Industrial Data Sharing: The Unintended Consequences of the EU's Data Act*

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Abstract

The Data Act is a new law forthcoming in the European Union that regulates access to the data produced by IoT devices, especially in an industrial context such as smart manufacturing or smart farming. It aims at facilitating the emergence of new, innovative data-driven services that ultimately yield more efficient market outcomes and higher consumer surplus. We offer a first analytical study of the economic consequences of the Data Act. Our analysis suggests that due the broad scope of the Data Act, in many situations, the Data Act may likely reduce, and not increase market efficiency. In particular, the Data Act runs potentially contrary to its policy objective when new data-driven services are substitutes to the IoT device manufacturer's own service, and the IoT manufacturer only has limited market power; or when the new service is a complement to the IoT device manufacturer's own service, irrespective of market power. Our analysis suggests that the Data Act should adopt a more targeted approach, depending on the type of data-driven service seeking access to data, and the market power of the IoT manufacturer that is required to provide data access.
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1 Introduction

The advent of the Fourth Industrial Revolution is expected to bring forth unprecedented advancements in the manufacturing industry, leading to the emergence of smart manufacturing as a transformative concept (Dalenogare, Benitez, Ayala, & Frank, 2018). Smart manufacturing, often referred to as the factory of the future or Industry 4.0, represents a convergence of several technological domains, including internet of things (IoT), artificial intelligence (AI), big data analytics, cloud computing, and cyber-physical systems (Kusiak, 2018). These technologies work in tandem to enable the digitalization and integration of the entire manufacturing value chain, from product design and development to production planning, operations, and supply chain management. By harnessing the power of real-time data, smart manufacturing empowers companies to make data-driven decisions, optimize processes, enhance quality control, and respond quickly to changing market demands.

One of the key pillars of smart manufacturing is the IoT, which enables the connectivity and communication of physical devices, machines, and sensors within a manufacturing ecosystem (Li, Xu, & Zhao, 2015). By facilitating the exchange of real-time information, IoT enables seamless coordination and synchronization across different stages of production, leading to increased productivity, reduced downtime, and improved overall equipment effectiveness. The integration of advanced analytics and big data in smart manufacturing allows for enhanced decision-making capabilities. By analyzing vast volumes of structured and unstructured data, manufacturers can gain valuable insights into production processes, ultimately leading to better products and reduced marginal costs.

However, the industrial users of smart manufacturing equipment, such as small and medium enterprises or farmers, often do not have immediate access to the data that they produce while using the smart machinery. Instead, the generated data is often exclusively controlled by the manufacturer of the smart machinery (European Commission, 2022a), who then provides access only through its own analytics service. For example, John Deere equips all of its tractors with sensors that continuously transmit data regarding soil and crop conditions. The company offers farmers the opportunity to subscribe and pay for access to

this information, which can assist them in making informed decisions, such as determining optimal crop planting locations (Bronson & Knezevic, 2016). However, third-party analytics providers are not entitled to receive access and thus, cannot improve upon the service offered by the manufacturer itself. And even if data access is provided, the costs for access are likely to be too high, as the bargaining power resides with the data holder.

The exclusive control of manufacturers over IoT data has been recognized as a policy concern by the European Commission (EC) and many of the stakeholders involved. The EC criticizes that innovation potential from data remains untapped because of insufficient access to IoT data, and that competition in IoT data markets is stifled due to the manufactures' exclusive control over the data their devices generate while being used by their (industrial) users (European Commission, 2022a). It is estimated that only 20% to 40% (depending on the industrial sector) of the economic potential of non-personal industrial data is currently realized (Deloitte, 2022).

Against this backdrop, the EU is about to introduce a new regulation, called the *Data Act* (DA), which grants industrial users access to the data that is produced by their IoT devices (European Commission, 2022b).[1] The DA has two key elements, whose economic consequences we consider in detail in this paper.

First, the DA grants industrial users access to the data that they generated while using some IoT device (such as smart machinery) continuously and in real-time. In particular, the DA enables industrial users to authorize a third-party (e.g., an alternative analytics provider) to access the data directly on their behalf from the manufacturer (e.g., the original data holder).

Second, the DA requires that the access seeker and the data holder negotiate a price for data access. In particular, the DA limits the bargaining power of the data holder, and increases the bargaining power of the access seeker, by demanding that the access royalty must be fair, reasonable and non-discriminatory (FRAND). In case the data recipient is a

[1]The European Commission presented its proposal for the Data Act on February 23, 2022. Based on this, the EU Council (heads of the member states), the EU Parliament and the European Commission derived a political agreement in the 'trilogue' meetings in July 2023 (European Parliament, n.d.) paving the way for the introduction of the DA.

small or micro-enterprise, the data holder can only demand a royalty that just covers the costs for providing access, which should be close to zero in most scenarios (Krämer, 2022).

In this paper, we formally analyze the economic consequences of the DA's business-to-business data sharing obligations in an industrial context using a game-theoretic model. With the exception of a few early policy reports (Kerber, 2023; Krämer, 2022; Martens, 2023), economic considerations on the implications of the DA are scant - and, to the best of our knowledge, this paper is the first to derive a rigorous formal framework to analyze the economic consequences of the DA. We show that, albeit having good intentions, the broad scope of the DA may likely yield some unintended consequences that ultimately reduce economic surplus.

We model a manufacturer that offers a smart machinery (IoT device) as well as a service that uses as an input the data collected by the smart machinery to an industrial user. For example, the IoT device could be a tractor, which is equipped with sensors, e.g., measuring the moistness of the soil or taking images of weeds, and sends that sensor data to a cloud service, which provides actionable insights to the farmer (industrial user), e.g., on the optimal period for planting or the optimal amount of weed remover.

We consider two cases. In the first case, the manufacturer's smart machinery and data-driven service are unbundled and are offered separately from each other. The industrial user can accept the smart machinery offer but it may not choose to consume the manufacturer's service. The third party access seeker provides an innovative data-driven service that is a direct substitute for the manufacturer's own data-driven service. In this case, the manufacturer may not want to accommodate the third party and denies it data access, confirming the policy makers concern that data-driven innovation potential may be left untapped. However, we find that the DA may not always necessarily improve welfare. By forcing access and limiting the manufacturer's bargaining power, the DA may lower the incentives of the manufacturer to produce an IoT device in the first place, especially when its market power is restricted, which may induce inefficient market entry by the IoT device manufacturer.

In the second case, the manufacturer chooses to bundle its smart machinery and data-

driven service, so, they can only be consumed together by the industrial user. The third-party data recipient now offers a (data-driven) service that is complementary to IoT device manufacturer's bundle since it requires access to the manufacturer's smart machine data in order to be provided. In this case, the manufacturer already has strong incentives to accommodate the new service provider, as it increases the value of its IoT product's ecosystem. However, the DA interferes in this market by limiting the manufacturer's bargaining power vis-à-vis the complementary service provider and thereby distorts the manufacturer's alignment with overall market efficiency, leading to less efficient market outcomes than without the DA.

We then look at the incentives of the IoT manufacturer to bundle its smart machinery and its data-driven service. We find that bundling emerges when the manufacturer has relatively low market power in its upstream market of smart machinery. The choice of bundling, when it is optimally made, it eliminates the risk of inefficient entry by the IoT manufacturer, but, it also makes it more likely that the DA will have a negative welfare impact.

In summary, we find that the DA is only effective when the manufacturer chooses not to bundle its IoT device with its data-driven service, and only for intermediate values of its market power, and/or if the DA does not limit the manufacturer's bargaining power vis-à-vis the alternative service provider too much.

Our paper has important implications for the ongoing policy debate on data sharing in industrial contexts, and the regulatory proposals, like the DA, that are meant to support it.

2 The Model

Market participants: We consider a scenario in which an industrial user (I) uses the IoT device of a manufacturer (M) in its production process in order to produce a final good for end users (E). The IoT device entails both a hardware component (h) and a software component (s_M). The software analyzes the data generated by the device and provides insights for the industrial user that lower the marginal costs of I's production process. There exists an independent software provider (S), who supplies an innovative software (s_S) that is a substitute to the manufacturer's own software, but requires access to the device data

which is under M's exclusive control.

Downstream production: Using the hardware and data-driven insights provided by M, I produces q units of a final product at marginal cost of c_M. End users' demand for the final product is given by a standard inverse demand function $p(q) = a - bq$, with $a, b > 0$. We assume that $a > c_M$, which is a necessary condition to ensure that the industrial user I produces positive output in equilibrium.

Manufacturer's market pricing and entry decisions: M demands a price of h for the hardware and a price of $s_M = w_M q$ for the software component from I.[2] As is typical in industrial context, the wholesale price for the service component depends on the scale of I's production output. M bears development costs of k for its device, and chooses to enter the market and supply its device only when it expects positive profits. In case M does not enter, we normalize M's and I's profit to zero. Throughout the paper we assume that k is not prohibitively large, so that M is present in the market when it does not have to provide data access to third parties. This is ensured for $k < \frac{(a-c_M)^2}{8b}$.

