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Can more perishable products be welfare-improving?

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Abstract

We examine how product perishability affects equilibrium behavior in the Stackelberg model, including firms' output decisions, profits, and welfare. We show that while both firms increase their production levels, aggregate sales decrease in equilibrium due to perishability. Welfare can, however, increase with more perishable products if firms are sufficiently cost symmetric.

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1 Introduction

Some industries operate as Stackelberg oligopolies, especially those with intense innovation, such as pharmaceuticals, batteries, robotics, and transportation.[1] While this literature has been extended along many dimensions,[2] it assumes that the leader's output does not suffer from perishability across periods, including damaged units due to extreme weather events, accidents at the warehouse or during transportation to stores, or theft.

U.S. retailers, for instance, lost $46.8 billion of sales in 2017 due to inventory shrink (losses related to accidents, theft, error, or fraud), according to National Retail Security Survey (2018); and nearly $163 billion inventory was lost annually in the world (Rockeman, 2022).. Therefore, industries exhibiting low inventory turnover ratios (sales over inventory), such as retail, consumer discretionary (e.g., automotive and household durable goods) and technology, are particularly subject to perishability issues; while industries with high inventory turnover ratios, such as tourism or financial services, are less affected by these issues.

While our model considers perishability, our setting extends to industries where the leader suffers more stringent government regulations, needs of government permits, or trial and error costs than the follower does, ultimately increasing the leader's effective cost of production more significantly than the follower's. Examples include regulated markets, such as pharmaceuticals[3] and petrochemicals, as well as other industries with intense R&D investments, where the leader may go through more unsuccessful trials than the follower, incurring more costs[4], or where some of the leader's innovations are not fully patentable thus giving rise to knowledge spillovers.

In this paper, we examine how equilibrium behavior in a Stackelberg model is affected by perishability, analyzing output decisions, profits, and welfare. First, we find that the leader increases its output to compensate for perishability. Second, the follower becomes less sensitive to the leader's production (as in models allowing for product differentiation), responding by increasing its output.

While each firm produces more units, aggregate sales decrease as a result of perishability. This yields two opposite welfare effects: on one hand, a more perishable product decreases consumer surplus and the leader's profits; but, on the other hand, it increases the follower's profits. We show that, when the leader enjoys a strong cost advantage relative to the follower, the first effect domi-

[1] For empirical studies, see Cooper et al. (2019) and Qiu et al. (2021).

[2] For instance, it considers several firms (Boyer and Moreaux, 1986; Sherali, 1984), welfare comparisons (Watt, 2002), mergers (Daughety, 1990; Huck, Konrad, and Müller, 2001; Heywood and McGinty, 2007, 2008), product differentiation (Ferreira et al., 2013), information asymmetry (Mukhopadhyay, Yue, and Zhu, 2011), uncertainty in costs (Cumbul, 2021) or in demand (Liu, 2005), and mixed oligopolies (Zikos, 2007). For a literature review, see Julien (2018).

[3] Consider for instance drugs combating Covid-19 such as Paxlovid (by Pfizer Inc.) and Molnupiravir (by Merck Sharp & Dohme LLC.), both being under intense scrutiny after receiving Emergency Use Authorization (EUA) in the US. It is expected that subsequent costs of producing derivative or generic drugs will be lower for entrants in the future.

[4] Examples include Samsung and Apple, being leaders in the development of smartphones, incuring more R&D costs than Chinese companies that entered the market years later, such as Huawei and Xiaomi, among others.

nates, and overall welfare decreases when products become more perishable. Otherwise, the second effect dominates and welfare increases. Intuitively, a more perishable product helps ameliorate the cost differential between the two firms, leading to a large increase in the follower's profits, which entails an overall welfare gain.

