Welfare Implications of Sequential Entry with Heterogeneous Firms

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Welfare Implications of Sequential Entry with Heterogeneous Firms*

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Abstract

Does free entry result in the socially preferred order of market entry for heterogeneous firms? This paper examines the welfare effects of sequential market entry by using a simple entry-deterrence model with heterogeneities in fixed and variable production costs among firms. In particular, we consider the question of whether a less or more efficient firm should be the first entrant into a new market from a welfare perspective. We show that the order of entry whereby a more efficient firm enters the market first may lead to welfare loss due to the less aggressive entry deterrence efforts made by the first entrant. Our findings have important policy implications with regard to the welfare consequences of free entry markets and the privatization of public monopolies through auctions.

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1 Introduction

The order of entry of firms into a new industry will determine the dynamics of the industry. When a more competitive firm enters a market first, it may easily be able to maintain its monopoly position by preventing the entry of less competitive firms. However, when a less competitive firm enters the market first, it may be difficult for it to prevent the entry of more competitive firms, which makes the market more competitive. Thus, the order of firm entry is important not only for firms but also for competition authorities.

In this paper, we examine the welfare effects of sequential market entry in a simple entry-deterrence model with heterogeneous firms. In particular, we consider the question of whether a less or more technologically efficient firm should be the first entrant to increase total surplus. If the monopoly position is exogenously given, then a monopoly by a more efficient firm will naturally yield greater total surplus than a monopoly by a less efficient firm. However, as shown in this paper, this logic does not hold if the monopoly status is maintained endogenously by the incumbent's (first entrant's) strategic measures to prevent the entry of potential competitors. This is because if a less efficient firm enters first, it will have to adopt more aggressive strategies of producing more (or charging a lower price) to deter the entry of a more efficient firm, which can be desirable for total surplus.

We confirm the logic that empowering a less efficient firm to enter a market first could lead to higher social surplus by considering two types of cost heterogeneities between firms: heterogeneities in fixed and variable production costs. We first show that if the firms differ only in their fixed production costs (we call this the case of *fixed cost heterogeneity*), total surplus can be *decreasing* in the first entrant's (incumbent's) advantages in its fixed costs against a potential entrant. This implies that providing a right of first entry into a market to a less efficient firm (rather than to a more efficient firm) may yield greater total surplus. Second, if the two firms differ only in their variable production costs (we call this the case of *variable cost heterogeneity*), the social surplus is increasing or decreasing in the first entrant's advantages in its variable costs, depending on the first entrant's strategies against the entrant (i.e., accommodating, deterring, and blockaded entries). The resulting social surplus is strictly greater in the case in which the more efficient firm is the first entrant than in the case in which the less efficient firm is the first entrant. Finally, we consider the mixed case in which two firms differ in both fixed and variable production costs and one firm has overall advantages vis-à-vis another (we call this the case of *overall cost advantage*). We show that even in the case in which one firm is absolutely inferior to the other, this inferior firm should be the first entrant to achieve higher total surplus in industries with large fixed costs.

Our findings have some important policy implications with regard to the welfare consequences of free entry markets and the privatization of state-owned (public) monopolies. First, as Tirole (1988) states, "some firms will enter the market early, possibly because of a technological lead"; a more technologically advanced firm is likely to be the first to enter a new market with free entry. Our results suggest that such a plausible order of entry may create social losses due to the *inefficient* strategy of deterring entry pursued by the first *efficient* entrant. Second, when a government sells a public monopoly to a private firm in a privatization auction, firms with better technology are expected to secure the right of the first entry (the incumbent position) because they can bid higher than other firms with less technology. However, our results suggest that such auction-based privatization approaches may undermine social surplus.

This paper is organized as follows: Section 2 reviews the existing literature on the theory of entry deterrence and sequential entry. Section 3 sets up the model and characterizes the equilibria under different strategies of the incumbent against the potential entrant. Section 4 investigates the effects of entry order on total surplus. Section 5 concludes the paper by discussing the policy implications of our findings, the relationship of our results to the existing literature, and the possible extensions of the model.

2 Related Literature

Economists have long studied the possibility of entry deterrence by an incumbent firm. The classical literature, such as Bain (1956) and Sylos-Labini (1962), shows that an incumbent firm can exercise first-mover advantages in choosing greater output (or lower prices) to deter entry (a.k.a. the Bain-Sylos postulate). Early theoretical studies such as Spence (1977) and Dixit (1980) focus on a commitment problem on the incumbent's entry-deterrence strategy and show that building an irreversible capacity prior to the entrants' decision can make the incumbent's strategy credible.[1] Our simple model also employs a Dixit-type framework in which an incumbent firm (as a Stackelberg leader) can hold excess capacity to deter entry.[2]

There are several empirical studies on whether and how firms invest in excess capacity to deter entry. Lieberman (1987) examines excess capacity investment to deter entry in a sample of thirty-eight chemical product industries and shows that incumbents rarely build excess capacity to deter entry. However, using hospital data from electrophysiological studies, Dafny (2005) finds evidence of entry-deterring investment, suggesting that hospitals could use experience to deter entry. Several empirical studies also find evidence of strategic actions by incumbent firms to deter entry: investing in hub-and-spoke networks in the airline industry (Aguirregabiria and Ho, 2010), expanding floor space in the American casino industry (Cookson, 2018), expanding capacities beyond demand growth in the global semiconductor manufacturing industry (Uzunca and Cassiman, 2020), and extending product lines in the UK pharmaceutical market (Bokhari and Yan, 2020).