Independent software provider: We focus our analysis on the interesting case envisioned by the DA, where S provides an innovative service that can lower I's marginal production costs to $c_S < c_M$. For example, S could provide a cloud service that is competing with that of the manufacturer and offers the same functionality, but has a higher accuracy, e.g. in detecting different types of weeds from image data, or combine the same hardware data with other data sources, e.g., uses not only soil moisture but also a weather forecast to determine the optimal planting period, and thereby provides better insights for the farmer. In this case, S supplies a software service that is superior to M's own service.

We normalize S's market entry cost to zero.[3] However, in order to be able to provide its independent service, S needs access to the data generated by the IoT device, which is under

[2] In order to reduce the burden on notation, we slightly abuse notation and use h and s to denote both the type of the IoT device component (hardware/software) as well as the price of the respective component.

[3] This assumption is without loss of generality with respect to the relevant market outcomes and insights provided below, but significantly reduces the complexity of the analysis.

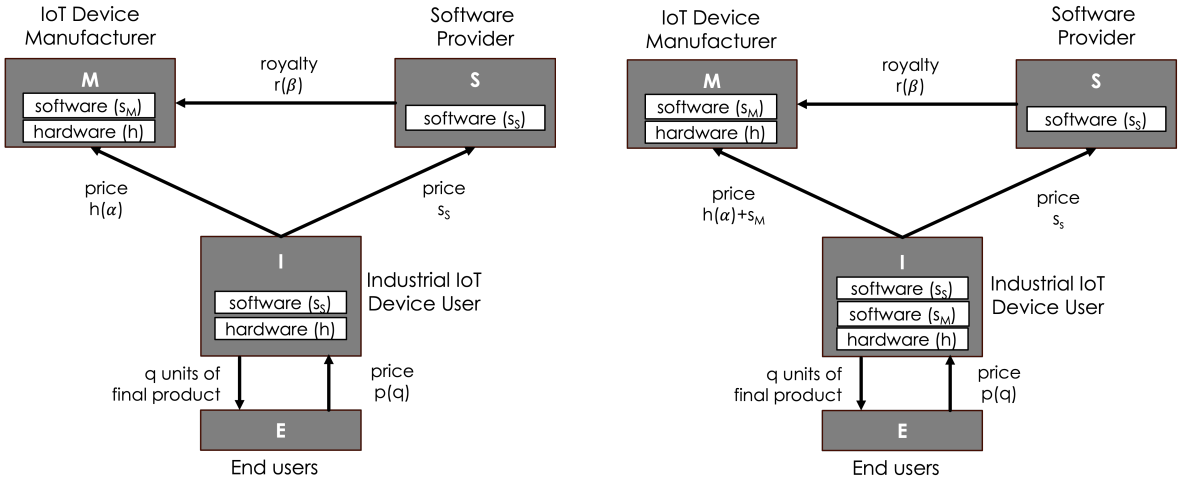
M's exclusive control. M can grant access to the data for a royalty fee r, or it can outright deny access. If provided access, S demands from I a wholesale price of $s_S = w_S\, q$ for its service.

If the manufacturer's hardware and software service are unbundled, I can decide whether to use M's hardware and software, paying a total price of $h + s_M$, or instead to use M's hardware with S's software, i.e., paying a total wholesale price of $h + s_S$. Under bundling, I buys both types of software, paying a total price of $h + s_M + s_S$. Whether S's can replace M's service depends on whether M has chosen to bundle its service with the hardware or not. In the case that a bundling strategy is adopted by the manufacturer, S's service is complementary to the manufacturer's bundled product since access to the IoT device in operation and its data is a necessary step to make S's service efficient and attractive.

Constrained market power: In our set-up, M is a monopolist and has market power over I and S when setting the hardware wholesale price for I and the royalty fee for S. In practice, market power can be constrained, either through the market structure (e.g., competition, outside options, or bargaining power of buyers), or through regulatory frameworks (e.g., competition law, or sectoral market rules), or both. We model these constraints of market power in a parsimonious and yet flexible way by introducing two parameters $\alpha \in (0, 1)$ and $\beta \in (0, 1)$ that reflect M's market power vis-á-vis I and S, respectively. More specifically, α denotes the maximum fraction of I's profit that can be extracted by M when selling its hardware. Note that if M's market power were unrestricted, M could always set the price for its hardware, h, so that it makes I indifferent between buying from M and I's outside option, which yields zero profit. Let $\overline{h}$ denote the maximum price that would yield zero profit for I, then $h(\alpha) = \alpha\, \overline{h}$ is the assumed price that emerges under M's constrained market power. A larger $\alpha \in (0, 1)$ represents a stronger market power of M over I, allowing it to charge a higher price for hardware.

Likewise, we introduce a restriction on the maximal r that M can charge from S. In particular, Article 9 of the EU's DA regulates that the compensation for data access demanded by M from S shall be FRAND and may in some cases, depending on the firm size of S,

Figure 1: Players and decision variables for the model variants when the manufacturer's hardware h and software s_M are unbundled and when they are bundled.



(a) Unbundled h and s_M **(b) Bundled h and s_M**

not exceed the cost of providing access (which we normalize to zero). Specifically, β is the bargaining power of S vis-a-vis M. That is $1-\beta$ is the maximum fraction of S's profit that can extracted by M through r. Let $\overline{r}$ denote the maximum royalty fee that would yield zero profit for S, then $r(\beta) = (1-\beta)\,\overline{r}$ is the assumed royalty fee that would emerge under M's constrained market power. As a larger β represents a strengthening of the position of S, a larger $\beta \in (0,1)$ represents a lower market power of M over S, allowing S to negotiate a lower access royalty fee. In particular, the regulations of the DA are intended to increase S's bargaining power over M by disallowing denial of access and by reducing the access fee. We denote S's increased bargaining power through the DA by β^{DA} which is taken to be higher than the bargaining power that S would have over M in the absence of the DA, i.e. $\beta^{DA} > \beta$.

Figure 1 and expressions (1) (2) and (3) summarize the payoffs and decision variables in the cases of unbudling and bundling.

Profits: The profits of M, S and I are given as follows:

$$\pi_M = \begin{cases} 0 & \text{if } M \text{ does not enter} \\ \pi_M^M = h(\alpha) + s_M - k & \text{if } M \text{ enters, } S \text{ denied access, or } S \text{ not chosen by } I \\ \pi_M^{MS} = h(\alpha) + s_M + r(\beta) - k & \text{if } M \text{ enters, } S \text{ chosen and } h \text{ and } s_M \text{ are bundled} \\ \pi_M^S = h(\alpha) + r(\beta) - k & \text{if } M \text{ enters, } S \text{ chosen and } h \text{ and } s_M \text{ are unbundled} \end{cases} \tag{1}$$

$$\pi_S = \begin{cases} 0 & \text{if } M \text{ does not enter or } S \text{ denied access or } S \text{ not chosen by } I \\ \pi_S^S = s_S - r(\beta) & \text{if } M \text{ enters and } S \text{ chosen by } I \end{cases} \tag{2}$$

$$\pi_I = \begin{cases} 0 & \text{if } M \text{ does not enter} \\ \pi_I^M = (p(q) - c_M)\, q - (h(\alpha) + s_M) & \text{if } M \text{ enters, } S \text{ denied access, or } S \text{ not chosen by } I \\ \pi_I^{MS} = (p(q) - c_S)\, q - (h(\alpha) + s_M + s_S) & \text{if } M \text{ enters, } S \text{ chosen and } h \text{ and } s_M \text{ are bundled} \\ \pi_I^S = (p(q) - c_S)q - (h(\alpha) + s_S) & \text{if } M \text{ enters, } S \text{ chosen and } h \text{ and } s_M \text{ are unbundled} \end{cases} \tag{3}$$

Timing: Finally, the timing of the game is as follows:

(1) M decides whether it will enter the market. If entry occurs, M decides whether S is allowed data access (only feasible if DA does not apply) and sets its hardware and software price for I and royalty fee for S.

(2) S chooses whether to enter and, if entry occurs, sets its software price for I.

(3) I chooses whether it will buy hardware and from who will buy software, and determines output quantity q. Demand, payments and profits are realized.

The timing reflects that M's decision whether to supply an IoT device and at which price is done before potential alternative service providers can develop and supply their software.[4]

3 Analysis

In the following we derive the equilibrium market outcomes with and without the DA for the case of unbundling and bundling of h and s_M. We derive the subgame perfect Nash equilibrium using backward induction. We then study the incentives of the manufacturer to bundle its two products as well as the overall implications of the introduction of the DA.

3.1 Unbundling

In the unbundling case, I can replace M's software by S's software component. This yields an efficiency gain for I's production process, as through the use of S's software, the marginal cost of production is reduced from c_M to $c_S < c_M$. In the absence of the DA, M can deny S access to the device data and thereby block entry of S. However, it can also accommodate entry and can negotiate a royalty fee for access with S depending on its market power β. In the presence of the DA, M always has to accommodate entry if this is beneficial to I. M can still demand a royalty fee, but the DA also constrains M bargaining power in negotiating this fee.

3.1.1 Market outcomes without DA

Stage 3: Decisions by I: In case S is chosen by I, I's optimal output is given by $q^S = \frac{a-c_S-w_S}{2b}$. In case S is not chosen, and I remains with M's service only, optimal output is given by $q^M = \frac{a-c_M-w_M}{2b}$. The industrial user selects the provider with the best software price - production efficiency combination. The industrial user selects S's offer over M's offer if $w_S < w_M - (c_S - c_M)$. Thus, in case S is allowed entry, the extra production efficiency

[4] An alternative timing, where M and S set their prices simultaneously would not qualitatively affect our results.

provided by S allows it to offer a software price above the price offer of M and still be selected in equilibrium as the wholesale provider if the efficiency gains it brings are sufficiently high.

