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Abstract

As cloud computing continues to expand, it has drawn significant attention from policymakers due to concerns over market concentration and potentially controversial practices employed by dominant providers. In this paper, we examine the impact of egress fees, which are imposed on users when switching providers. Using a two-period horizontal differentiated duopoly model, we analyze their effects on firms and society. Our findings reveal that cloud providers have strong incentives to implement egress fees, yet these fees harm users. Regulating egress fees has often been evoked as a solution, ranging from banning them to capping them at the cost of transfer. We find that regulation improves user surplus, but excessive regulation, such as banning such fees, may harm total welfare when providers' data-transfer costs or users' operational switching costs are high. We also find that regulation can have opposing effects on societal outcomes: while it may incentivize cloud providers to increase switching costs for users, thereby harming society, it may also stimulate cloud usage, a consideration that may matter in policy environments where increasing cloud adoption is itself an objective.

JEL Classification: K21, L13, L51, L86, O33

Keywords: cloud computing, egress fees, anti-competitive practices.

1 Introduction

Cloud computing has become a critical input for modern businesses. This is a service market that is highly concentrated. Amazon Web Services (AWS), Microsoft Azure, and Google Cloud Platform (GCP) together account for over 60% of the global market.[1] As regulators have turned their attention to this sector, one practice has attracted particular scrutiny from competition authorities: egress fees. Cloud providers typically allow users to upload data at no charge, but impose egress fees when users transfer data out, whether to migrate to a rival provider or simply to retrieve their own data. Although some bandwidth costs are genuinely incurred during data transfer, egress fees charged by the major hyperscalers are estimated to be five to ten times higher than those of smaller rivals, and widely regarded as substantially exceeding cost.[2] In its final report on the UK cloud market, the Competition and Markets Authority (2025) identified egress fees as a barrier to switching and outlined potential remedies ranging from a full ban to a cap at providers' actual costs. The European Data Act, adopted in November 2023, prohibits egress fees after a three-year transition period (Article 29).

Despite this regulatory interest, the economic effects of egress fees and their regulation are not well understood. Do egress fees harm users? Does banning them improve welfare? Can providers find ways to neutralize regulation?

To address these questions, we propose a two-period horizontal differentiated duopoly model in which cloud providers compete for users whose preferences evolve across periods, reflecting the dynamic nature of cloud adoption. Providers set first-period prices and egress fees upfront; second-period prices are set after users have chosen a first-period provider. Users who switch incur the egress fee charged by their original provider, as well as a switching cost reflecting the operational burden of migrating workloads. The original provider also bears transfer costs when a user departs, in particular outbound bandwidth costs associated with data transfer. We compare a setting with unrestricted egress fee to a setting with an exogenous cap. This allows us to examine the full range of regulatory regimes governing egress fees, from laissez-faire to a complete ban. Our analysis throws light on the advisability of the regulations which have been imposed, but also help to understand better the economics of this important sector.

Our main findings are as follows. Under laissez-faire, Cloud Service Providers use egress fees to lock in users: they compete aggressively on price in the first period and then raise prices in the second, once users face the prospect of paying to leave. This hold-up logic

[1] As of Q4 2025, AWS leads the global cloud market with a 28% share, followed by Azure at 21%, and GCP at 14%: `https://www.statista.com/chart/18819/worldwide-market-share-of-leading-cloud-infrastructure-service-providers/`.

[2] ACM: Netherlands Authority for Consumers and Markets (2022) and Ofcom (2023) provide evidence suggesting that egress fees charged by the hyperscalers have exceeded the incremental cost of providing data transfer. In particular, Ofcom (2023) indicates that AWS, Azure and GCP charged egress fees which were 5–10 times higher than smaller rivals, such as OVHcloud and Oracle (see Figure 5.4 on page 121).

benefits firms and harms users. A cap on egress fees reverses this pattern. Second-period prices fall substantially, more than enough to offset any increase in first-period prices, so user surplus rises unambiguously under regulation. Suppliers are always worse off.

The welfare picture is more nuanced, and hinges on the rate of switching. Under laissez-faire, egress fees deter users from switching, and the equilibrium rate of switching is inefficiently low. A cap raises the switching rate and, for moderate caps, improves welfare. But because users do not internalize providers' data-transfer costs, a sufficiently tight cap can induce excessive switching. A full ban is therefore not always welfare-improving; it does not always maximize user surplus either, since when the cap is tight, first-period prices may rise, whereas under milder regulation they decline.

Another contribution concerns the response of cloud service providers to regulation. We show that they may have strategic incentives to raise users' switching costs in response to a cap on egress fees, for instance by deepening reliance on proprietary tools. This occurs when switching costs are already high, or when they are moderate but regulation is loose enough that higher switching costs increase profits through their effect on first-period competition. This result has direct relevance for the Data Act, which not only bans egress fees but also mandates portability and interoperability between cloud providers (Article 23). The two provisions are complements: without interoperability requirements, banning egress fees could induce providers to substitute toward non-contractual switching costs that are harder to regulate.

We also extend the baseline model in two directions. First, we show that if firms can offer long-term contracts that specify both-period prices alongside egress fees, then egress fees become irrelevant: firms can replicate any outcome achievable with a given fee by adjusting their intertemporal price structure. This result has a practical implication for regulators: the effectiveness of egress fee caps depends critically on what other instruments providers retain. Second, we introduce an initial stage in which users choose the intensity of their cloud usage. Regulation raises equilibrium data usage, which is a direct benefit in policy environments where expanding cloud adoption is itself an objective (as in the European Commission's digital strategy), though again a complete ban does not necessarily maximize this effect.

The rest of the paper is organized as follows. Section 2 reviews the related literature. Section 3 sets out the model. Section 4 characterizes the equilibrium under laissez-faire and establishes that egress fees lead to inefficiently low switching. Section 5 analyzes the effects of a cap on egress fees: we derive conditions under which regulation improves welfare, and show that providers may respond by raising users' switching costs. Section 6 considers long-term contracts and shows that, when firms can freely restructure intertemporal prices, egress fee caps become ineffective. Section 7 endogenizes cloud usage and establishes that regulation unambiguously increases data adoption. In Section 8 we discuss how our stylized framework can inform the regulation of egress fees while highlighting industry features that are not captured by the model but may nevertheless be important for assessing the effects of public policy.

2 Literature Review

Our paper is related to several strands of work on cloud markets, dynamic competition with switching, and fee regulation.

A first strand studies the cloud sector itself. Leka (2022) describes key institutional features of cloud infrastructure and common provider practices. Jin, Peng and Wang (2023) quantify the welfare gains from cloud computing, with a particular emphasis on consumer inertia. Ciet and Verdier (2023) study the incentives of competing banks to outsource their payment services to a cloud-based common infrastructure, managed by a private third-party provider. Brand, Demirer, Finucane and Kreps (2024) examine how the use of cloud computing resources affects firm productivity. Biglaiser, Crémer and Mantovani (2024) review the economics of cloud services and associated policy issues, with particular attention to conduct by dominant providers, including egress fees. While they highlight the importance of egress fees for competition policy, they do not offer a tractable framework to characterize their socially optimal level.

Gans, Hervé and Masri (2023) provide a related analysis, discussing the effects of eliminating egress fees. They assume, however, that in the absence of regulation, egress fees would equal the marginal cost of egress data, which implies that regulation is necessarily inefficient. Our duopoly framework instead lets equilibrium fees emerge from dynamic competition, so that the welfare effect of a cap is a genuine question rather than a foregone conclusion. Do and Miklós-Thal (2025) is perhaps the closest paper on the welfare effects of banning above-cost egress fees: they show that, when users multi-cloud, egress fees can serve as a price-discrimination instrument against multi-cloud demand, so that a ban has ambiguous welfare effects. Our mechanism is complementary and distinct: we abstract from multi-homing and focus instead on dynamic hold-up, showing that a ban can be welfare-reducing even absent any price-discrimination motive.

A related set of papers studies contractual and design instruments that, like egress fees, affect switching between cloud providers. Bergemann and Wang (2025) and Bergemann and Deb (2025) analyze committed-spend contracts, under which providers offer better terms to users who commit to a minimum level of future spending, and show that such contracts can implement optimal dynamic pricing under demand uncertainty in a monopoly setting. Hosseini, Farahani and Kumar (2026) analyze providers' incentives to make platforms compatible in a multi-cloud setting, finding that compatibility can soften competition and raise prices. Their focus on design choices is complementary to ours: we take horizontal differentiation as given and study how regulation of fees interacts with a related design margin, namely the operational cost of switching.

A broader literature examines pricing schemes used by cloud providers, including reservation- versus utilization-based pricing, subscription pricing under entry risk, capacity allocation, and the effects of latency, auto-scaling, and reliability tiering on pricing decisions.[3] Egress fees have received little attention in this literature. We address this gap by analyzing how they affect pricing decisions, can be used as a lock-in mechanism, and shape competition between cloud providers.

