Social Efficiency of Entry in a Vertical Structure with Third Degree Price Discrimination*

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Submission: May 20, 2021
Revised version (R1): Oct 4, 2021
Revised version (R2): Dec 2, 2021
Accepted: January 9, 2022

Abstract

We study social efficiency of entry in the presence of downstream cost asymmetry and upstream price discrimination. We show that entry is excessive when the entrants are highly inefficient, and it is insufficient when either the entrants are efficient or their inefficiency is low. The results are in sharp contrast to the existing literature considering upstream uniform pricing (Cao and Wang, 2020), as discriminatory pricing alters the relative strengths of the business-stealing, business-creation and production-(in)efficiency effects.

Key words: excessive entry; insufficient entry; vertical market; price discrimination

JEL Classification: L13; L40

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*We thank the editor, Ronald Peeters, and two anonymous reviewers for their constructive comments and suggestions that have helped to greatly improve the paper. Financial support from the Humanity and Social Science Planning Foundation of the Ministry of Education of China (Grant No. 20YJA790001) is gratefully acknowledged.

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1 Introduction

The literature on social efficiency of entry got momentum with the seminal paper by Mankiw and Whinston (1986), which shows that entry is socially excessive in an oligopolistic market with homogeneous products, identical firms and scale economies. The *business-stealing* effect is the reason for "excessive entry". As Vives (1988) suggests, the issue of socially excessive or insufficient entry is not of purely academic interest. It is commonly observed that governments in many countries take actions to foster or deter entry into particular industries. For example, in the postwar period, preventing excessive entry was a guiding principle in the Japanese industrial policy (see Suzumura, 1995; Suzumura and Kiyono, 1987). In many countries, governments also often encourage entry by means of start-up grants, guaranteed loans, preferential tax treatments, or other forms of subsidies.

While the influential paper by Mankiw and Whinston (1986) creates the rationale for anti-competitive entry regulation in certain markets, it is limited due to its attention on competitive input markets, while significant amount of strategic input price determination occurs in reality. If the input markets are imperfectly competitive, entry affects not only rivalry among firms in the relevant market, but also the input prices. Considering symmetric input suppliers and symmetric final goods producers, Ghosh and Morita (2007a, b) show that entry can be insufficient in the presence of strategic input price determination. The strategic input price determination creates a *business-creation* effect, as entry in the downstream (upstream) sector increases profits of the firms in the upstream (downstream) sector.

Although Ghosh and Morita (2007a, b) consider vertical relationships, their focus on symmetric firms is restrictive, since cost asymmetry in competing firms is very common in the reality. Technological difference between the firms could be a simple reason for creating cost asymmetry. Cao and Wang (2020), which we review later, examine social efficiency of entry in the presence of strategic input price determination when the final goods producers differ in costs. However, they assume that the input supplier charges uniform prices, while it is well known that third degree price discrimination is the optimal pricing strategy of the input suppliers when there are asymmetric final goods producers (Yoshida, 2000).[1] Although institutional restrictions, such as Robinson-Patman Act in the USA, or the arbitrage possibility may prevent the input suppliers to choose its optimal pricing strategy, third-degree price discrimination is widely observed in the reality in the presence of different final good producers or retailers. Villas-Boas (2009) provides examples of third-degree price discrimination in different markets, as shown in the following

[1]Yoshida (2000) studies the effect of third-degree price discrimination on industry output and welfare without considering the welfare effects of entry. For some other papers on price discrimination by the input suppliers to the competing final goods producers, see, Katz (1987), DeGraba (1990), Yoshida (2000), Inderst and Valletti (2009), and O'Brien (2014).

quote:

> *"Wholesale price discrimination is commonly practiced in many markets. Examples include markets such as petroleum distribution, steel, heavy trucking, tobacco, and pharmaceuticals. In several countries, milk and other dairy products are sold using government-administered or -sanctioned discriminatory pricing schemes. Wholesale price discrimination practices are also used for services such as loans, insurance, and advertising."*
>
> —*Villas-Boas (2009, p. 20)*

Empirical evidence for discriminatory pricing being employed in vertical relations is presented, for instance, by Villas-Boas (2009) for the coffee industry in Germany, and by Coloma (2003) for the gasoline market in Argentina. Furthermore, notable cases of discriminatory pricing include Glaxo Wellcome (Commission decision 2001/791/EC) in the pharmaceutical industry and Souris/Topps (Commission decision COMP/C-3/37.980) in the toy industry.

As was first reasoned by Katz (1989), the upstream manufacturer may influence the number of downstream firms through its pricing policy.[2] Also in legal practice it has been argued that upstream pricing strategies have an impact on the downstream industry structure such as the number of active firms and markets that are served.[3] Yet, there is little knowledge about how third degree price discrimination affects social efficiency of free entry in the downstream sector with either efficient or inefficient entrants. As such, this paper aims to examine social efficiency of entry in a final goods market in the presence of strategic input price determination when the final goods producers are asymmetric in costs.

To address this issue, we consider an economy with an input supplier, exogenously given incumbent final goods producers and a large number of potential entrant final goods producers, who decide whether to enter the market. We derive the sufficient conditions for excessive and insufficient entry in a general demand setup and provide an example with a linear demand function. We show that entry in the final goods market is socially excessive if the entrants are highly inefficient. Otherwise, entry is socially insufficient. In addition to the business-stealing and business-creation effects discussed in the literature, we identify a new effect, called *production-(in)efficiency* effect, in the downstream sector in the presence of downstream cost asymmetry, which creates different input-price effects for the entrants depending on the relative cost efficiencies of the entrants and the incumbents. As explained below, interactions among the

[2]As said in Katz (1989, p.694), "There are several ways in which the manufacturer may influence the number of retailers. [. . .] [T]he manufacturer may indirectly control the number of dealers through his pricing policy [. . .]."