[1] For other important theoretical studies on entry deterrence, see Spulber (1981), Bernheim (1984), Fudenberg and Tirole (1984), and Vives (1988). Additionally, for surveys of the theoretical literature, see Neven (1989), Wilson (1992), and Belleflamme and Peitz (2015).

[2] Anderson and Engers (1994) endogenize the entry time in a (symmetric) Stackelberg-type model of entry deterrence and show that the welfare effect of fixed and marginal costs crucially depends on the market regime, i.e., accommodating, deterring, and blockaded entry.

Our paper is closely related to the literature on sequential entry. Several theoretical studies investigate the plausible entry order of heterogeneous firms. As Tirole (1988) states, "some firms will enter the market early, possibly because of a technological lead," and many theoretical studies show that the order of entry into a market reflects relative efficiency. Quint and Einav (2005) show that more efficient firms enter a market early in a war-of-attrition model with gradually sunk entry costs. Pawlina and Kort (2006) investigate the consequences of exogenous asymmetry in the (fixed) entry cost and show that the firm with the lowest cost always invests weakly earlier than the opponent.[3] Following Berry (1992), some empirical studies also assume this natural entry order. For example, Scott Morton (1999) assumes that firms with the lowest entry costs enter a market first. Our study contributes to the literature by suggesting that such natural entry sequences may be undesirable from a welfare perspective due to the high competitiveness of the incumbent firm.

Our study also relates to the literature that investigates the welfare effects of firm heterogeneity in oligopoly models. Lahiri and Ono (1988) show that the elimination of minor (less efficient) firms improves average production efficiencies and may thereby enhance welfare. Additionally, Mukherjee and Ray (2014) show that the entry of a less efficient firm with lower R&D (not production) technology can reduce welfare. Whereas these two studies, which do not consider entry deterrence, suggest that keeping less efficient firms out of the market may enhance welfare through production and investment efficiency effects, our study suggests that keeping more efficient firms out of the market may enhance welfare through aggressive entry deterrence of a less efficient incumbent.[4]

3 The model

Consider two firms intending to enter a certain new market. Entry is assumed to be sequential, meaning that only a single firm can enter first and can act as an incumbent (we call it Firm I). The incumbent can deter or accommodate the entry of another firm (a potential entrant, Firm E) by credibly committing to its output level (e.g., by building capacity or using long-term contracts as in Spence (1977), Dixit (1980), and Aghion and Bolton (1987)).[5]

Firm i's ($i \in \{I, E\}$) profits are given by $\pi_i = P(Q)q_i - C_i(q_i)$, where $P(Q)$ is the price (or inverse demand), $Q \equiv q_I + q_E$ is the total output, q_i is Firm i's output, and $C_i(q_i)$ is Firm i's cost. We assume that the inverse demand function is $P(Q) = a - Q$ ($Q \equiv q_I + q_E$) to obtain clear results.

[3] Riordan (1992) shows that in a two-firm asymmetric game, entry in a market occurs in the order of firm efficiency. However, Argenziano and Schmidt-Dengler (2012) offer a counterexample in a model with more than two firms where the order of entry may not reflect the efficiency ranking.

[4] Furthermore, there are two studies showing that an incumbent can use weak firms as an instrument to prevent the entry of much stronger firms. Ashiya (2000) shows that an incumbent firm may intentionally allow the entry of a weak (less efficient) firm to stop the entry of a strong (more efficient) firm. Makadok and Ross (2018) show that an incumbent may not drive a weak (less efficient) rival from the market to prevent a much stronger (more efficient) rival from entering the market instead.

[5] The basic framework of our model is similar to that used in Cabral and Ross (2008) in that an incumbent and entrant play a Stackelberg capacity-setting game.

The cost function is given by

$$C_i(q_i) = \begin{cases} f_i + v_i q_i & \text{if} \quad q_i > 0, \\ 0 & \text{if} \quad q_i = 0, \end{cases}$$

where f_i is the fixed setup (or entry) cost and v_i is the variable (or marginal) cost. The two firms must incur fixed setup costs when they enter the new market. As detailed in Section 4.1, we allow for cost heterogeneity between firms in terms of fixed and variable costs.

The timing of the game is as follows. In the first stage of the game, one of the two firms enters a market, which we call Firm I, and chooses its capacity (or, equivalently, output) level. In the second stage, another firm (Firm E) decides whether to enter the market, and if it enters, it chooses its capacity (or output) level. We assume that the firms choose capacities when they enter and that their output always equals their capacity. We compare total surplus in different sequences of firm entry to answer the question of whether a more or less efficient firm should be the first entrant from a welfare perspective.