From a methodological perspective, our model connects to the literatures on switching costs and break-up fees. Switching costs are user-borne costs of moving from one supplier to another, rather than financial charges imposed by the supplier (Klemperer, 1987; Chen, 1997; Taylor, 2003). A key question in this literature is whether market forces generate too much or too little switching relative to the social optimum. We show that, in the cloud setting, switching is inefficiently low when egress fees are unregulated, efficient when fees are capped at the provider's data-transfer cost, and excessive when fees are regulated below that cost. Break-up fees, by contrast, are contractual charges paid when a user terminates a relationship, and are common in long-term service contracts such as mobile, cable, and satellite television services (following the seminal contribution of Aghion and Bolton, 1987).[4] Unlike egress fees, they typically arise when a customer exits a contractual arrangement altogether rather than when data or usage is transferred to a competing provider.

Our framework is methodologically closest to Caminal and Matutes (1990) and Fudenberg and Tirole (2000), but differs in three respects. First, we incorporate exogenous cloud-relevant switching frictions on both sides of the market: provider data-transfer costs and user operational switching costs. Second, we study the optimal design of caps on egress fees, whereas the break-up fee literature does not analyze regulation of seller-imposed exit charges. Third, because the break-up fee literature abstracts from regulation, firms there have no incentive to raise non-contractual switching costs—raising fees dominates. In our regulated setting, firms can substitute contractual fees (which transfer revenue to them) with non-price frictions (which do not), and this substitution margin is central to our second main result.

Our paper also connects to recent theoretical work on fee regulation and platform price caps (Gomes and Mantovani, 2025; Wang and Wright, 2025; Bisceglia and Tirole, 2023).[5] While these papers are not specific to cloud egress fees, they provide useful guidance for

[3] See, among others, Retana, Forman, Narasimhan, Niculescu and Wu (2018), Chen, Lee and Moinzadeh (2019), Li and Kumar (2018), Li and Kumar (2022), Gera and Xia (2011), Shen and Li (2015), Cheng, Li and Naranjo (2016), Fazli, Sayedi and Shulman (2018), and Brand, Castillo, Lohani and Musolff (2025).

[4] The European Commission and various U.S. state regulators have examined these fees in broadband and telecommunications contracts. See Bedre-Defolie and Biglaiser (2017) for discussion.

[5] Empirical papers addressing the issue of capping commission fees include Li and Wang (2025) and Sullivan (2024), which study the US regulation that capped commission rates for independent food delivery companies during the COVID-19 pandemic, as well as Lasio, Ma, Mantovani, Reggiani and Duch-Brown (2025), who develop a structural model of the hospitality industry to analyze the possibility of capping commission fees for large OTAs such as Booking.com.

cap design under strategic firm responses. The closest is Wang and Wright (2025), who study how platforms adjust pricing structure in response to fee caps. Our contribution is to characterize cap design when providers can also react on a non-price margin by raising user switching frictions, which introduces a substitution effect that, to our knowledge, has not been examined in this literature.

3 The model

We consider a model with two horizontally differentiated cloud providers (firms A and B), located at the extremes of a Hotelling segment, and a unit mass of users, uniformly distributed along the segment. There are two periods of the game, and users' preferences are independent across the two periods.[6] In any given period, using a cloud provider located at a distance d delivers a gross utility $v - \tau d$, where τ denotes the transportation (mismatch) cost. Firms' marginal cost is c.

First period At $t = 1$, the following occurs:

- Nature draws the location of the users. A user located in x incurs a transportation cost τx if it buys from A, and $\tau(1 - x)$ if it buys from B.
- Firms choose: (1) a price p_1^i for users buying from firm $i \in \{A, B\}$ must pay; and (2) an *egress fee* f^i that users who buy from i in $t = 1$ will have to pay to transfer their data to firm $-i$ if they switch in $t = 2$.
- Having learned their locations, users choose their first-period provider.

Second period At $t = 2$, the following occurs:

- Nature draws the location of the users.
- Firms choose their second-period price p_2^i.
- Having learned their second-period location, users choose their second-period providers; those who switch from firm i to firm $-i$ must pay the egress fee f^i to firm i and incur a switching cost s.[7] In this case, the period-1 provider also incurs an egress cost k for transferring the users' data to the other firm.

[6] The assumption that locations change between periods captures the idea that product features and/or user needs may evolve over time, so that the firm best suited to satisfy such needs change. Early-stage AI startups often choose Amazon Web Services for its flexible pay-as-you-go pricing and extensive AI/ML tools. As they scale and require high-performance GPUs (e.g., NVIDIA A100s) or specialized hardware, they may consider alternatives such as Google Cloud or Microsoft Azure, which offer differentiated AI infrastructure, notably TPUs in the case of Google Cloud.

[7] When switching occurs, users incur operational and resource costs, including the time and effort required to onboard a new provider and train staff on new tools and processes. For example, serverless and machine learning services offered by Amazon Web Services, Microsoft Azure, or Google Cloud

To ensure the existence of an interior solution with a positive number of switchers we need the following assumption.

Assumption 1 (Interior Solution)**.** $\tau > k + s$.

First-best benchmark In this Hotelling model with a covered market and unit demand, total welfare is maximized when (i) transportation costs are minimized in the second period, and (ii) users switch if and only if the transportation costs savings from switching are larger than the total switching costs $s + k$. This means that a user who bought from A in the first period, and whose second-period location is y, should switch to B if and only if $\tau(2y - 1) > k + s$, *i.e.,* if $y > \frac{1}{2} + \frac{k+s}{2\tau} \equiv \widehat{y}_A^*$. Similarly, a period 1 user of B should switch if and only if $y < \frac{1}{2} - \frac{k+s}{2\tau} \equiv \widehat{y}_B^*$.

4 Equilibrium in the laisser-faire regime

Under laisser-faire, firms are free to set egress fees. We solve the game by backward induction. Our main results are given by Lemma 1 and Corollary 1. We comment on the main economic lessons of this analysis after stating the results.

4.1 Second period

A user located at y who bought from firm A in the first period obtains utility $v - \tau y - p_2^A$ if it stays with A in $t = 2$, and $v - \tau(1 - y) - p_2^B - f^A - s$ if it switches to B. Therefore, it will stay with A if and only if

$$y \leq \frac{\tau + p_2^B - p_2^A + f^A + s}{2\tau} \equiv \widehat{y}_A. \tag{1}$$

Similarly, a user who bought from B in the first period will switch to A if and only if

$$y \leq \frac{\tau + p_2^B - p_2^A - f^B - s}{2\,\tau} \equiv \widehat{y}_B. \tag{2}$$

Call n_1^A and n_1^B the first-period market shares. The second-period profit of firm A is

$$\pi_2^A = n_1^A \Big[\widehat{y}_A(p_2^A - c) + (1 - \widehat{y}_A)(f^A - k)\Big] + n_1^B \widehat{y}_B(p_2^A - c).$$

The first term on the right-hand side corresponds to the profit that firm A realizes from its own first-period users: either they stay with A and the firm obtains a margin $p_2^A - c$,

are often ecosystem-specific, so migrating workloads may require substantial re-engineering. Similarly, databases such as Amazon DynamoDB or Google BigQuery rely on proprietary architectures that are not directly compatible with competing services. Jin et al. (2023) document "significant costs in adopting new products offered by the same provider" (page 3). *A fortiori,* we would assume that there are significant costs in changing suppliers.

or they switch, in which case firm A pockets the egress fee f^A and pays the egress cost k. The second term represents the profit that A obtains from B's first-period users. A symmetric expression holds for B's profit. Using the Expressions (1) and (2) for $\widehat{y}_A$ and $\widehat{y}_B$, one can rewrite the profit for $i = A, B$ as follows:

$$\pi_2^i = \left(\frac{\tau + p_2^{-i} - p_2^i}{2\,\tau}\right)\left(p_2^i - c - (f^i - k)n_1^i\right) \\ + (p_2^i - c)\left(n_1^i \frac{f^i + s}{2\,\tau} - n_1^{-i}\frac{f^{-i} + s}{2\,\tau}\right) + (f^i - k)n_1^i\left(1 - \frac{f^i + s}{2\,\tau}\right).$$

The first term represents the static Hotelling demand times the "economic" mark-up. It includes the opportunity cost of not collecting egress fees from previous users who stay with i, $((f^i - k)n_1^i)$. In this first term, one can see that egress fees play a role analogous to that of marginal costs, thereby pushing second-period prices up. The second term represents the unit margin times a term that reflects how egress fees affect the demand elasticity of users, depending on their first-period choice: previous i users have a lower price elasticity than previous $-i$ users for product i. While this term can be positive or negative off-equilibrium, it will be zero in a symmetric equilibrium. The third term captures the increased revenue from egress fees, and is independent of p_2^i.

