Digital Economy

Modeling the economics of information-sharing

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- **Information is any inference from data,** which can be either valuable (informative) or not (non-informative).
- Conditional to context, **information-sharing within markets can be either welfare improving or welfare reducing,** and it can **either foster or subdue competition.**
- Within any given market, **the static effects of information-sharing on the efficiency and degree of competition will depend on both the nature of competition** among market players **and the type of uncertainty** that such information addresses.
- In dynamic model settings, **information-sharing between competing firms of sensitive commercial data can facilitate collusion.**
- **Digital platforms challenge this wisdom** regarding the damaging effects of information-sharing, **especially in a setting of competition "for" the market.**
- Together with competition analysis, **privacy and data security measures are important elements to be considered, particularly when dealing with personal data-sharing.**
- An additional competition challenge comes from **the use of artificial intelligence,** which at any firm **may effectively "coordinate" prices with competing firm's algorithms,** without any explicit mandate to do so.

1. Introduction

Digital markets rely heavily on vast amounts of personal and non-personal data to supply innovation in goods and services captured through, for example, platforms or multi-platforms. The latter has spurred strong policy efforts to set rules for firms on data acquisition, processing and security[1], and also prompting the development of on data-sharing to foster competition and innovation in those new markets[2]. Both policy approaches have led to a surge in spending in data infrastructure and governance within corporations.

Despite high efforts to set clear rules, there is still work to do on that front. Recently, some Big Tech companies made a call for global standards for data-sharing[3]. What does this mean for social interests? The stakes at hand are multiple for both social welfare and distribution; from the fundamental right for an individual's privacy to the economic balance of market power, innovation and competition. Implications can be even deeper, with effects on democratic debate, rising concerns over data sovereignty and national security[4].

This note sets a framework to understand the economics of data-sharing, focusing on three areas: competition, market efficiency and welfare distribution. In other words, this note limits the analysis to economics, yet acknowledging that most of the issues at stake are also a matter of political economy, justice and law[5].

[1] For example, in Europe, GDPR set the rules aimed to protect personal data subjects (individuals) and how to comply with it by data controllers (firms), while CCPA is the equivalent for California.

[2] Under a consumer's consent regime (opt-in), PSD2 directive in Europe grants access to potential rivals –third parties or alternative suppliers- of costumer transactional data and banks account information, with the aim to foster competition in some layer of financial services, specifically, payment systems.

[3] *"Facebook calls for new global standard on data-sharing"*, Financial Times, September 4 2019.

[4] Some guidelines to curb misinformation and "hate" speech inside platforms are already in place in some countries.

[5] For example, privacy concerns and well defined property or usage rights over personal or non-personal data is mostly a matter of both public and private law.

2. The value of information

There are two conventional ways to approach the value of information. One way is measuring costs: the resources and effort needed to process a given dataset and transform it into information. The other is focusing on demand: the value that users assign to a given piece of information or signal.