3.1 Equilibrium

The game is solved backwards. In the second stage, the potential entrant, Firm E, chooses its output level when it enters the market. The profit maximization problem is $\max_{q_E} \pi_E \equiv P(Q)q_E - C_E(q_E)$ given the incumbent firm's output, q_I. The first-order condition is:

$$\frac{\partial P(Q)}{\partial q_E} q_E + P(Q) - C'_E(q_E) = 0,$$

which yields Firm E's best response $q_E^Y(q_I)$.[6] The superscript Y denotes the variable in the case in which Firm E enters into the market. Using a linear demand specification, it reduces to $q_E^Y(q_I) = (a - v_E - q_I)/2$, and the associated profits are $\pi_E^Y(q_I) = (a - v_E - q_I)^2/4 - f_E$. When Firm E does not enter the market, its output is $q_E^N = 0$ and its profit is $\pi_E^N = 0$, where the superscript N denotes the variable without entry. Naturally, Firm E enters the market as long as $\pi_E^Y(q_I) \geq \pi_E^N$.

In the first stage, Firm I chooses the output level depending on the profitability of entry deterrence. There are three cases for Firm I to consider: the cases of *entry accommodation*, *entry deterrence*, and *blockaded entry*. When Firm I chooses entry accommodation, it simply chooses the Stackelberg leader's output level, and Firm E enters and chooses the Stackelberg follower's output level. When Firm I chooses entry deterrence, it chooses the output level such that Firm E's expected profits from entering the market are zero. In the case of blockaded entry, Firm I can choose an unconstrained monopoly output level that is sufficient to deter entry by the potential entrant.

[6] The second-order condition is satisfied when $\partial^2 P(Q)/\partial q_E^2 + 2\partial P(Q)/\partial q_E - C''_E < 0$ because we assume interior solutions.

In the case of entry accommodation, the profit maximization problem for Firm I is given by $\max_{q_I} P(Q)\, q_I - C_I(q_I)$, where $Q = q_I + q_E^Y(q_I)$. The first-order condition is:

$$\frac{\partial P(Q)}{\partial q_I} q_I + \frac{\partial P(Q)}{\partial q_E^Y(q_I)} \frac{dq_E^Y(q_I)}{dq_I} q_I + P(Q) - C_I'(q_I) = 0,$$

which gives us the equilibrium output for Firm I as $q_I^A(v_E, v_I)$ and the equilibrium profits as $\pi_I^A(v_E, v_I, f_I)$.[7] The superscript A refers to the case of entry accommodation. Then we have the equilibrium output and profits for Firm E as $q_E^A(v_E, v_I)$ and $\pi_E^A(v_E, v_I, f_E)$, respectively, and the equilibrium price as $P^A(v_E, v_I)$.

In the case of entry deterrence, Firm I chooses the output such that Firm E's expected profits from entering the market are zero. Therefore, the entry-deterrence output, q_I^D, is given such that $\pi_E^Y(q_I^D) = \pi_E^N$, where the superscript D refers to the case of entry deterrence. The equality yields the equilibrium output $q_I^D(v_E, f_E)$ and profits $\pi_I^D(v_I, v_E, f_I, f_E)$.

In the case of blockaded entry, Firm E would find it is unprofitable to enter even if Firm I chose the unconstrained monopoly output level. Thus, we have the usual monopoly output, $q_I^B(v_I)$, that satisfies

$$\frac{dP(q_I^B)}{dq_I} q_I^B + P(q_I^B) - C_I'(q_I^B) = 0 \quad \text{and} \quad q_E = 0,$$

where the superscript B refers to the case of blockaded entry. The associated equilibrium profit and price are given by $\pi_I^B(v_I, f_I)$ and $P^B(v_I)$, respectively.

For a linear demand specification ($P = a - Q$), the equilibrium outputs, profits, and prices in each case are shown in Table 1. Note that the entry-deterrence output and price, q_I^D and P^D, depend only on the potential entrant's cost, that is v_E and f_E, and not on the incumbent' cost. Additionally, q_I^D is decreasing in v_E and f_E, implying that the incumbent can easily prevent entry by producing less output if the potential entrant has higher fixed and variable costs.

3.2 Endogenous Market Structure and the Total Surplus

Here, we derive the conditions under which the incumbent accommodates, deters, or blockades the entry of the potential entrant and investigate what market structure is endogenously determined.

Entry accommodation occurs iff $\phi_{D,A} \equiv \pi_I^D - \pi_I^A < 0$, and blockaded entry occurs iff $\phi_{B,D} \equiv q_I^B - q_I^D \geq 0$. Then, entry deterrence occurs iff $\phi_{B,D} < 0 \leq \phi_{D,A}$. For a linear demand specification, these critical values are obtained as follows:

$$\begin{aligned} \phi_{D,A} &= \left(a - v_E - 2\sqrt{f_E}\right)\left(v_E - v_I + 2\sqrt{f_E}\right) - \frac{(a + v_E - 2v_I)^2}{8}, \\ \phi_{B,D} &= 2\sqrt{f_E} + v_E - \frac{a + v_I}{2}. \end{aligned}$$

[7] We assume that the second-order condition is satisfied.