Each firm maximizes its profit with respect to p_2^i. Solving for the equilibrium, we obtain the prices as a function of egress fees and first-period market shares:

$$p_2^i(f^i, n_1^i, n_1^{-i}) = c + \tau + f^i n_1^i - \frac{k\,(2n_1^i + n_1^{-i})}{3} + \frac{s\,(n_1^i - n_1^{-i})}{3}. \tag{3}$$

4.2 First period

In the first period, users expect future prices $p_2^{i,e}$. If they buy from A in the first period, they expect to buy again from A if

$$y \leq \widehat{y}_A^e \equiv \frac{\tau + +p_2^{B,e} - p_2^{A,e} + f^A + s}{2\,\tau},$$

with the threshold $\widehat{y}_B^e$ defined similarly. Then, given observed first-period prices p_1^i, fees f^i, and expectations about future prices $p_2^{i,e}$, the expected utility of a user located at x who buys from A in the first period is

$$u_A(x) = v - \tau x - p_1^A + \delta\Big(\widehat{y}_A^e E[v - \tau y - p_2^{A,e} \mid y \leq \widehat{y}_A^e] \\ + (1 - \widehat{y}_A^e)E[v - \tau(1 - y) - p_2^{B,e} - f^A - s \mid y > \widehat{y}_A^e]\Big).$$

Similarly, if a user buys from B in the first period its expected utility is

$$u_B(x) = v - \tau(1-x) - p_1^B + \delta\Big(\widehat{y}_B^e E[v - \tau y - p_2^{A,e} - f^B - sq \mid y < \widehat{y}_B^e] \\ + (1-\widehat{y}_B^e)E[v - \tau(1-y) - p_2^{B,e} \mid y \geq \widehat{y}_B^e]\Big).$$

The indifferent user is located at $\widehat{x}$ such that $u_A(\widehat{x}) = u_B(\widehat{x})$. By imposing $\widehat{x} \equiv n_1^A$ we then obtain the first-period demands (see Appendix A). Making appropriate substitutions allows us to express intertemporal profits as functions of first-period prices and egress fees.

4.3 Equilibrium under laissez-faire

The intertemporal profit of firm i is

$$\Pi^i(p_1^i, p_1^{-i}, f^i, f^{-i}) = (p_1^i - c)n_1^i(p_1^i, p_1^{-i}, f^i, f^{-i}) + \delta\pi_2^i\left(n_1^i(p_1^i, p_1^{-i}, f^i, f^{-i}), f^i, f^{-i}\right).$$

Solving the system of first-order conditions $\frac{\partial\Pi^i}{\partial p_1^i} = \frac{\partial\Pi^i}{\partial f^i} = 0$ and imposing symmetry leads to the following characterization of equilibrium.[8]

Lemma 1. *Prices and profits under laisser-faire (L) are*

$$p_1^L = c + \tau - \frac{2\delta}{9}(\tau - k - s)\,;\; p_2^L = c + \tau + \frac{1}{3}(\tau - k - s)\,;\; f^L = \frac{2\tau + k - 2s}{3},$$

$$\Pi^L = (1+\delta)\frac{\tau}{2} + \frac{\delta(2\tau - k - s)(\tau - k - s)}{18\tau}.$$

Lemma 1 has several useful implications. First, in equilibrium $p_1^L < c + \tau < p_2^L$. This fits the standard pattern in dynamic models with switching costs: firms compete aggressively in period 1 to attract users, and then harvest their installed base in period 2, once users have become partially locked in. As a consequence, the first-period prices are smaller than $c + \tau$, the price in the static Hotelling model without switching or egress costs and without egress fees, whereas the second-period prices are larger.

Second, the equilibrium egress fee increases in k but decreases in s. An increase in the egress cost k raises the equilibrium fee, but less than one-for-one: part of the increase in the cost of losing a user is passed on to existing users, while the rest is absorbed by the firm. By contrast, an increase in user switching costs s reduces the equilibrium egress fee, indicating that contractual (f) and technical (s) exit costs are substitutes. We return below to the implications of this effect for equilibrium prices.

Third, consider the effect of k on prices. Lemma 1 implies that $\partial p_1^L/\partial k > 0$ and $\partial p_2^L/\partial k < 0$. The effect on the first-period price is natural: attracting a user in period 1 becomes less valuable when k is higher, because some of these users will switch in period 2,

[8] Since firms are symmetric, we omit the firm index and write Π^L instead of $\Pi^{i,L}$, $i \in \{A, B\}$.

and the firm then bears a higher egress cost. Since the pass-through of k into f^L is incomplete, this reduces the profitability of acquiring users in period 1 and softens competition, so p_1^L increases. The effect on the second-period price goes in the opposite direction: when k is higher, losing an incumbent user becomes more costly, so firms compete more aggressively to retain them, which lowers p_2^L.

Fourth, the effect of s on prices may at first seem counterintuitive. Indeed, Lemma 1 implies that $\partial p_1^L/\partial s > 0$ and $\partial p_2^L/\partial s < 0$, whereas in standard switching-cost models one typically expects higher switching costs to intensify first-period and relax second-period competition. The key point here is that changes in s also affect the equilibrium egress fee. In particular, an increase in s reduces f^L. As a result, attracting a user in period 1 becomes less valuable, because the firm expects to extract less surplus from a future switcher; this softens period-1 competition and raises p_1^L. At the same time, the lower egress fee means that, in period 2, firms are more willing to fight to keep their users, which drives p_2^L down.

Finally, profits are decreasing in both k and s. A higher k directly raises the cost of user departure, while a higher s reduces the equilibrium egress fee and lowers the second-period price. In both cases, the net effect is to reduce equilibrium profits. That is, total surplus falls with both costs, and firms bear part of the resulting loss.

In equilibrium, first-period A users switch if their second-period location is to the right of $\widehat{y}_A^L \equiv \frac{5}{6} + \frac{k+s}{6\tau}$. This threshold is larger than the welfare-maximizing one $\widehat{y}_A^* = \frac{1}{2} + \frac{k+s}{2\tau}$ under Assumption 1. Thus, an immediate corollary is:

Corollary 1. *In equilibrium, users switch less than at the social optimum.*

Turning to welfare measures, the user surplus is

$$CS = 2\int_0^{1/2} \left[v - \tau x - p_1^* + \delta \int_0^{\widehat{y}_A} (v - \tau y - p_2^*)\, dy \right.$$
$$\left. + \delta \int_{\widehat{y}_A}^1 (v - \tau(1-y) - p_2^* - f^* - s)\, dy \right] dx.$$

The first integral corresponds to the first period utility if the user is located to the left of 1/2 (and therefore buys from firm A). The second and third integrals correspond to the second-period utility, if the user remains with A (when $y < \widehat{y}_A$) or switches and pays the egress fee. Substituting equilibrium prices and fees, we obtain

$$CS^L = \left(v - c - \frac{5\tau}{4}\right)(1+\delta) - \frac{\delta(12\tau^2 - 2\tau(k+s) - (k+s)^2)}{36\tau}. \tag{4}$$

The expression for total welfare immediately follows:

$$SW^L = \left(v - c - \frac{\tau}{4}\right)(1+\delta) - \frac{\delta(4\tau^2 + 10\tau(k+s) - 5(k+s)^2)}{36\tau}. \tag{5}$$

Note that both user surplus and social welfare depend on k and s only through $k+s$ (as do the profits of the firms), despite the fact that changes of the costs of users and suppliers would seem to have different strategic implications. Welfare is a decreasing function in $k+s$ while user surplus is an increasing function. The latter result can be explained by the fact that the total payment by users drops in both the cost of transferring data and user switching costs. This is evident from the price expressions in Lemma 1: for higher values of k and s, the decline in second-period prices more than offsets the increase in first-period prices, thus benefiting users. Although higher transfer costs increase equilibrium egress fees, they also reduce equilibrium second-period prices. Since all users pay the second-period price while only switchers pay egress fees, the price effect dominates in expectation, so expected user payments fall with k.

5 Cap on egress fees

5.1 Equilibrium in the regulated regime

We now turn to an examination of the policy which is often favored by competition authorities: imposing a cap of egress fees. For this, we assume that firms are constrained by regulation to set egress fees below some level $\bar{f}$, which is small enough to be binding.

Assumption 2 (Regulated regime)**.** $\overline{f} \leq \frac{2\tau+k-2s}{3} = f^L$.

Plugging the regulated fee into the best reply functions and solving for the new equilibrium, we obtain the following expressions:

Lemma 2. *First-period equilibrium expressions under regulation are given by:*

$$\overline{p_1}(\overline{f}) = c + \tau - \frac{\delta(\tau - \overline{f} - s)(3\overline{f} - k + 2s)}{3\tau},\ \overline{p_2}(\overline{f}) = c + \tau + \frac{\overline{f} - k}{2},$$

$$\overline{\Pi}(\overline{f}) = (1+\delta)\frac{\tau}{2} - \frac{\delta(4\tau(k+s) - (\overline{f}+s)(3\overline{f}+k+4s))}{12\tau},$$

$$\overline{CS}(\overline{f}) = \left(v - c - \frac{5\tau}{4}\right)(1+\delta) + \frac{\delta(2\tau(k+s) - (\overline{f}+s)(9\overline{f} - 4k + 5s))}{12\tau},$$

$$\overline{SW}(\overline{f}) = \left(v - c - \frac{\tau}{4}\right)(1+\delta) - \frac{\delta(2\tau(k+s) + (\overline{f}+s)(\overline{f} - 2k - s))}{4\tau}.$$

Lemma 2 yields several useful implications. In equilibrium, first-period prices are smaller than second-period prices, as under the case of laissez-faire, only when regulation is loose, whereas the opposite holds when regulation is tight.[9] This is because users can easily switch, forcing firms to substantially lower second-period prices to retain them.