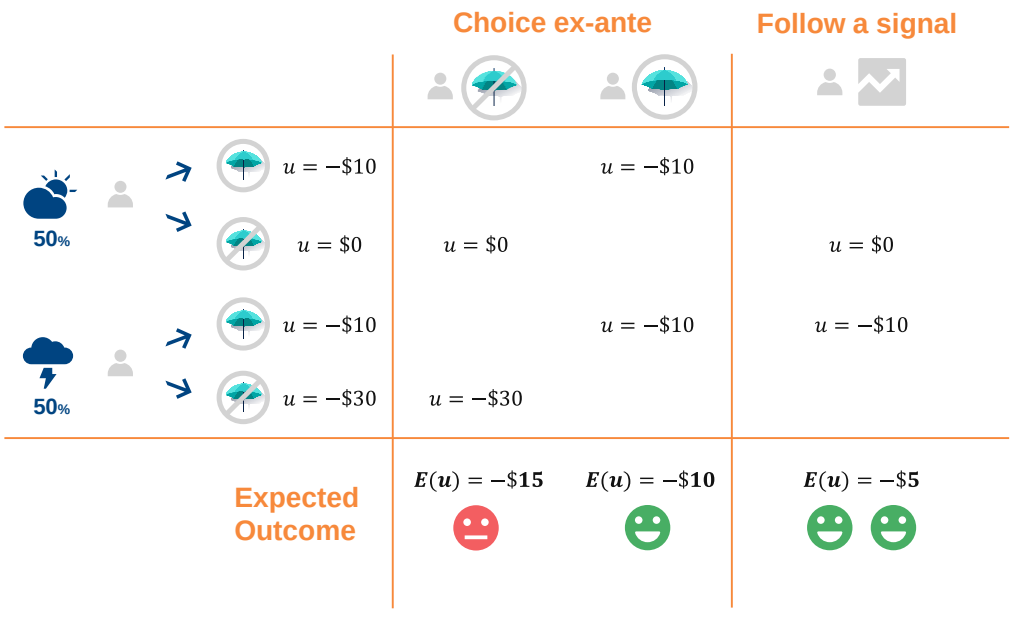
The second approach is the one in which most of the literature of information economics has focused since Akerlof's seminal paper on the market for lemons (1974). In this framework, agents are willing-to-pay for a (costless) signal that reveals information on quality –or any hidden characteristic- of a given good or service[6]. In a nutshell, when talking about the value of information we need to think in a world of decisions under uncertainty.

Example: "The value of an accurate weather signal"

Assume a situation where you need to decide whether to go out to the street with or without an umbrella (Figure 1). The public knows ex-ante that the day will be cloudy with a 50% chance of rain. The costs of going out without an umbrella given a rainy day are the cost of wearing wet clothes all day or alternatively the cost of an umbrella in extreme high demand (let say $30). If rain does not show-up and you decide to go-out without an umbrella, you don't suffer nor have to pay anything (with utility of $0). If a rainy day does or doesn't show-up but you take the umbrella out anyway, you only bear the cost of carrying the umbrella all day (effort cost of $10), but in any case you don't get wet.

Under these circumstances, and assuming risk neutrality, your ex-ante rational choice should be to go-out with an umbrella, as you face lower expected costs (of -$10). Think of carrying-on the umbrella all-day long as the cost of insurance against rain on a suspiciously cloudy day.

Figure 1. **THE VALUE OF AN ACCURATE WEATHER SIGNAL**



Source: BBVA Research.

[6] Actually one of the policy prescriptions following Akerlof work is the need for regulation that sets quality standards or screening mechanisms, mostly targeted to highly asymmetric markets. However, under very narrow assumptions, reputational markets -trough repeated interactions between producers and consumers- can dissipate part of the information asymmetry, with some chances that the strategic firm always supplies high quality in equilibrium (see Mailath and Samuelson, 2006).

In this context, how much are you willing to pay for a reliable signal which allows anyone to reveal the true nature of weather conditions? Let's assume that we follow exactly what the signaler says –a reputable weather TV-guy[7]. It is easy to show that under these assumptions, the willingness-to-pay for the signal is at most $5 -as it leaves anyone indifferent compared to the best choice ex-ante. The later willingness-to-pay for the signal is the value of information. Alternatively, the value of information can be understood as the benefits of making better (ex-ante) choices[8].

Up to now, we know how to value information, but what is the role of information, and information-sharing, for welfare and competition in markets? To address these questions, in the next section an information-sharing model is formalized between similar firms competing in a specific product market.

3. A model of competition, information and information-sharing

Let's assume two firms i=1,2 that compete simultaneously in a product market with aggregate production $Q = \sum_{i=1}^{2} q_i$, both with symmetric technology and cost function $C(q_i) = cq_i$. There is uncertainty over demand, modeled as $P = \theta - (b/2)Q$, where P is the price that consumers are willing to pay for a unit of Q. Uncertainty over the willingness-to-pay arises as there are two possible values for θ. If demand is high then $(\theta = \theta^H)$ and if demand is low then $(\theta = \theta^L)$ where $\theta^H > \theta^L$. Firms do not know the actual value of theta, they only know a probability distribution for theta (p^H, p^L) where $p^H + p^L = 1$.

