponding inverse residual demand. Therefore, this seller will choose points, and thus combinations of quantity and price (x_i, p), that belong to this inverse residual demand curve in order to maximize expected profits. From (5) and taking into account that the slope of the inverse residual demand curve is constant, it follows that this curve is uniquely determined by its intercept (I_i), or equivalently, by the average of other traders' signals $(\overline{s}_{-i})$. Thus, for each realization of the competitors' signal (s_{-i}), seller i chooses the quantity in order to maximize the following objective function:

$$\left(I_i - d x_i\right) x_i - \left((1-\chi)\mathbb{E}\left[\theta_i | s_i, \overline{s}_{-i}\right] + \chi \mathbb{E}\left[\theta_i | s_i\right]\right) x_i - \frac{\lambda}{2} x_i^2. \tag{28}$$

The first order condition of the optimization problem is given in by

$$I_i - 2d x_i - \left((1-\chi)\mathbb{E}\left[\theta_i | s_i, \overline{s}_{-i}\right] + \chi \mathbb{E}\left[\theta_i | s_i\right]\right) - \lambda x_i = 0.$$

The second order sufficient condition for a maximum of the objective function given in (28) is $2d + \lambda > 0$, which implies that $d + \lambda > 0$. Solving the first order condition for x_i yields

$$x_i\left(\overline{s}_{-i}; s_i\right) = \frac{I_i - \left((1-\chi)\mathbb{E}\left[\theta_i | s_i, \overline{s}_{-i}\right] + \chi \mathbb{E}\left[\theta_i | s_i\right]\right)}{2d + \lambda}. \tag{29}$$

Plugging the expressions of $\mathbb{E}\left[\theta_i | s_i, \overline{s}_{-i}\right]$ and $\mathbb{E}\left[\theta_i | s_i\right]$ given in (1) and (2) into (29) and, then, substituting the resulting expression into (5), the price can be written as a function of the rivals' average signals since

$$\begin{aligned} p\left(\overline{s}_{-i}; s_i\right) = {} & \frac{d\left((1-\chi)\Psi + a(d+\lambda)(N-1)\right)}{2d+\lambda} \overline{s}_{-i} + \frac{d\left(\chi \Lambda_0 + (1-\chi)\Xi\right)}{2d+\lambda} s_i \\ & + \frac{d\left(1 - \chi\Lambda_0 - (1-\chi)(\Psi + \Xi)\right)\mu + d(d+\lambda)\left(\frac{\alpha}{\beta} - (N-1)b\right)}{2d+\lambda}. \end{aligned} \tag{30}$$

In particular, equations (29) and (30) determine the profit maximization quantity, $x_i\left(\overline{s}_{-i}; s_i\right)$, and the corresponding price $p\left(\overline{s}_{-i}; s_i\right)$ for each realization of other traders' signals $(\overline{s}_{-i})$. Therefore, they represent in parametrized form, seller i's set of ex-post optimal points as his or her residual demand shifts (as $\overline{s}_{-i}$ changes). Since $\overline{s}_{-i}$ is a scalar, these optimal combinations of quantities and prices along i's residual demand curves form a one-dimensional curve in the quantity-price space. In addition, we can isolate $\overline{s}_{-i}$ from (30), we can write $\overline{s}_{-i}$ in terms of p and s_i. This implies that the optimal quantity given in (29) can be written in terms of p and s_i. Hence, $x_i = X_i(p; s_i)$. Therefore, from equation (30), we infer than in equilibrium, a seller can infer the same information from observing the private signal and the rivals' average signal, or the private signal and the market price. Taking into account this fact and that $I_i = p + d x_i$, the optimal quantity for seller i given in (29) can be rewritten as the expression given by (8).

Finally, we would like to point out that no two realizations of the inverse demand curve (i.e., two different values of $\overline{s}_{-i}$) can intersect. This condition together with the uniqueness of $p\left(\overline{s}_{-i}; s_i\right)$, indicates that the supply curve $X_i(p; s_i)$ intersects seller i's inverse residual demand curve once and only once for each $\overline{s}_{-i}$, at $p\left(\overline{s}_{-i}; s_i\right)$. This allows us to conclude that $X_i(p; s_i)$ is the unique optimal supply function in response to the supply functions of other sellers.