Our welfare results go in line with Lahiri and Ono's (1988) where, in an oligopoly competing simultaneously, they show that an increase in cost asymmetry can be welfare improving. Similarly, we show that the increase in cost asymmetry (in our setting, because the leader's product is more perishable) becomes welfare improving under larger parameter conditions than in Lahiri and Ono (1988). This literature has considered variations, such as the proportion of efficient firms and entry, Zhao (2001) and Mukherjee et al. (2009), and taxation, Dinda and Mukherjee (2014) and Wang et al. (2019a). However, all the above studies consider Cournot competition. In a Stackelberg setting allowing for cost asymmetry, Mukherjee and Zhao (2009) and Yoshida (2016) show that an increase in the number of inefficient followers can increase the leader's profits, as in our paper where the leader produces more units in equilibrium to compensate for a higher degree of perishability; and Wang et al. (2019b), which analyze how the change in the number of relatively efficient leaders affects consumer surplus and welfare in different tax regimes.[5]

From a policy perspective, our findings suggest that policies lowering regulation costs, facilitating permits, and reducing firms' trial and error costs are welfare-improving when the leader (after taking into account the cost of perishability) has a large cost disadvantage; but can lead to welfare losses otherwise. Hence, these policies are justified in markets where the leader enjoys a large cost advantage, but become welfare reducing otherwise.

The paper is organized as follows. Section 2 presents the model. Section 3 examines equilibrium behavior, including profit and welfare comparisons; and finally, section 4 concludes.

2 Model

Consider two firms sequentially competing in quantities (à la Stackelberg) where, in the first period, the leader (firm 1) chooses its output, q_1; and, in the second period, after observing q_1, the follower (firm 2) responds selecting its output, q_2. Firms face an inverse demand function $p(Q) = 1 - Q$, where $Q = q_1 + q_2$ denotes aggregate output. We assume that firms' marginal costs, c_1 and c_2, satisfy $0 \leq c_1 \leq c_2 < \frac{1}{3}$, where the upper bound on costs guarantees that both firms are active under all parameter conditions.

Production is sold in the second period, but a share $\gamma \in [0, 1]$ of the leader's output perishes between the first and second period, meaning that the leader only sells $(1 - \gamma) q_1$ units in the second

[5] Pal and Sarkar (2001) also considers a Stackelberg model with asymmetric costs, but assumes a "hierarchical" setting, where every firms decides output in each stage, instead of all leaders (all followers) choosing their output in the first (second) stage.

period whereas the follower sells all its production (q_2 units). The loss of γq_1 can be due to any of the factors described in the previous section.

3 Equilibrium analysis

Second period. From our above discussion, a total of $(1-\gamma)\,q_1+q_2$ units are brought to the market, implying that the follower solves

$$\max_{q_2\geq 0}\ \pi_2\,(q_2)=[1-(1-\gamma)\,q_1-q_2]\,q_2-c_2q_2$$

which yields the following best response function,

$$q_2(q_1)=\begin{cases}\frac{1-c_2}{2}-\frac{1-\gamma}{2}q_1 & \text{for all } q_1\leq\frac{1-c_2}{1-\gamma}\\ 0 & \text{otherwise.}\end{cases}$$

As expected, when products do not perish across periods, $\gamma=0$, this best response function coincides with standard Stackelberg models, $q_2(q_1)=\frac{1-c_2}{2}-\frac{1}{2}q_1$ for all $q_1\leq 1-c_2$, but zero otherwise; as figure 1 depicts. When products become more perishable, however, the best response function is flatter. Intuitively, the follower is less affected by a given increase in the leader's output (higher q_1) when a smaller share of this output reaches the second period (higher γ). In the extreme case where $\gamma=1$, the follower is unaffected by q_1, producing the monopoly output $q_2=\frac{1-c_2}{2}$.

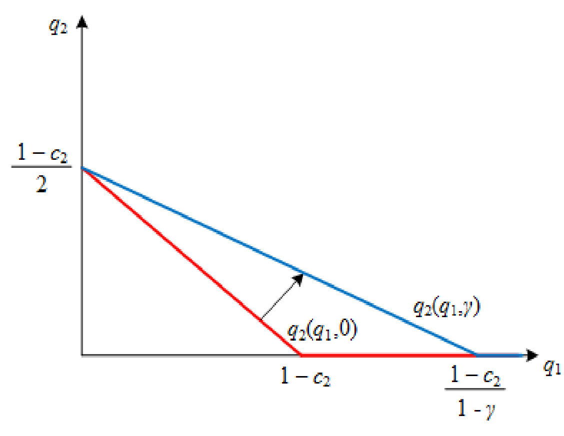

Figure 1. Follower's best response function as a function of γ.

