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The Incidence on Prices and Efficiency Consequences

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Tax Reform on Monopoly Platformer in Borderless Economy: The Incidence on Prices and Efficiency Consequences*

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Abstract

As development of online market brings ongoing concerns that foreign app suppliers avoid value-added tax (VAT) in a domestic country, some countries design a tax reform which makes platform pay VAT instead of app suppliers (platform taxation). In the market where the monopoly platformer determines the prices of the network good and the commission fee of the platform services (with online apps as a representative example), this study investigates whether the prevention of tax leaks by platform tax improves the welfare of the host country, as well as the extent of the cross-market incidence of the two-sided market. We find that the tax reform reduces foreign app suppliers and consumption of a network good such as smartphones, with substantial extent of cross-market pass-through. The effect of the tax reform on home app suppliers crucially depends on the responsiveness of the app supplies from the number of users, which we call entry elasticity. Platform tax also increases the tax burden laid on the network product, but the monopoly seller let the increase of the tax burden born entirely by consumers. We also show that digitalization reduces the loss of welfare as well as tax planning by the platformer.

Keywords: Value-added tax; Tax reform; Digital economy; Platform; Network externality

JEL classification number: F23; H26;

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1 Introduction

Development of online technologies has allowed firms to run business online and made collecting consumption-based tax revenues difficult. For example, worldwide total revenues of app market in 2022 was 437 billion U.S. dollars and a market volume of 781 billion U.S. dollars is expected by 2029.[1] Although such a huge online market and potentially large sources for tax revenues from consumption, governments have sometimes failed to enforce foreign firms' tax payments. This is because online firms can make profits from foreign countries without having any stand-alone subsidiaries, since transactions are either intangible or difficult to capture for tax purposes. Therefore, an argument about "border tax" has grown and some policy changes have been conducted.[2] For the cross-boarder transactions, recently there has been a large shift from the source principle to the destination principle.[3]

Although this policy shift is expected to fix unfair tax treatment among online platformers locating different countries, there remains an issue of the destination principle when online content providers serve their contents from abroad. For example, more than half of top-hundred smartphone games in Japan in 2022 were developed and released by foreign firms but some of these companies avoid paying tax to Japan.[4] Because several foreign online-game/app suppliers do not have their entity in Japan, it is difficult for Japanese tax authority to collect value-added tax (VAT) from them. As the general consumption tax is one of the important and stable sources of tax revenues, such tax avoidance behaviors worsen welfare by leading to a reduction in public good provisions, and some additional policy designs are required.[5]

To address this issue, some new tax reforms have recently been in effect. Japanese government, for example, aims at implementing a new tax rule in 2025 that makes online platformers instead of foreign app suppliers pay VAT (platform tax).[6] Because foreign app suppliers cannot avoid VAT

[1] See `https://www.statista.com/outlook/amo/app/worldwide`, accessed 2025 February 5th.

[2] There exists a long discussion on border tax from the viewpoint of tangible trasnsaction. Keen (2007) and Keen (2008), for example, showed that a large fraction of the VAT in developing countries accrued on the national boarder, so that the administrative feature of the boarder tax, whose administration costs are as low as the import tariff, remains valid for the importing goods. However, an important omission from this argument is the case of services, especially online services, where the provision of the service is not constrained by the physical national boarders.

[3] A famous example of the tax leak in the former system is the case of ebooks and the digital musical contents provided by Amazon.jp. With the reason that these services are provided through an American corporate Amazon.com Int'l Sales, Inc.. Amazon.jp was exempted from paying the VAT from Japanese customers. This unfair tax treatment to domestic content providers was removed in 2015, by changing the digital NEXUS of VAT from the provider to the customer of the digital services.

[4] See `https://www.nikkei.com/article/DGKKZO67632310X10C23A1MM8000/`, accessed 2025 February 5th. In addition, Japanese tax authority penalised Epic Games, a United States (U.S.) company supplying an online game "Fortnite", with more than 23 million U.S. dollars for their under-reporting (`https://www.nikkei.com/article/DGXZQOUE253190V21C23A0000000/`, accessed 2025 February 5th).

[5] The overall share of consumption taxes in Organisation for Economic Co-operation and Development (OECD) countries are around 30% (OECD, 2024).

[6] See `https://www.nikkei.com/article/DGXZQOUA052NL0V01C23A1000000/` and `https://news.bloombergtax.`

payment under the new rule, the Japanese government estimates to increase tax revenues by 154 U.S. million dollars per year. Canada also introduced a similar rule which obliges platformers to report information on foreign sellers and their sales, which is helpful for the authority to collect tax revenues from foreign online vendors.[7] Moreover, these new rules to prevent foreign content suppliers from avoiding taxes by using platformers pursue fair tax burdens between domestic and foreign content suppliers and seem to be desirable for a country which introduces it.