Third step. From (8) and the market clearing condition, the equilibrium price is given by

$$p = \frac{(d+\lambda)\alpha + \beta\left((1-\chi)\sum_{j=1}^{N}\mathbb{E}\left[\theta_j | s_j, p\right] + \chi \sum_{j=1}^{N}\mathbb{E}\left[\theta_j | s_j\right]\right)}{d + \lambda + N\beta}.$$

Plugging (2) and (9) into the previous expression and isolating p, we have

$$p = \frac{(d+\lambda)\alpha + N\beta\mu - N\beta(1-\chi)\Lambda_p \mathbb{E}[p] + N\beta\left((1-\chi)\Lambda_s + \chi\Lambda_0\right)\left(\overline{s} - \mu\right)}{d + \lambda + N\beta\left(1 - (1-\chi)\Lambda_p\right)}.$$

Taking expectations and isolating $\mathbb{E}[p]$ from the resulting expression, we obtain

$$\mathbb{E}[p] = \alpha - \frac{N\beta}{d + \lambda + N\beta}(\alpha - \mu). \tag{31}$$

Hence, we have

$$p = \alpha - \frac{N\beta}{d + \lambda + N\beta}(\alpha - \mu) + A\left(\overline{s} - \mu\right), \tag{32}$$

where

$$A = \frac{N\beta((1-\chi)\Lambda_s + \chi\Lambda_0)}{d + \lambda + N\beta\left(1 - (1-\chi)\Lambda_p\right)}. \tag{33}$$

Hence,

$$\bar{s}_{-i} = \frac{N}{(N-1)A}p - \frac{N}{(N-1)A}\left(\frac{(d+\lambda)\alpha + N\beta\mu}{d+\lambda+N\beta} - A\left(\mu - \frac{s_i}{N}\right)\right).$$

Using the previous expression and (1), we get

$$\mathbb{E}\left[\theta_i | s_i, p\right] = \mu + \left(\Xi - \frac{\Psi}{N-1}\right)(s_i - \mu) + \frac{N\Psi}{(N-1)A}\left(p - \frac{(d+\lambda)\alpha + N\beta\mu}{d+\lambda+N\beta}\right).$$

Thus, Λ_s satisfies the expression given in (10) and

$$\Lambda_p = \frac{N\Psi}{A(N-1)}. \tag{34}$$

Substituting (33) into the previous expression for Λ_p and isolating Λ_p in the resulting expression, we obtain the expression for Λ_p given in (10).

Fourth step. By substituting expressions (2) and (9) into (8) and identifying coefficients, it follows that the equilibrium supply function coefficients (i.e., a^*, b^*, and c^*) solve the system of equation given by (12)-(14). Then, using (14) and (10) in (7) and after some algebra, it follows that d^* is a root of the following polynomial:

$$R(d; M) = (M+N)d^2 + (\beta N(N-2-M) + \lambda(M+N))d - \lambda\beta N(M+1).$$

Note that, since $\lambda > 0$, this polynomial has a positive and a negative root. Given that the unique root that is compatible with the second order condition is the highest one and the fact that $R(N\beta; M) > 0$, we conclude that d^* satisfies (15) and $0 < d^* < N\beta$. □

Proof of Corollary 1. (*i*) The expressions for the equilibrium price and its expected value given in (16) and (17) directly follows from (31) and (32). In addition, plugging the expression of Λ_p given in (34) into (33), isolating A^* and using the expressions of the inference coefficients in the resulting formula, we get (18).
(*ii*) Concerning the average quantity supplied to the market ($\overline{x}^*$), note combining the market clearing condition stated in Definition 2 and (32), equation (19) is obtained. Additionally, from (4), we have that $x_i^* - \overline{x}^* = a^*\left(\overline{s} - s_i\right)$, which is equivalent to (20). Finally, taking expectations in the previous two expressions, we get (21). □

Proof of Proposition 2. (*i*) and (*ii*) Define $F(d,\chi) = R(d; M)$. Direct computations yield that $\frac{\partial F}{\partial \chi}(d^*, \chi) = \frac{\partial R}{\partial M}(d^*; M)\frac{\partial M}{\partial \chi} > 0$ since $d^* + \lambda > 0$ and $d^* < N\beta$. Moreover, we know that in equilibrium $\frac{\partial F}{\partial d}(d^*, \chi) > 0$. Applying the Implicit Function Theorem, we get $\frac{\partial d^*}{\partial \chi} < 0$.

Using the expression of d^*, $\frac{\partial d^*}{\partial \chi} < 0$ implies that $\frac{\partial c^*}{\partial \chi} > 0$. In addition, it is easy to see that the numerator of a^* in (12) increases in χ and the denominator decreases in χ. Consequently, $\frac{\partial a^*}{\partial \chi} > 0$. With regards to b^*, using expression (13) and the fact that both M and d^* decrease in cursedness, it follows that b^* decreases in χ. □