Therefore, perishability generates a similar effect in the follower's best response function as product differentiation does (a flattening effect), attenuating firms' output competition.[6]

First period. The leader anticipates the follower's best response function, $q_2(q_1)$, and chooses q_1 to solve

$$\max_{q_1 \geq 0} \ \pi_1(q_1) = [1 - (1-\gamma) q_1 - q_2(q_1)] (1-\gamma) q_1 - c_1 q_1$$

which we identify in the next lemma. For compactness, we normalize the leader's cost to $\widetilde{c}_1 \equiv \frac{c_1}{1-\gamma}$, which denotes the "effective cost" of producing and bringing one more unit of output to the market. If $\gamma = 0$, this cost is just $\widetilde{c}_1 = c_1$, but otherwise the effective cost increases, becoming infinite when $\gamma \to 1$.

Lemma 1. *The leader's equilibrium output is* $q_1^*(\gamma) = \frac{1+c_2-2\widetilde{c}_1}{2(1-\gamma)}$, *which is positive if and only if* $\widetilde{c}_1 < \bar{c}_1 \equiv \frac{1+c_2}{2}$, *and* $q_1^*(\gamma)$ *is unambiguously decreasing (increasing) in* $\widetilde{c}_1$ (c_2). *In addition,* $q_1^*(\gamma)$ *unambiguously increases in* γ *as long as it produces positive units.*

Therefore, the leader's output decreases in its own marginal costs but increases in its rival's. When products become more perishable (higher γ), two effects arise: a direct effect, reducing the proportion of leader's output that reaches the second period; and an indirect effect, making the leader produce more units to compensate for the higher perishability. When the leader benefits from a significant cost advantage, $\widetilde{c}_1 < \bar{c}_1$, the indirect effect dominates because it is relatively easy for the leader to compensate the effects of perishability, leading to an overall increase in $q_1^*(\gamma)$.

Since $0 \leq c_1 \leq c_2 < \frac{1}{3}$ by assumption, the leader produces a positive output if $\widetilde{c}_1$ lies below cutoff $\bar{c}_1$ and the 45-degree line, that is, $\widetilde{c}_1 < \min\{\bar{c}_1, c_2\}$. In addition, when firms are symmetric, $c_1 = c_2 = c$, the cost condition $\widetilde{c}_1 < \bar{c}_1$ simplifies to $\frac{c}{1-\gamma} < \frac{1+c}{2}$, or $c < \frac{1-\gamma}{1+\gamma}$, which is unambiguously decreasing in γ. Hence, when products are completely perishable ($\gamma = 1$), the cutoff becomes zero, i.e., $c < 0$, implying that the leader is inactive regardless of its cost. In contrast, when products are non-perishable ($\gamma = 0$) the condition simplifies to $c < 1$, entailing that the leader is active for all admissible parameters.

Inserting $q_1^* = \frac{1+c_2-2\widetilde{c}_1}{2(1-\gamma)}$ into the follower's best response function, the follower's equilibrium output becomes $q_2^* = \frac{1-3c_2+2\widetilde{c}_1}{4}$, which is positive for all admissible parameters.[7] The next proposition analyzes the comparative statics of our equilibrium results with respect to parameter γ.

Proposition 1. *The leader's equilibrium profit unambiguously decreases in* γ, *but the follower's equilibrium output and profit increase in* γ.

Intuitively, the leader hurts when products become more perishable (higher γ), but the follower benefits. In particular, an increase in γ produces two effects on the follower's output: a direct

[6] For instance, if firms face an inverse demand function similar to that in Singh and Vives (1984), $p_i(q_i, q_j) = 1 - q_i + \lambda q_j$, where parameter $\lambda \in [0,1]$ denotes product differentiation, i.e., $\lambda = 0$ indicates completely differentiated whereas $\lambda = 1$ entails homogeneous products. In this setting, the follower's best response function becomes $q_i(q_j) = \frac{1-c_i}{2} - \frac{\lambda}{2} q_j$, which is flatter when products are more differentiated (lower λ).

[7] Equilibrium output $q_2^* > 0$ since $c_1 \leq c_2 < \frac{1}{3}$ by definition.