Interestingly, contrary to what happens in the laissez-faire case, k and s do not play the same role in the equilibrium. In particular, the effect of k on prices is the same as under laissez-faire, whereas the effect of s differs. Notice first that $\overline{p_2}(\overline{f})$ does not depend on user switching costs s, given that users are equally split in the first period under a symmetric equilibrium and, unlike the laissez-faire case, the regulated fee is independent of s.[10] Moreover, the effect of s on first-period prices depends on both the intensity of regulation and the level of user switching costs:

Lemma 3. $\frac{\partial \overline{p_1}(\overline{f})}{\partial s} > 0$ *if* $\overline{f} > \frac{2\tau+k-4s}{5}$*, which is always the case when* $2\tau + k - 4s < 0$*.*

When both s and $\overline{f}$ are small compared to k and τ, $\overline{p_1}$ is decreasing in s, which is the intuitive case: because firms expect to be able to exploit their captive users later on, they compete harder in the first stage. When either s is large, or when $\overline{f}$ is large, then the reverse holds, due to an effect identified by Klemperer (1987): as switching costs get larger, users expect that the relatively larger firm will charge a relatively high price in the second period, which makes users less keen on going to a firm that decreases its price. That is, the first-period price elasticity is lower than with a smaller s, which leads to prices going up.[11]

In equilibrium, users who bought from A in the first period switch to B if their second-period location lies to the right of $\widehat{y}_A(\overline{f}) \equiv \frac{1}{2} + \frac{\overline{f}+s}{2\tau}$.[12] This threshold coincides with the welfare-maximizing one, $\widehat{y}_A^* = \frac{1}{2} + \frac{k+s}{2\tau}$, when $\overline{f} = k$.

Corollary 2. *The socially optimal level of egress fees is equal to the providers' egress cost:* $f^* = k$*.*

As in the laissez-faire case, profits always decrease with k, while user surplus increases in k. The effect of s is however ambiguous for both expressions, as it reflects price patterns explained above: profits are generally increasing in user switching costs with high values of s and decreasing otherwise, while user surplus is decreasing in user switching costs with high values of s and is increasing otherwise. Remember that $\overline{p_2}(\overline{f})$ does not depend on user switching costs s, hence, it is the impact of s on first-period prices (see Lemma

[9]More precisely, $\overline{p_1}(\overline{f}) < \overline{p_2}(\overline{f})$ if $\overline{f} > \frac{2\delta(k-5s)+t(3+6\delta)-\sqrt{4\delta^2(k+s)^2-12\delta(k+s)t(5+2\delta)+9(t+2t\delta)^2}}{12\delta}$.

[10]See again the expression for second-period equilibrium prices in (3): the last term, which contains s, simplifies to zero in a symmetric equilibrium where first-period demands are equal to 1/2, and egress fees are fixed to $\overline{f}$, which does not depend on s. Although this result follows from the Hotelling setting with symmetric firms, it captures an important feature of regulation: when egress fees are exogenously set, firms' second-period pricing decisions are less affected by the intensity of user switching costs.

[11]It is also straightforward to see that $\frac{\partial^2 \overline{p_1}}{\partial \overline{f} \partial s} > 0$.

[12]The share of users who switch in the second period is then $1 - \widehat{y}_A(\overline{f}) = \frac{1}{2} - \frac{\overline{f}+s}{2\tau}$. For an interior solution with a positive number of switchers we need that $\tau > \overline{f} + s$. As it can be easily ascertained, this condition always holds when considering Assumptions 1 and 2 together.

3), together with its effect on user switching, that drives the results.[13] This could alter how firms strategically influence user switching costs, as we will see in Section 5.3. Social welfare is decreasing in either type of switching cost.

5.2 Regulation's effects

We now examine the effects of regulation, beginning with a comparison of prices under regulation and laissez-faire, assuming that Assumptions 1 and 2 simultaneously hold.

Lemma 4. *Imposing a cap $\overline{f} \leq f^L$ on egress fees:*

- *lowers second-period price p_2.*
- *increases first-period price p_1 if $\overline{f} < \frac{\tau-3s}{3}$, and lowers it otherwise. In particular, if $s > \tau/3$, a cap always decreases p_1.*

A binding cap on egress fees intensifies competition in the second period, because firms are more willing to lower their price to retain users. The effect of the cap on first-period prices is more subtle. A standard intuition is that a lower fee makes attracting first-period users less profitable, thereby leading to softer competition in the first period. This is indeed the case when $\overline{f} < \frac{\tau-3s}{3}$. But, when the cap is less stringent, the main effect of the cap is to increase the elasticity of first-period demand. Indeed, without a cap when firm i lowers its price p_1^i, users expect firm i to gain market shares and therefore to charge a higher p_2^i, in part because of its ability to charge egress fees. This makes users somewhat reluctant to respond to the price decrease p_1^i. When fees are capped, however, users expect firm i to raise p_2^i by a smaller amount, and so they are more responsive in period 1. Consequently, a moderate cap leads to more intense first-period competition. As a result, the potential for a cap on egress fees to intensify competition in both periods is larger in markets characterized by high switching costs and low product differentiation.

Figure 1 exhibits first-period prices under the two regimes, laissez-faire and regulation as a function of the exogenous fee cap (ranging from 0 to f^L) for different values of user switching costs. In Panel (a), s is small compared to τ. For small values of f^L, the first-period price is larger under regulation than under laissez-faire and decreasing in f^L; for higher values, regulation leads to a lower first-period price. In Panels (b) and (c), s is sufficiently large to guarantee that first-period prices are lower under regulation than under laissez-faire for any fee cap. Notice that in Panel (b) $\overline{p_1}(\overline{f})$ first decreases and then increases in the fee cap, whereas in Panel (c) it increases monotonically.

[13]However, profits and user surplus do not always move in opposite directions as s changes, since the thresholds at which their derivatives change sign depend on other factors, including the effect of s on demand through prices and switching rates.

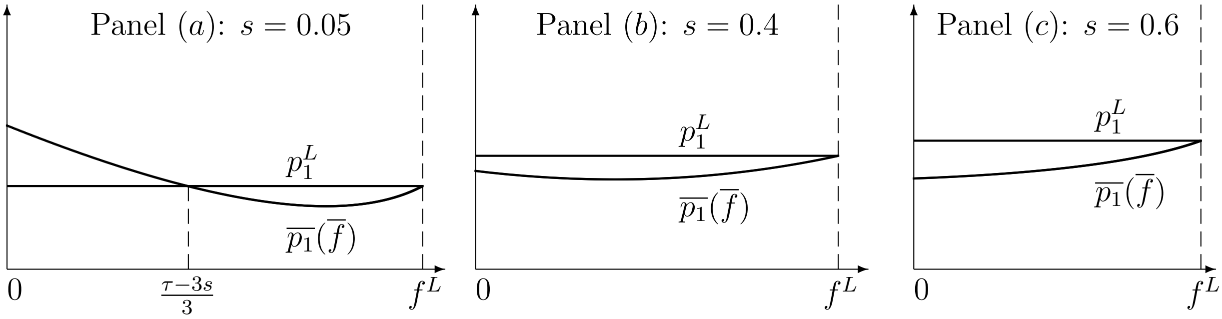

Figure 1: The figure illustrates Lemma 4 with $\tau = 1$ and three different values of s: $s = 0.05$ in Panel (a); $s = 0.4$ in Panel (b); $s = 0.6$ in Panel (c). In all three panels, $\delta = 0.3$, $c = 0.1$, $k = 0.2$.

Turning to the evaluation of firms' profits and user surplus, considering the equilibrium values derived in Lemmas 1 and 2 and in Expression (4), we find

$$\overline{\Pi}(\overline{f}) - \Pi^L = -\frac{\delta(2\tau - 3\overline{f} + k - 2s)(2\tau + 3\overline{f} + 2k + 5s)}{36\tau} \leq 0,$$
$$\overline{CS}(\overline{f}) - CS^L = \frac{\delta(2\tau - 3\overline{f} + k - 2s)(6\tau + 9\overline{f} - k + 8s)}{36\tau} \geq 0,$$

given that $2\tau - 3\overline{f} + k - 2s \geq 0$ and $6\tau + 9\overline{f} - k + 8s \geq 0$ by the combination of Assumptions 1 and 2. Clearly, both profit and user surplus differences converge to zero for $\overline{f} = f^L$. These results are summarized below:

Corollary 3. *Firms' profits are smaller with regulated egress fees than with laissez-faire, while users' surplus is larger.*

The regulation of egress fees below the laissez-faire level reduces the firms' ability to retain users in the second period, thus inducing them to lower second-period prices in proportion to the intensity of regulation. Although firms attempt to recover part of this profit loss by raising first-period prices when regulation is tight, their profits are always lower than under laissez-faire, and decrease with the intensity of regulation. Users always gain from regulation, even when first-period prices rise, because when this occurs second-period prices are much lower than under laissez-faire. However, user surplus is not necessarily monotonic in the fee cap, as suggested by Panel (a) (and, to some extent, by Panel (b)) of Figure 2; indeed one can easily show the following corollary.

Corollary 4. *User surplus is maximized at* $f^U = \max(0, \frac{2k-7s}{9})$.