Proof of Corollary 2. (*i*) Differentiating expressions (17) and (21) with respect to χ, we have $\frac{\partial \mathbb{E}[p^*]}{\partial \chi} = \frac{N\beta(\alpha-\mu)}{(d^*+\lambda+N\beta)^2}\frac{\partial d^*}{\partial \chi}$ and $\frac{\partial \mathbb{E}[x_i^*]}{\partial \chi} = -\frac{\alpha-\mu}{(d^*+\lambda+N\beta)^2}\frac{\partial d^*}{\partial \chi}$, respectively. Given that $\alpha > \mu$ and $\frac{\partial d^*}{\partial \chi} < 0$, we get $\frac{\partial \mathbb{E}[p^*]}{\partial \chi} < 0$ and $\frac{\partial \mathbb{E}[x_i^*]}{\partial \chi} > 0$.
(*ii*) Using (8), it follows that $p = (1-\chi)\mathbb{E}\left[\theta_i | s_i, p\right] + \chi\mathbb{E}\left[\theta_i | s_i\right] + (d+\lambda)x_i$. Hence, the difference between the market price and the seller i's marginal cost, $p - \left(\theta_i + \lambda x_i\right)$, is given by

$$(1-\chi)\mathbb{E}\left[\theta_i | s_i, p\right] + \chi\mathbb{E}\left[\theta_i | s_i\right] + dx_i - \theta_i.$$

Taking expectations in the previous expression, we get that the expected price-cost margin in equilibrium is given by $d^*\mathbb{E}\left[x_i^*\right]$, which can be written as $d^*\frac{\alpha-\mu}{d^*+\lambda+N\beta}$ because of Corollary 1. Differentiating with respect to χ, it follows that $\frac{\partial}{\partial \chi}\left(d^*\mathbb{E}\left[x_i^*\right]\right) = (\alpha-\mu)\frac{\lambda+N\beta}{(d^*+\lambda+N\beta)^2}\frac{\partial d^*}{\partial \chi} < 0$, since $\alpha > \mu$ and $\frac{\partial d^*}{\partial \chi} < 0$. □

Proof of Proposition 3. (*i*) Using expression (22) and taking into account that the last two terms of this expression are lower than 1, it follows that $A^O > A^*$.
(*ii*) Differentiating the expression of A^* given in (18) with respect to χ, we get

$$\frac{\partial A^*}{\partial \chi} = -\frac{\frac{\rho\sigma_\theta^2\sigma_\varepsilon^2(N-1)}{\left(\sigma_\theta^2+\sigma_\varepsilon^2\right)\left((1+\rho(N-1))\sigma_\theta^2+\sigma_\varepsilon^2\right)}}{\frac{d^*+\lambda}{N\beta}+1} - \frac{\frac{\sigma_\theta^2}{\sigma_\theta^2+\sigma_\varepsilon^2} + (1-\chi)\frac{\rho\sigma_\theta^2\sigma_\varepsilon^2(N-1)}{\left(\sigma_\theta^2+\sigma_\varepsilon^2\right)\left((1+\rho(N-1))\sigma_\theta^2+\sigma_\varepsilon^2\right)}}{N\beta\left(\frac{d^*+\lambda}{N\beta}+1\right)^2}\frac{\partial d^*}{\partial \chi}.$$

Note that $\frac{\partial d^*}{\partial \chi} = \frac{\partial d^*}{\partial M}\frac{\partial M}{\partial \chi}$. Moreover, we have that

$$\frac{\partial M}{\partial \chi} = -\frac{N\rho\sigma_\varepsilon^2\left(\sigma_\theta^2+\sigma_\varepsilon^2\right)\left((1-\rho)\sigma_\theta^2+\sigma_\varepsilon^2\right)}{\left((1+\rho(N-1))\sigma_\theta^2+\sigma_\varepsilon^2\right)\left((1-\rho)\left(\sigma_\theta^2+\sigma_\varepsilon^2\right)+\chi\rho\sigma_\varepsilon^2\right)^2} \text{ and}$$

$$\frac{\partial d^*}{\partial M} = \frac{(d^*+\lambda)(N\beta-d^*)}{2d^*(M+N)+(\beta N(N-2-M)+\lambda(M+N))}.$$

Combining these expressions, and taking into account that

$$\left(d^*+\lambda\right)\left(N\beta-d^*\right) = \frac{d^*(N-1)(d^*+\lambda+N\beta)}{M+1}$$

and that

$$\chi = \frac{\frac{M}{N\rho\sigma_\varepsilon^2}(\rho-1)\left((1+\rho(N-1))\sigma_\theta^2+\sigma_\varepsilon^2\right)+1}{\frac{M}{N}\frac{(1+\rho(N-1))\sigma_\theta^2+\sigma_\varepsilon^2}{\sigma_\theta^2+\sigma_\varepsilon^2}+1},$$