[3]See the case of Akzo N. V. v. USITC, 808 Fed 2d 1471, 1488-89 (Fed. Circ. 1986) in Herweg and Müller (2012).

business-stealing, business-creation and production-(in)efficiency effects are responsible for the results.

Using a linear demand function, Cao and Wang (2020) examine social efficiency of entry in the presence of strategic input price determination when the final goods producers differ in costs. They consider uniform input pricing and show that downstream entry can be socially insufficient (excessive) when entrants are sufficiently inefficient (efficient). In both Cao and Wang (2020) and our paper, the business-stealing, business-creation and production-(in)efficiency effects are present. However, our results under discriminatory pricing are completely opposite to theirs under uniform pricing. Doing the analysis with a general demand function and further illustrating the results with a linear demand function, we show that entry in the final goods market is socially excessive (insufficient) if the entrants are highly inefficient (otherwise).

The main reason is due to the fact that price discrimination benefits inefficient firms, and therefore, increases (reduces) the business-stealing effect when the entrants are inefficient (efficient). When the entrants are sufficiently inefficient, the increase in the business-stealing effect may lead to excessive entry in the downstream market. Thus, our analysis suggests that discriminatory input prices completely alter the government policy towards downstream entry in vertical markets. Hence, our paper contributes to the literature by highlighting that whether the government should adopt pro- or anti-competitive policies critically depends on the pricing strategies of the input suppliers; if the government allows input price discrimination then the entry policies can be opposite compared to the situation where input price discrimination is not allowed.

The remainder of the paper is organized as follows. After the literature review, Section 3 describes the basic model with downstream cost asymmetry and upstream price discrimination. We derive the results using a general demand function in Section 4, and provide an example with a linear demand function in Section 5. Section 6 concludes.

2 A survey of relevant literature

In a Cournot oligopoly with homogenous products, Mankiw and Whinston (1986) and Suzumura and Kiyono (1987) show that if the equilibrium output of each firm falls as the number of firms in the industry increases (a “business-stealing effect”), entry is always socially excessive. Entry is socially excessive (insufficient) if the free entry equilibrium number of firms is more (less) than the welfare maximizing number of firms. This result, often called “excess entry theorem”, has created significant interest in analyzing the welfare effects of entry in oligopolistic markets. Ghosh and Saha (2007) further show that excessive entry can occur without scale economies but in the presence of marginal cost difference. In their model, entrants are assumed to be less efficient in comparison to incumbents. However, the result of excessive entry has been challenged in different contexts, such as differentiated products (Kendall and Tsui, 2011; Gu and Wenzel, 2012; and Basak and Petrakis, 2021), spatial competition (Matsumura and Okamura, 2006), technology licensing (Mukherjee and Mukherjee, 2008), incumbent leadership (Mukherjee, 2012a), endogenous R&D (Mukherjee, 2012b), foreign competition (Marjit and Mukherjee, 2013), and complementary industries (Chen et al., 2019). The finding of insufficient entry indicates that entry regulation may not be justified in oligopolistic industries with such considerations. However, vertical relationships between industries, which are common and important, are ignored in these papers.

Another strand of literature examines social efficiency of free entry in vertically related markets with strategic input price determination. In such cases, entry affects not only rivalry among firms in the relevant market, but also the input prices. Ghosh and Morita (2007a) analyze free downstream entry under a firm-specific vertically related industry with symmetric final goods producers. They show that a higher bargaining power of the upstream agent reduces the incentive for downstream entry significantly, and may create insufficient entry. By contrast, Ghosh and Morita (2007b) study free entry of symmetric firms in the upstream sector with a fixed number of downstream firms, and show the possibility of insufficient entry. Their insufficient entry result occurs even if free entry of symmetric firms occur in the downstream market with a fixed number of upstream firms. The existence of the "business-creation" effect is the reason for insufficient entry in Ghosh and Morita (2007a, b). Basak and Mukherjee (2016) consider a vertically related industry with identical downstream entrants, and show that social desirability of entry depends on returns to scale. Entry is socially insufficient under constant returns but it is socially excessive under decreasing returns if the cost of entry is sufficiently low. These papers although consider vertically related industries with strategic input price determination, they focus on symmetric firms. However, as pointed out by Ghosh and Saha (2007),[4] ignoring cost asymmetry can lead to entry regulation policies that are qualitatively wrong.

As discussed in detail in the introduction, Cao and Wang (2020) consider social efficiency of entry in a vertical structure with downstream cost asymmetry. However, our results under discriminatory pricing are completely opposite to theirs under uniform pricing.