We now turn to the analysis of the welfare effect of regulation. In this model with a covered market, welfare is determined by the rate of switching in the second period. Indeed, both under laissez-faire and regulated fees, the first-period allocation of users is optimal, with each firm serving the users that are closest to it. Recall that, under laissez-faire, the threshold $\widehat{y}_A^L$ for first-period users of A to switch is higher than the socially optimal one $\widehat{y}_A^*$ (Corollary 1). With a cap on egress fees, the threshold $\widehat{y}_A(\overline{f})$ depends on the regulated fee, and can even be set to maximize welfare (Corollary 2). With linear transportation costs, whether the regulation improves welfare or not depends therefore on whether $\widehat{y}_A(\overline{f})$ or $\widehat{y}_A^L$ is closer to $\widehat{y}_A^*$. Using the equilibrium values derived in Lemma 2 and in Expression (5), straightforward calculations show that:

$$\overline{SW}(\overline{f}) - SW^L = \frac{\delta(2\tau - 3\overline{f} + k - 2s)(2\tau + 3\overline{f} - 5k - 2s)}{36\tau} \propto (2\tau + 3\overline{f} - 5k - 2s),$$

and then lead to the following proposition.

Proposition 1. *Welfare is higher with an egress fee cap, provided that* $\overline{f} > \frac{5k+2s-2\tau}{3}$. *In particular, if* $5k + 2s - 2\tau < 0$, *any cap is better than laissez-faire. If* $5k + 2s - 2\tau > 0$, *a total ban on egress fees or a very stringent cap lowers welfare.*

There is too little switching under laissez-faire. Imposing a moderate limitation on the egress fee increases the swithing rate, thus improving welfare. When the cost of transferring data k and user switching costs s are sufficiently low compared to τ, a cap equal to zero substantially increases user welfare without excessively reducing firms' profits. However, in other cases, a stringent cap (or a full ban) may lead to too much switching in equilibrium due to users not taking into account the firms' costs of switching. Total welfare may then be lower under regulation as firms cannot recover the cost of transferring data when users switch excessively (high k), or when users derive limited benefits from the fee cap (high s). In such cases, the gain in user surplus does not offset the loss in firm profits.

Figure 2 summarizes the effect of regulation for firms, users, and total welfare. Panel (a) shows when s is sufficiently low relative to k user welfare is maximized for a positive value of the egress fees, whereas in the other panels a ban on egress fees maximizes user surplus. In this panel, total welfare is always higher under regulation than under laissez-faire. For a given k, Panel (b) illustrates a case in which user surplus increases with s, thereby compensating for the reduction in firms' profits, so that welfare is again always higher under regulation regardless of the level of $\overline{f}$. For higher levels of s, Panel (c) illustrates instead the case in which user surplus decreases with s, showing that total welfare may decline under regulation. This occurs in particular when firms are unable to charge sufficiently high egress fees. Similar patterns to those in the three panels would be obtained by fixing s and progressively increasing k (see Figure 3 in Appendix B). The threshold value $\widetilde{f}$, which appears in Panel (b), will be characterized in the next section.

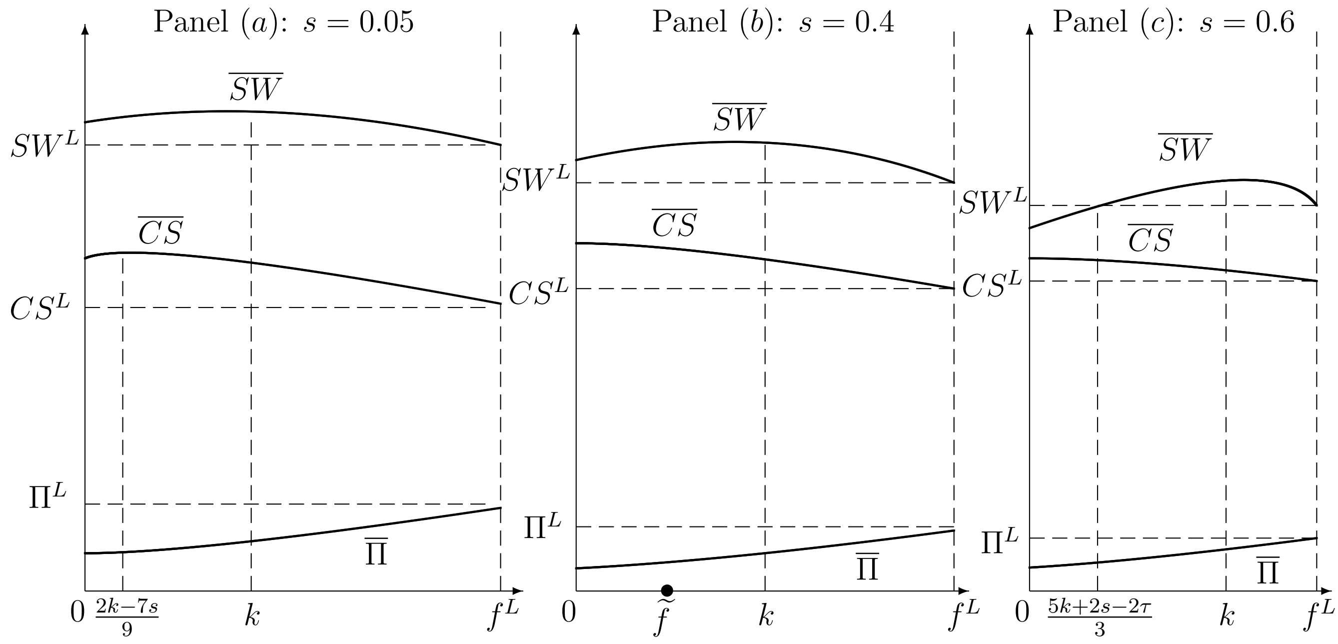

Figure 2: Relevant equilibrium expression for $\delta = 0.3$, $c = 0.1$, $k = 0.2$, $\tau = 1$, $v = 4$, and three different values of s: $s = 0.05$ in Panel (a); $s = 0.4$ in Panel (b); $s = 0.6$ in Panel (c)

5.3 Incentives to increase user switching costs

Switching costs are not entirely exogenous: cloud providers can shape interoperability through product and design choices—for instance by adopting proprietary APIs, relying on incompatible data formats, or promoting vendor-specific development tools (which raise migration costs), but they can also decrease switching cost by supporting open standards, improving portability tools, or offering migration assistance (which lower them)—so that the operational cost s of moving between providers is partly endogenous. Importantly, these choices affect portability *symmetrically*: they make it easier or harder to switch in either direction between providers. This is in contrast to an egress fee f^i which only affects users who leave firm i.

As we pointed out in Section 4.3, in the absence of regulation firms' profits are decreasing in s: intuitively, when firms are free to levy egress fees f^i, they have no incentives to raise user switching costs s, as these do not directly generate revenue. However, a cap on egress fees may alter providers' incentives and induce them to introduce symmetric non-price switching costs, for instance by making portability more difficult. Indeed, by taking the derivative of the profits in Lemma 2 with respect to s we obtain the following proposition.

Proposition 2. *When egress fees are capped at $\overline{f}$, firms' profits are increasing in s if and only if $\overline{f} > \frac{4\tau-k-8s}{7} \equiv \widetilde{f}$. If $4\tau - k - 8s < 0$, any cap will give firms an incentives to increase switching costs.*

When user switching costs are already high, or when they are not very high but regulation is loose, cloud providers may have an incentive to raise user switching costs. This is clearly generating a welfare loss since neither the firms nor the users get a direct monetary benefit from higher switching costs; the firms would prefer to have higher egress fees since this transfers money to them, while users are indifferent between an equal increase in either switching costs or egress fees.

Figure 2 shows cases where regulation may incentivize firms to make their products less compatible, raising switching costs for users. In particular, this occurs when s is high, as represented in Panel (c), or when s is lower, but egress fees are high ($\overline{f} > \widetilde{f}$), as shown in Panel ($b$). In these circumstances, regulating egress fees can have unintended effects in terms of increasing the cost of switching for users. Consider for example the situation in Panel (b): a regulator maximizing social welfare should impose an egress fee equal to k, as we know from Corollary 2. However, this decision may trigger a reaction by firms to raise switching costs, possibly reproducing a scenario like the one in Panel (c), where welfare is lower. The alternative could be to impose a cap $\overline{f} \leq \widetilde{f}$, which does not give incentives for firms to raise user switching costs, but maximizes neither total welfare nor user surplus.

6 Long term contracts and price-discrimination

In this section we discuss the robustness of our results to alternative assumptions about the types of contracts that firms can offer.We find that when firms can freely restructure intertemporal prices through long-term contracts, egress fees become redundant instruments.

6.1 Long term contracts

Consider now an alternative model, in which firms can commit to long-term contracts. The timing is as follows. At $t = 1$, each firm $i \in \{A, B\}$ offers a contract consisting of a first-period price p_1^i, a second-period price p_2^i, and an egress fee f^i. Users then choose their first-period provider. At $t = 2$, firms may also offer *short-term* contracts to attract new users. We denote the short-term price of firm i by r_2^i. Users draw a new location on the Hotelling line, and choose their provider for period 2. If a user initially subscribed to firm A, staying implies paying p_2^A; switching to B requires paying $r_2^B + f^A$ and bearing a cost s of switching.