from expression (11), it follows that

$$\frac{\partial A^*}{\partial \chi} = \frac{N(N-1)\beta\rho\sigma_\theta^2\sigma_\varepsilon^2\left(\left((1+\rho(N-1))\sigma_\theta^2+\sigma_\varepsilon^2\right)M+N\left(\sigma_\theta^2+\sigma_\varepsilon^2\right)\right)}{\left((1+\rho(N-1))\sigma_\theta^2+\sigma_\varepsilon^2\right)\left(\sigma_\theta^2+\sigma_\varepsilon^2\right)\left((1-\rho)\sigma_\theta^2+\sigma_\varepsilon^2\right)(d^*+\lambda+N\beta)}$$
$$\times\left(-\frac{(1-\rho)\sigma_\theta^2+\sigma_\varepsilon^2}{\left((1+\rho(N-1))\sigma_\theta^2+\sigma_\varepsilon^2\right)M+N\left(\sigma_\theta^2+\sigma_\varepsilon^2\right)}+\frac{d^*}{2d^*(M+N)+\beta N(N-2-M)+\lambda(M+N)}\right).$$

Using the fact that d^* is a root of the polynomial $R(d;M)$, the last fraction in the previous expression satisfies

$$\frac{d^*}{2d^*(M+N)+\beta N(N-2-M)+\lambda(M+N)} = \frac{(d^*)^2}{(M+N)(d^*)^2+N(M+1)\beta\lambda}.$$

Therefore, it follows that

$$sign\left(\frac{\partial A^*}{\partial \chi}\right) = sign(H(\chi)), \tag{35}$$

with $H(\chi) = \frac{(d^*)^2}{\beta\lambda} - \frac{(1-\rho)\sigma_\theta^2+\sigma_\varepsilon^2}{\rho\sigma_\theta^2}$. Using Proposition 2, we know that d^* decreases in χ. Therefore, $H(\chi)$ decreases in χ. Then, we distinguish three cases.

Let $\overline{E} = \frac{N^2\beta}{\lambda}$ and $\underline{E} = \frac{1}{\beta\lambda}\left(\frac{-\beta(N-2)-\lambda+\sqrt{(\beta(N-2)+\lambda)^2+4\beta\lambda}}{2}\right)^2$.

Case a: $\lim_{\chi\to 1} H(\chi) \geq 0$ $\left(\text{i.e., } \underline{E} \geq \frac{(1-\rho)\sigma_\theta^2+\sigma_\varepsilon^2}{\rho\sigma_\theta^2}\right)$. In this case, from (35), we conclude that A^* increases with cursedness for all χ.

Case b: $H(0) \leq 0$ $\left(\text{i.e., } \frac{\left(d^*|_{\chi=0}\right)^2}{\beta\lambda} \leq \frac{(1-\rho)\sigma_\theta^2+\sigma_\varepsilon^2}{\rho\sigma_\theta^2}\right)$. In this case, from (35), we conclude that A^* decreases with cursedness for all χ.

Case c: $\lim_{\chi\to 1} H(\chi) < 0$ and $H(0) > 0$. In this case we have that there exists a value of χ, denoted by $\hat{\chi}$, with $0 < \hat{\chi} < 1$, such that A^* increases with cursedness if and only if $\chi < \hat{\chi}$.

Let us define $F(\rho) = H(0)$ and $G(\rho) = \lim_{\chi\to 1} H(\chi)$. Both functions increase with ρ and satisfy $\lim_{\rho\to 0} F(\rho) = \lim_{\rho\to 0} G(\rho) = -\infty$. Then, we distinguish two cases: $F(1) \leq 0$ and $F(1) > 0$.

Case 1: $F(1) \leq 0,$ $\left(\text{i.e., } \frac{\sigma_\varepsilon^2}{\sigma_\theta^2} \geq \lim_{\rho\to 1}\frac{\left(d^*|_{\chi=0}\right)^2}{\beta\lambda} = \overline{E}\right)$. As $F(\rho)$ is an increasing function in ρ, in this case $F(\rho) = H(0) \leq 0$ for all ρ. Therefore, we are in Case b, and we conclude that A^* decreases with cursedness for all χ.