Stage 2: Decisions by S: S can offer its software only if it is granted data access by M. In this case, S sets a price that is just low enough to outcompete the price of M, i.e., $s_S = w_S\, q$ with $w_S = w_M + c_M - c_S$, as long as this price is high enough to recover the royalty fee, i.e. $s_S \geq r(\beta)$. Otherwise, S will not enter and not offer its software.

Stage 1: Decisions by M: First, assume M enters and allows access by S. Without the DA, M allows access only if it ultimately benefits from S replacing its own software. M can reap additional profits from the royalty fee and can also set a higher hardware price, as I's productive efficiency is increased through the alternative software. Accordingly, M sets the maximal royalty fee that is feasible given S's bargaining power, i.e., $r(\beta)^{S,*} = (1-\beta)s_S = (1-\beta)\, w_S\, q^S$. Similarly, M sets a hardware price that maximizes its profits, given market power restrictions, i.e. $h(\alpha)^{S,*} = \alpha(p(q) - c_S - w_S)q^S$. Note that both, $r(\beta)^{S,*}$ and $h(\alpha)^{S,*}$ depend on w_S, the marginal software price chosen by S. Anticipating how S's price setting affects its profit, M does not have any incentive to compete with S at a marginal software price w_M above or below the price $w_S^{S,*}$ that maximizes $\pi_M^S(h(\alpha)^{S,*}, r(\beta)^{S,*})$, provided that at that price both M and S earn non-negative profits. Note that M can implement the marginal software price set by S that maximizes its own profit by choosing its own price w_M such that $w_M^{S,*} = w_S^{S,*} - (c_M - c_S)$ (see S's pricing decision in Stage 2 above). If instead one of the zero profit constraints by M and S becomes binding, the binding condition determines the equilibrium price and output. The following lemma describes the equilibrium outcome when participation constraints are either slack (interior solution) or binding.

Lemma 1. *When M enters, software provider S is allowed access and h and s_M are unbun-*

dled, then S is chosen by I and the equilibrium prices and output are as follows:

$$w_S^{S,*} = \begin{cases} w_{S1}^{S,*} = \frac{1-\beta-\alpha}{2-2\beta-\alpha}(a-c_S), \quad \textit{if} \quad \beta \in (0, \beta_M^{th}) \quad \textit{and} \quad \alpha \in (0, \alpha^{th}), \\ \textit{or,} \quad \beta \in (0, \beta_S^{th}) \quad \textit{and} \quad \alpha \in [\alpha^{th}, 1), \\ w_{S2}^{S,*} = 0, \quad \textit{if} \quad \beta \in [\beta_S^{th}, 1) \quad \textit{and} \quad \alpha \in [\alpha^{th}, 1), \end{cases} \tag{4}$$

where, $\beta_S^{th} = 1-\alpha$, $\beta_M^{th} = \frac{(a-c_S)^2-4bk-2\sqrt{bk(4bk-\alpha(a-c_S)^2)}}{(a-c_S)^2}$ *and* $\alpha^{th} = \frac{4bk}{(a-c_S)^2}$.

$$q^{S,*} = \begin{cases} q_1^{S,*} = \frac{(1-\beta)(a-c_S)}{2b(2-2\beta-\alpha)}, \quad \textit{if} \quad \beta \in (0, \beta_M^{th}) \quad \textit{and} \quad \alpha \in (0, \alpha^{th}), \\ \textit{or,} \quad \beta \in (0, \beta_S^{th}) \quad \textit{and} \quad \alpha \in [\alpha^{th}, 1), \\ q_2^{S,*} = \frac{a-c_S}{2b}, \quad \textit{if} \quad \beta \in [\beta_S^{th}, 1) \quad \textit{and} \quad \alpha \in (\alpha^{th}, 1). \end{cases} \tag{5}$$

$$\begin{aligned} h(\alpha)^{S,*} &= \alpha(a - b\,q^{S,*} - c_S - w_S^{S,*})\,q^{S,*}, \quad s_M^{S,*} = (w_S^{S,*} - (c_M - c_S))\,q^{S,*} \\ s_S^{S,*} &= w_S^{S,*}\,q^{S,*}, \quad \textit{and} \quad r(\beta)^{S,*} = (1-\beta)\,w_S^{S,*}\,q^{S,*}. \end{aligned} \tag{6}$$

Now assume M enters, but does not allow access by S. In this case, M is the only software provider available to I, and M chooses a hardware price $h(\alpha)^{M,*} = \alpha(p(q) - c_M - w_M)q^M$ and a marginal software price w_M that maximizes $\pi_M^M(h(\alpha)^{M,*})$. The next lemma describes the equilibrium prices in this case.

Lemma 2. *When M enters and S is denied access, then M is the only software provider and the equilibrium prices and output are as follows:*

$$w_M^{M,*} = \frac{1-\alpha}{2-\alpha}(a-c_M), \quad \textit{and} \quad q^{M,*} = \frac{a-c_M}{2b(2-\alpha)} \tag{7}$$

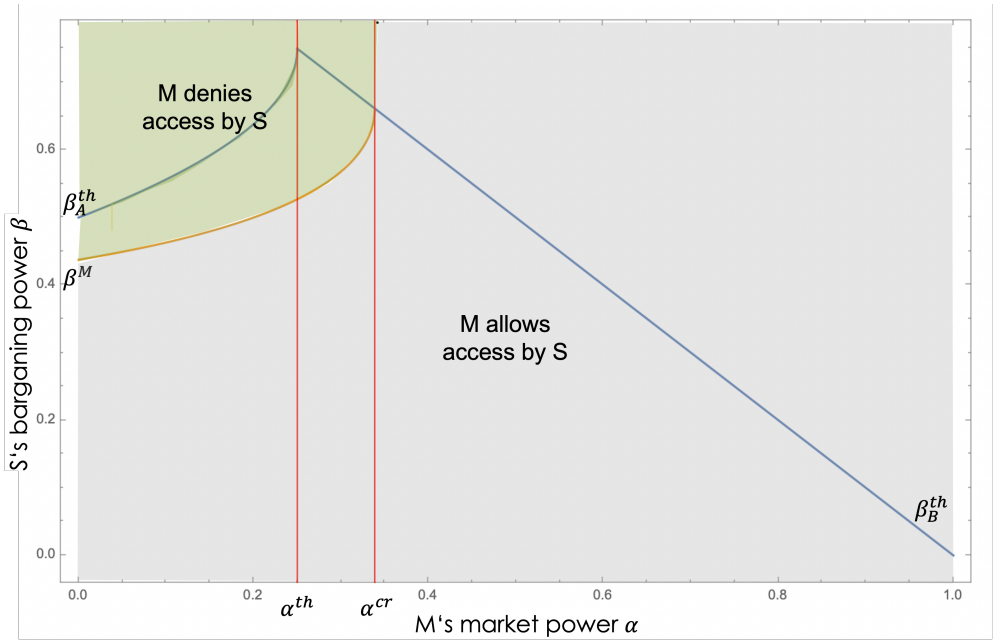
$$h(\alpha)^{M,*} = \alpha(a - b\,q^{M,*} - c_M - w_M^{M,*})\,q^{M,*}, \quad \textit{and} \quad s_M^{M,*} = w_M^{M,*}\,q^{M,*} \tag{8}$$

Whether or not M enters the market, and which of the two types of equilibria occurs, depends crucially on the market power and bargaining power parameters α and β. The following lemma characterizes the equilibrium market outcome.

Lemma 3. *When h and s_M are unbundled, and in the absence of the DA, the following market outcomes emerge:*

1. *M enters the market, and allows access by S for $\beta \in (0, \beta^M)$ and $\alpha \in (0, \alpha^{cr})$, or, $\beta \in (0,1)$ and $\alpha \in [\alpha^{cr}, 1)$, with $\alpha^{cr} = 1 - \sqrt{\frac{2a(c_M - c_S) - c_M^2 + c_S^2}{(a-c_S)^2}}$ and $\beta^M = 1 - \frac{(a-c_M)^2}{(2-\alpha)(a-c_S)^2} - \sqrt{\frac{(a-c_M)^2\left(a^2(1-\alpha)^2 - 2a(c_M - (2-\alpha)\alpha c_S) - (2-\alpha)\alpha c_S^2 + c_M^2\right)}{(\alpha-2)^2(a-c_S)^4}}$.*
2. *Otherwise, M enters and denies access by S.*

Figure 2: Market outcomes under unbundling and without DA regulation



M blocks the entry of S when it has limited bargaining power and limited market power (green area). However, M accommodates entry by S otherwise (gray area). Figure derived for $a = 1, b = 0.4, k = 0.1, c_M = 0.4, c_S = 0.2$.

Figure 2 visualizes the market outcomes denoted by Lemma 3. When M has limited bargaining power such that $\beta > \beta^M$ and therefore cannot extract a sufficient royalty fee from S, it prefers to deny access to S. However, if M's market power is large $\alpha > \alpha^{cr}$, then M prefers entry of S irrespective of its bargaining power. This is because for high levels of α, M can compensate for the loss in software sales by increasing the hardware price to I, which has increased efficiency and profits, thanks to the innovative service provided by S.