Second-period behavior. A user who purchased from A at $t = 1$ remains with A in period 2 if

$$y < \widehat{y}_A \equiv \frac{\tau + r_2^B - p_2^A + f^A + s}{2\tau},$$

and a user who purchased from B switches to A if

$$y < \widehat{y}_B \equiv \frac{\tau + p_2^B - r_2^A - f^B - s}{2\tau}.$$

Firm A's profit in the second period is therefore

$$\pi_2^A = x_A \Big[(p_2^A - c)\, \widehat{y}_A + (f^A - k)\, (1 - \widehat{y}_A) \Big] + (1 - x_A)(r_2^A - c)\, \widehat{y}_B.$$

This yields the following equilibrium short-term prices.

$$r_2^i = \frac{c - f^j - s + p_2^j + \tau}{2}, \qquad i \neq j.$$

First-period demand. At $t = 1$, users choose between providers based on total discounted utility. The indifferent user x satisfies

$$\tau x + p_1^A + \delta U_2^A(x) = \tau(1 - x) + p_1^B + \delta U_2^B(x),$$

where $U_2^i(x)$ is the expected second-period utility if the user buys from provider i at $t = 1$. From this, we obtain the demand share $x_A(p_1^A, p_1^B, p_2^A, p_2^B, f^A, f^B)$.

First-period profits and equilibrium. Firm A's total discounted profit is

$$\Pi^A = (p_1^A - c)\, x_A(\cdot) + \delta\, \pi_2^A(\cdot).$$

The three first-order conditions for p_1^i, p_2^i, f^i are not independent of one another. Indeed, starting from any contract with these fees, a joint deviation to $(p_1^i - \delta\varepsilon,\ p_2^i + \varepsilon,\ f^i + \varepsilon)$ leaves firm i's discounted profit unchanged. Intuitively, raising both the second-period price and the egress fee by ε increases the revenue extracted in period 2 without affecting users' second-period choices, since these only depend on $p_2^i - f^i$. The resulting gain in second-period profit is exactly offset, along the optimality conditions, by lowering the first-period price by $\delta\varepsilon$. Hence there exists a continuum of solutions indexed by f.

$$p_1^{LT} = c + \tau + \delta \left(\frac{\tau + 2k - s}{3} - f \right), \qquad p_2^{LT} = c + f - \frac{2k - s + \tau}{3}.$$

The equilibrium level of profit is $\Pi^{LT} = \frac{\tau}{2} + \frac{\delta}{18\tau} \left(k + s - \tau \right)^2$. It is independent of f, as are user surplus and total welfare.

Proposition 3. *If firms can offer long-term contracts, a cap on egress fees has no effect on user surplus, profit and welfare.*

Even though egress fees have no effect in this model, the result should not be interpreted as saying that egress fees and long term contracts are equivalent. Indeed, the equilibrium level of profit and surplus are different in the two cases. The message is rather that, conditional on firms offering long term contracts, giving them the ability to charge egress fees does not change anything. This has an important lesson for regulators. Before regulating egress fees, they should take stock of the instruments that cloud service providers have to counteract this regulation.

7 Endogenous Data Usage

So far, cloud usage was fixed. We now consider a setting in which users also choose how intensively to rely on cloud infrastructure.

We add an initial stage of the game in which, at $t = 0$, users choose the intensity of their cloud usage. We assume that the per-period gross utility of cloud usage is $V(q) = vq - q^2/2$. In terms of our model, each user chooses how many "units of cloud" it will need, q. This captures the idea that users can choose in which applications to use the cloud, and that this decision is somewhat sticky, due to the presence of unmodeled adjustment costs or specific contracts. OpenAI, for example, has recently signed a five-year, \$300 billion contract with Oracle Cloud, committing to use its infrastructure for large-scale AI workloads for a predetermined cloud capacity.

The analysis carried out in the benchmark scenario is now extended to compute the demand of cloud usage under the two scenarios, laissez-faire vs. regulation. Suppose that a user expects other users to demand q^* units of cloud, and therefore expects prices to be given by $p_1^*(q^*)$, $p_2^*(q^*)$ and $f^*(q^*)$. The expected surplus of a user, when choosing a demand level $\tilde{q}$, can be written as follows:

$$\begin{aligned} CS(\tilde{q}, q^*) = 2 \int_0^{1/2} \Bigg[& V(\tilde{q}) - \tau x - p_1^*(q^*)\tilde{q} \\ & + \delta \int_0^{\widehat{y}_A} \left(V(\tilde{q}) - \tau y - p_2^*(q^*)\tilde{q} \right) dy \\ & + \delta \int_{\widehat{y}_A}^1 \left(V(\tilde{q}) - \tau(1-y) - p_2^*(q^*)\tilde{q} - f^*(q^*)\tilde{q} - s\tilde{q} \right) dy \Bigg] dx. \end{aligned} \tag{6}$$

The equilibrium q^* satisfies $\frac{\partial CS(\tilde{q}, q^*)}{\partial \tilde{q}}|_{\tilde{q}=q^*} = 0$. The solution is reported in Appendix B, where we also show that the comparison of equilibrium profits and user surplus under laissez-faire and regulation does not depend on q, making it meaningless to compare the differences obtained by inserting q^L and $\overline{q}$ into the relative expressions. Moreover, in terms of welfare, the qualitative results of Proposition 1 continue to hold, as the comparison between laissez-faire and regulation still hinges on the interplay between switching costs k and s on one side and the intensity of regulation $\overline{f}$ on the other side. The results of Proposition 2 are also robust to this extension, and we can characterize the conditions under which regulation induces providers to increase user switching costs, and these conditions are analogous to those in the baseline model.

What is therefore interesting to evaluate is whether regulation leads users to consume more or fewer units of cloud units, and whether it is possible to identify an "optimal" level of regulation in terms of data usage. We find that:

Proposition 4 (**Cloud usage**). *Compared to a laissez-faire scenario, regulating egress fees increases cloud usage, which is maximized when* $f^C = \max(0, \frac{k-2s}{3})$.

Capping egress fees is therefore useful to promote cloud usage. There are instances where cloud adoption among firms is a tangible policy objective. For example, the European Commission's cloud policy seeks to strengthen Europe's cloud and edge computing capacity by supporting firms' transition to cloud services and by simplifying regulatory and procurement procedures to boost uptake among businesses. The regulation suggested by our analysis can therefore be useful for this purpose.

8 Conclusions

Cloud computing has fundamentally transformed the way businesses and organizations manage their IT systems. By utilizing distributed networks of servers and software, cloud systems have enabled the delivery of faster, more reliable, and scalable computing services. Competition authorities have, however, been concerned by some of the practices of the largest suppliers; we have developed a formal model which illustrates some of the reasons for these concerns.

We have focused on egress fees and developed a two-period model which takes into account both the cost of transferring data for providers and the cost of switching for users. Our baseline model focused on short-term contracts, which are those commonly adopted by cloud providers, but we also considered long-term contracts.

Our analysis shows that, within the confines of our model, cloud providers have strong incentives to impose egress fees and that users are significantly harmed by them. We also show that regulation, under the form of a cap on egress fees, raises user surplus but does not necessarily increase total welfare because it may induce excessive switching. In particular, a full ban on egress fees can reduce welfare when switching costs are high for either firms or users. Moreover, restrictions on egress fees may lead cloud providers to raise users' switching costs, which can further reduce welfare. At the same time, regulation can have a beneficial effect by encouraging greater data usage by users, which may generate broader social benefits.

The implication for regulators is that caution is warranted when intervening in sectors whose economic dynamics are not yet fully understood. We recognize the concerns raised by certain business practices in highly concentrated industries, such as cloud computing.

However, much remains unclear about the mechanisms through which these markets operate. Even in our simplified framework, the analysis highlights that regulation can have unintended consequences, particularly once the strategic responses by firms are taken into account. In particular, we show that when firms are prevented from freely setting egress fees, they may instead seek to increase revenue by encouraging user retention through higher switching costs. Of course we abstracted from many important market features including asymmetries between providers, dynamic entry and exit, and from the multi-product nature of cloud services. We believe nonetheless that the mechanisms we identify are robust to such extensions, and that our framework captures the essential strategic logic that any serious regulatory analysis of this sector must confront.

Interestingly, the Data Act does not merely ban egress fees; it also contains provisions designed to promote portability and interoperability among cloud service providers. In particular, Article 23(1) introduces the principle of functional equivalence for cloud computing services. This principle is intended to make it easier for cloud users to switch providers and to facilitate interoperability across cloud platforms. Whether this principle can be effectively implemented and how it may affect firms' incentives to innovate in computing services that match users' needs are important questions that lie beyond the scope of our analysis.