Case 2: $F(1) > 0,$ $\left(\text{i.e., } \frac{\sigma_\varepsilon^2}{\sigma_\theta^2} < \lim_{\rho\to 1}\frac{\left(d^*|_{\chi=0}\right)^2}{\beta\lambda} = \overline{E}\right)$. In this case, there exists a value of ρ, denoted by $\hat{\rho}$ (which is the solution of $\frac{(1-\rho)\sigma_\theta^2+\sigma_\varepsilon^2}{\rho\sigma_\theta^2} = \frac{\left(d^*|_{\chi=0}\right)^2}{\beta\lambda}$), such that $H(0) > 0$ if and only if $\rho > \hat{\rho}$. Therefore,

- if $\rho \leq \hat{\rho}$, then $H(0) \leq 0$. Therefore, we are in Case b, and we conclude that A^* decreases with cursedness for all χ.
- if $\rho > \hat{\rho}$, then $H(0) > 0$. Then, we distinguish two subcases: 2.1) $G(1) \leq 0$ and 2.2) $G(1) > 0$.
  - **Case 2.1:** $G(1) < 0$ $\left(\text{i.e., } \frac{\sigma_\varepsilon^2}{\sigma_\theta^2} > \frac{\left(\lim_{\chi\to 1} d^*\right)^2}{\beta\lambda}\right)$. As $G(\rho)$ is an increasing function in ρ, in this case $G(\rho) = \lim_{\chi\to 1} H(\chi) < 0$ for all ρ. Since $H(0) > 0$, we are in Case c, and therefore, we conclude that A^* increases with cursedness if and only if $\chi < \hat{\chi}$.
  - **Case 2.2:** $G(1) \geq 0$ $\left(\text{i.e., } \frac{\sigma_\varepsilon^2}{\sigma_\theta^2} \leq \frac{\left(\lim_{\chi\to 1} d^*\right)^2}{\beta\lambda}\right)$. In this case, there exists a value of ρ, denoted by $\hat{\hat{\rho}}$, which is the solution of $\frac{(1-\rho)\sigma_\theta^2+\sigma_\varepsilon^2}{\rho\sigma_\theta^2} = \frac{\left(\lim_{\chi\to 1} d^*\right)^2}{\beta\lambda}$ and satisfies $\hat{\rho} < \hat{\hat{\rho}}$, such that $G(\rho) = \lim_{\chi\to 1} H(\chi) < 0$ if and only if $\rho < \hat{\hat{\rho}}$. Then, if $\rho \geq \hat{\hat{\rho}}$, then $\lim_{\chi\to 1} H(\chi) \geq 0$. Thus, we are in Case a, and therefore, we conclude that A^* increases with cursedness for all χ. Otherwise, i.e., if $\rho < \hat{\hat{\rho}}$, $\lim_{\chi\to 1} H(\chi) < 0$. Given that in Case 2 $\rho > \hat{\rho}$, it holds $H(0) > 0$. Then, we are in Case c, and therefore, we conclude that A^* increases with cursedness if and only if $\chi < \hat{\chi}$. $\square$

Proof of Proposition 4. (*i*) and (*ii*) From Proposition 3, we know that under these parameter configurations A^* increases with cursedness. Consequently, the first term in expression (23) increases with cursedness. From Proposition 2, it follows that the second term in expression (23) always increases with cursedness. Therefore, we can conclude that in these cases $var[x_i^*]$ increases with cursedness. To end this proof, note that a necessary condition to obtain the reversal result is that A^* decreases with cursedness. According to Proposition 3, this always occurs in Case 1, where the following inequality holds: $\frac{\sigma_\varepsilon^2}{\sigma_\theta^2} \geq \overline{E}$. $\square$

Proof of Corollary 3. (*i*) When the demand is perfectly inelastic, the optimal quantity supplied by seller i is given by

$$x_i^* = \frac{Q}{N} + a^* \left(\overline{s} - s_i\right). \tag{36}$$

Hence, $var[x_i^*] = (a^*)^2 var[\overline{s} - s_i]$, which allows us to conclude that in this case $var[x_i^*]$ increases with cursedness since $\frac{\partial a^*}{\partial \chi} > 0$ (see Proposition 2).

(*ii*) From Remark 1, Corollary 1 and (11), it follows that

$$a^* = \frac{N\sigma_\theta^2}{\lambda\left(M\left(\sigma_\theta^2\left(\rho(N-1)+1\right)+\sigma_\varepsilon^2\right)+N\left(\sigma_\theta^2+\sigma_\varepsilon^2\right)\right)} \text{ and}$$

$$A^* = \frac{\beta N^2 (M+1)\sigma_\theta^2}{(N\beta+\lambda)\left(M\left(\sigma_\theta^2\left(\rho(N-1)+1\right)+\sigma_\varepsilon^2\right)+N\left(\sigma_\theta^2+\sigma_\varepsilon^2\right)\right)}.$$