(positive) effect, from the flatting of its best response function, making this firm more "immune" to the leader's output choice, which leads to an increase in q_2 for a given q_1. On the other hand, an increase in γ produces an indirect (negative) effect on the follower's output, since q_1 increases, leading to a reduction in q_2. Overall, Proposition 1 shows that the first (positive) effect dominates, leading to an overall increase in the follower's output and profit.[8]

3.1 Welfare analysis

Proposition 2. *Aggregate sales, $(1-\gamma)\, q_1^* + q_2^*$, are decreasing in γ.*

Therefore, while both firms may increase their output when products become more perishable (higher γ, as shown in Lemma 1), aggregate sales, $(1-\gamma)\, q_1^* + q_2^*$, unambiguously decrease in γ, ultimately increasing prices and decreasing consumer surplus.

We next investigate the comparative statics of social welfare with respect to γ. For presentation purposes, we "denormalize" the leader's cost, from $\widetilde{c}_1 \equiv \frac{c_1}{1-\gamma}$ to c_1, to depict our results as a function of γ.

Proposition 3. *Social welfare decreases in γ if and only if $c_1 < c_1^{SW}(\gamma) \equiv \frac{(1-\gamma)(5+9c_2)}{14}$, where cutoff $c_1^{SW}(\gamma)$ satisfies $c_1^{SW}(\gamma) < \frac{(1-\gamma)(1+c_2)}{2} \equiv c_1(\gamma)$ for all admissible parameters.*

Our results in Lemma 1 and Proposition 3 then give rise to three regions: (i) if $c_1 < c_1^{SW}(\gamma)$, the leader is active and welfare decreases when products become more perishable (higher γ); (ii) if $c_1^{SW}(\gamma) \leq c_1 < c_1(\gamma)$, the leader is still active but welfare now increases in γ; and (iii) otherwise, the leader is inactive.

In the case that firms are symmetric, $c_1 = c_2 = c$, these cutoffs simplify to $c_1(\gamma) = \frac{1-\gamma}{1+\gamma}$ and $c_1^{SW}(\gamma) = \frac{5(1-\gamma)}{5+9\gamma}$, which satisfy $c_1(\gamma) > c_1^{SW}(\gamma)$ for all values of γ; as illustrated in figure 2.

[8] Technically, two cases arise. First, if c_1 satisfies $\frac{c_1(\gamma)}{2} \leq c_1 < c_1(\gamma)$, where $c_1(\gamma) \equiv \frac{(1-\gamma)(1+c_2)}{2}$, the direct (positive) effect remains but the indirect (negative) effect vanishes, yielding an unambiguous increase in the follower's output and profit. Second, if $c_1 < \frac{c_1(\gamma)}{2}$, the direct and indirect effects arise, but the direct effect dominates, implying that overall firm 2's output increases. Therefore, firm 2's output increases in both cases.

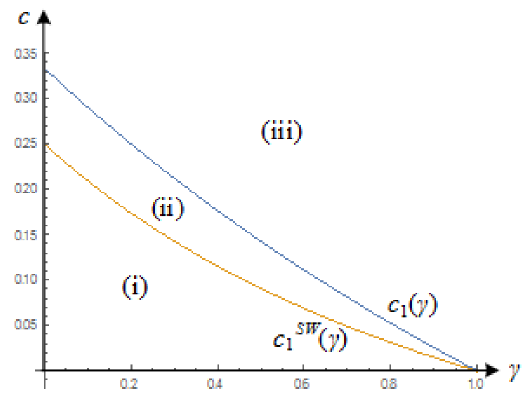

Figure 2. Welfare analysis with cost symmetry.

Intuitively, more perishable products lead to a positive welfare effect (higher profits for the follower, as shown in Proposition 1) and two negative welfare effects (loss in consumer surplus, as shown in Proposition 2, and reduction in the leader's profits, as shown in Proposition 1). As a consequence, when the leader's cost advantage is relatively strong, $c_1 < c_1^{SW}(\gamma)$ in region (i), its profit loss is so severe that overall welfare decreases. In contrast, when firms are more symmetric (in region ii), the follower's profit gain dominates the welfare losses, leading to an overall increase in welfare.

Our above analysis assumes that consumer and producer surplus receive the same weight in the welfare function, $W = CS + PS$, where $PS = \pi_1 + \pi_2$. In most contexts, consumer surplus may have a larger weight than producer surplus, entailing that $W(\lambda) = \lambda CS + (1-\lambda)PS$, where $\lambda \geq 1/2$. In this setting, more perishable products become welfare reducing under larger parameter conditions, graphically expanding region (i) while shrinking region (ii).