For simplicity, the information structure is of common knowledge, but nature reveals type θ to only one firm who privately knows true willingness-to-pay. We will assume that competition is a la Cournot, so each firm chooses an output strategy (q_i^H, q_i^L) that maximizes expected profits given its conjecture over rivals' output strategy[9].

Only one informed firm

When only one firm has an informational advantage, the equilibrium is asymmetric, as shown in Figure 2. The blue (red) line is the best response of the informed firm when consumers have high (low) willingness-to-pay. Accordingly, the black line is the best response of the non-informed firm that expects that the grey line is "on average" the best response of the informed firm.

The dots over the dashed grey-line characterize the equilibrium. In this case, the non-informed firm produces the same output independent of consumer willingness-to-pay, $q_2^H = q_2^L$. Meanwhile, the advantaged firm produces more (less) when consumer's valuation for the good is high (low), $q_1^H > q_1^L$.

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[7] The signal could be a message, such as "take the umbrella" and "do not take the umbrella", or a binary –green and red- traffic light.

[8] More formally, assume that information set $\boldsymbol{\Omega}$ is of common knowledge and we need to make a choice over uncertain prospects $\boldsymbol{a}$ and $\boldsymbol{b}$. Information set $\boldsymbol{\Omega}$ are public odds for different nature states and the preference of $\boldsymbol{a}$ over $\boldsymbol{b}$ implies that expected value from $\boldsymbol{a}$ is higher $\Leftrightarrow$ $(a \mid \boldsymbol{\Omega}) \geq U(b \mid \boldsymbol{\Omega})$.

Let's assume there is another –larger- set of verifiable information $\boldsymbol{\Omega}'$, privately known or own. The value of $\boldsymbol{\Omega}'$ is zero if our choice does not change given this new information set. So, if $(a \mid \boldsymbol{\Omega}') \geq U(b \mid \boldsymbol{\Omega}')$ then $\boldsymbol{\Omega}'$ is non-informational or a noisy data set.

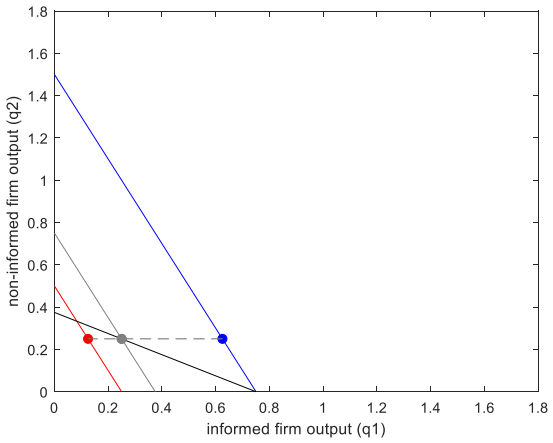
Alternatively, if our choice changes from $\boldsymbol{a}$ to $\boldsymbol{b}$, so that $(a \mid \boldsymbol{\Omega}') \leq U(b \mid \boldsymbol{\Omega}')$, implies $\boldsymbol{\Omega}'$ have implicit valuable data. We can define the private value of information as $(b \mid \boldsymbol{\Omega}') - U(a \mid \boldsymbol{\Omega})$, if generating or acquiring $\boldsymbol{\Omega}'$ do not entail costs.

Bounded rationality and behavioral discipline show us that the way $\boldsymbol{\Omega}$ and options are presented, ordered and processed can modify preferences over options. We do not considering any sort of cognitive biases or environment-dependent preferences (or preference internalities). For example, by well-known paradoxes of expected utility theory shown by Allais (1953) and Ellsberg (1961), among others.