3.1.2 Welfare impact of the DA

Against this backdrop, we can now derive the impact of the DA on market outcomes and social welfare. As it is typical for the assessment of regulatory interventions, we adopt a consumer welfare standard. In our model, consumer welfare depends on the equilibrium output q^* and is given by:

$$CS(q^*) = \int_0^{q^*} p(q)dq - p(q^*)q^* = \frac{1}{2}b(q^*)^2 \tag{9}$$

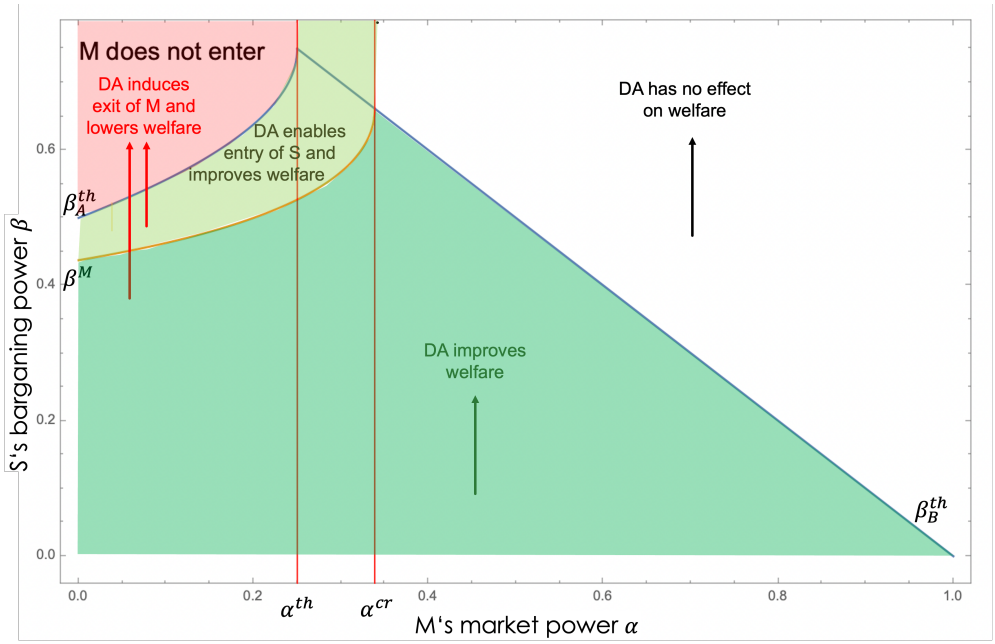
Consequently, a higher output by I is always desirable from a regulatory point of view. Further, consumer welfare is aligned with the industrial user's incentives, who also makes higher profits when q is higher in equilibrium, as a higher equilibrium output is the result of higher production efficiency. Together, this yields the following lemma:

Lemma 4. *When h and s_M are unbundled, entry by S is socially desirable and strictly preferred by I for all $\beta \in (0,1)$ when $\alpha \in [\alpha^{th}, 1)$ and for all $\beta \in (0, \beta_M^{th})$ when $\alpha \in (0, \alpha^{th})$.*

The lemma shows in particular that entry by S would be socially desirable and preferred by I in areas where S is denied access by M in an unregulated environment (cp. Lemma 3). This gives rise to a potentially positive welfare effect of the DA, as the DA allows I the right to grant access by S even in situations in which S would not have received access by M voluntarily. This situation occurs in the light green area in Figure 3.

However, in this area, the DA also alters the manufacturer's pricing strategy. Without the option to outright block entry of S, the manufacturer can yet choose to fight entry by adopting a more aggressive pricing strategy for its software component, as I chooses the software component that offers the most attractive combination of price and production efficiency. We find that for low levels of market power $\alpha \in (0, \alpha^{th})$, S outprices M and is selected as the software provider (see the Appendix for a formal exposition). As a result, M does not have any incentives to fight entry. For higher values of $\alpha \in [\alpha^{th}, 1)$, the manufacturer is able to outprice the alternative software provider S if it chooses to fight. However, M still prefers not to fight entry, because it would have to price its software so low that its profits

Figure 3: Welfare effects of the DA under unbundling. Arrows indicate welfare effects of an increase in S's bargaining power β induced by the DA.



In the red area, the mandated access by the DA leads M not to enter, although it would have entered without the DA. In the green areas the DA improves welfare. Arrows indicate effects of an increase in S's bargaining power β due to the DA. Figure derived for $a = 1, b = 0.4, k = 0.1, c_M = 0.4, c_S = 0.2$.

would be lower than if it would accommodate entry by S. This is an additional effect of the DA: It does not only reduce the ability of the M but also its incentives to block entry. Taken together, the DA improves welfare in the light green area in Figure 3.

The DA not only enables entry of S in cases in which it would have been blocked otherwise, but it also increases the bargaining power β of S, which leads to a reduction in the access royalty r that S has to pay to M. An increase in β has more nuanced effects on market outcomes and welfare when S provides a substitute software component.

When S's bargaining power β is low prior to the DA (corresponding to the dark green area in Figure 3), the equilibrium price is $w_{S1}^{S,*} > 0$ (see Lemma 1), which is strictly decreasing in β. This increases productive efficiency and output of I, and hence the DA increases welfare in this area. The intuition is as follows: When β increases, the royalty fee, r, is reduced,

which makes this a less important source of revenue for M. Instead, revenues coming through the hardware price, h, become more important to M. As a result, M has an incentive to increase the production efficiency of I in order to be able to collect a higher hardware price. Therefore, M finds it profitable to induce the software provider S to adopt a lower price, by lowering its own software price accordingly, so that I's marginal costs are decreased, and consequently production efficiency and output are increased.

To sum up, the positive welfare effects of the DA can be grouped into two categories: i) the dark green area in Figure 3, where the DA increases productive efficiency, and; ii) the light green area in Figure 3, where the DA leads to socially efficient entry by the service provider S, correcting in this way the market failure that stems from the disincentives of M to accommodate S's entry. Specifically, in the region in the light green area where $\beta > \beta_B^{th}$, the DA improves efficiency both in production and entry.

When S's bargaining power is already high prior to the DA (corresponding to the white area in Figure 3), the equilibrium price is $w_{S2}^{S,*} = 0$ and the equilibrium royalty, r, is already at zero as well. Hence, an increase in bargaining power β cannot further lower these prices and hence has no effect on I's productive efficiency and welfare.

An increase in S's bargaining power can also have adverse welfare effects when M's market power is rather limited ($\alpha < \alpha^{th}$). In this case, if the DA increases β beyond the threshold β_A^{th}, so that allowed royalty fee is reduced so much (and, due to M's limited market power, cannot be compensated by an increase in the hardware price), that M cannot recover its fixed cost k anymore, then M would not enter in the first place. This scenario corresponds to the red area in Figure 3. Further, the increase in S's bargaining power (indicated by the red arrows) can push the market outcome into the red area, where M does not enter. Consequently, in all these cases (and depending on the increase in β) the DA lowers welfare, as innovative manufacturers of IoT devices are discouraged from offering their products (e.g., smart machine).

It is important to keep in mind that the DA is especially designed for situations in which M would block entry of S otherwise (i.e., the light green area in Figure 3). However, we find

that M only blocks entry if it has limited market power *and* bargaining power. But it is also in this area, where M may choose not to enter if the DA forces access by S and reduces M's bargaining power further. Thus, ironically, the negative effects of the DA are especially likely when the DA has the potential to enable entry of an alternative software provider.

Proposition 1. *When the manufacturer M chooses to unbundle its hardware h and software service s_M, the Data Act increases consumer welfare and the industrial user I's profit in the presence of a software provider S seeking access to data produced by an IoT device manufactured by M if*

i) M has relatively high market power ($\alpha \geq \alpha^{cr}$) and S's bargaining power prior to the application of the Data Act is modest ($\beta < \beta_B^{th}$), or

ii) M has intermediate market power ($\alpha^{th} \leq \alpha < \alpha^{cr}$), or

iii) M has relatively low market power ($\alpha < \alpha^{th}$) and the policy does not increase S's bargaining power too much ($\beta^{DA} < \beta_A^{th}$).

Otherwise, if M has relatively low market power ($\alpha < \alpha^{th}$) and the policy increases S's bargaining power beyond β_A^{th}, M would not supply its IoT product anymore, leading to a reduction in consumer welfare.

3.2 Bundling

We now consider the case where M bundles its hardware h and software s_M. S's software service can now be used by I in addition to M's service in order to reduce its marginal production costs from c_M to $c_S < c_M$.

3.2.1 Market outcomes without DA

The analysis under bundling differs from that presented in Subsection 3.1, as I has to bear the cost of both software components in case it selects S, but also because S and M are not competing for the selection by I. We again proceed by backward induction to derive the equilibrium outcome.

Stage 3: Decisions by I: I's optimal output with S is $q^{MS} = \frac{a-c_S-w_M-w_S}{2b}$, and without S it is $q^M = \frac{a-c_M-w_M}{2b}$. Consequently, I chooses S when the additional marginal production efficiency by S outweighs the additional marginal costs, i.e., $w_S \leq c_M - c_S$.