3.2 Connection to Lahiri and Ono (1988)

Our findings go in line with those in Lahiri and Ono (1988). In the context of cost-asymmetric firms competing à la Cournot, they show that if a major firm in the industry (i.e., whose market share is above 1/3) experiences a cost increase, total welfare decreases. In our context, the leader's market share is $\alpha_L = \frac{(1-\gamma)q_1^*}{Q^*}$, which satisfies $\alpha_L > 1/3$ if and only if $c_1 < c_1^{OS}(\gamma) \equiv \frac{(1-\gamma)(3+7c_2)}{10}$, where superscript OS denotes "output share." In this case, however, an increase in its cost asymmetry (which occurs when parameter γ increases) yields a welfare loss if and only if $c_1 < c_1^{SW}(\gamma) \equiv \frac{(1-\gamma)(5+9c_2)}{14}$ (see Proposition 3), where $c_1^{SW}(\gamma) > c_1^{OS}(\gamma)$ because $c_1^{OS}(\gamma) - c_1^{SW}(\gamma) = -\frac{2(1-\gamma)(1-c_2)}{35} < 0$ for all parameter values.

This comparison gives rise to three regions: (i) when c_1 is relatively low, $c_1 < c_1^{OS}(\gamma)$, the leader is the major firm, and an increase in its cost differential (higher γ) yields an increase in total welfare; (ii) when c_1 is intermediate, $c_1^{OS}(\gamma) \leq c_1 < c_1^{SW}(\gamma)$, the leader is no longer the major firm, but an increase in the leader's cost differential (higher γ) still produces a welfare gain; and (iii) otherwise, the leader is not the major firm, but an increase in the leader's cost differential yields a welfare loss. Regions (i) and (iii) are analogous to Lahiri and Ono (1988) where, intuitively, the leader's cost efficiency is sufficiently intense (small) to entail a welfare gain (loss, respectively). Region (ii), however, only arises in our setting, implying that sequential competition allows cost increases to yield welfare gains under a larger set of parameters than when firms compete simultaneously. In other words, the leader's cost inefficiency must be more significant (higher c_1) for an increase in cost asymmetries (higher γ) to become welfare reducing.

4 Conclusions

Overall, our results suggest that, if products become more perishable (because of inventory losses, for instance, when firms face more frequent extreme climate events or thefts), welfare would decrease, but only when firms are relatively cost asymmetric. Intuitively, the leader is relatively efficient, being socially optimal for this firm to produce more units than the follower. In this setting, investments that help reduce inventory losses –informally, "protecting" the leader's cost advantage– would be welfare improving.

In contrast, when firms are relavively cost symmetric, our findings indicate that more perishable products yield welfare gains. In this context, both firms are relatively similar but the follower suffers no perishability issues, enabling this firm to bring more units to final customers to compensate for the leader's inventory losses, ultimately increasing social welfare. Therefore, our results suggest that, in this setting, there is no need of policies helping the leader reduce the perishability of its products; otherwise, the enactment of these policies would be welfare reducing.

5 Appendix

5.1 *Proof of Lemma 1*

Differentiating $\pi_1(q_1)$ with respect to q_1, and assuming an interior solution, yields $\frac{(1-\gamma)[1+c_2-2(1-\gamma)q_1]-2c_1}{2} = 0$. Solving for q_1, yields $q_1^* = \frac{(1-\gamma)(1+c_2)-2c_1}{2(1-\gamma)^2}$. Dividing numerator and denominator by $(1-\gamma)$, yields $q_1^* = \frac{1+c_2-2\widetilde{c}_1}{2(1-\gamma)}$, where $\widetilde{c}_1 \equiv \frac{c_1}{1-\gamma}$. This output level is positive if and only if $\widetilde{c}_1 < \frac{1+c_2}{2}$. In addition, q_1^* satisfies $\frac{\partial q_1^*}{\partial \gamma} = \frac{1+c_2-2\widetilde{c}_1}{2(1-\gamma)^2} > 0$, which holds if $\widetilde{c}_1 < \frac{1+c_2}{2}$.