[9] Equilibrium definition is Bayesian Nash.

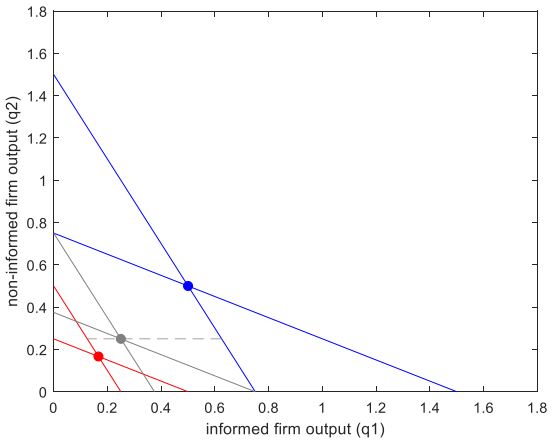
These results have various implications for both expected welfare and welfare distribution, when compared to a full information case.

Figure 2. **FIRM STRATEGY SPACE** (only one firm informed)*



Source: BBVA Research.
*Figure assumptions: $c = 0.5; b = 2; \theta = (2,1); p^H = 0.25$

Figure 3. **FIRM STRATEGY SPACE** (both firms fully informed)*



Source: BBVA Research.
*Figure assumptions: $c = 0.5; b = 2; \theta = (2,1); p^H = 0.25$

Both firms fully informed

In the symmetric case, when both firms know actual demand, equilibrium output changes to the one shown in Figure 3. The blue (red) lines are the best responses of each firm when consumer valuation is high (low). Accordingly, the blue and red dot characterizes the equilibrium outputs for every type of consumer, with high and low willingness-to-pay, respectively. Finally, the grey dot shows the expected supply of each firm before knowing actual demand[10].

Table 1 and 2 illustrate market outcomes in both competition cases: when only one firm has informational advantage and when all firms have full information. In expected terms, both total output and prices are the same. Nonetheless, when information is asymmetric, there is less (more) fierce competition in high (low) willingness-to-pay environments, relative to the case when both firms are fully informed, as shown by a lower (higher) total output and higher (lower) market prices.

Table 1. **EQUILIBIRUM OUTCOME** (with only firm 1 informed)*

Consumer type	Firm output		Market outcome		Firm profits		Welfare	
θ	q_1	q_2	Q	P	π_1	π_2	CS	W
High (θ^H)	0.625	0.250	**0.875**	**1.125**	0.391	0.156	0.383	0.930
Low (θ^L)	0.125	0.250	**0.375**	**0.625**	0.016	0.031	0.070	0.117
Expected	0.250	0.250	0.500	0.750	**0.109**	**0.063**	**0.148**	**0.320**

Source: BBVA Research.
*Table assumptions: $c = 0.5; b = 2; \theta = (2,1); p^H = 0.25$

Table 2. **EQUILIBRIUM OUTCOME** (with both firms informed)*

Consumer type	Firm output		Market outcome		Firm profits		Welfare	
θ	q_1	q_2	Q	P	π_1	π_2	CS	W
High (θ^H)	0.500	0.500	**1.000**	**1.000**	0.250	0.250	0.500	1.000
Low (θ^L)	0.167	0.167	**0.333**	**0.667**	0.028	0.028	0.056	0.111
Expected	0.250	0.250	0.500	0.750	**0.083**	**0.083**	**0.167**	**0.333**

Source: BBVA Research.
*Table assumptions: $c = 0.5; b = 2; \theta = (2,1); p^H = 0.25$

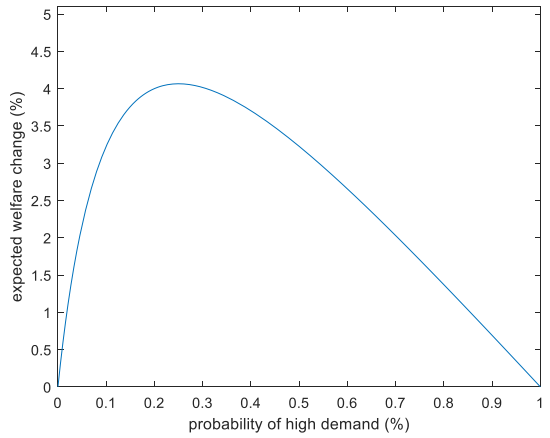
[10] Dashed grey line, which characterize asymmetric information equilibrium, was plotted only for comparative purposes.