Pagnozzi et al. (2016) consider endogenous entry of manufacturers (the upstream agents) which do vertical contracting with exclusive retailers (the downstream agents). They find that the number of manufacturers is socially excessive. However, their framework is different from ours. Unlike our paper, they consider that a manufacturer is paired with a retailer and therefore, there is no issue of discriminatory or uniform vertical pricing in their paper. Further, unlike

[4]Ghosh and Saha (2007) consider cost asymmetry in their model, but focus on a horizontal market without iterations with upstream supplier(s).

us, they consider inelastic demand function, private information about the retailer's cost, and endogenous entry of the upstream agents. Pagnozzi et al. (2021) consider vertical contracts between a manufacturer and multiple retailers. They find that the number of retailers is socially excessive. However, unlike us, they consider symmetric retailers (the downstream agents), quantity forcing contracts offered by the manufacturer, and the number of retailers is determined by the manufacturer rather than the zero profit condition.[5]

For a representative sample of other papers on social efficiency of entry, see, Von Weizsäcker (1980), Okuno-Fujiwara and Suzumura (1993), Anderson et al. (1995), Fudenberg and Tirole (2000), Anderson and de Palma (2001), Cabral (2004), Mougeot and Naegelen (2005), Stähler and Upmann (2008), Crampes et al. (2009), Spulber (2013), Amir et al. (2014), and De Pinto and Goerke (2019, 2020).

3 The Model Setup

Consider a vertical market with an input supplier, and a large number of final goods producers, including m incumbents and a large number of potential entrants. In the upstream sector, the input supplier produces an intermediate product with a constant marginal cost which is normalized to zero, and sets the input price for each type of final good producers.

In the downstream sector, potential entrants decide whether or not to enter the market. We assume that all entrants incur the same fixed cost, $F > 0$. The number of entrants entering the market is determined through the free entry condition. The incumbent final goods producers are already in the market. Since the fixed costs incurred by them are sunk and would not affect our results, we ignore them. We also ignore the integer constraint that helps to eliminate the reason for insufficient entry in Mankiw and Whinston (1986). This is also a common practice in the excess entry and related literature. After entry, all downstream firms transform inputs into a homogeneous final product with a fixed one-to-one technology. The marginal costs of production for the incumbents and the entrants are c and d, respectively.[6] The inverse market demand function is $p(Q)$, where Q is the industry output and $p'(Q) < 0$. Denote by q_i and q_j the output for each incumbent and entrant that entered the market, respectively. If n entrants entered the market, we have $Q = \sum_{i=1}^{m} q_i + \sum_{j=1}^{n} q_j$. In the following, we continue to use subscripts "i" for incumbents and "j" for entrants that entered the market.

In our model, entrants can be either inefficient with $d > c$ or efficient with $d < c$. Ghosh and Saha (2007) and Mukherjee (2012a) consider cost asymmetry amongst firms. In their model,

[5] Etro (2011), Reisinger and Schnitzer (2012), and Pagnozzi and Piccolo (2017) consider entry in the presence of vertical contracting in different situations but do not look at social efficiency of entry.

[6] One explanation for such cost asymmetry is as follows. The costs c and d are the per-unit costs for another essential input sold in the competitive market and the difference in cost is due to the difference in input coefficient.

the incumbent is an efficient firm while all entrants are identically inefficient firms, i.e., $d > c$. This may happen if knowledge about the incumbent's technology spills over to the potential entrants in the market. However, the strength of the patent system and/or the complexity of the technology affect the benefit from knowledge spillover, and leads to a higher marginal cost for entrants. In addition, we also consider the possibility that entrants are more efficient in production, i.e., $d < c$ (see Porter, 1979; and Lin et al., 2009), which may happen when the technology diffusion occurs and the entrants are better in distributions. Alternatively, the entrants might acquire newer and more advanced technologies and/or production lines (equipments) with the fixed setup costs. In Porter (1979), entrants may well be more efficient than the more experienced incumbents if they have built the newest plant. Empirically, Lin et al. (2009) demonstrate that new entrants are slightly more efficient than incumbents with the data of Chinese banks for the period 1997-2006.

We consider the following game. At stage 1, downstream entrants decide whether or not to enter the market. At stage 2, the input supplier determines the input prices w_c and w_d for the incumbents and the entrants. At stage 3, the downstream firms (i.e., incumbents and entrants that entered the market) produce outputs q_i and q_j simultaneously like Cournot oligopolists, and the profits are realized. We study the subgame perfect equilibrium of this game.

In the following, we assume that (i) the value of m is such that it allows at least one entrant to enter, and (ii) even if $c > d$, it will not make production by the incumbents unprofitable.

4 The Analysis and Results

We assume that $p(Q)$ is continuously differentiable with $p'(Q)+Qp''(Q) < 0$. This assumption ensures that each firm's quantity reaction curve is downward-sloping. It is equivalent to $p'(Q)+q_i p''(Q) < 0$ (see Shapiro, 1989), which guarantees the existence of a Cournot equilibrium in homogeneous good markets. With constant marginal costs, this condition is also sufficient for uniqueness and stability of Cournot equilibrium.

If n entrants enter the market, the $m+n$ firms compete like Cournot oligopolists. At stage 3, given the input prices, each incumbent chooses q_i to maximize profit

$$\pi_i(q_i, q_j) = (p(Q) - c - w_c)\, q_i, \quad i = 1, 2, \cdots, m,$$

and each of the n entrants determines q_j to maximize profit

$$\pi_j(q_i, q_j) = (p(Q) - d - w_d)\, q_j - F, \quad j = 1, 2, \cdots, n,$$

where $Q = \sum_{i=1}^{m} q_i + \sum_{j=1}^{n} q_j$. The first order conditions are given by

$$\begin{cases} p(Q) - c - w_c + p'(Q)q_i = 0, & i = 1, 2, \cdots, m; \\ p(Q) - d - w_d + p'(Q)q_j = 0, & j = 1, 2, \cdots, n. \end{cases} \tag{1}$$

Since the second order conditions are satisfied, solving the first order conditions lead to the equilibrium quantities. The equilibrium quantities are determined by

$$q_i^*(w_c, w_d) = \frac{p(Q^*) - c - w_c}{-p'(Q^*)}, \quad \text{and} \quad q_j^*(w_c, w_d) = \frac{p(Q^*) - d - w_d}{-p'(Q^*)}, \tag{2}$$

where $Q^* = mq_i^* + nq_j^*$. Given the input prices w_c and w_d, $w_c + c$ is the effective marginal cost for incumbents and $w_d + d$ is that for entrants. Indicated by (1), the firms with a higher effective marginal cost produce less compared to those with a lower effective marginal cost.