5.2 *Proof of Proposition 1*

Substituting q_1^* into the leader's profit function, we find $\pi_1^* = \frac{[(1-\gamma)(1+c_2)-2c_1]^2}{8(1-\gamma)^2}$, which reduces to $\frac{(1-2c_1+c_2)^2}{8}$ when $\gamma = 0$. In addition, π_1^* satisfies $\frac{\partial \pi_1^*}{\partial \gamma} = -\frac{c_1[(1-\gamma)(1+c_2)-2c_1]}{2(1-\gamma)^3} < 0$.

Inserting $q_1^* = \frac{(1-\gamma)(1+c_2)-2c_1}{2(1-\gamma)^2}$ into the follower's best response function, we find $q_2^* = \frac{(1-\gamma)(1-3c_2)+2c_1}{4(1-\gamma)}$, which satisfies $\frac{\partial q_2^*}{\partial \gamma} = \frac{c_1}{2(1-\gamma)^2} > 0$. Finally, substituting q_1^* and q_2^* into the follower's profit function, yields $\pi_2^* = \left(\frac{(1-\gamma)(1-3c_2)+2c_1}{4(1-\gamma)}\right)^2 = (q_2^*)^2$, implying that the follower's profit unambiguously increases in γ.

5.3 *Proof of Proposition 2*

Aggregate sales become

$$
\begin{aligned}
Q^* \equiv (1-\gamma)\, q_1^* + q_2^* &= \frac{(1-\gamma)\,(1+c_2)-2c_1}{2\,(1-\gamma)} + \frac{(1-\gamma)\,(1-3c_2)+2c_1}{4\,(1-\gamma)} \\
&= \frac{(1-\gamma)\,(3-c_2)-2c_1}{4\,(1-\gamma)}
\end{aligned}
$$

which decreases in c_1 and c_2, and in γ since $\frac{\partial Q^*}{\partial \gamma} = -\frac{c_1}{2(1-\gamma)^2} < 0$. In addition, the equilibrium price becomes $p^* = 1 - Q^* = \frac{(1-\gamma)(1+c_2)+2c_1}{4(1-\gamma)}$, which increases in c_1 and c_2, and in γ because $\frac{\partial p^*}{\partial \gamma} = \frac{c_1}{2(1-\gamma)^2} > 0$.

5.4 *Proof of Proposition 3*

Social welfare is $SW^* = CS^* + \pi_1^* + \pi_2^*$,

$$
\begin{aligned}
SW^* &= \frac{[(1-\gamma)\,(3-c_2)-2c_1]^2}{32\,(1-\gamma)^2} + \frac{[(1-\gamma)\,(1+c_2)-2c_1]^2}{8\,(1-\gamma)^2} + \frac{[(1-\gamma)\,(1-3c_2)+2c_1]^2}{16\,(1-\gamma)^2} \\
&= \frac{(1-\gamma)^2\left(15-10c_2+23c_2^2\right) - 4c_1\,(1-\gamma)\,(5+9c_2) + 28c_1^2}{32\,(1-\gamma)^2}
\end{aligned}
$$

which satisfies $\frac{\partial SW^*}{\partial \gamma} = \frac{c_1[14c_1-(1-\gamma)(5+9c_2)]}{8(1-\gamma)^3} < 0$ if and only if $c_1 < c_1^{SW}(\gamma) \equiv \frac{(1-\gamma)(5+9c_2)}{14}$. Cutoff $c_1^{SW}(\gamma)$ satisfies $c_1^{SW}(\gamma) < c_1(\gamma)$ for all admissible parameters since $c_1^{SW}(\gamma) = \frac{(1-\gamma)(5+9c_2)}{14} < \frac{(1-\gamma)(1+c_2)}{2} = c_1(\gamma)$ simplifies to $2\,(1-\gamma)\,c_2 < 2\,(1-\gamma)$, which holds because $c_2 < 1$ by definition.

References

[1] Boyer, M. and M. Moreaux (1986) "Perfect competition as the limit of a hierarchical market game," Economics Letters, 22(2-3), pp. 115-118.

[2] Cooper, M., J. Lee, J. Beck, J.D. Fishman, M. Gillett, Z. Papakipos, A. Zhang, J. Ramos, and A. Shah (2019) "Stackelberg Punishment and Bully-Proofing Autonomous Vehicles," in *Social Robotics,* M. Salichs, S.S. Ge, E.I. Barakova, and J.-J. Cabibihan (eds.), Springer International Publishing, 11876, pp. 368–377.