In terms of welfare (Table 1 and 2), we see that information asymmetry allows the advantaged firm $i=1$ to exploit informational rents in high-valuation environments that outweigh the lower profits extracted in states where demand is low. Under asymmetric information, the advantaged firm is expected to be better-off than under full information. However, this higher expected gain comes at the cost of lower expected wellbeing for both the rival firm and consumers.

Information sharing, welfare and distribution

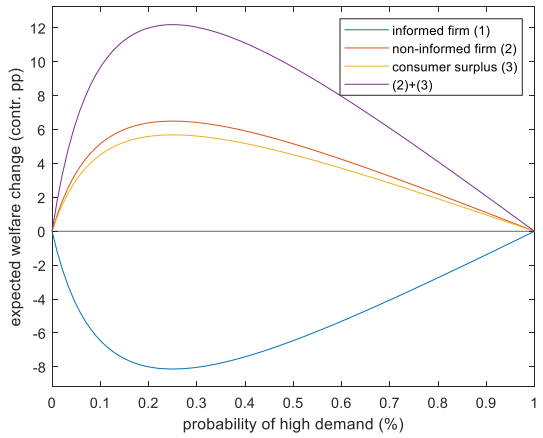
Informational asymmetries force the disadvantaged firm to supply too little (much) when demand is high (low), relative to both its informed rival and the full-information scenario[11]. Moreover, policies facilitating information-sharing are a-priori welfare enhancing because gains are strictly positive for any probability distribution of consumers' willingness-to-pay[12] (Figure 4).

Figure 4. **DATA SHARING: NET IMPACT ON WELFARE** (%)*



Source: BBVA Research.
*Figure assumptions: $c = 0.5; b = 2; \theta = (2,1); p^H = 0.25$

Figure 5. **DISTRIBUTION OF WELFARE IMPACT** (contr. pp)*



Source: BBVA Research.
*Figure assumptions: $c = 0.5; b = 2; \theta = (2,1); p^H = 0.25$

Figure 5 shows the decomposition of welfare gains when the advantaged firm is forced to share its information to the rival firm. Before sharing its information, the favored firm can exploit "informational rents" at the expense of both non-informed firm and consumers' welfare. However, once that information is disclosed to the other firm, the latter and consumers are better-off. In contrast, the initially-favored firm loses its informational rents and is worse-off.

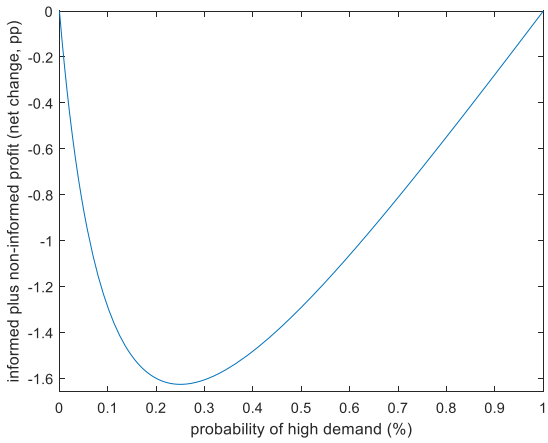
Unilateral incentives to share information

In our example for analysis, we show that when information is shared, market well-being increases, despite the fact that the advantaged firm is worse-off. However, has the advantaged firm a unilateral incentive to share the willingness-to-pay information of consumers to its rivals firms? It is easy to show that, in the specific Cournot setting, not sharing is a dominant strategy for the informed firm (Figure 6).