Now we consider the second stage in which the upstream supplier determines input prices w_c and w_d to maximize its profit $\Pi(w_c, w_d) = mw_c q_i^* + nw_d q_j^*$. The second order conditions are assumed to be satisfied. By solving the first order conditions (see the calculations in Appendix A), the equilibrium input prices are determined by

$$\begin{cases} w_c^* & = -p'(Q^*)\left(q_i^* + Q^*\right) - p''(Q^*)\left(mq_i^{*2} + nq_j^{*2}\right); \\ w_d^* & = -p'(Q^*)\left(q_j^* + Q^*\right) - p''(Q^*)\left(mq_i^{*2} + nq_j^{*2}\right). \end{cases} \tag{3}$$

Lemma 1. *The equilibrium input prices satisfy that $w_d^* - w_c^* = (c - d)/2$. Further, the effective marginal costs satisfy that $(w_d^* + d) - (w_c^* + c) = (d - c)/2$.*

Implied by Lemma 1, the supplier charges a higher (lower) price for efficient (inefficient) producers, which reduces the gap in effective marginal costs between the two types of firms.[7] As in the literature (DeGraba, 1990; and Yoshida, 2000), such price discrimination benefits inefficient firms by shifting production from efficient firms to inefficient ones, thus creating production inefficiency.

We can further obtain the profits of the incumbents and the entrants by incorporating the equilibrium input prices and quantities into the profit functions:

$$\pi_i = \left(p(Q^*) - c - w_c^*\right) q_i^*, \quad \text{and} \quad \pi_j = \left(p(Q^*) - d - w_d^*\right) q_j^* - F. \tag{4}$$

At stage 1, the equilibrium number of entrants that entered the market, n^*, is given by the zero profit condition $\pi_j = 0$. By (1) and (4), we obtain that $\pi_j = -p'(Q^*)(q_j^*)^2 - F$. Thus, the

[7]The gap is $|c - d|/2$ under price discrimination instead of $|c - d|$ under uniform pricing.

equilibrium n^* under free entry solves

$$F = -p'(Q^*)(q_j^*)^2. \tag{5}$$

We assume that $F \leq -p'(Q^*)(q_j^*)^2$ at $n = 1$ such that at least one entrant enters the market. Given c, as d falls, it increases market entry by increasing the gross profits of the entrants.

It follows that, in free entry equilibrium,

$$q_j^* = \sqrt{-F/p'(Q^*)}, \quad \text{and} \quad q_i^* = q_j^* + \frac{c-d}{2p'(Q^*)}. \tag{6}$$

Apparently, $q_j^* > 0$. We further assume that $F > (c-d)^2/(-4p'(Q^*))$ such that $q_i^* > 0$ in equilibrium (see the details in Appendix C).

As in Mankiw and Whinston (1986) and Ghosh and Morita (2007b), we assume that the demand is well defined such that $\partial Q^*/\partial n > 0$, $\partial q_i^*/\partial n < 0$ and $\partial q_j^*/\partial n < 0$. That is, the post-entry equilibrium aggregate output rises with the number of firms entering the industry, but the output per firm falls as the number of firms in the industry increases (i.e., a "business-stealing" effect is present).

Next consider the welfare maximizing number of entrants. Following the literature, the social planner determines the welfare maximizing number of firms, conditional on Cournot competition. That is, even if the social planner may control the number of entrants entering, she cannot control the firms' behavior in the product market. We assume that the incumbents innovated their technologies and entered the market already. So, the government's choice is to determine the number of entrants. One might think that the number of incumbents in the market is the outcome of a previous government decision on firm-entry.

The welfare, which is the sum of consumer surplus and total net profits of the input supplier, the incumbent final goods producers and the entrant final goods producers, is

$$SW = \int_0^{Q^*(n)} p(t)dt - mcq_i^*(n) - ndq_j^*(n) - nF. \tag{7}$$

The derivative of welfare with respect to the number of entrants is given by

$$\frac{\partial SW}{\partial n} = (p-c)m\frac{\partial q_i^*(n)}{\partial n} + (p-d)n\frac{\partial q_j^*(n)}{\partial n} + (p-d)q_j^*(n) - F, \tag{8}$$

where $\partial q_i^*(n)/\partial n < 0$ and $\partial q_j^*(n)/\partial n < 0$.

Evaluating (8) at the free entry equilibrium number of entrants yields (see the calculations in Appendix D)

$$\frac{\partial SW}{\partial n}\mid_{n=n^*}=\underbrace{(p-w_c^*-c)m\frac{\partial q_i^*(n)}{\partial n}+(p-w_d^*-d)n\frac{\partial q_j^*(n)}{\partial n}}_{\text{business-stealing effect}}+\underbrace{\frac{\partial mq_i^*(n)}{\partial n}w_c^*+\frac{\partial nq_j^*(n)}{\partial n}w_d^*}_{\text{business-creation effect}}. \tag{9}$$

Like the existing literature, such as Ghosh and Morita (2007a, b) and Basak and Mukherjee (2016), entry creates two effects: the business-stealing effect and the business-creation effect, as shown in (9). The respective strength of these effects determine whether entry will be excessive or insufficient. However, due to the existence of asymmetric final goods producers, the business-stealing effect in our analysis includes a *production-inefficiency* effect when $d > c$ or a *production-efficiency* effect when $d < c$. When the entrants have higher (lower) marginal costs than the incumbents, entry creates production inefficiency (efficiency) by stealing business from the incumbents. As a result, some of the outputs that used to be produced by the low-cost (high-cost) incumbents will be produced by high-cost (low-cost) entrants ex-post entry.