Therefore, expression (23) becomes

$$var[x_i^*] = \frac{\left(\frac{\beta N^2(M+1)\sigma_\theta^2}{(\lambda+N\beta)\left(M\left(\sigma_\theta^2(\rho(N-1)+1)+\sigma_\varepsilon^2\right)+N\left(\sigma_\theta^2+\sigma_\varepsilon^2\right)\right)}\right)^2}{(N\beta)^2}\,\frac{\sigma_\theta^2(1+(N-1)\rho)+\sigma_\varepsilon^2}{N} + $$
$$+\left(\frac{N\sigma_\theta^2}{\lambda\left(M\left(\sigma_\theta^2\left(\rho(N-1)+1\right)+\sigma_\varepsilon^2\right)+N\left(\sigma_\theta^2+\sigma_\varepsilon^2\right)\right)}\right)^2 \frac{N-1}{N}\left((1-\rho)\sigma_\theta^2+\sigma_\varepsilon^2\right).$$

Differentiating with respect to χ, we have that $\frac{\partial var[x_i^*]}{\partial \chi} = \frac{\partial var[x_i^*]}{\partial M}\frac{\partial M}{\partial \chi}$. Given that $\frac{\partial M}{\partial \chi} < 0$, it follows that $sign\left(\frac{\partial var[x_i^*]}{\partial \chi}\right) = -sign\left(\frac{\partial var[x_i^*]}{\partial M}\right)$. In addition,

$$\frac{\partial var[x_i^*]}{\partial M} = -\frac{2N(N-1)\sigma_\theta^4\left(\sigma_\theta^2(1-\rho)+\sigma_\varepsilon^2\right)\left(\sigma_\theta^2(1+(N-1)\rho)+\sigma_\varepsilon^2\right)\left(N^2\beta^2 - M\lambda^2 + 2N\beta\lambda\right)}{\lambda^2(\lambda+N\beta)^2\left(\left(\left(\sigma_\theta^2(1+\rho(N-1))+\sigma_\varepsilon^2\right)M + N\left(\sigma_\theta^2+\sigma_\varepsilon^2\right)\right)\right)^3},$$

which is positive (and hence, $\frac{\partial var[x_i^*]}{\partial \chi} < 0$) if and only if $\beta < \frac{\lambda\left(\sqrt{M+1}-1\right)}{N}$. $\square$

Proof of Lemma 2. With regards to the aggregate inefficiency term in (24), denoted by AI^*, note that

$$sign\left(\frac{\partial AI^*}{\partial \chi}\right) = sign\left(\frac{\partial}{\partial \chi}\mathbb{E}\left[\left(\overline{x}^* - \overline{x}^O\right)^2\right]\right),$$

since $\mathbb{E}\left[\left(\overline{x}^{*}-\overline{x}^{O}\right)^{2}\right]$ is given in equation (25), and its following expansion which is derived using (18) and (19). Therefore, $\left(\mathbb{E}\left[\overline{x}^{*}-\overline{x}^{O}\right]\right)^{2}$ depends on χ through price impact and it is increasing in d^{*}. Combining this fact with Proposition 2, we get that $\left(\mathbb{E}\left[\overline{x}^{*}-\overline{x}^{O}\right]\right)^{2}$ decreases with cursedness. Moreover, given that $A^{O}>A^{*}$, it follows that $var\left[\overline{x}^{*}-\overline{x}^{O}\right]$ increases (decreases) with cursedness if and only if the coefficient A^{*} decreases (increases) with cursedness. Using Proposition 3, the results stated in the statement of this proposition follow. □

Proof of Lemma 3. Concerning distributive inefficiency term in (24), denoted by DI^{*}, note that

$$sign\left(\frac{\partial DI^{*}}{\partial\chi}\right)=sign\left(\frac{\partial}{\partial\chi}\mathbb{E}\left[\left(u_{i}^{*}-u_{i}^{O}\right)^{2}\right]\right),$$

for a given i, $i=1,\dots,N$. Using Corollary 1, we have the expression given in equation (26). Thus,

$$\frac{\partial}{\partial\chi}\mathbb{E}\left[\left(u_{i}^{*}-u_{i}^{O}\right)^{2}\right]=2\left(a^{*}-a^{O}\right)\frac{\partial a^{*}}{\partial\chi}var\left[\overline{s}-s_{i}\right].$$

Combining this expression with Proposition 2, it follows that $sign\left(\frac{\partial DI^{*}}{\partial\chi}\right)=sign\left(a^{*}-a^{O}\right)$. Direct computations yield $a^{*}-a^{O}=\frac{(1-\rho)\sigma_{\theta}^{2}G(\chi)}{(d^{*}+\lambda)\left((1-\rho)\sigma_{\theta}^{2}+\sigma_{\varepsilon}^{2}\right)}$, with $G(\chi)=\frac{\chi\rho\sigma_{\varepsilon}^{2}}{\left(\sigma_{\theta}^{2}+\sigma_{\varepsilon}^{2}\right)(1-\rho)}-\frac{d^{*}}{\lambda}$. Given that d^{*} decreases with χ, we have that $G(\chi)$ is an increasing function in χ. In addition,

$$G(0)<0\text{ and }\lim_{\chi\to1}G(\chi)=\frac{\rho\sigma_{\varepsilon}^{2}}{\left(\sigma_{\theta}^{2}+\sigma_{\varepsilon}^{2}\right)(1-\rho)}-\frac{-\beta(N-2)-\lambda+\sqrt{(\beta(N-2)+\lambda)^{2}+4\beta\lambda}}{2\lambda}.$$