However, understanding such welfare effects of a tax reform beyond tax revenues is crucially important once we consider a digital market. Since online markets are characterized by oligopoly with a few gigantic firms with price setting power, tax incidence and welfare effects of shrinking online platform market can be sizable compared to one with perfect competition.[8] Moreover, the size of so-called two-sided market (online platforms such as App Store and Google Store) is determined by network externalities. An attractiveness of a platform is determined by the numbers of consumers and app suppliers: more individuals in a platform increases profitability of app suppliers and more apps in a platform increases consumers willingness to enter the platform.[9] In turn, consumers and even home app suppliers may suffer from the reform due to a downsized platform, which is conceptually argued by Cui (2019). Therefore, whether a country has welfare gains from the introduction of such a tax reform is an important issue, so we explore conditions under which introducing the tax reform hurts the country's welfare. In particular, the following two questions are addressed in the study. When the monopoly platformer reacts to tax reform through price changes, does the reform benefit domestic consumers and content suppliers, and improve domestic welfare? Also, when the number of network users and the number of providers of platform services (with online apps as a representative example) reinforce each other through network externalities, how much of burdens from the tax reform is accrued to whom?

With the above concerns, we combine Kao and Mukunoki (2022) and Wu et al. (2023) to construct a theoretical model with two different country's app suppliers, and examine how the tax reform affects home country. Specifically, our model considers a foreign monopoly platformer (such as Apple) who operates its online platform (App Store) for home consumers who use a network good

com/daily-tax-report-international/japans-vat-reforms-will-impact-major-digital-platform-operators, accessed 2025 February 5th.

[7]See https://www.canada.ca/en/revenue-agency/news/newsroom/tax-tips/tax-tips-2024/operating-digital-platform.html, accessed 2025 February 5th.

[8]For example, Johansson et al. (2017) showed that industries with a strong presence of tax-planning multinational corporations tend to be concentrated. This implies that tax reform relating to online platformers has secondary effects on the two-sided markets, which is in question.

[9]Such positive spillovers between consumer- and producer-sides are known as an indirect network externalities while network externality is categorized into indirect and direct network externlities. See Zodrow (2003) for a discussion on network externalities in the context of taxation.

for the access to the platform (iPhone). Via the platform, both home and foreign app suppliers provide their apps to home consumers.

Before the tax reform is implemented, more foreign app suppliers enter the online market than home app suppliers because foreign app suppliers can avoid VAT payments. Once the tax reform is in effect and foreign app suppliers are subject to tax burden via the platformer, this location advantage for tax saving disappears and the number of foreign app suppliers decreases. As such a decline in the foreign app suppliers lowers attractiveness of the platform, the platformer sets a lower commission fee but foreign app suppliers face a higher tax-included commission fee. Importantly, as the platformer also holds the price-making power for the network good with which consumers get access to the platform, there arises a pass through as a substantial increase in the price of the network good. As the two pass through effects make the platform less attractive, the tax reform downsizes the platform in the sense of the numbers of both users and app suppliers. Further results on the tax incidence of prices are as follows. The platformer maintains its per-unit tax burden after the tax reform. Due to the monopoly setting, the platformer puts burden from the tax reform on the network-good consumers and foreign consumers. Specifically, our theoretical model shows that more than 40% of burden from the tax reform goes to home consumers.

Interestingly, our model finds that the tax reform can increase the number of home app suppliers. This is because the reform removes location advantage of foreign app suppliers who are not subject to VAT payments and is expected to induce more entries of home app suppliers. However, the reform causes a downsized platform, which decreases profitability of home app suppliers. We show that the introduction of the tax reform *decreases* the number of home app suppliers and producer surplus of home app suppliers when the responsiveness of the app supplies from the number of users, which we call *entry elasticity* is high. We also show that this elasticity is characterized by the number of potential app producers and firm heterogeneity. As the mechanism stems from the indirect network externality, this result is two-sided specific and relevant for online platforms.

Furthermore, this entry elasticity also affects the consumer surplus and the tax revenue. If entry elasticity is low, the efficient domestic firms' entry mentioned above as the fair-tax effect is relatively strong in comparison to the exit response due to the downsized market, so the decrease of the consumer surplus by the network-good users is curved. Also, lower entry elasticity increases the tax revenue as a result of tax reform.

Platform tax also increases the tax burden laid on the network product, but the monopoly seller let the increase of the tax burden born entirely by consumers. We also show that digitalization reduces the loss of welfare as well as tax planning by the platformer.

This study contributes to several strands of literature. First, as our main focus is on the tax reform in the context of digital economy, we add new insights in the growing literature on international tax and digital economy. In the literature of Public Economics, some studies explored international tax and e-commerce.[10] Aiura and Ogawa (2024) compared outcomes under the destination and origin principle and concluded that tax competition on e-commerce under destination principle is more intense than that under origin principle.