Further decomposing the business-stealing effect in (9) with the consideration of downstream cost asymmetry leads to result in the following proposition immediately.

Proposition 1. *In a vertical market with downstream cost asymmetry and upstream price discrimination, entry is insufficient (excessive) when*

$$\underbrace{(p-w_d^*-d)\left(m\frac{\partial q_i^*(n)}{\partial n}+n\frac{\partial q_j^*(n)}{\partial n}\right)}_{\textit{pure business-stealing effect}}+\underbrace{\frac{m(d-c)}{2}\frac{\partial q_i^*(n)}{\partial n}}_{\textit{production-(in)efficiency effect}}+\underbrace{\frac{\partial mq_i^*(n)}{\partial n}w_c^*+\frac{\partial nq_j^*(n)}{\partial n}w_d^*}_{\textit{business-creation effect}}$$

is positive (negative).

The above condition in Proposition 1 is equivalent to $\frac{\partial SW}{\partial n}\mid_{n=n^*}> (<0)$. Specifically, we mention the "*pure business-stealing*" effect to show the amount of business stealing that could occur if the incumbents and the entrants have the same marginal costs. This effect is similar to the existing literature. Similarly, the business-creation effect is also similar to the existing literature. However, if $d > c$, the "production-inefficiency effect" shows the extra cost imposed on the society due to the existence of asymmetric final goods producers since the outputs are transferred from the low-cost incumbents to the high-cost entrants. The strength of the production-inefficiency effect increases as $(d-c)$ increases. Apparently, there will be no production-inefficiency effect if $d = c$.

It follows from Proposition 1 that excessive entry is more plausible if d is sufficiently higher than c so that the production-inefficiency effect is stronger. However, if d is close to c, the production-inefficiency effect is weaker and excessive entry is less plausible. If $d < c$, now we get production efficiency instead of production inefficiency, since the low-cost entrants steal business from the high-cost incumbents. Hence, excessive entry is even less plausible. We show these results more clearly in the next section by considering an example with a linear demand curve.

Klemperer (1988) showed the effects of production inefficiency without a vertical structure. Hence, he did not have the business-creation effect mentioned above. On the other hand, Ghosh and Morita (2007a, b) and Basak and Mukherjee (2016) did not have the production-(in)efficiency effect. Our analysis brings all these effects – pure business-stealing, business-creation and production-(in)efficiency – in one framework.

5 The Case of a Linear Demand

For a clear illustration of our findings, we consider in this section that the inverse demand for the final goods is linear: $p = a - Q$, where $0 < c < a$ and $0 < d < a$. We have $p' = -1$, and $p'' = p''' = 0$. Our calculations mirror those in the previous section.

At stage 3, given the input prices, each incumbent i chooses q_i to maximize its profit $\pi_i(q_i, q_j) = (a - Q - c - w_c)\, q_i$, and each entrant j determines q_j to maximize its profit $\pi_j(q_i, q_j) = (a - Q - d - w_d)\, q_j - F$. Solving the first order conditions leads to the quantities as follows:

$$\begin{cases} q_i^* &= \frac{(a+dn-(1+n)(c+w_c)+nw_d)}{(1+m+n)}; \\ q_j^* &= \frac{(a+cm+mw_c-(1+m)(d+w_d))}{(1+m+n)}. \end{cases} \tag{10}$$

The second order conditions are satisfied.

At stage 2, the input supplier determines input prices w_c and w_d by maximizing $\Pi(w_c, w_d) = mw_c q_i + nw_d q_j$. Solving the first order conditions leads to

$$w_c^* = (a - c)/2; \quad \text{and} \quad w_d^* = (a - d)/2. \tag{11}$$

The second order conditions are satisfied. Indicated by (11), the equilibrium input prices are not affected by the numbers of incumbents and entrants under linear demand. This is due to the reason explained in Dhillon and Petrakis (2002), which show that the price charged by an industry-wide upstream agent does not depend on the market parameters, such as the number of firms, the degree of product substitutability, and the intensity of market competition, if the firm's equilibrium output and profit are log-linear in the price changed by the upstream agent and the market parameters.

By (10) and (11), we further obtain the equilibrium outputs as

$$q_i^*(n) = \frac{a + dn - c(1+n)}{2(1+m+n)}, q_j^*(n) = \frac{a + cm - d(1+m)}{2(1+m+n)}, Q^*(n) = \frac{a(m+n) - cm - dn}{2(1+m+n)}.$$

Note that all firms are assumed to be active. Simple calculations lead to

$$\frac{\partial q_i^*(n)}{\partial n} < 0, \quad \frac{\partial q_j^*(n)}{\partial n} < 0, \quad \text{and} \quad \frac{\partial Q^*(n)}{\partial n} > 0,$$

which reveals the business-stealing effect of entry in the final goods market, and the business-creation effect of entry in the input sector.[8] It is worth emphasizing that the industry output and therefore, the consumer surplus (which is given by $CS = (Q^*(n))^2/2$) increase with entry.