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A Indifferent User

The indifferent user is located at $\widehat{x}$ such that $u_A(\widehat{x}) = u_B(\widehat{x})$, i.e.

$$\widehat{x} = n_1^A(p_1^A, p_1^B, p_2^{A,e}, p_2^{B,e}, f^A, f^B) = \frac{\tau - p_1^A + p_1^B}{2\,\tau} + \frac{\delta}{(2\,\tau)^2}\Big((f^B + s)\Big(\tau - p_2^{B,e} + p_2^{A,e} - \frac{f^B + s}{2}\Big) - (f^A + s)\Big(\tau - p_2^{A,e} + p_2^{B,e} - \frac{f^A + s}{2}\Big)\Big).$$

In an equilibrium with rational expectations, we must have $p_2^{i,e} = p_2^i(f^i, n_1^i, n_1^{-i})$, with $p_2^i(f^i, n_1^i, n_1^{-i})$ from Lemma 1. Making these substitutions and solving for $\widehat{x}$ gives:

$$\widehat{x} = n_1^A(p_1^A, p_1^B, f^A, f^B) = \frac{\tau - p_1^A + p_1^B}{2\,\tau + \delta\frac{(f^A+f^B+2s)(3(f^A+f^B)-2k+4s)}{6\,\tau}} + \delta\,\frac{(f^A + f^B + 2s)(3(f^A + f^B) - 2k + 4s) - 6\,\tau(f^A - f^B)}{2(12\tau^2 + \delta(f^A + f^B + 2s)(3(f^A + f^B) - 2k + 4s))}.$$

B Endogenous data usage

By using per-period gross utility $V(q) = vq - q^2/2$ and starting from the second period, a user will stay with A if and only if

$$y \leq \frac{\tau/q + p_2^B - p_2^A + f^A + s}{2\tau/q} \equiv \widehat{y}_A,$$

whereas a user who bought from B in the first period will switch to A if and only if

$$y \leq \frac{\tau/q + p_2^B - p_2^A - f^B - s}{2\,\tau/q} \equiv \widehat{y}_B.$$

Suppose that all users have a cloud usage of q, and that the first period market shares are n_1^A and n_1^B. The second-period profit of firm A is:

$$\pi_2^A = n_1^A\left(\widehat{y}_A(p_2^A - c)q + (1 - \widehat{y_A})(f^A - k)q\right) + n_1^B\widehat{y}_B(p_2^A - c)q,$$

and similarly for firm B. Replicating the analysis of the baseline model, we substitute the expressions for $\widehat{y}_A$ and $\widehat{y}_B$ and rewrite profits accordingly. Solving for equilibrium, we obtain second-period prices as functions of egress fees and first-period market shares, analogously to Expression 3.

$$p_2^i(f^i, n_1^i, n_1^{-i}) = c + \frac{\tau}{q} + f^i n_1^i - \frac{k\,(2n_1^i + n_1^{-i})}{3} + \frac{s\,(n_1^i - n_1^{-i})}{3}$$

The equilibrium profit is

$$\pi_2^i(f^i, f^{-i}, n_1^i, n_1^{-i}, q) = \Bigg(\frac{\tau/q}{2} + (f^i - k)n_1^i - \frac{(f^i + f^{-i} + 2s)(f^i - k)}{8\,\tau/q}\big(1 - (n_1^A - n_1^B)^2\big) + \frac{(k+s)^2(n_1^i - n_1^{-i})^2}{18\,\tau/q} + \frac{(k+s)(n_1^i - n_1^{-i})}{3}\Bigg)q.$$

In the first period, a user expects future prices $p_2^{i,e}$. If they buy from A in the first period, they therefore expect to buy again from A if $y \leq \widehat{y}_A^e = \frac{\tau/q + f^A + s - p_2^{A,e} + p_2^{B,e}}{2\,\tau/q}$. The threshold $\widehat{y}_B^e$ is defined similarly. Then, given observed prices p_1^i, fees f^i, and expectations about future prices $p_2^{i,e}$, the expected utility of a user located in x if he buys from A in the first period is

$$u_A(x) = vq - \frac{q^2}{2} - \tau x - p_1^A q + \delta\Big(\widehat{y}_A^e E[vq - \frac{q^2}{2} - \tau y - p_2^{A,e} q \mid y \leq \widehat{y}_A^e] + (1 - \widehat{y}_A^e)E[vq - \frac{q^2}{2} - \tau(1-y) - p_2^{B,e} q - f^A q - sq \mid y > \widehat{y}_A^e]\Big).$$

Similarly, a user who buys from B in the first period obtains an expected utility equal to

$$u_B(x) = vq - \frac{q^2}{2} - \tau(1-x) - p_1^B q + \delta\Big(\widehat{y}_B^e E[vq - \frac{q^2}{2} - \tau y - p_2^{A,e} q - f^B q - sq \mid y < \widehat{y}_B^e] + (1 - \widehat{y}_B^e)E[vq - \frac{q^2}{2} - \tau(1-y) - p_2^{B,e} q \mid y \geq \widehat{y}_B^e]\Big).$$

The indifferent user is thus located at $\widehat{x}$ such that $u_A(\widehat{x}) = u_B(\widehat{x})$, i.e.

$$\widehat{x} = \frac{\tau/q - p_1^A + p_1^B}{2\,\tau/q} + \frac{\delta}{(2\,\tau/q)^2}\Big(\tilde{f}^B\Big(\frac{\tau}{q} - p_2^{B,e} + p_2^{A,e} - \frac{\tilde{f}^B}{2}\Big) - \tilde{f}^A\Big(\frac{\tau}{q} - p_2^{A,e} + p_2^{B,e} - \frac{\tilde{f}^A}{2}\Big)\Big) \tag{7}$$

where $\tilde{f}^i = f^i + s$, $i \in \{A, B\}$.

In an equilibrium with rational expectations, we must have $p_2^{i,e} = \widetilde{p_2^i}(\widehat{x}, f^A, f^B)$. Making these substitutions in (7) and solving for $\widehat{x}$ gives:

$$\widehat{x} = n_1^A(p_1^A, p_1^B, f^A, f^B) = \frac{\tau/q - p_1^A + p_1^B}{2\,\tau/q + \delta\frac{(f^A+f^B+2s)(3(f^A+f^B)-2k+4s)}{6\,\tau/q}} + \delta\,\frac{(f^A + f^B + 2s)(3(f^A + f^B) - 2k + 4s) - 6\,\tau/q(f^A - f^B)}{2(12(\tau/q)^2 + \delta(f^A + f^B + 2s)(3(f^A + f^B) - 2k + 4s))}.$$

The intertemporal profit of firm $i = A, B$, is

$$\Pi^i(p_1^i, p_1^{-i}, f^i, f^{-i}, q) = (p_1^i - c)qn_1^i(p_1^i, p_1^{-i}, f^i, f^{-i}) + \delta\pi_2^i\left(n_1^i(p_1^i, p_1^{-i}, f^i, f^{-i}), f^i, f^{-i}, q\right).$$

Laissez-faire Solving the system of first-order conditions $\frac{\partial\Pi^i}{\partial p_1^i} = \frac{\partial\Pi^i}{\partial f^i} = 0$ and imposing symmetry leads to the following equilibrium result (we omit again $i = A, B$ for brevity):

$$p_1^L(q) = c + \frac{\tau}{q} - \frac{2\delta}{9}\left(\frac{\tau}{q} - k - s\right);\ p_2^L(q) = c + \frac{\tau}{q} + \frac{1}{3}\left(\frac{\tau}{q} - k - s\right);\ f^L(q) = \frac{1}{3}\left(\frac{2\tau}{q} + k - 2s\right).$$

These expressions are analogous to those obtained in Lemma 1 upon replacing τ with τ/q. Note that prices and egress fees are decreasing in q: a higher q increases demand elasticity, because any price increase applies to more units.

The share of users who switch is $1 - \widehat{y}_A = \frac{1}{6} - \frac{k+s}{6\tau/q}$. For an interior solution with a positive number of switchers we need to assume that:

Assumption 3 (Interior Solution)**.** $\frac{\tau}{q} > k + s$.

Substituting equilibrium prices into the expression for intertemporal profit we obtain the equilibrium profits as a function of q:

$$\Pi^L(q) = (1+\delta)\frac{\tau}{2} + \frac{\delta(2\tau/q - k - s)(\tau/q - k - s)\,q}{18\tau/q}.$$

Turning to welfare measures, for a given value of q, we obtain:

$$CS^L(q) = \left(v - c - \frac{q}{2} - \frac{5\tau}{4q}\right)q(1+\delta) - \frac{\delta(12(\tau/q)^2 - 2\tau/q(k+s) - (k+s)^2)\,q}{36\tau/q}.$$

The expression for total welfare follows immediately:[14]

$$SW^L(q) = \left(v - c - \frac{q}{2} - \frac{\tau}{4q}\right)q(1+\delta) - \frac{\delta(4(\tau/q)^2 + 10\tau/q(k+s) - 5(k+s)^2)\,q}{36\tau/q}.$$

Finally, substituting equilibrium prices into (6) and solving for $\frac{\partial CS(\tilde{q}, q^*)}{\partial\tilde{q}}|_{\tilde{q}=q^*} = 0$, we obtain the equilibrium level of data usage under laissez-faire

$$q^L = \frac{3\big((k+s)\delta + 6(1+\delta)(v-c)\big) + \sqrt{\begin{array}{l}8(9+11\delta)\big((k+s)^2\delta - 18\tau(1+\delta)\big)\\ \qquad + 9((k+s)\delta + 6(1+\delta)(v-c))^2\end{array}}}{2(18(1+\delta) - (k+s)^2\delta/\tau)}.$$

[14]Under our specification, where the gross utility of cloud usage is $V(q) = vq - q^2/2$, the benchmark Hotelling expressions (i.e., without egress fees and with no switching costs) for user surplus and total surplus are respectively given by:

$$CS = \left(v - c - \frac{q}{2} - \frac{5\tau}{4q} + v\right)q(1+\delta),\ SW = \left(v - c - \frac{q}{2} - \frac{\tau}{4q} + v\right)q(1+\delta).$$

Regulation Consider the case of regulation. The analysis mirrors that of laissez-faire, except for the fact that fees are set at $\bar{f}$. First-period equilibrium prices are given by

$$\overline{p_1}(q,\overline{f}) = c + \frac{\tau}{q} - \frac{\delta(\tau/q - \overline{f} - s)(3\overline{f} - k + 2s)}{3\tau/q},\ \overline{p_2}(q,\overline{f}) = c + \frac{\tau}{q} + \frac{\overline{f} - k}{2}.$$

The share of users who switch in the second period is $1 - \widehat{y}_A = \frac{1}{2} - \frac{k+s}{2\tau/q}$. For an interior solution with a positive number of switchers we need to assume that $\overline{f} + s < \frac{\tau}{q}$. Moreover, for the cap to be binding, we need to impose the condition $\overline{f} \leq f^L(q) = \frac{1}{3}\left(\frac{2\tau}{q} + k - 2s\right)$. As in the baseline model, the latter condition is more restrictive than the the former under Assumption 3. The following assumption is therefore necessary for the regulated regime:

Assumption 4 (Regulated regime)**.** $\overline{f} \leq f^L(q) = \frac{1}{3}\left(\frac{2\tau}{q} + k - 2s\right) = f^L(q)$.