Table 1: Equilibrium outputs, profits, and prices for linear demand

		Entry Accommodation ($k = A$)	Entry Deterrence ($k = D$)	Blockaded Entry ($k = B$)
Outputs	q_I^k	$\frac{a + v_E - 2v_I}{2}$	$a - v_E - 2\sqrt{f_E}$	$\frac{a - v_I}{2}$
	q_E^k	$\frac{a - 3v_E + 2v_I}{4}$	0	0
Profits	π_I^k	$\frac{(a + v_E - 2v_I)^2}{8} - f_I$	$(a - v_E - 2\sqrt{f_E})(v_E - v_I + 2\sqrt{f_E}) - f_I$	$(a - v_I)^2 - f_I$
	π_E^k	$\frac{(a - 3v_E + 2v_I)^2}{16} - f_E$	0	0
Price	P^k	$\frac{a + v_E + 2v_I}{4}$	$v_E + 2\sqrt{f_E}$	$\frac{a + v_I}{2}$

Depending on the sign conditions of the two critical values $\phi_{D,A}$ and $\phi_{B,D}$, the market structure (monopoly or duopoly) and the equilibrium patterns are endogenously characterized.

The equilibrium total surplus (or "welfare") for each case, defined by the sum of consumer and producer surplus, is given by:

$$\begin{aligned}
W^A &\equiv \int_0^{Q^A} P(s)ds - C_I(q_I^A) - C_E(q_E^A) && \text{for} \quad \phi_{D,A} < 0,\\
W^D &\equiv \int_0^{q_I^D} P(s)ds - C_I(q_I^D) && \text{for} \quad \phi_{B,D} < 0 \leq \phi_{D,A},\\
W^B &\equiv \int_0^{q_I^B} P(s)ds - C_I(q_I^B) && \text{for} \quad \phi_{B,D} \geq 0.
\end{aligned}$$

4 Welfare Effect of Cost Heterogeneities

This section introduces three types of cost heterogeneity between firms. We define the two firms' variable and fixed costs as follows:

$$\begin{aligned}
v_I &\equiv (1 - \delta_v)v, \quad v_E \equiv \delta_v v,\\
f_I &\equiv (1 - \delta_f)f, \quad f_E \equiv \delta_f f,
\end{aligned}$$

where $v > 0$ and $f > 0$ are variable and fixed cost parameters, respectively, that are common to both firms. The degree of cost heterogeneity is expressed by $\delta_v \in (0, 1)$ and $\delta_f \in (0, 1)$. When $\delta_v = \delta_f = 1/2$, the incumbent (Firm I) and the potential entrant (Firm E) are symmetric. The closer δ_v and δ_f are to 1, the lower the variable and fixed costs that the incumbent has than the potential entrant.

We consider the following three cases of cost heterogeneity between firms: fixed cost heterogeneity, variable cost heterogeneity, and an overall cost advantage. In the fixed cost heterogeneity case, we investigate the effect of changes in δ_f on the equilibrium variables, given that both firms have the same variable cost parameter (i.e., $\delta_v = 1/2$). In the variable cost heterogeneity case, we investigate the effect of changes in δ_v, given that both firms have the same fixed cost (i.e., $\delta_f = 1/2$). In the final case of overall cost advantages, we want to investigate the effect of overall changes in both cost parameters, so we assume $\delta_v = \delta_f = \bar{\delta}$ and investigate the effect of changes in $\bar{\delta}$. Such stark specifications make the analysis of the welfare effect of cost heterogeneities intuitive and simple.

4.1 The Case of Fixed Cost Heterogeneity

First, we examine the welfare effect of the fixed cost heterogeneity between two firms. In the case of entry accommodation, we easily find that $\partial W^A/\partial \delta_f = 0$ always holds because both firms operate in the market and the sum of the fixed costs of both firms is always constant.

In the case of entry deterrence, the effect of changes in fixed cost heterogeneity (δ_f) on the equilibrium output (q_I^D) is given by total differentiation of the condition $\pi_E^Y = 0$ in q_I^D and δ_f:

$$\left[P'(Q) q_E^Y(q_I^D) + (\underbrace{P'(Q) q_E^Y(q_I^D) + P(Q) - \delta_v v}_{d\pi_E/dq_E = 0}) \frac{\partial q_E^Y(q_I^D)}{\partial q_I^D} \right] dq_I^D - \left[f \right] d\delta_f = 0.$$

Then, we have

$$\frac{dq_I^D}{d\delta_f} = \frac{f}{P'(Q) q_E^Y(q_I^D)} < 0, \tag{1}$$

which implies that the greater the fixed costs of the potential entrant are, the smaller the equilibrium (entry deterrence) output the first entrant offers.

The welfare effect of a change in the fixed cost advantage is given by

$$\begin{aligned} \left.\frac{\partial W^D}{\partial \delta_f}\right|_{\delta_v = 1/2} &= \left[P\left(q_I^D\right) - \frac{1}{2} v \right] \frac{dq_I^D}{d\delta_f} + f \\ &= f \left[1 - \frac{P\left(q_I^D\right) - (1/2)v}{P\left(q_I^D + q_E^Y(q_I^D)\right) - (1/2)v} \right] < 0. \end{aligned} \tag{2}$$

Because $\frac{P\left(q_I^D\right) - (1/2)v}{P\left(q_I^D + q_E^Y(q_I^D)\right) - (1/2)v} > 1$, the welfare effect of an increase in the first entrant's relative fixed cost advantage is always negative. For a linear demand specification, it reduces to

$$\frac{\partial W^D}{\partial \delta_f} = -\frac{f[\sqrt{\delta_f f} + (2\delta_v - 1)v]}{\sqrt{\delta_f f}},$$