Stage 2: Decisions by S: Anticipating I's choice, S optimally prices its software such that it maximizes $s_S = w_S q^S$. This yields $w_S^*(w_M) = \frac{1}{2}(a - c_S - w_M)$ provided $w_S^* \leq c_M - c_S$. Otherwise, S sets $w_S^* = c_M - c_S$.

Stage 1: Decisions by M: First assume M enters and blocks access by S. Then the equilibrium prices are readily given by Lemma 2. Now assume M accommodates entry by S. Similar to the case with a competing software provider, M sets the maximal royalty fee that is feasible given S's bargaining power, i.e., $r(\beta)^{MS,*} = (1-\beta)\, w_S^*\, q$. and the maximal hardware price given market power restrictions, i.e., $h(\alpha)^{MS,*} = \alpha(p(q) - c_S - w_M - w_S^*)q$. M then selects the profit maximizing $w_M^{MS,*}$ internalizing how its price affects I's final output, as well as the royalty fee and hardware price.

Lemma 5. *Under bundling of h and s_M, when M enters and software provider S is allowed access, then S is chosen by I and the equilibrium prices and output are as follows:*

$$w_M^{MS,*} = \begin{cases} w_{M,1}^{MS,*} & = \frac{(2\beta-\alpha)(a-c_S)}{2-\alpha+2\beta}, \quad \textit{if} \quad \beta \geq \beta_C^{th}, \\ w_{M,2}^{MS,*} & = \frac{(1-\alpha)(a-c_M)-(1-\beta)(c_M-c_S)}{2-\alpha}, \quad \textit{otherwise.} \end{cases} \tag{10}$$

$$w_S^{MS,*} = \begin{cases} w_{S,1}^{MS,*} & = \frac{(a-c_S)}{2-\alpha+2\beta}, \quad \textit{if} \quad \beta \geq \beta_C^{th}, \\ w_{S,2}^{MS,*} & = c_M - c_S, \quad \textit{otherwise.} \end{cases} \tag{11}$$

$$q^{MS,*} = \begin{cases} q_1^{MS,*} & = \frac{a-c_S}{4b+2b(2\beta-\alpha)}, \quad \textit{if} \quad \beta \geq \beta_C^{th}, \\ q_2^{MS,*} & = \frac{(a-c_S)-\beta(c_M-c_S)}{4b-2\alpha b}, \quad \textit{otherwise.} \end{cases} \tag{12}$$

where $\beta_C^{th} = \frac{\alpha}{2} + \frac{a-c_S}{2(c_M-c_S)} - 1$.

$$\begin{aligned} h(\alpha)^{MS,*} &= \alpha(a - b\,q^{MS,*} - c_S - w_M^{MS,*} - w_S^{MS,*})\,q^{MS,*}, \quad s_M^{MS,*} = w_M^{MS,*}\,q^{MS,*}, \\ r(\beta)^{MS,*} &= (1-\beta)\,w_S^{MS,*}\,q^{MS,*}, \quad \textit{and} \quad s_S^{MS,*} = w_S^{MS,*}\,q^{S,*}. \end{aligned} \tag{13}$$

The next lemma shows that M always prefers to accommodate entry by S, because S increases the value of its IoT device by providing additional efficiency gains, but - contrary to the case of unbundling of h and s_M - does not replace or compete with its own software.

Lemma 6. *Under bundling of h and s_M and without the DA, M always enters and allows access by S.*

3.2.2 Welfare impact of the DA

First, note that entry by S is always socially desirable and preferred by I. S adds efficiency to I's production process and never charges more than the efficiency gain provided.

Lemma 7. *Under bundling of h and s_M, entry by S is always socially desirable and strictly preferred by I.*

Recall from Lemma 6 that M always invites entry by S. Thus, there is no market failure from blocked entry that could be corrected by the DA. In reverse, – and following as corollary from Lemma 6 – the DA also does not distort the incentives of M to enter. Since M prefers to accommodate S irrespective of its bargaining power β, the DA cannot induce market exit by M even if the DA negatively affects M's bargaining power.

Although the DA does not induce market entry or exit by M or S, it nevertheless affects market outcomes by altering S's bargaining power. We find that an increase in β always lowers I's and M's profit as well as consumer surplus. The intuition for this result is as follows: Without the DA, M's incentives are largely aligned with consumer surplus (and I). M has an incentive to accommodate S because it thereby increases the efficiency of its IoT device ecosystem, which it can then leverage through its hardware and software price. Indeed, note from the prices in Lemma 5 that the larger M's market power (α), and the lower

S bargaining power (β) the lower it would set its marginal software price $w_M^{MS,*}$, possibly even below zero, in order to incentivize I to increase its output and profits, which M can then extract through the hardware price.

An exogenous increase in β through the DA distorts these incentives and induces a higher marginal software price by M. Albeit S's marginal software price is lowered as β is increased, the overall effect on the sum of the marginal software prices by M and S that have to be born by I (since s_M and s_S are complements) is negative, which eventually lowers I's efficiency, output and thus consumer surplus.

Notice that it is this increase in M's software price that ultimately yields the negative consequences of the DA in the case of complementary third-party software providers. In the case of substitutes, the industrial user only buys software from S, which it can offer at a lower price (or is able to offer it at all) due to the DA. In case of complementary software, the industrial user still needs to buy M's software in addition to S's software and pays a higher price overall, as M is less able to internalize I's efficiency gain due to a decrease in its bargaining power vis-á-vis the software provider S.

The next proposition summarizes our findings on the welfare implications of the DA under bundling.

Proposition 2. *When the manufacturer M bundles its hardware and software component, the Data Act always lowers consumer welfare and the industrial user's (I) profit in the presence of a software provider (S) seeking access to data produced by an IoT device manufactured by M.*

3.3 Manufacturer's incentives to bundle its hardware and software without the Data Act

Since bundling and unbundling of hardware h and software s_M lead to different welfare implications for the DA, in this section, we study the incentives of M to bundle its two products without and with the DA.

The timing of the game needs to be slightly adjusted to accommodate M's bundling

strategy decision. In Stage 1 of the game, M again decides whether it will enter the market. If entry occurs, M decides whether it will bundle its hardware and software before deciding about allowing data access (if DA does not apply), its products price(s) and the royalty fee. The rest stages of the timing remain the same.

3.3.1 M's incentives to adopt a bundling strategy without the DA

In the absence of the DA and under unbundling, M always enters the market but it blocks S's entry for $\beta \in [\beta^M, 1)$ and $\alpha \in (0, \alpha^{cr})$, following Lemma 3. Otherwise, M accommodates S's entry.

Lemma 8. *When $\beta \in [\beta^M, 1)$ and $\alpha \in (0, \alpha^{cr})$, M prefers to bundle its hardware h and software s_M and accommodates S's entry for:*

- $\beta \in [\beta^M, 1)$ *and* $\alpha \in (0, \alpha^{cr})$ *if there is a very high efficiency gain from S's entry such that:* $a - c_M \leq \frac{1}{2}(\sqrt{3+2\sqrt{3}} + \sqrt{3})(c_M - c_S)$,
- $\beta \in [\beta^M, 1)$ *and* $\alpha \in (0, \alpha_2^{cr}]$, *where* $\alpha_2^{cr} = 2\left(1 - \frac{1}{\frac{(a-c_S)^2}{(a-c_M)^2} - 1}\right)$, *or,* $\beta \in [\beta^M, \beta_S^{th})$ *and* $\alpha \in (\alpha_2^{cr}, \alpha^{cr})$, *where* $\beta_S^{th} = \frac{2-\alpha}{\alpha}\left(\frac{(a-c_S)^2}{(a-c_M)^2} - 1\right)$, *if there is a high efficiency gain from S's entry such that:* $(1+\sqrt{2})(c_M - c_S) > a - c_M > \frac{1}{2}(\sqrt{3+2\sqrt{3}} + \sqrt{3})(c_M - c_S)$,
- $\beta \in [\beta^M, 1)$ *and* $\alpha \in (0, \alpha_2^{cr}]$, *or,* $\beta \in [\beta^M, \beta_S^{th})$ *and* $\alpha \in (\alpha_2^{cr}, \alpha_3^{cr})$, *where* $\alpha_3^{cr} = \frac{2(a-c_S)(c_M-c_S)-(a-c_M)^2}{(a-c_S)(c_M-c_S)}$, *if the efficiency gain from S's entry is intermediate,* $(1+\sqrt{3})(c_M - c_S) > a - c_M > (1+\sqrt{2})(c_M - c_S)$,
- $\beta \in [\beta^M, \min\{1, \beta_C^{th}\})$ *and* $\alpha \in (\alpha_3^{cr}, \alpha^{cr})$, *if* $(1+\sqrt{3})(c_M - c_S) > a - c_M \geq (1+\sqrt{2})(c_M - c_S)$,
- $\beta \in [\beta^M, \min\{1, \beta_C^{th}\})$ *and* $\alpha \in (0, \alpha^{cr})$, *if the efficiency gain from S's entry is low,* $a - c_M \geq (1+\sqrt{3})(c_M - c_S)$.

Otherwise, M chooses to unbundle its two products and blocks S's entry.