Substituting equilibrium prices into the expression for intertemporal profits gives:

$$\overline{\Pi}(q,\overline{f}) \ = \ (1+\delta)\,\frac{\tau}{2} \ - \ \frac{\delta(4\tau/q(k+s) - (\overline{f}+s)(3\overline{f}+k+4s))q}{12\tau/q}.$$

User surplus and total welfare for a given level of q and $\overline{f}$ are respectively given by:

$$\overline{CS}(q,\overline{f}) = \left(v - c - \frac{q}{2} - \frac{5\tau}{4q}\right) q(1+\delta) + \frac{\delta(2\tau/q(k+s) - (\overline{f}+s)(9\overline{f} - 4k + 5s))\,q}{12\tau/q},$$

$$\overline{SW}(q,\overline{f}) = \left(v - c - \frac{q}{2} - \frac{\tau}{4q}\right) q(1+\delta) - \frac{\delta(2\tau/q(k+s) + (\overline{f}+s)(\overline{f} - 2k - s))q}{4\tau/q}.$$

Finally, for the case of exogenous regulation, user demand of cloud services is:

$$\overline{q} = \frac{6(1+\delta)(v-c) + (k+s)\delta + \sqrt{\begin{aligned}&\big((k+s)\delta + 6(1+\delta)(v-c)\big)^2\\ &\qquad - 24(1+\delta)\big((\overline{f}+s)(3\overline{f} - 2k + s)\delta + 6\tau(1+\delta)\big)\end{aligned}}}{2\big((\overline{f}+s)(3\overline{f} - 2k + s)\delta/\tau + 6(1+\delta)\big)}.$$

B.1 Regulation effects

Turning to the evaluation of firms' profits and user surplus, we find that:

$$\overline{\Pi}_i(q,\overline{f}) - \Pi_i^L(q) \ = -\frac{\delta(2\tau/q - 3\overline{f} + k - 2s)(2\tau/q + 3\overline{f} + 2k + 5s)q}{36\tau/q} \leq 0,$$

$$\overline{CS}(q,\overline{f}) - CS^L(q) \ = \ \frac{\delta(2\tau/q - 3\overline{f} + k - 2s)(6\tau/q + 9\overline{f} - k + 8s)q}{36\tau/q} \geq 0,$$

given that $2\tau/q - 3\overline{f} + k - 2s \geq 0$ and $6\tau/q + 9\overline{f} - k + 8s)q \geq 0$ by Assumptions 3 and 4, with both differences converging to zero for $\overline{f} = f^L(q)$. It follows therefore that our main results on profits and users do not depend on data usage.

When considering total welfare, we obtain instead:

$$\overline{SW}(q,\overline{f}) - SW^L(q) = \frac{\delta(2\tau/q - 3\overline{f} + k - 2s)(2\tau/q + 3\overline{f} - 5k - 2s)q}{36\tau/q}$$
$$\propto (2\tau/q + 3\overline{f} - 5k - 2s).$$

Similar to Proposition 1, we find that: $\overline{SW}(q,\overline{f}) \geq SW^L(q)$ when $\overline{f} > \frac{5k+2s-2\tau/q}{3}$. Moreover, if $5k+2s-2\tau/q < 0$, any cap is better than laissez-faire, and if $5k+2s-2\tau/q > 0$, then a ban on egress fees lowers welfare. Notice that the threshold value below which regulation lowers welfare increases with q. This implies that, while regulation increases data usage, it also amplifies the losses associated with switching. When users switch excessively, due to a tight cap, total welfare may then decline because of the costs induced by such switching.

Substituting the optimal values of q^L and $\overline{q}$ into the respective expressions for social welfare under laissez-faire and regulation renders the analysis analytically intractable. However, numerical simulations confirm the results of the baseline model. Figure 3, for instance, illustrates the equilibrium outcomes obtained when q^L and $\overline{q}$ are substituted into the relevant expressions, together with a representation of the corresponding equilibrium levels of cloud usage. We present our main results by considering two values of k and setting $s = 0$ for simplicity. Panel (a) corresponds to a relatively low value of k and shows that welfare is always higher under regulation, reaching its maximum at the efficient level $\overline{f} = k$. In Panel (b), where k is larger, there are parameter configurations in which welfare is lower under regulation, particularly when the fee cap is tight. For higher values of k, the reduction in firm profits, evidenced by their consistent decline, is only partially offset by an increase in user surplus, resulting in total welfare levels below those under laissez-faire when $\overline{f}$ approaches zero.

B.2 Incentives to increase user switching costs

The main results of Section 5.3 extend to the case of endogenous q. For a given q, it can be easily verified that equilibrium profits under laissez-faire are always decreasing in user switching costs s. Under regulation, however, this relationship depends on the different parameters, in particular on the interplay between s and $\overline{f}$, as in the baseline model with $q = 1$. Similarly to Proposition 2, we find that, under a fee cap, firms' profits are increasing in s if and only if $\overline{f}(q) > \frac{4\tau/q-k-8s}{7} \equiv \widetilde{f}(q)$, which always holds when $4\tau/q - k - 8s < 0$. Hence, once again, incentives to raise switching costs arise when these costs are already high, or when they are moderate but regulation remains loose. Note that the threshold value $\widetilde{f}(q)$ is decreasing in q. As shown in Proposition 4, regulation increases data usage, making it more likely that the parameter region in which firms respond to the fee cap by increasing user switching costs is reached.

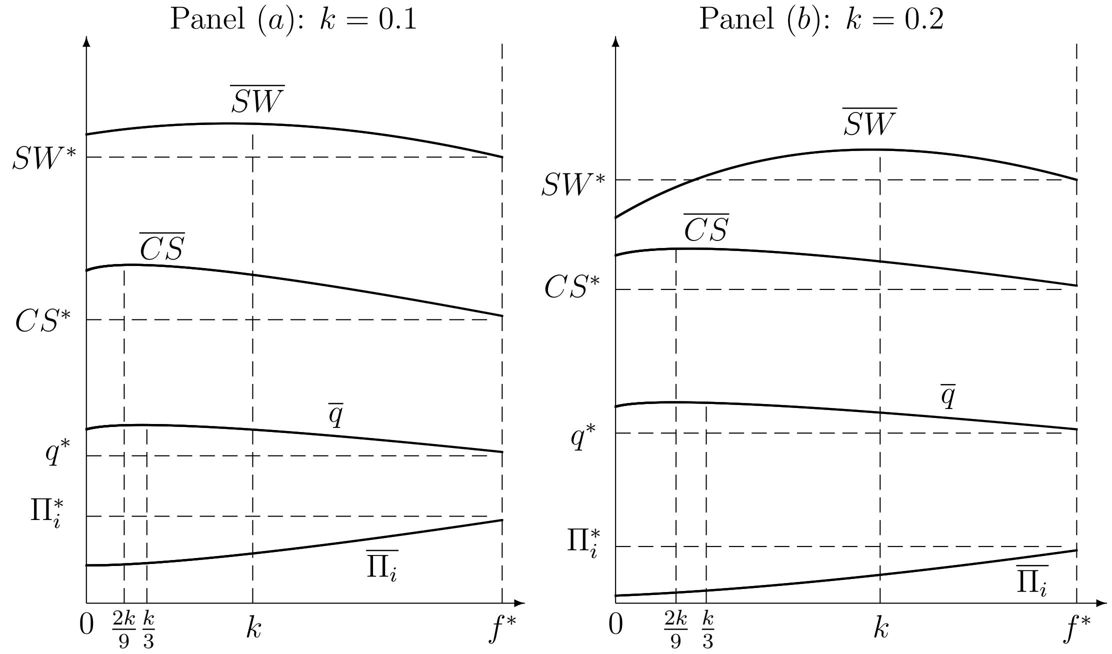

Figure 3: Relevant equilibrium expression for $s = 0$, $\delta = 0.3$, $v = 4$, $c = 0.1$, $\tau = 1$, and two different values of k: $k = 0.1$ in Panel (a), $k = 0.2$ in Panel (b).