[11] Output adjustments across consumer's type –or state of nature- are distorted, leading to a misallocation problem: allocative inefficiency across both firms and demand/consumers type.

[12] Welfare improvements can be higher when the information asymmetry is too severe that the informed firm does not supply in low-valuations environments (in a corner solution). However, this equilibrium will only be possible when θ^H is highly likely, that is, for some range of high values of p^H. Or alternatively, when $\theta^H - \theta^L$ is sufficiently high.

Figure 6. **NET IMPACT ON FIRMS PROFITS** (contr. pp)*



Source: BBVA Research.
*Figure assumptions: $c = 0.5; b = 2; \theta = (2,1); p^H = 0.25$

Profit losses for the informed firm cannot be fully offset by any feasible monetary transfer coming from the non-informed rival who leaves both firms better-off. There is an incentive to demand but not to supply that information. In this context, the likely profit gains of the non-informed firm falls short for information exchange to materialize. So information markets fail to allow efficiency in the product market, giving plausible arguments for policy interventions to encourage -or even force- information-sharing among firms.

4. Generalizing the model´s results

Up to now, the model is based on specific assumptions about the nature of competition. Yet some results can be generalized to different competition settings. In particular, **and following the existing literature[13], the overall effects in welfare and efficiency will depend on the nature of competition and the type of uncertainty.**

Nature of competition

As in the Cournot model above, the nature of competition can be one of strategic substitution between firms' actions, where the marginal profitability of a firm's action (e.g., producing an additional unit) decreases with a stronger action of its rivals. Alternatively, competition can be one of strategic complementarity between firms' actions, where marginal profitability of a firm's action increases with a stronger action of its rivals (for example, in Bertrand types of competition for prices).

Type of uncertainty

As in the model above, uncertainty can be aggregate – i.e., common to all market players-, or idiosyncratic –i.e., specific to each player, such as each firm's specific costs or the willingness-to-pay of a specific consumers given differentiated products.

[13] As vastly shown by early research on the field, such as in Vives (1984, 2002, 2007), Gal-Or (1985) and Kühn and Vives (1994)

Table 3, shows a summary of the welfare effects of information sharing under different market settings.

Table 3. **INFORMATION SHARING, EXPECTED IMPACT ON COMPETITION AND WELFARE***

			THE NATURE OF COMPETITION			
			Strategic substitutes (Cournot)		Strategic complements (Bertrand)	
			Consumer surplus	Social welfare	Consumer surplus	Social welfare
TYPE OF UNCERTAINTY	Aggregate (common value)	Cost	POSITIVE	POSITIVE	?	POSITIVE
		Demand	POSITIVE	POSITIVE	NEGATIVE	NEGATIVE (poor subs or lots of firms)
	Firm specific (private value)	Cost	NEGATIVE (with few firms)	POSITIVE	NEGATIVE (with few firms)	NEGATIVE
		Demand	NEGATIVE (with few firms)	POSITIVE	NEGATIVE	NEGATIVE (monopolistic competition)

Source: BBVA Research. * If conditions in brackets are not meet, results tend to ambiguity; "?" implies ambiguity.

As in the previous section, unilateral incentives to share information will depend on the nature of markets. Generally speaking, firms will only share verifiable information unilaterally if it is profitable for them. Table 4 summarizes those incentives for different market settings.

Table 4. **UNILATERAL INCENTIVES TO SHARE INFORMATION***

			THE NATURE OF COMPETITION	
			Strategic substitutes (Cournot)	Strategic complements (Bertrand)
TYPE OF UNCERTAINTY	Aggregate (common value)	Cost	NO	?
		Demand	NO	YES
	Firm specific (private value)	Cost	YES	NO (with few firms)
		Demand	YES	YES

Source: BBVA Research. * If conditions in brackets are not meet, results tend to ambiguity; "?" implies ambiguity.