Notice that $\lim_{\chi\to1}G(\chi)$ as a function of ρ is an increasing function. Moreover, $\lim_{\rho\to0}\left(\lim_{\chi\to1}G(\chi)\right)<0$ and $\lim_{\rho\to1}\left(\lim_{\chi\to1}G(\chi)\right)=\infty$. Thus, there exists a unique value of ρ, denoted by $\widehat{\rho}_{DI}$, which is the solution of $\lim_{\chi\to1}G(\chi)=0$. Hence, we distinguish two cases: 1) $\rho\le\widehat{\rho}_{DI}$ and 2) $\rho>\widehat{\rho}_{DI}$.

Case 1: If $\rho\le\widehat{\rho}_{DI}$, then $\lim_{\chi\to1}G(\chi)\le0$. Given that $G(\chi)$ is an increasing function in χ, we conclude that $G(\chi)<0$ for all χ, and hence, $\frac{\partial DI^{*}}{\partial\chi}<0$ for all $\chi<1$.

Case 2: If $\rho>\widehat{\rho}_{DI}$, then $\lim_{\chi\to1}G(\chi)>0$. Thus, $G(\chi)<0$, and hence, $\frac{\partial DI^{*}}{\partial\chi}<0$, provided that χ is low enough. By contrast, when χ is high enough, $G(\chi)>0$, and hence, $\frac{\partial DI^{*}}{\partial\chi}>0$. □

Proof of Proposition 6. The proof of this proposition directly follows from Lemmas 2 and 3. □

Proof of Corollary 4. (*i*) When β converges to infinity and $\frac{\alpha}{\beta}$ converges to Q, $\lim_{\beta\to\infty}x_{i}^{O}=\lim_{\beta\to\infty}x_{i}^{*}=\frac{Q}{N}$, which implies that in this limiting case the aggregate inefficiency vanishes. With respect to expected distributive inefficiency, the equation that characterizes $\widehat{\rho}_{DI}$ becomes $\frac{\rho\sigma_{\varepsilon}^{2}}{\left(\sigma_{\theta}^{2}+\sigma_{\varepsilon}^{2}\right)(1-\rho)}=\frac{1}{N-2}$, which implies that $\widehat{\rho}_{DI}=\frac{\sigma_{\theta}^{2}+\sigma_{\varepsilon}^{2}}{\sigma_{\theta}^{2}+(N-1)\sigma_{\varepsilon}^{2}}$.

(*ii*) Combining (12), (18), (24), (25), (26), and taking into account that under perfect competition we have that $d=0$, we obtain

$$\mathbb{E}\left[DWL^{*}\right]=\frac{\chi^{2}\rho^{2}\sigma_{\theta}^{4}\sigma_{\varepsilon}^{4}(N-1)^{2}}{2\left((1+\rho(N-1))\sigma_{\theta}^{2}+\sigma_{\varepsilon}^{2}\right)\left(\sigma_{\theta}^{2}+\sigma_{\varepsilon}^{2}\right)^{2}(\lambda+N\beta)}+\frac{\chi^{2}(N-1)\sigma_{\theta}^{4}\rho^{2}\sigma_{\varepsilon}^{4}}{2\left((1-\rho)\sigma_{\theta}^{2}+\sigma_{\varepsilon}^{2}\right)\left(\sigma_{\theta}^{2}+\sigma_{\varepsilon}^{2}\right)^{2}\lambda},$$

which implies that $\mathbb{E}\left[DWL^{*}\right]$ increases with χ. □

Proof of Proposition 7. When the demand is perfectly inelastic, the quantity supplied by seller i is given by (36) and the equilibrium price satisfies

$$p^{*}=\mu+\frac{(d^{*}+\lambda)Q}{N}+A^{*}\left(\overline{s}-\mu\right).\tag{37}$$

Direct computations yield equation (27) in the text, which displays $\mathbb{E}[\pi_{i}^{*}]$. Concerning the first term of (27) we have $\mathbb{E}\left[p^{*}-\theta_{i}-\frac{\lambda}{2}x_{i}^{*}\right]\times\mathbb{E}\left[x_{i}^{*}\right]=\left(\frac{(d^{*}+\lambda)Q}{N}-\frac{\lambda}{2}\frac{Q}{N}\right)\frac{Q}{N}=\frac{2d^{*}+\lambda}{2}\frac{Q^{2}}{N^{2}}$.