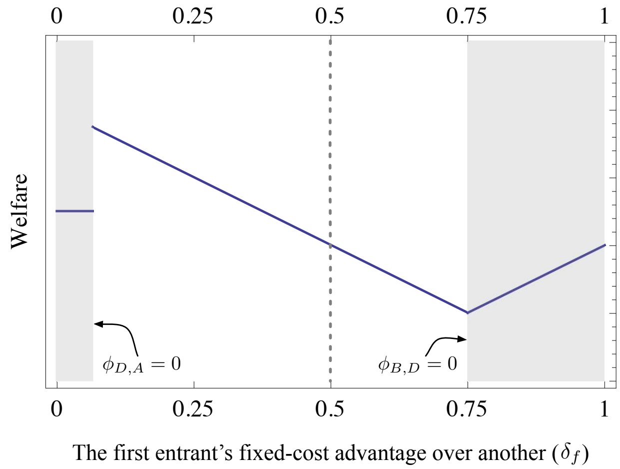

Figure 1: Welfare under fixed cost advantage ($a = 50$, $v = 2$, $\delta_v = 1/2$, $f = 200$)

and substituting $\delta_v = 1/2$ into the above yields $\partial W^D/\partial\delta_f = -f < 0$, indicating that an increase in the first entrant's relative fixed cost advantage harms welfare. The intuition behind the result is as follows. An increase in δ_f has two opposite effects on total surplus: the first is the positive direct effect from the smaller fixed cost of the incumbent, which is expressed by the first term in blankets in Eq. (2); the second is the negative effect from the smaller entry-deterrence output chosen by the incumbent, as shown in Eq. (1). Because the latter dominates the former, the improved relative efficiency on the fixed cost of the incumbent against the potential entrant reduces total surplus in the case of entry deterrence.

On the other hand, in the case of blockaded entry, we easily find that $\partial W^B/\partial\delta_f = f > 0$ holds, implying that the improved efficiency on the fixed cost of the incumbent is always beneficial to total surplus. Thus, we have the following proposition.

Proposition 1 *In the case of fixed cost heterogeneity, equilibrium welfare is independent, decreasing, and increasing in the first entrant's fixed cost advantage if the subsequent entry is accommodated, deterred, and blockaded, respectively.*

Figure 1 illustrates the welfare effect of fixed cost heterogeneity for a linear demand specification. The horizontal axis represents the value of δ_f (the relative efficiency of the first entrant's fixed costs). The dotted vertical line of $\delta_f = 1/2$ corresponds to the case of symmetric firms. The shaded area around $\delta_f = 0$ represents the region of entry accommodation ($\phi_{D,A} < 0$), in which the potential entrant's fixed costs are so small that the incumbent cannot deter entry. The other shaded area around $\delta_f = 1$ corresponds to the region of blockaded entry ($\phi_{B,D} \geq 0$), in which the potential entrant's fixed costs are so large relative to the first entrant's that there is no need for the incumbent to undertake any entry-deterrence strategies. The interim, non-shaded area corresponds to the case of entry deterrence. As shown in Proposition 1, the welfare is decreasing and increasing in δ_f in the entry deterrence and blockaded entry areas, respectively.

Now, we have the following corollary that answers the question of which firm, the more efficient or less efficient firm, should be the first entrant.

Corollary 1 *In the case of fixed cost heterogeneity with a linear demand specification, a less efficient firm entering the market first leads to a higher total surplus for* $f < \frac{3}{128}(2a - v)^2$.

As shown in Figure 1, in the entry-deterrence area, welfare is always greater if the incumbent has a higher fixed cost than the entrant. Therefore, providing the right of first entry to a less efficient firm is socially beneficial because the less efficient incumbent chooses greater output to deter the more efficient potential entrant, as shown in Eq. (1). The comparison of welfare in the other two areas, entry accommodation and blockaded entry, is somewhat difficult, but we easily find the sufficient condition in which providing the right of first entry to a less efficient firm is socially beneficial. The sufficient condition is $W^A|_{\delta_f=0} - W^B|_{\delta_f=1} = \frac{3}{128}(2a - v)^2 - f > 0$, which corresponds to the condition that the welfare on the left side region of $\delta_f = 1/2$ in Figure 1 is always higher than that on the right side of it.

4.2 The Case of Variable Cost Heterogeneity

Here, we examine the welfare effect of the variable cost heterogeneity between two firms. First, in the case of entry accommodation, we have

$$\begin{aligned}
\frac{dW^A}{d\delta_v} &= P(Q^A)\frac{dQ^A}{d\delta_v} - v\left[(1-\delta_v)\frac{dq_I^A}{d\delta_v} + \delta_v\frac{dq_E^A}{d\delta_v}\right] + v\left(q_I^A - q_E^A\right) \\
&= \left[P'(Q^A)q_I^A\right]\frac{dq_I^A}{d\delta_v} + \left[P'(Q^A)q_E^A\right]\frac{dq_E^A}{d\delta_v} + v\left(q_I^A - q_E^A\right) \\
&= q_I^A\underbrace{\left[P'(Q^A)\frac{dq_I^A}{d\delta_v} + v\right]}_{+\text{ or }-} + q_E^A\underbrace{\left[P'(Q^A)\frac{dq_E^A}{d\delta_v} - v\right]}_{+\text{ or }-}.
\end{aligned}$$