[3] Cumbul, E. (2021) "Stackelberg versus Cournot oligopoly with private information," International Journal of Industrial Organization, 74, 102674.

[4] Daughety, A. (1990) "Beneficial Concentration," American Economic Review, 80(5), pp 1231-37.

[5] Dinda, S., and Mukherjee, A. (2014) "A note on the adverse effect of competition on consumers," Journal of Public Economic Theory, 16, pp. 157–163.

[6] Ferreira, F.A., Ferreira, F., Ferreira, M., and Pinto, A.A. (2013) "Flexibility in a Stackelberg leadership with differentiated goods," Optimization: A Journal of Mathematical Programming and Operations Research, 64(4), pp. 877-893.

[7] Heywood, J. and M. McGinty (2007) "Mergers among leaders and mergers among followers," Economics Bulletin, 12(12), pp. 1-7.

[8] Heywood, J. and M. McGinty (2008) "Leading and merging: convex costs, Stackelberg, and the merger paradox," Southern Economic Journal, 74(3), pp. 879-893.

[9] Huck, S., Konrad, K.A., and Müller W. (2001) "Big fish eat small fish: On merger in Stackelberg markets," Economics Letters, 73(2), pp. 213-217.

[10] Julien, L. A. (2018) "Stackelberg games," in *Handbook of Game Theory and Industrial Organization*, Volume I, Luis C. Corchón and Marco A. Marini (eds.), Edward Elgar Publishing.

[11] Lahiri, S. and Y. Ono (1988) "Helping Minor Firms Reduces Welfare," Economic Journal, 98, pp. 1199-1202.

[12] Liu, Z. (2005) "Stackelberg leadership with demand uncertainty," Managerial and Decision Economics, 26(5), pp. 345-350.

[13] Mukherjee, A., and Zhao, L., (2009) "Profit Raising Entry," Journal of Industrial Economics, 57, 870.

[14] Mukherjee, A., Broll, U., & Mukherjee, S. (2009). The welfare effects of entry: The role of the input market. Journal of Economics, 98, pp. 189–201.

[15] Mukhopadhyay, S, Yue, X. and Zhu, X. (2011) "A Stackelberg model of pricing of complementary goods under information asymmetry," International Journal of Production Economics, 134, pp. 424-433.

[16] National Retail Security Survey (2018), National Retail Federation, June 6th.

[17] Pal, D., and Sarkar, J. (2001) "A Stackelberg Oligopoly with Nonidentical Firms," Bulletin of Economic Research, 53(2), pp. 127-134.

[18] Qiu, H., W. Gu, L. Wang, G. Pan, Y. Xu, and Z. Wu (2021) "Trilayer Stackelberg Game Approach for Robustly Power Management in Community Grids," IEEE Transactions on Industrial Informatics, 17(6), pp. 4073–4083.

[19] Rockeman, O. (2022) "Oversupply, Damage Sees $163 Billion in Inventory Tossed Annually," Bloomberg Newsletter, November 10th.

[20] Sherali, H. (1984) "A multiple leader Stackelberg model and analysis", Operation Research, 32, pp. 390-404.

[21] Wang, L. F. S., Zeng, C. H., and Zhang, Q. D. (2019a) "Indirect taxation and undesirable competition," Economics Letters, 181, pp. 104–106.

[22] Wang, L., Zeng, C., and Zhang, Q. (2019b) "Indirect taxation and consumer welfare in an asymmetric Stackelberg oligopoly," North American Journal of Economics and Finance, 50, 101034.

[23] Watt, R. (2002) "A generalized oligopoly model", Metroeconomica, 53, pp. 46-55.

[24] Yoshida, S. (2016) "Market competition, firm profits and welfare in a Stackelberg oligopoly with cost asymmetry," Graduate School of Economics, Osaka University, Working paper series.

[25] Zhao, J. G. (2001) "A characterization for the negative welfare effects of cost reduction in Cournot oligopoly," International Journal of Industrial Organization, 19, pp. 455–469.

[26] Zikos, V. (2007) "Stackelberg mixed oligopoly with asymmetric subsidies," Economics Bulletin, 12(13), pp. 1-5.