In relation to the second term of $\mathbb{E}[\pi_i^*]$, using expressions (36) and (37), we have $cov\left[p^* - \theta_i - \frac{\lambda}{2}x_i^*, x_i^*\right] =$

$$= \frac{(N-1)\,\sigma_\theta^4\left(\left(\sigma_\theta^2+\sigma_\varepsilon^2\right)(1-\rho)+\chi\rho\sigma_\varepsilon^2\right)\left((2d^*+\lambda)\left(\sigma_\theta^2+\sigma_\varepsilon^2\right)(1-\rho)-\chi\lambda\rho\sigma_\varepsilon^2\right)}{2N\left(\sigma_\theta^2+\sigma_\varepsilon^2\right)^2(d^*+\lambda)^2\left((1-\rho)\,\sigma_\theta^2+\sigma_\varepsilon^2\right)}.$$

Differentiating this expression with respect to cursedness, it follows that

$$\frac{\partial}{\partial\chi}cov[p^* - \theta_i - \frac{\lambda}{2}x_i^*, x_i^*] > 0 \text{ is equivalent to } d^*\left(\sigma_\theta^2+\sigma_\varepsilon^2\right)(1-\rho) - \lambda\chi\rho\sigma_\varepsilon^2 > 0.$$

In addition, since in this case $d^* = \frac{\lambda(M+1)}{N-2-M}$, we get

$$d^*\left(\sigma_\theta^2+\sigma_\varepsilon^2\right)(1-\rho)-\lambda\chi\rho\sigma_\varepsilon^2 = \frac{\lambda K(\chi)}{\left((1+\rho(N-1))\,\sigma_\theta^2+\sigma_\varepsilon^2\right)(N-2-M)},$$

with

$$K(\chi) = \left(\sigma_\theta^2+\sigma_\varepsilon^2\right)\left((1-\rho)\,\sigma_\theta^2+\sigma_\varepsilon^2\right)(1-\rho+N\rho) - \rho\sigma_\varepsilon^2(N-1)\left(2\left((1-\rho)\,\sigma_\theta^2+\sigma_\varepsilon^2\right)+N\rho\sigma_\theta^2\right)\chi.$$

Since $N-2-M>0$, then $sign\left(d^*\left(\sigma_\theta^2+\sigma_\varepsilon^2\right)(1-\rho)-\lambda\chi\rho\sigma_\varepsilon^2\right) = sign(K(\chi))$. Furthermore, given that $K(\chi)$ decreases with χ and the value of $K(1)$, it follows that

- if $\rho < \frac{\sigma_\theta^2+\sigma_\varepsilon^2}{\sigma_\theta^2+(N-1)\sigma_\varepsilon^2}$, then $K(\chi)>0$ for all the feasible values of χ, which implies that $\frac{\partial}{\partial\chi}cov[p^*-\theta_i-\frac{\lambda}{2}x_i^*, x_i^*]>0$;
- if $\rho \geq \frac{\sigma_\theta^2+\sigma_\varepsilon^2}{\sigma_\theta^2+(N-1)\sigma_\varepsilon^2}$, then $K(\chi)>0$ $(K(\chi)<0)$ for all the feasible values of χ such that $\chi<\overline{\chi}$ $\left(\chi>\overline{\chi}\right)$, where

$$\overline{\chi} = \frac{\left(\sigma_\theta^2+\sigma_\varepsilon^2\right)\left((1-\rho)\,\sigma_\theta^2+\sigma_\varepsilon^2\right)(1+\rho(N-1))}{\rho\sigma_\varepsilon^2(N-1)\left(2\left((1-\rho)\,\sigma_\theta^2+\sigma_\varepsilon^2\right)+N\rho\sigma_\theta^2\right)},$$

  which implies that $\frac{\partial}{\partial\chi}cov[p^*-\theta_i-\frac{\lambda}{2}x_i^*, x_i^*] > (<) 0$ if and only if $\chi < (>) \overline{\chi}$.

On the basis of the above, we conclude that if Q is high enough, then $\mathbb{E}[\pi_i^*]$ decreases with χ. By contrast, when Q is low enough, the opposite result holds provided that ρ is low enough or χ is low enough and $\rho<1$. It can be seen that when $\rho=1$ all the feasible values of χ satisfy $\chi>\overline{\chi}$. Therefore, in this case the second term of expected profits always decreases with cursedness. Hence, when $\rho=1$ we find that sellers' expected profits always decrease with cursedness. □

Appendix B. Supplementary material

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jet.2024.105935.

Data availability

No data was used for the research described in the article.

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