5. Information-sharing and competition policy

The model above is static, yet in dynamic model settings information-sharing can facilitate collusion. The reason is that information sharing can be a mechanism through which to coordinate and monitor compliance among firms to any non-competitive agreement on output or prices. Independently, we know that when information is unilaterally shared, there are profitable reasons for doing it. Disentangle motives for information-sharing agreements among competing firms is difficult. This presents a challenge for antitrust enforcement, especially when a market is

composed of few or very patient competitors that communicate sensitive data –for example, disaggregated firm level data.

Antitrust practice in the EU tends to favor the "parallelism plus" doctrine when assessing information agreements among competitors. To prove infringement, this criterion takes into account evidence of both "market behavior" (such as inference over price and cost correlations) and "facilitating practices" (such as explicit communication of future prices or actions). For example, future price information can be shared publicly or privately, potentially leading to different market outcomes and competition stances. In the first case, public announcements can be understood as a price commitment to consumers; while in the second, as an anticompetitive practice.

Communication of intended future actions among firms is even more sensitive to markets, yet in practice competition authorities have a hard time verifying the informativeness of such signals. Additionally, there are exemption rules through which firms can justify formal information-sharing agreements –justification based on potential efficiency gains that could be passed-on to (lower) prices[14].

There is a long literature that looks into the social desirability of information-sharing according to how its content can facilitate or not collusion among competitors[15]. Figure 7, shows the main conclusions of those studies.

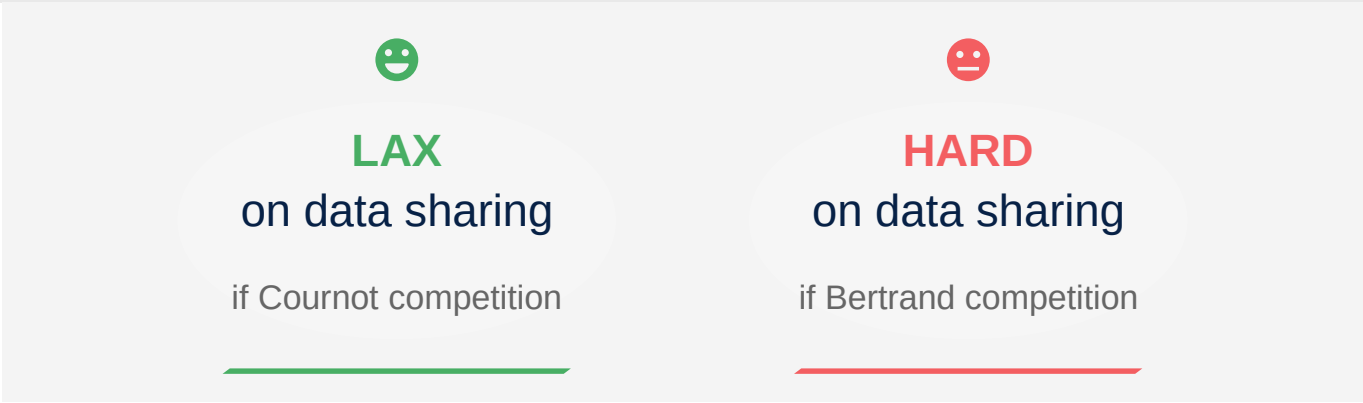
Figure 7. **CONTENT OF DATA BEING SHARED: RISK OF COLLUSION AND DESIRABLE POLICY STANCE**

Source: BBVA Research, based on Vives (2007).

Moreover, as observed in the previous sections and stressed in Figure 8, when there is convincing evidence of unconcentrated markets, the nature of competition should also determine the stance of authorities: policy can be lax if competition is of Cournot type and harsh if it is of Bertrand type. Yet doing so is not easy as authorities need first to empirically attest how firms compete (on price or quantity) in any given market.

[14] Although the burden of proof rests on the firms, according to [Art. 81(3)] of the EU antitrust regulation.
[15] See Vives (2007).