In this region of the $\alpha - \beta$ space, the efficiency gain that stems from the size of the step $c_M - c_S$, namely, how much the industrial user I can save in terms of marginal cost of production is crucial for M's decision to bundle or not to bundle its products. Bundling always implies that M accommodates S's entry. If instead, M offers its two products separately, it blocks entry following Lemma 3.

If the step $c_M - c_S$ is very high as in the first bullet point of Lemma 8, then β_S^{th}, defined as the threshold above which M prefers unbudling and to block S's entry, is greater than 1, $\beta_S^{th} > 1$ (while, $\beta_C^{th} < 1$). Hence, $\beta < \beta_S^{th}$, which implies that M prefers the bundling strategy and S's entry $\forall \beta \in [\beta^M, 1)$ and $\forall \alpha \in (0, \alpha^{cr})$. This is because M fully internalizes the production efficiency benefits as M and S act as providers of complementary goods. Since, S's brings large efficiency gains in the production of the downstream market, M can capture substantial benefits from its hardware price h, even if $\alpha < \alpha^{cr}$ and the bundling strategy and $S's$ entry is desirable.

As the step $c_M - c_S$ declines, thresholds β^M, β_S^{th}, α_2^{cr} and α_3^{cr} decrease, while thresholds β_C^{th} and α^{cr} increase. So, as $c_M - c_S$ moves to lower values, we first see the range of values of $M's$ market power α, $\alpha \in (0, \alpha_2^{cr}]$ over which M prefers bundling $\forall \beta \in [\beta^M, 1)$, shrinks to lower values of α. However, there is an expanding region of $\alpha \in (\alpha_2^{cr}, \alpha^{cr})$ in which M develops incentives to unbundle its two products and block S's entry for $\beta \in [\beta_S^{th}, 1)$ in the expense of the range of values of β for which M prefers the bundle (second and third bullet points of Lemma 8).

When $c_M - c_S$ takes intermediate or further decreases to low values (fourth and fifth bullet points of Lemma 8), we see that the region in which M prefers bundling starts expanding again suggesting that the efficiency gains of S's entry affect M's incentives to bundle its products in a nonlinear way. This expansion in the region of the $\alpha - \beta$ space where bundling is selected is observed because it is now the exterior solution of Lemma 5 with $\beta < \beta_C^{th}$ that becomes more relevant since β_C^{th} increases as $c_M - c_S$ drops. Under this solution, M prefers bundling for a greater range of values of both α and β. When $\beta_C^{th} \geq 1$, M prefers bundling for $\beta \in [\beta^M, 1)$ and $\alpha \in (0, \alpha^{cr})$. Namely, M always prefers bundling in this region of the

$\alpha - \beta$ space both when $c_M - c_S$ is very high and low.

So far, we focused on the region where $\beta \in [\beta^M, 1)$ and $\alpha \in (0, \alpha^{cr})$, namely, the region where under unbundling, M blocks S's entry. We now discuss M's incentives to bundle its hardware and software for the region of the $\alpha - \beta$ space for which M accommodates entry in Lemma 3.

In such a case, M chooses to bundle its two products only when $\pi_M^{MS}(h(\alpha)^{MS,*}, s_S^{MS,*}, s_M^{MS,*}, r(\beta)^{MS,*}) > \pi_M^{S}(h(\alpha)^{S,*}, s_S^{S,*}, r(\beta)^{S,*})$ following equilibria (6) and (13), for $\beta \in (0, \beta^M)$ and $\alpha \in [0, \alpha^{cr})$, or, $\beta \in (0, 1)$ and $\alpha \in [\alpha^{cr}, 1)$.

Lemma 9. *When $\beta \in (0, \beta^M)$ and $\alpha \in (0, \alpha^{cr})$, or, $\beta \in (0, 1)$ and $\alpha \in [\alpha^{cr}, 1)$, M, a sufficient condition for M to chooses to bundle its hardware and software is $\alpha \leq \frac{2\beta(1-\beta)}{2-\beta}$.*

Further sufficient and necessary conditions for bundling being M's equilibrium strategy are presented in the Appendix. The bundling option becomes a more attractive option for M when its market power α is not so high. It is then that it can leverage its presence in both hardware and software markets in order to make a better deal with the industrial user I and extract higher rents from the downstream market. The exact threshold of α under which M prefers the bundling strategy depends on the bargaining power of service provider S, β which defines how much payoff M can get from sharing its data with service provider S. A lower benefit for M from data sharing leads to a higher threshold of market power α under which bundling is the preferred strategy.

3.4 Manufacturer's incentives to bundle its hardware and software with the Data Act

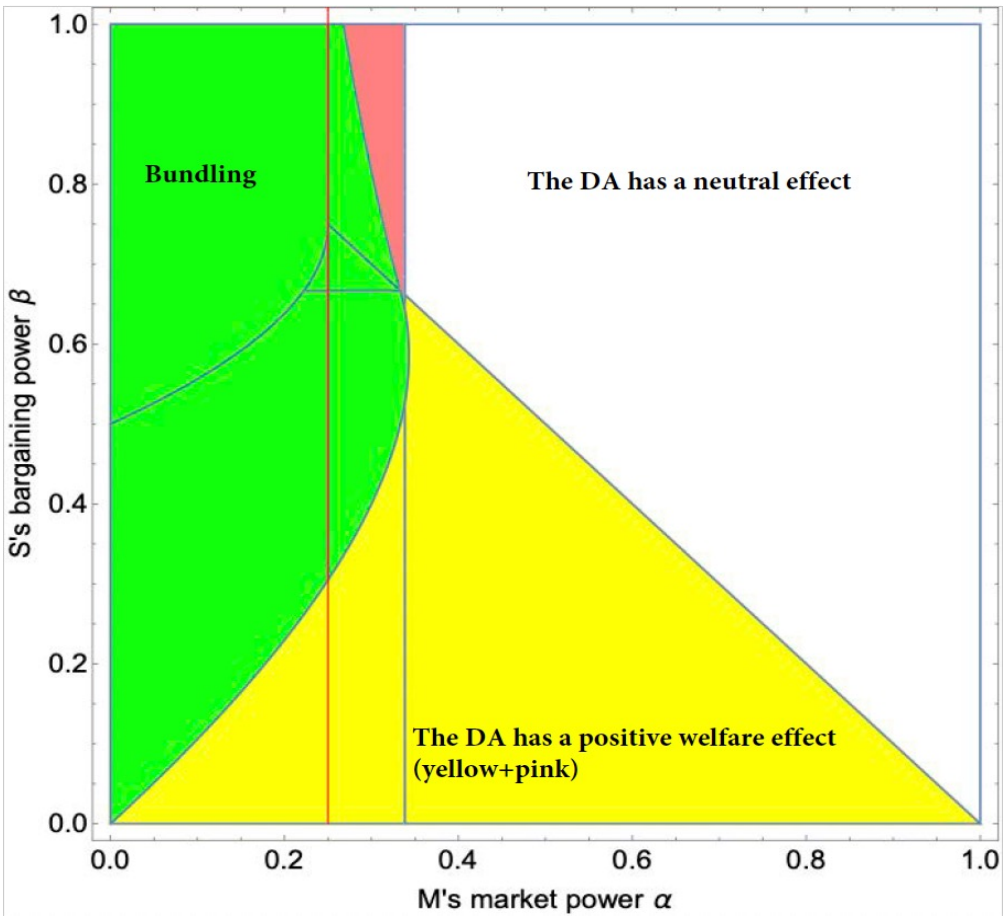
Under the DA, as we have shown, when $\beta > \beta_A^{th}$ and $a < a^{th}$, under unbundling, M does not enter the market and it has a zero payoff. In contrast, under bundling, it enters the market and has a positive payoff. So, M chooses to enter and bundle its hardware and software for these values of α and β.

If instead, $\beta \in (\beta^M, \beta_A^{th})$ and $\alpha \in \left(0, \alpha^{th}\right)$ or $\beta \in (\beta^M, 1)$ and $\alpha \in \left(\alpha^{th}, \alpha^{cr}\right)$, unbundling is a less attractive strategy under the DA because M is not able to block S's entry. As

a result, it chooses to bundle its products under the DA more often than when the DA is absent.

For $\beta \in (0, \beta^M)$ and $\alpha \in (0, \alpha^{cr})$, or, $\beta \in (0, 1)$ and $\alpha \in [\alpha^{cr}, 1)$ the analysis is identical as in the case without the DA. M has the same incentives to bundle its hardware and software both with the DA and without.

Figure 4: Bundling and unbundling strategies under the DA.



In the green area, M chooses to bundle its hardware and software. In the yellow and pink areas, the DA improves welfare. Figure derived for $a = 1, b = 0.4, k = 0.1, c_M = 0.4, c_S = 0.2$.

So, the DA leads to more bundling in equilibrium but also to more entry by the M because it now always enters. While the bundling strategy removes the negative implications for M's entry, especially for low market power α and high bargaining power β, it does not necessarily lead to an improvement in consumer welfare. This is because, as illustrated above, under

bundling the DA has negative welfare effects.