At stage 1, the equilibrium number of entrants that entered the market, n^*, is given by the zero profit condition $\pi_j = 0$. Straightforward calculations lead to

$$n^* = \frac{a + cm - d(1+m) - 2\sqrt{F}(1+m)}{2\sqrt{F}}. \tag{12}$$

We assume that $a > 2\sqrt{F}(2+m) + (1+m)d - cm$ such that at least one entrant enters the market. Incorporating both (11) and (12) into (10) yields

$$q_i^* = \frac{1}{2}(d-c) + \sqrt{F}; \quad \text{and} \quad q_j^* = \sqrt{F}. \tag{13}$$

In equilibrium, each entrant's quantity is independent of marginal costs, while each incumbent's quantity decreases (increases) with its (rivals') marginal cost. We assume that $2\sqrt{F} > c - d$ which ensures positive quantities in equilibrium.

Let SW^* denote the equilibrium social welfare, and $\Delta = c - d$ denote the cost difference between the incumbents and the entrants, where $2\sqrt{F} > \Delta$, which ensures positive individual quantities for all firms in equilibrium. We have the results in the following lemma.

Lemma 2. *In equilibrium, (i) $\partial n^*/\partial m < 0$, and $\partial n^*/\partial \Delta > 0$, (ii) $\partial SW^*/\partial m > (<)0$ when $\sqrt{F} > (<)\Delta$, and $\partial SW^*/\partial \Delta < (>)0$ when $3\sqrt{F} > (<)2\Delta$.*

The results in Lemma 2(i) are quite intuitive. An increase in the number of incumbents reduces the profitability of entrants, and therefore, deters entrants, while an increase in the cost difference (through either an increase in the marginal cost of incumbents or a decrease in that of entrants) does the opposite, and therefore, encourages entrants. Indicated by Lemma 2(ii), when Δ is large (i.e., the incumbents are very inefficient), the entry deterrence effect of

[8]It can be shown that $\frac{\partial \Pi(w_c, w_d)}{\partial n} = \frac{\partial(m w_c^* q_i^* + n w_d^* q_j^*)}{\partial n} = \frac{(a+cm-d(1+m))^2}{4(1+m+n)^2} > 0$, which illustrates the positive business-creation effect of entry.

m, i.e.,$\partial n^*/\partial m < 0$, reduces social welfare because relatively fewer efficient firms enter the market. By contrast, the entry encouragement effect of Δ, i.e., $\partial n^*/\partial \Delta > 0$, improves social welfare because more efficient firms enter the market.

Next consider the welfare maximizing number of entrants. In stage 1, welfare is

$$SW = m\pi_i + n\pi_j + \Pi + Q^2/2, \tag{14}$$

which leads to

$$\frac{\partial SW}{\partial n} = \frac{(a + cm - d(1 + m))H_1(m, n)}{4(1 + m + n)^3} - F, \tag{15}$$

where $H_1(m, n) = a(2+m+n)+cm(3+2m+2n)-d(2+n+2m(2+m+n))$. Evaluating (15) at the free entry equilibrium number of firms yields

$$\frac{\partial SW}{\partial n} \mid_{n=n^*} = \frac{F\left(2\sqrt{F} + (c - d)m\right)}{a - (1 + m)d + mc}, \tag{16}$$

which is positive when $2\sqrt{F} > m(d - c)$, and negative otherwise.

Recall that the condition $2\sqrt{F} > c - d$ is assumed to ensure positive quantities in equilibrium. With inefficient entrants (i.e., $d > c$), this assumption is automatically satisfied with a positive fixed cost. In equilibrium, entry is insufficient when the cost gap between entrants and incumbents (i.e., $d - c$) is small and/or the number of incumbents (i.e., m) is small. With efficient entrants (i.e., $d < c$), (16) is always positive, which implies that entry is always insufficient as long as the assumption on fixed entry cost holds. We summarize our results in the following proposition.

Proposition 2. *Under linear demand, entry is insufficient if and only if* $2\sqrt{F} > \max\{m(d - c), c - d\}$.

That is, when entrants are more efficient, entry is always insufficient. When entrants are less efficient, entry is insufficient (excessive) when the cost gap is small (large). The reasons for our results are as follows.

First, entry creates a pure *business-stealing effect* in the downstream sector and a *business-creation effect* in the upstream sector as in the literature.

Second, if $d < c$, stealing business from the high-cost incumbents creates a positive *production-efficiency effect* by reducing the total cost of production in the industry. By analogy, entry creates a negative *production-inefficiency effect* if $d > c$.

Third, if $d < (>)c$, price discrimination hurts (benefits) the efficient (inefficient) entrants and reduces (improves) the pure *business-stealing effect*. This effect generated by price discrimination is new in our paper and is critical to our findings.

When the entrants are more efficient, i.e., $d < c$, the combined effects of business-creation and production-efficiency dominate the pure business-stealing effect, and lead to insufficient entry. When the entrants are inefficient, i.e., $d > c$, *production-inefficiency* occurs by shifting market share from the efficient incumbents to the inefficient entrants. If the entrants are not very inefficient in comparison to incumbents (i.e., $d - c < 2\sqrt{F}/m$), the business-creation effect dominates the combined effect of pure business-stealing and production-inefficiency, which leads to insufficient entry. However, when the entrants are sufficiently inefficient (i.e., $d - c > 2\sqrt{F}/m$), the pure business-stealing effect and the production-inefficiency effect dominate the business-creation effect, which creates excessive entry.