The sign of the above derivative is ambiguous and depends on both the absolute value of the variable cost v, the heterogeneity parameter δ_v, and the relative magnitude of q_I^A and q_E^A. If δ_v is sufficiently small (i.e., the first entrant is much less efficient), it may hold that $q_I^A < q_E^A$. In that case, an increase in δ_v (an improvement in the relative efficiency in the variable costs of the first entrant) reduces the total surplus by causing production substitution from a more efficient Stackelberg follower to a less efficient Stackelberg leader. On the other hand, if δ_v is large enough (i.e., the first entrant is much more efficient), an increase in δ_v causes production substitution from a less efficient Stackelberg follower to a more efficient leader, which improves total surplus. The result is a Stackelberg version of Salant and Shaffer's (1999) finding that the total surplus is increasing in the dispersion of marginal costs among Cournot-competing firms.

Second, in the case of entry deterrence, the total differentiation of $\pi_E^Y = 0$ in q_I^D and δ_v yields the following:

$$\left[P'(Q)q_E^Y(q_I^D) + \underbrace{(P'(Q)q_E^Y(q_I^D) + P(Q) - \delta_v v)}_{\partial\pi_E/\partial q_E = 0} \frac{\partial q_E^Y(q_I^D)}{\partial q_I^D} \right] dq_I^D - \left[v q_E^Y(q_I^D) \right] d\delta_v = 0.$$

Then we have

$$\frac{dq_I^D}{d\delta_v} = \frac{v}{P'(Q)} < 0, \tag{3}$$

implying that the greater the variable costs of the potential entrant are, the smaller the entry-deterrence output the first entrant offers.

Now, we have the welfare effect of a change in variable cost heterogeneity as

$$\begin{aligned} \frac{\partial W^D}{\partial \delta_v} &= \left[P\left(q_I^D\right) - (1-\delta_v)v \right] \frac{dq_I^D}{d\delta_v} + v q_I^D \\ &= \left(P\left(q_I^D\right) - (1-\delta_v)v\right) \frac{v}{P'(Q)} + v q_I^D \\ &= v \left[\frac{P\left(q_I^D\right) + P'(Q)q_I^D - (1-\delta_v)v}{P'(Q)} \right] > 0. \end{aligned}$$

The sign condition of the above comes from $q_I^D > q_I^A$ and

$$P(q_I^D) + P'(Q)q_I^D - (1-\delta_v)v < P(Q) + P'(Q)q_I^A - (1-\delta_v)v = 0.$$

For a linear demand specification, we have $dW^D/d\delta_v = v\left[a + v - \left(4\sqrt{\delta_f f} + 3\delta_v\right)\right] > 0$. From $\phi_{B,D} < 0$, in the linear demand function case, the sign of the welfare effect of a change in the variable cost advantage is positive. Although the improved relative efficiency of the variable cost of the incumbent reduces the entry-deterrence output, as shown in Eq. (3), it directly improves the incumbent's production efficiency. Therefore, an increase in δ_v in the entry-deterrence region necessarily enhances welfare.

Third, in the case of blockaded entry, the welfare effect of changes in δ_v is obviously positive:

$$\frac{dW^B}{d\delta_v} = \left[P(q_I^B) - (1-\delta_v)v\right] \frac{dq_I^B}{d\delta_v} + v q_I^B > 0,$$

and $dW^B/d\delta_v = 3v[a - v(1-\delta_v)]/4 > 0$ for a linear specification. Therefore, we have the following proposition.

Proposition 2 *In the case of variable cost heterogeneity, equilibrium welfare is strictly increasing in the first entrant's variable cost advantages if the subsequent entry is deterred and blockaded. It*

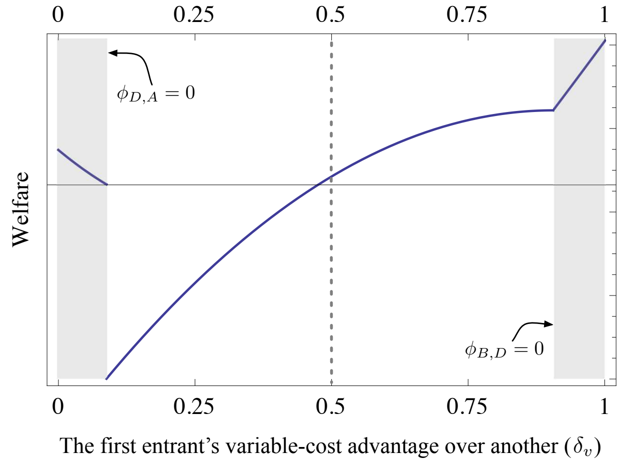

Figure 2: Welfare under variable cost advantage ($a = 30$, $v = 8$, $\delta_f = 1/2$, $f = 33$)

may be decreasing in the case of entry accommodation for small δ_v*.*

Figure 2 depicts the welfare effect of variable cost heterogeneity. In the figure, the horizontal axis represents the incumbent's variable cost advantage over the potential entrant, δ_v. The dotted vertical line $\delta_v = 1/2$ represents the symmetric case. We can see from the figure that total surplus is decreasing in δ_v only in the region of entry accommodation. This is due to the inefficient production substitution effect mentioned above. Therefore, an improvement in the relative efficiency of the variable costs of the first entrant is beneficial to welfare except for the entry accommodation case.