Figure 4 presents the welfare implications of the DA when M considers to bundle its products. For relatively low market power α, bundling is strictly preferred by M. While, this eliminates the incentives of M not to enter the market, its entry expands now the negative welfare implications of the DA in all the green area. The DA is beneficial for a smaller range of parameters α and β. The DA is more likely to improve consumer welfare for intermediate values of market power α. It has no effect on welfare for higher values of α and it reduces welfare for lower values of α due to the complementarities between the two competing services the bundling strategy introduces.

4 Conclusions and policy implications

The Data Act is a new regulation in the European Union that mandates manufacturers of IoT devices to provide users access to the data that was generated through the usage of the device. It is particularly targeted to provide industrial users of smart machinery (such as in smart manufacturing, and smart farming) access to non-personal machine data. Specifically, the Data Act provides industrial users with a right to transfer generated IoT data to third-party service providers, who can use this data to provide either complementary or substitutive data-driven services. Further, the Data Act improves the bargaining power of data access seekers in negotiating a (lower) price for data access.

We have considered whether the Data Act would indeed improve market outcomes in an industrial production context, where an industrial user could lower its marginal costs of production when providing data access to an innovative service provider that either produces an innovative data-driven service that is complementary to the service offered by the manufacturer, or a substitutive service that can replace the manufacturer's vertically integrated service.

In the scenario, where the new service is complementary to the service offered by the manufacturer of the smart machinery so that both are used by the industrial user, the Data Act is rather likely to reduce market efficiency than to improve it. This is because the

manufacturer already has incentives to share data with the complementary service provider irrespective of a regulatory mandate because the new service improves production efficiency without replacing the manufacturer's own service. In this scenarios, the manufacturer's incentives are already well aligned with those of the industrial user and welfare. As the Data Act strengthens the third-party service provider's bargaining power vis-á-vis the manufacturer, the manufacturer's incentives change and are less aligned with market efficiency. This distorts market outcomes and reduces consumer welfare.

In the case where the manufacturer's and third party's services are substitutes, such that the industrial users would choose only to use one of them, we find that the manufacturer may indeed foreclose entry of the alternative service provider, even if it would be efficient from a social welfare perspective. Here, the welfare implications of the Data Act are more nuanced. On the one hand, the Data Act may indeed promote efficient entry of the innovative new service provider. This is the intended policy objective of the Data Act. Specifically, the Data Act is effective in situations where the manufacturer has high market power (e.g., when the manufacturer faces little competition by other manufacturers or is a de-facto monopolist), then the manufacturer is able to expropriate much of the industrial users' profits through the price of the smart machinery. In this case, the manufacturer would have provided access to a substitute software provider anyway (as it can extract more surplus from the industrial user through an increased hardware price), but the DA improves market outcomes by reducing the price of the innovative service offered by the third party. The Data Act can also improve market efficiency when the manufacturer has low market power, but only if the manufacturer retains a sufficient degree of bargaining power over the alternative service provider. Otherwise, the manufacturer may choose not to supply its IoT device anymore, because it cannot retain sufficient profits anymore to recover its fixed costs.

We find that there is a fine line, where the Data Act can turn from good to bad. An IoT device manufacturer only has incentives to block entry of an innovative alternative service provider if that provider offers a substitute service and if the manufacturer has rather low market power and bargaining power. In this parameter region, where the Data Act have

arguably has the most visible impact, because it allows entry by third-party innovators, the Data Act is also potentially the most harmful, as it may induce inefficient exit of innovative IoT device manufactures.

Thus, the Data Act runs the risk of killing the goose that lays the golden eggs, when it mandates data-sharing obligations in conjunction with strict limitations of the manufacturer's (data holder's) bargaining power over the data access price. The Data Act is unambiguously welfare-increasing only in cases where the manufacturer has a strong market position and can expropriate much of the industrial users' surplus. Albeit, this is the picture often painted by policymakers and the rationale for introducing the Data Act, in reality, the relative market power of the manufacturer over the industrial users spans a large spectrum. While in some scenarios the manufacturer can be considered to have high market power (e.g., when a dominant manufacturer, like John Deere, supplies machinery to a relatively small enterprise such as a farmer), the reverse also holds true in many cases (e.g., a small manufacturer provides machinery to a large industrial user such as a car manufacturer). Nevertheless, the Data Act provides a one-size-fits-all approach to these economically very different situations that, as we have shown, can lead to some unintended negative welfare consequences.

Our analysis suggests that the Data Act, or similar regulations in other jurisdictions that may follow the Data Act's example, should be applied not in a horizontal fashion, irrespective of the manufacturer's market power and type of third-party access seeker, but rather applied sector-specific, taking the specifics of the access scenarios and competitive landscape into account.

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A Appendix

Proof of Lemma 1

We compute the market equilibrium by backward induction focusing on the subgame in which service provider S enters the market and is granted data access by M in exchange for royalty fee $r(\beta)$.

In Stage 3, when provider S is chosen by the industrial user I, I's profit function per (3) is $\pi_I^S(q) = (p(q) - c_S - w_S)q - h(\alpha)$. User I chooses the quantity of the good produced to maximize $\pi_I^S(q)$, $q^S = \arg\max_q\{\pi_I^S(q)\}$, which leads to

$$q^S(w_S) = \frac{a - c_S - w_S}{2b}.$$

In this case, I reaches profit level $\pi_I^S(q^S) = \frac{(a-c_S-w_S)^2}{4b} - h(a)$. When provider S is not chosen by I, M's is the only service used in I's production. As a result, I's profit function is $\pi_I^M(q) = (p(q) - c_M - w_M)q - h(\alpha)$. I chooses output level $q^M = \arg\max_q\{\pi_I^M(q)\}$ which leads to

$$q^M(w_M) = \frac{a - c_M - w_M}{2b}.$$

The corresponding profit of I, in this case, is $\pi_I^M(q^M) = \frac{(a-c_M-w_M)^2}{4b} - h(a)$.

Industrial user I chooses service provider S only if $\pi_I^S(q^S) \geq \pi_I^M(q^M) \Leftrightarrow w_S \leq w_M + c_M - c_S$. Provider S is selected by I only if its price w_S is not excessively high with respect to the price w_M set by M for its own service and the production efficiency S brings to the downstream market.

In Stage 2, per (2), provider S's profit function if it is chosen by I is $\pi_S^S(w_S; r) = w_S q^S(w_S) - r(\beta)$. Otherwise, S's profit is zero. S chooses its price offering w_S such that it maximizes its profit π_S^S subject to the constraint $w_S \leq w_M + c_M - c_S$ and that its maximum profit is non-negative. These two constraints are in fact necessary conditions for S's market entry. Service provider S will never enter the market if any of these two conditions are violated. So, without loss of generality, we consider these two conditions as necessary for this subgame to emerge.

It is $w_S^* = \arg\max_{w_S}\{\pi_S^S(w_S; r)\}$, which gives,

$$w_S^* = \frac{a - c_S}{2}.$$

The respective S's profit is $\pi_S^S(w_S^*; r) = \frac{(a-c_S)^2}{8b} - r(\beta)$. This solution of the maximization problem is relevant only when $w_M \geq \frac{a+c_S}{2} - c_M$ and $\pi_S^S(w_S^*; r) \geq 0$.

In Stage 1, since in this subgame service provider S enters the market and is granted access to data to provide a more efficient service than M's service, M sets its pricing schedules and royalty fee accordingly. M finds optimal to set its royalty $r(\beta)$ as high as possible given S's entry and bargaining power β. This amounts to $r(\beta)^{S,*} = (1 - \beta) w_S q^S(w_S)$, since $\bar{r} = w_S q^S(w_S)$. So, S' profit is $\pi_S^S(w_S; \beta) = \beta w_S q^S(w_S)$.

At the same time, it is $\bar{h} = \frac{(a-c_S-w_S)^2}{4b}$. So, M finds it optimal to set its hardware price at a level, $h^{S,*}(\alpha) = \alpha\frac{(a-c_S-w_S)^2}{4b}$. Industrial user I earns $\pi_I^S(w_S; \alpha) = (1-\alpha)\frac{(a-c_S-w_S)^2}{4b}$.

Hence, the profit of M is $\pi_M^{MS}(w_S; \alpha, \beta) = \alpha\frac{(a-c_S-w_S)^2}{4b} + (1-\beta)w_S\frac{a-c_S-w_S}{2b} - k$. Since M and S compete in prices, M can affect S's chosen price w_S by adjusting w_M in such a way so that w_S maximizes π_M^{MS}. The price w_S that maximizes π_M^{MS} is

$$w_{S1}^{S,*} = \frac{1 - \beta - \alpha}{2 - 2\beta - \alpha}(a - c_S).$$

M can ensure that the equilibrium price set by S is equal to $w_{S1}^{S,*}$ by setting its own price at $w_M^{S,*} = w_{S1}^{S,*} + c_S - c_M$, provided that $\pi_M^{MS}(w_{S1}^{S,*}; \alpha, \beta) \geq 0$ and $\pi_S^S(w_{S1}^{S,*}; \beta) \geq 0$. If these two participation constraints are satisfied, then we can easily verify that $w_{S1}^{S,*} < w_S^*$. Due

to price competition, service provider S is unable to reach its unconstrained optimal price level w_S^*. M by setting its price to $w_M^{S,*}$, it ensures that the constraint $w_S \leq w_M + c_M - c_S$ is binding and therefore the price set in equilibrium by S equals $w_{S1}^{S,*}$.