Figure 8. **DESIRABLE STANCE OF DATA-SHARING AND THE NATURE OF COMPETITION**



Source: BBVA Research, based on Vives (2007).

6. Further topics: data, platforms and privacy

Are data and information the same thing?

Information is what can be inferred from data, but the economic approach does not usually distinguish between the two. This difference is relevant and poses some limitations for analysis, though these can be overcome by taking into account the technology behind data-inference.

Leaving aside relevant aspects on the nature of goods, raw resources and ideas can be interpreted in the same way: there is plenty of raw material underground –such as raw copper- and they are worth zero unless some value is added to them, for example, by mining or refining.

One way to resolve this distinction is through signal or information intermediaries. At first, it was a way to understand communication among market players, and then adapted to understand intermediaries motives and interests. For example, a signaler (let's say Facebook, Google or Equifax) takes data and add-value to it with some technology and supplies a message or information to the market at a given price (what and who to target political campaign, advertising, telemarketing, loans and creditworthiness).

In this context, differences in technology to process the same set of data can lead to different information. Think of a signaler or intermediary that supplies information with a less accurate technology (low quality or noisy) and other that supplies more accurate information with a better technology (high quality). At some point (e.g. expiring patent) a better inference technology may spillover, as all intermediaries supply good quality signals (accurate information).

However, signalers do not always have an incentive to provide precise information because they might reduce future sales. To some extent they face incentives to supply noisy information or to exclude buyers, as a way to maximize the value of the data they provide to the market. Overall, they could exert market power over the value of information. Rules that foster competition could place limits to this power, allowing intermediaries to compete for accuracy while minimizing noisy outcomes.

As we showed previously, the more firms have relatively accurate information of a given parameter of demand (e.g. a customer's address that perfectly correlates with willingness-to-pay), both the "informational rent" and the value of information tend to be lower.

Platforms, algorithms, data-sharing rules and privacy

The literature on platforms -two-sided or multi-sided markets- tends to assume some kind of price competition. So, as we show, in those settings detailed data-sharing of proxies to individual's willingness-to-pay could reduce consumers' welfare. However, recent research show that a higher consumer wellbeing due to data-sharing could be possible when information intermediaries compete for data acquisition of consumers (Ichihashi, 2020) [16].

In this context, data interoperability -which reproduce consumers' data footprint from incumbents platforms into a rivals platform- could allow higher competition "for" the market, but still lead to competition problems "in" the market[17]. For itself, the case for artificial intelligence (AI) algorithms and collusion risks rise further challenges to antitrust policy, independent of the data-sharing policy that could be put into place. The use of AI may effectively "coordinate" prices with competing firm's algorithms, without any explicit mandate to do so (Calvano E., et al 2018). Further research is needed on this aspect and on the interaction of both dimensions of competition.

Finally, data can be excluded from competing firms due to licensing contracts or by the outcomes of a consent regime (opt-in/opt-out) despite being a non-rival good[18]. Nevertheless, privacy concerns and data security measures and costs are important elements to be considered, particularly when individuals' data are shared. The over-collection of data can be understood as form of exploitation of an individual's privacy[19]. Under certain domains, market efficiency could be attained in a world with no privacy (Acquisti, et. al, 2016), but when privacy is valued differently across individuals, distortion and externalities from data markets emerge (Acemoglu et. al, 2019).

7. References

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[16] However, results are weak and not generalizable due to multiple equilibria; some outcomes show no gains for consumers' wellbeing, and only a redistribution of welfare between data intermediaries and good producing firms. Other interesting result comes from the role of information design –how data is partitioned- and the way data concentrates in the upstream markets.

[17] For example, there is no convincing evidence that data portability facilitates market entry (Lam and Liu, 2018).

[18] Goods that are non-rival but excludable are known as "club" goods. In most "club" arrangements, you need a membership to be part of it.

[19] Similarly to the overexploitation of a common resource.

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