Now, we have the following corollary.

Corollary 2 *In the case of variable cost heterogeneity with a linear demand specification, a more efficient firm entering the market first leads to a higher total surplus.*

The result is quite intuitive: the lower the variable cost the incumbent (or the first entrant) has, the higher the total surplus. This can be confirmed by comparing the welfare level on the left side of $\delta_v = 1/2$ with that on the right side of it (or by folding the figure along the dotted line in the middle). Therefore, providing a right of first entry into a market to a more efficient firm is socially beneficial, which is in contrast to the case of fixed cost heterogeneity.

4.3 The Case of Overall Cost Advantage

Thus far, we have separately investigated the welfare effects of fixed and variable cost heterogeneity. Here, we consider the case in which one firm has advantages over the other in terms of both fixed and variable costs, which we call the case of overall cost advantage. In what follows, we assume that $\delta_f = \delta_v = \bar{\delta}$ and investigate the effect of changes in $\bar{\delta}$. Of course, it seems to be somewhat

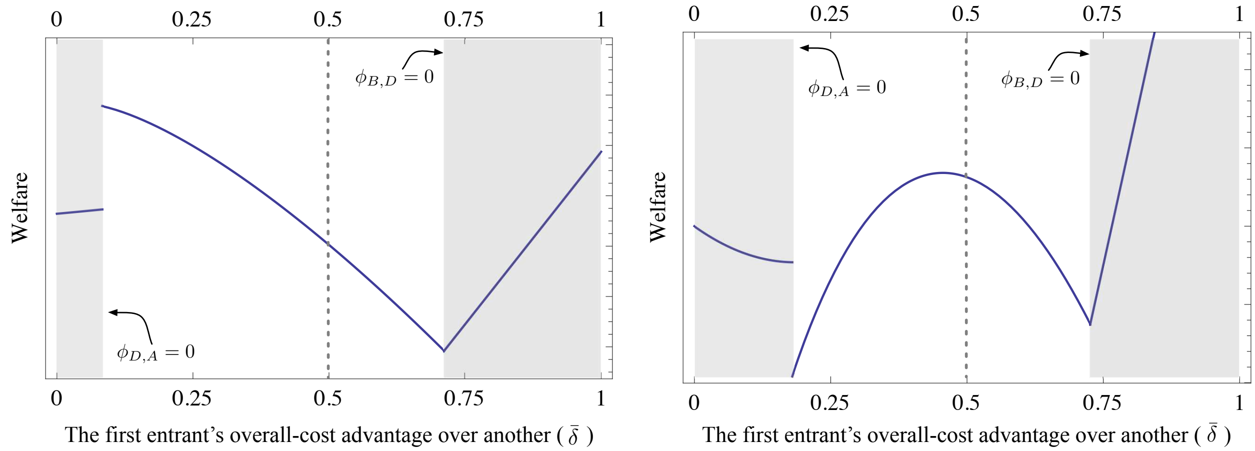

Figure 3: Welfare under overall-cost advantage

(left) $a = 50,\ v = 2,\ f = 200$; (right) $a = 30,\ v = 5,\ f = 50$.

impractical to express the cost disparities between firms as a constant rate, but it is a reasonable simplification to consider the effect of the overall technology gap between firms.

Now, combining the results obtained in the last two subsections, we have the following proposition.

Proposition 3 *In the case of overall cost advantage, depending on the relative magnitude of variable and fixed costs, equilibrium welfare is increasing or decreasing in the relative efficiency of the first entrant in both variable and fixed costs if subsequent entry is accommodated or deterred and is strictly increasing if subsequent entry is blockaded.*

When the fixed costs account for a larger proportion of the total production costs, then the welfare under entry deterrence is more likely to decrease in the first entrant's relative efficiency $\bar{\delta}$. On the other hand, when the variable costs account for a large proportion, the welfare under entry deterrence may be increasing or inverse-U shaped (have a maximum value for a certain value of $\bar{\delta}$). Figure 3 depicts the equilibrium welfare in the case of overall cost advantage for a larger value of f $(f/v = 100)$ in the left panel and for a smaller value of f $(f/v = 10)$ in the right panel.

Now, the final corollary is immediate.

Corollary 3 *In the case of an overall cost advantage with a linear demand specification, when fixed costs account for a larger share in production, a less efficient firm entering the market first leads to higher total surplus.*

Corollary 3 indicates that which firm, the more or less efficient firm, should be the first entrant depends on the relative magnitude of variable and fixed costs in production processes. As shown in the left panel of Figure 3, when the fixed costs are significant in production, the welfare on the left side of $\bar{\delta} = 0.5$ is generally higher than that on the right side of it, which implies that a less efficient firm should be the first entrant. On the other hand, as shown in the right panel of Figure 3, when the fixed costs are not significant in production, the welfare on the left side of $\bar{\delta} = 0.5$ is generally lower than that on the right side of it, which implies that a more efficient firm should be the first entrant. Therefore, we can conclude that the proportion of fixed to variable costs is crucial for determining the welfare effects of entry order.