To verify that this is indeed the equilibrium when the participation constraints for M and S are satisfied, note that S does not have incentives to unilaterally deviate from equilibrium price $w_{S1}^{S,*}$ given that M's price offer is $w_M^{S,*}$. S is worse off if it undercuts with a lower wholesale price offer because in such a case it realizes a lower profit. If instead, S deviates by offering a higher price, then it loses access to the downstream market since the industrial user does not find anymore profitable to choose S's service in its industrial production. Since M as a first mover accommodates entry and agrees to share data with S, it does not have any incentive to initially offer a price other than $w_M^{S,*}$ because this is the price that maximizes its profit when S enters. With any other wholesale price offer, lower or higher than $w_M^{S,*}$, M gets a lower payoff.

This is the interior equilibrium when the two participation constraints by M and S are satisfied. So, it suffices to study whether and when the participation constraints become binding with respect to the interior equilibrium.

Let β_S^{th} be defined such that $\pi_S^S(w_{S1}^{S,*}; \beta = \beta_S^{th}) = 0$. Solving this equation we find that $\beta_S^{th} = 1 - \alpha$. For $\beta \in [\beta_S^{th}, 1)$, S's participation constraint is binding under $w_{S1}^{S,*}$. The S's binding constraint changes the equilibrium pricing strategy for S. Solving the binding constraint we find that that

$$w_{S2}^{S,*} = 0.$$

This is an equilibrium only when M gets a non-negative payoff. Note that $\pi_M^{MS}(w_{S2}^{S,*}; \alpha, \beta \in [\beta_S^{th}, 1)) \geq 0$ is equivalent to $\alpha \geq \alpha^{th} \equiv \frac{4bk}{(a-c_S)^2}$. So, $w_{S2}^{S,*}$ is an equilibrium for $\beta \in [\beta_S^{th}, 1)$ and $\alpha \in [\alpha^{th}, 1)$.

Moreover, note that $\pi_M^{MS}(w_{S1}^{S,*}; \alpha \in (\alpha^{th}, 1), \beta) > 0$, $\forall \beta \in (0, 1)$. So, for $\alpha \in (\alpha^{th}, 1)$, it is the S's participation constraint that becomes binding as β becomes greater than β_S^{th} while M's participation constraint is slack. We have two price equilibria: $w_{S1}^{S,*}$ which is valid for $\beta \in (0, \beta_S^{th})$ and $w_{S2}^{S,*}$ which is valid for $\beta \in [\beta_S^{th}, 1)$.

Let now $\alpha \in (0, \alpha^{th})$. We define β_M^{th} such that $\pi_M^{MS}(w_{S1}^{S,*}; \alpha \in (0, \alpha^{th}], \beta = \beta_M^{th}) = 0$. Solving this equation we find that $\beta_M^{th} = \frac{(a-c_S)^2 - 4bk - 2\sqrt{bk(4bk - \alpha(a-c_S)^2)}}{(a-c_S)^2}$. We can verify that $\beta_M^{th} < \beta_S^{th}$. So, as β increases, M's participation constraint becomes binding at lower values of β than S's participation constraint. For $\beta \in (0, \beta_M^{th})$ participation constraints are again slack and equilibrium $w_{S1}^{S,*}$ is achieved. For $\beta \geq \beta_M^{th}$, there is no equilibrium in which both M and S have non-negative profits.

By substituting the price equilibria to $q^{S,*} = q^S(w_S^{S,*})$, $h^{S,*}(\alpha)$, $r(\beta)^{S,*}$ as well as to $s_M^{S,*} = (w_S^{S,*} + c_S - c_M)q^{S,*}$ and $s_M^{S,*} = w_S^{S,*}q^{S,*}$ we derive the rest of the expressions included in Lemma 1.

Proof of Lemma 2

We compute the market equilibrium by backward induction for the subgame in which there is no entry by S. The output schedule that maximizes I's profit π_I^M in (3), in this case is

$$q^M(w_M) = \frac{a - c_M - w_M}{2b}.$$

The resulting profits for user I are:

$$\pi_I^M(w_M; \alpha) = (1 - \alpha)\frac{(a - c_M - w_M)^2}{4b}.$$

M chooses wholesale price w_M in order to maximize $\pi_M^M(w_M; \alpha)$ from (1). The corresponding equilibrium price is the $w_M^{M,*}$ is

$$w_M^{M,*} = \frac{1 - \alpha}{2 - \alpha}(a - c_M).$$

Substituting $w_M^{M,*}$ in q^M we derive the equilibrium quantity $q^{M,*}$. The production schedule $s_M^{M,*}$ immediately follows. Moreover, in this case, it is $\bar{h} = \frac{(a-c_M-w_M)^2}{4b}$, so, M finds it optimal to set its hardware price equal to $h^{M,*}(\alpha) = \alpha\frac{(a-c_M-w_M)^2}{4b}$.

Proof of Lemma 3

We need to compare the equilibrium profits of M in the subgame where M enters and S is chosen and in the subgame where M enters and S is denied data access and therefore does not enter the market.

In the former case, M's profit is

$$\pi_M^{S,*} = \begin{cases} \frac{(1-\beta)^2(a-c_S)^2}{4b(2-2\beta-\alpha)} - k, & \text{under } w_{S1}^{S,*}, \\ \alpha\frac{(a-c_S)^2}{4b} - k, & \text{under } w_{S2}^{S,*}, \end{cases}$$

while in the later case, M's profit becomes

$$\pi_M^{M,*} = \frac{(a-c_M)^2}{4b(2-\alpha)} - k.$$

By comparing $\pi_M^{S,*}$ under $w_{S2}^{S,*}$ with $\beta \in [\beta_S^{th}, 1)$ and $\alpha \in [a^{th}, 1)$ and $\pi_M^{M,*}$ we conclude that there exists a unique level of α, $\alpha^{cr} = 1 - \sqrt{\frac{2a(c_M-c_S)-c_M^2+c_S^2}{(a-c_S)^2}} > \alpha^{th}$ such that M allows market access by S for $\alpha \in [a^{cr}, 1)$ while it denies access for $\alpha \in [a^{th}, a^{cr})$.

By comparing $\pi_M^{S,*}$ under $w_{S1}^{S,*}$ with $\beta \in (0, \beta_S^{th})$ and $\alpha \in [a^{th}, 1)$ or $\beta \in (0, \beta_M^{th})$ and $\alpha \in (0, a^{th})$ and $\pi_M^{M,*}$, we conclude that M accommodates entry for $\alpha \in [a^{cr}, 1)$. In addition, there is a positive bargaining power level $\beta^M = 1 - \frac{(a-c_M)^2}{(2-\alpha)(a-c_S)^2} - \sqrt{\frac{(a-c_M)^2\left(a^2(1-\alpha)^2-2a(c_M-(2-\alpha)\alpha c_S)-(2-\alpha)\alpha c_S^2+c_M^2\right)}{(\alpha-2)^2(a-c_S)^4}}$, where $\beta^M < \min\{\beta_S^{th}, \beta_M^{th}\}$, such that

- for $\alpha \in \left(a^{th}, \alpha^{cr}\right)$, M allows entry for $\beta \in (0, \beta^M]$ and denies access for $\beta \in (\beta^M, \beta_S^{th})$,
- for $\alpha \in \left(0, \alpha^{th}\right)$, M allows entry for $\beta \in (0, \beta^M]$ and denies access for $\beta \in (\beta^M, \beta_M^{th})$.

In addition, as already discussed in the proof of Lemma 1, S does not enter for $\beta \geq \beta_M^{th}$ and $\alpha \in (0, \alpha^{th})$.

Proof of Lemma 4

Given expression (9), it suffices to compare $q^{S,*}$ from (5) and $q^{M,*}$ from (7). When $\beta \in [\beta_S^{th}, 1)$ and $\alpha \in [\alpha^{th}, 1)$, we can verify that $q_2^{S,*} > q^{M,*}$. So, entry is socially desirable.

When, instead, $\beta \in (0, \beta_S^{th})$ and $\alpha \in [\alpha^{th}, 1)$, note that $\frac{\partial q_1^{S,*}}{\partial \beta} < 0$ and that $q_1^{S,*}(\beta \to 0) > q^{M,*}$. Hence, entry is socially desirable for $\beta \in (0, \beta_S^{th})$ and $\alpha \in [\alpha^{th}, 1)$. The same applies for $\beta \in (0, \beta_M^{th})$ and $\alpha \in (0, \alpha^{th})$ since $\beta_M^{th} < \beta_S^{th}$.

M's incentives to fight vs. accommodate entry under the DA

From Lemma 3 and Lemma 4 we conclude that both M and I have incentives to accommodate entry by S for $\beta \in (0, \beta^M)$ and $\alpha \in \left(0, \alpha^{th}\right)$, or, $\beta \in (0, 1)$ and $\alpha \in [\alpha^{cr}, 1)$. Hence, in such a case, under the DA, M adopts a pricing strategy as illustrated in Lemma 1 and in equilibrium, I authorises S's data access to M's data and it uses third-party provider's service in downstream production instead of the IT service of M.

So, it suffices to investigate whether M accommodates or fights entry in the remaining combinations of α and β for which, under the DA, industrial user I authorizes S's entry and data access.

Rest of proofs is work in progress