It is very important to note that our results under price discrimination are in sharp contrast to those obtained under uniform pricing by Cao and Wang (2020). The main reason is that inefficient firms benefit from price discrimination with a lowered input price. As such, price discrimination shifts production from efficient firms to inefficient firms, which therefore encourages (deters) entry of inefficient (efficient) entrants. Hence, if the entrants are inefficient (efficient), discriminatory pricing can create more (less) equilibrium number of firms compared to uniform pricing, which leads to higher (lower) industry output and consumer surplus under discriminatory pricing compared to uniform pricing. In this context, the result under uniform pricing is no longer true, implying the policy implications are significantly changed.

In this section, we consider a linear inverse demand function. However, the result that entry is always insufficient if $d \leq c$ critically depends on the shape of the demand function. To see that, we assume $d = c$ and rewrite (9) as

$$\frac{\partial SW}{\partial n} \mid_{n=n^*} = \underbrace{(p - w^* - c)(m\frac{\partial q_i^*(n)}{\partial n} + n\frac{\partial q_j^*(n)}{\partial n})}_{\text{business-stealing effect}} + \underbrace{(\frac{\partial m q_i^*(n)}{\partial n} + \frac{\partial n q_j^*(n)}{\partial n})w^*}_{\text{business-creation effect}},$$

where w^* denotes the uniform input price in equilibrium. Apparently, the production-(in)efficiency effect disappears if $d = c$.

If the demand is such that the business-stealing effect is dominated by the business-creation effect, i.e.,

$$(p - c)\left(m\frac{\partial q_i^*(n)}{\partial n} + n\frac{\partial q_j^*(n)}{\partial n}\right) + q_j^*(n)w^* > 0, \tag{17}$$

entry of firms is socially desirable which implies insufficient entry. In this case, if $d < c$, entry of firms should be insufficient because (i) entry of efficient firms creates a positive production-efficiency effect, and (ii) the discriminated pricing reduces the pure business-stealing effect. The condition in (17) holds true under a broad class of demand functions, including the linear demand studied in this section.

If the demand is such that condition (17) does not hold for $d = c$, entry is socially excessive at $d = c$. Since the equilibrium values are continuous in d, we can then say that although $d < c$ helps to increase the possibility of insufficient entry by creating the production efficiency effect, entry will still be excessive for some values of d which are lower but close to c.

6 Concluding Remarks

Free entry in a horizontal market has been well understood since Mankiw and Whinston (1986). Recently, the literature has examined free entry in vertical markets but with the consideration of identical firms. However, the real life situation is often different, where the entrants may be either more or less efficient than the incumbents. When we consider imitators which enters the market with knowledge spillover, the entrants may be inefficient due to the patent system and/or the complexity of the technology. In other situations where entrants have built the newest plants, they are more likely to be the efficient ones in production.

With such consideration, we propose a model of vertical relations with an input supplier and asymmetric final goods producers, including a fixed number of incumbents and a large number of potential entrants. We focus on entry in the final goods market with price discrimination by the input supplier. Our results suggest that the welfare effects of entry critically depend on the cost asymmetry between the incumbents and the entrants. When entrants are sufficiently inefficient, the positive business-creation effect is dominated by the negative business-stealing effect and production-inefficiency effect, and leads to excessive entry. Otherwise, when entrants are efficient or entrants are inefficient but the cost gap between the entrants and the incumbents is small, the negative business-stealing effect and the production-(in)efficiency effect are dominated and entry is insufficient. Our analysis indicates that the results in the vertical literature with identical firms are not necessarily valid when cost asymmetry and price discrimination are taken into consideration.

Appendix: Proofs

Appendix A: The derivation of (3)

In the second stage, the standard first order conditions are

$$\begin{cases} \frac{\partial \Pi(w_c,w_d)}{\partial w_c} & = mq_i^* + mw_c\frac{\partial q_i^*}{\partial w_c} + nw_d\frac{\partial q_j^*}{\partial w_c} = 0, \\ \frac{\partial \Pi(w_c,w_d)}{\partial w_d} & = mw_c\frac{\partial q_i^*}{\partial w_d} + nq_j^* + nw_d\frac{\partial q_j^*}{\partial w_d} = 0. \end{cases}$$

Differentiating the two equations in (1) with respect to w_c yields

$$\begin{cases} \frac{\partial q_i^*}{\partial w_c} & = \frac{(n+1)p'(Q^*)+p''(Q^*)nq_j^*}{p'(Q^*)((m+n+1)p'(Q^*)+Q^*p''(Q^*))} < 0; \\ \frac{\partial q_j^*}{\partial w_c} & = -\frac{mp'(Q^*)+mp''(Q^*)q_j^*}{p'(Q^*)((m+n+1)p'(Q^*)+Q^*p''(Q^*))} > 0. \end{cases}$$

Similarly, differentiating the two equations in (1) with respect to w_d yields

$$\begin{cases} \frac{\partial q_i^*}{\partial w_d} & = -\frac{np'(Q^*)+np''(Q^*)q_i^*}{p'(Q^*)((m+n+1)p'(Q^*)+Q^*p''(Q^*))} > 0; \\ \frac{\partial q_j^*}{\partial w_d} & = \frac{(m+1)p'(Q^*)+p''(Q^*)mq_i^*}{p'(Q^*)((m+n+1)p'(Q^*)+Q^*p''(Q^*))} < 0. \end{cases}$$

Incorporating the expressions of $\frac{\partial q_i^*}{\partial w_c}, \frac{\partial q_j^*}{\partial w_c}, \frac{\partial q_i^*}{\partial w_d}, \frac{\partial q_j^*}{\partial w_d}$ into the first order conditions leads to the equilibrium input prices in (3).