5 Discussion and Concluding Remarks

In this section, we conclude the paper by briefly discussing some extensions of the basic setup and some policy implications of our analysis.

This paper has investigated the socially beneficial order of entry into a new market for heterogeneous firms. We have shown that the plausible order of entry, where a more efficient firm enters into a market first, may lead to social inefficiency because of the less aggressive entry deterrence of the first entrant. Even if one firm is absolutely inferior in both variable and fixed production costs over another, it may be preferable in terms of welfare to let the inefficient firm enter the market first.

Two possible extensions of our basic model can be noted. The first extension is to consider cost heterogeneity such that one firm has lower fixed costs and higher variable costs than another. Suppose the case of $v_I < v_E$ and $f_I > f_E$. Then, it can be seen immediately from Corollaries 1 and 2 that the incumbent firm will produce greater Stackelberg, entry-deterrence, or monopoly outputs at lower variable costs, which is necessarily desirable for total surplus. Suppose now the opposite case of $v_I > v_E$ and $f_I < f_E$. Then, the incumbent firm will produce smaller Stackelberg, entry-deterrence, or monopoly outputs at higher variable costs, which is necessarily undesirable for total surplus. Therefore, we can state that if the government can grant a firm the right to be the first to enter a market, it is desirable to grant it to a firm with relatively lower variable and higher fixed costs.

The second extension is to consider what would happen if the firms were to engage in price (Bertrand) competition with entry deterrence instead of Stackelberg output competition. Consider the sequential price competition between Firms I and E producing homogeneous products. In the case of fixed cost heterogeneity (with equal variable costs $v_I = v_E$), then only a firm with lower fixed costs can exist, irrespective of the order of entry. This is because there are second-mover advantages in this class of price competition, so it is impossible for a firm with higher fixed costs to deter the entry of a firm with lower fixed costs. Additionally, in the case of variable cost heterogeneity (with equal fixed costs $f_I = f_E$), only a firm with lower variable costs can exist, irrespective of the order of entry. These results indicate that even if a less efficient firm enters the market first, only a more efficient firm would survive in the market by setting a monopoly price or a price that prevents the less efficient firm from (re-)entering the market. Therefore, the order of entry does not matter for welfare in the case of price competition.

Our results have important policy implications for the means of privatizing public monopolies. Since the 1980s, the world has experienced a massive liberalization and privatization of public-sector companies that provide, for example, water and sanitation, urban and local transportation, garbage disposal, postal services, electricity, and gas. Generally, these public services incur large fixed costs to operate. Public auction (competitive bidding) is one of the popular privatization methods to allocate the ownership rights of such public companies.[8] If a government sells a monopoly public firm in privatization auctions, the winner will be the firm with the most efficient management and operation technologies. However, as shown in this paper, granting a firm with efficient technologies the right to enter the market first may not be desirable from a social welfare point of view because the winning firm can easily prevent others from entering the market.[9]

Finally, our results have two important implications for competition policy, particularly with respect to entry regulation. First, our result suggests that free entry can lead to social inefficiency for a different reason than in the "excess entry" result of Mankiw and Whinston (1986). The seminal work of Mankiw and Whinston (1986) shows that the free-entry number of firms is socially excessive in oligopolistic industries in the presence of scale economies because new market entrants essentially steal business from incumbents, which leads to a wasteful use of resources of entrants' fixed costs.[10] In contrast, our inefficiency result comes from the less aggressive entry-deterrence efforts by a more efficient first entrant (incumbent). Given that it is plausible that more efficient firms would enter a new market first,[11] our conclusion highlights a new inefficiency in free entry markets: a plausible entry order under free entry can lead to social inefficiency in the presence of scale economies and heterogeneous production costs among firms.

Second, our result suggests that if the monopoly position is secured through successful entry deterrence, then a more efficient firm, rather than a less efficient firm, should be eliminated from (or should be placed outside) the market, which is in stark contrast to a series of studies beginning with Lahiri and Ono (1988). Lahiri and Ono (1988) show that eliminating firms with less efficient variable costs from a market improves average production efficiency and may improve welfare. The similar efficient effect works in the result of Salant and Shaffer (1999) where an increased variance in firms' variable costs lowers average variable costs per unit of output sold, which improves welfare.

[8] For more information on the example, method, and the integrated review of privatization, see Vickers and Yarrow (1991), Berg and Berg (1997), and Bognetti and Obermann (2008).

[9] Our results suggest that it may be better for social welfare to give the right to enter the market first to a less efficient firm rather than to a more efficient firm. However, while the government can select the most efficient firm through auctions, information problems make it difficult for the government to select an inefficient firm. In this case, it may still be better to allocate the ownership rights of public monopolies at random than to allocate them through auctions.

[10] Mukherjee (2012) shows that the free-entry number of firms can be socially insufficient in an industry with a quantity-setting leader and many followers when the variable production costs of the market leader are much lower than those of followers.

[11] As mentioned in Section 2, many theoretical and empirical studies show and assume that it is plausible that more efficient firms enter a market early (e.g., Tirole 1988; Berry 1992; Scott Morton 1999; Quint and Einav 2005; Pawlina and Kort 2006).

In contrast, our study suggests that the opposite conclusion can be drawn when we consider the presence of fixed costs and the first entrant's entry deterrence behavior.

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