Appendix B: Proof of Lemma 1

By (3), we obtain that $w_d^* - w_c^* = p'(Q^*)(q_i^* - q_j^*)$. Furthermore, the equilibrium outcomes should satisfy the first order conditions in (1), which leads to $w_d^* - w_c^* = c - d + p'(Q^*)(q_j^* - q_i^*) = c - d - (w_d^* - w_c^*)$. Therefore, we have $w_d^* - w_c^* = (c-d)/2$. Further, we get $(w_d^* + d) - (w_c^* + c) = (d-c)/2$. Hence, $(w_d^* + d) - (w_c^* + c)$ increases with $(d-c)$.

Appendix C: Equilibrium Outputs

In stage 1, incorporating (3) into (2) leads to the equilibrium quantities as functions of the number of entrants, i.e., n, which are implicitly determined by

$$\begin{cases} q_i^*(n) & = \frac{p(Q^*(n))-c+p'(Q^*(n))\left(q_i^*(n)+Q^*(n)\right)+p''(Q^*(n))\left(m(q_i^*(n))^2+n(q_j^*(n))^2\right)}{-p'(Q^*(n))}; \\ q_j^*(n) & = \frac{p(Q^*(n))-d+p'(Q^*(n))\left(q_j^*(n)+Q^*(n)\right)+p''(Q^*(n))\left(m(q_i^*(n))^2+n(q_j^*(n))^2\right)}{-p'(Q^*(n))}, \end{cases}$$

where $Q^*(n) = mq_i^*(n) + nq_j^*(n)$.

We next verify the assumption which grantees positive quantities. As we see in (6), entrants always produce positive quantities, i.e., $q_j^* > 0$. Furthermore, if incumbents are more efficient (i.e., $c < d$), they produce positive quantities. Otherwise, following (6), incumbents are active in production only when the cost difference is small such that $(c-d)^2 < -4Fp'(Q^*)$.

Appendix D: Proof of Proposition 1

Simple calculations lead to

$$\begin{aligned}
\frac{\partial SW}{\partial n}\,|_{n=n^*} &= (p-c)m\frac{\partial q_i^*(n)}{\partial n} + (p-d)n\frac{\partial q_j^*(n)}{\partial n} + (p-d)q_j^*(n) + P'(Q^*)(q_j^*(n))^2 \\
&= (p-c)m\frac{\partial q_i^*(n)}{\partial n} + (p-d)n\frac{\partial q_j^*(n)}{\partial n} + w_d^* q_j^*(n) \\
&= \underbrace{(p-w_c^*-c)m\frac{\partial q_i^*(n)}{\partial n} + (p-w_d^*-d)n\frac{\partial q_j^*(n)}{\partial n}}_{\text{business-stealing effect}} + \underbrace{\frac{\partial m q_i^*(n)}{\partial n}w_c^* + \frac{\partial n q_j^*(n)}{\partial n}w_d^*}_{\text{business-creation effect}} \\
&= \underbrace{(p-w_d^*-d)\left(m\frac{\partial q_i^*(n)}{\partial n} + n\frac{\partial q_j^*(n)}{\partial n}\right)}_{\text{pure business-stealing effect}} + \underbrace{m((w_d^*+d)-(w_c^*+c))\frac{\partial q_i^*(n)}{\partial n}}_{\text{production-(in)efficiency effect}} + \underbrace{\frac{\partial m q_i^*(n)}{\partial n}w_c^* + \frac{\partial n q_j^*(n)}{\partial n}w_d^*}_{\text{business-creation effect}}, \\
&= \underbrace{(p-w_d^*-d)\left(m\frac{\partial q_i^*(n)}{\partial n} + n\frac{\partial q_j^*(n)}{\partial n}\right)}_{\text{pure business-stealing effect}} + \underbrace{\frac{m(d-c)}{2}\frac{\partial q_i^*(n)}{\partial n}}_{\text{production-(in)efficiency effect}} + \underbrace{\frac{\partial m q_i^*(n)}{\partial n}w_c^* + \frac{\partial n q_j^*(n)}{\partial n}w_d^*}_{\text{business-creation effect}}.
\end{aligned}$$

The second equality follows because we have $P'(Q^*)q_j^*(n) = -(P(Q^*) - d - w_d^*)$ by (2), and the last equality follows because we have $(w_d^* + d) - (w_c^* + c) = (d-c)/2$ in Lemma 1.

Appendix E: Proof of Lemma 2

It follows from (12) that $\partial n^*/\partial m = (\Delta - 2\sqrt{F})/(2\sqrt{F}) < 0$, and $\partial n^*/\partial \Delta = m/(2\sqrt{F}) > 0$. Furthermore, simple calculations lead to $\partial SW^*/\partial m = (\Delta - 2\sqrt{F})(\Delta - \sqrt{F})/2$ and $\partial SW^*/\partial \Delta = m(\Delta - 3\sqrt{F}/2)$. which yield the results in Lemma 2(ii).

Appendix F: Proof of Proposition 2

The denominator of (16) is positive since $a > 2\sqrt{F}(2+m) + (1+m)d - mc$. The sign of (16) is positive if $2\sqrt{F} + (c-d)m > 0$, which reduces to $d - c < 2\sqrt{F}/m$.

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