Second, our research also relates to a growing literature of the tax incidence in a platform model (Agrawal and Fox (2017)). Kind et al. (2008) and several others that followed (see Belleflamme and Toulemonde (2018) and Kind and Koethenbuerger (2018)) analyze taxation in a two-sided market, which shows that ad-valorem taxes don't necessarily dominate unit taxes, which is not consistent with well-known results proposed by Suits and Musgrave (1953). This study is distinct from previous studies because we focus on the tax incidence of requiring platformer to pay taxes, rather than on a comparison of ad-valorem taxes and unit taxes. Some studies examine the impact of taxing platfomer on the entry and exit behavior of consumers and producers. Bourreau et al. (2018) shows that under certain conditions, taxation of data collection by platformer would increase tax revenues through the entry of users. Tremblay (2018) shows that differential taxation on sales of a platformer encourages the entry of agents in one side but discourages the entry of agents in the other side. Unlike these studies, our study provides implications of taxing on platformer for the entry behavior of domestic and foreign producers.

Third, Mukunoki and Okoshi (2025) examined a multi-country two-sided market model similar to ours with transfer-pricing (TP) regulation and showed that tighter TP regulation harms the high-tax countries since it affects the firms' incentive for investments in online technology.[11] Unlike Mukunoki and Okoshi (2025), however, our model shows positive tax revenue effects at the expense of less entry of foreign app suppliers. This affects entry and exit of domestic firms due to equal-footed competition and endogenous network size through network externalities, which this study explores.

The reminder of the paper is organized as follows. Section 2 introduces the model whereas the third section derives the equilibrium. Section 4 examines welfare analysis. Sections 5, 6 and 7 argue some extensions. The last section concludes.

[10] See Agrawal and Fox (2017) for the discussion on the destination principle as the appropriate taxation rule for consumption taxation of cross-border trade.

[11] In their model, TP regulation increases (corporate) tax revenues from MNEs but reduces MNEs' investments in online technology affecting sizes of network externalities. Our work is in a similar line in that closing the loophole of international taxation harms the MNE's real activity and host country's welfare.

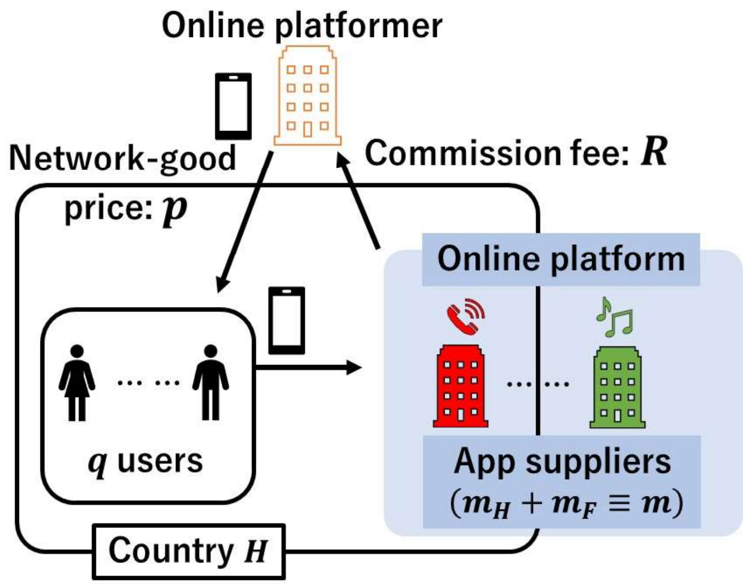


Figure 1: Fig: Model

2 Basic setup

Our model is drawn in Figure 1. Consider a digital economy in home country, labeled country H. A foreign firm, referred to as the *platformer*, has its own online technology to operate its platform such as App Store in country H. For consumers in country H to have access to the platform, they need to buy a platform-specific network good such as iPhone which is supplied by the platformer.

Following Wu et al. (2023), consumers are heterogeneous in their preference over the network good. The aggregate demand is determined through a conventional microfounded model by (see Appendix A):

$$q(p) = \nu + \alpha m - p. \tag{1}$$

where where ν and p represent the maximum willingness to pat for the good and the price of the goods and the second term αm is the consumer-side network effects.[12] The consumer-side network externality is captured by the second term: m represents the total number of apps sold in the platforms and α is the degree of consumer-side network externality. Because more apps provide consumers of the good with a wider variety of app options and allow them to use their favorite apps, they increase the willingness to pay for the network good.[13]

Note that such an increase in willingness to pay for the good matters with not only the number

[12]We assume that $\nu > p$ holds in the equilibrium throughout the analysis. This means that some consumers still want to consume the network good even if there are no additional gains from the network. This is realistic assumption because such an indirect externality arises if there are some consumers and app suppliers recognizes entry to the app market is profitable.

[13]This is known as an indirect network externalities. We discuss a direct network externality in section 6.

of apps but also the speed of internet connection. Online apps such as online games and video meetings often require a high speed internet connection. Therefore, consumers receive large gains from the network good if they are in a better digitalized environment. The network parameter α reflects the level of digitization and we interpret an exogenous increase of α as digitization as an introduction of 6G, for example, allows high-speed data transfer.[14]

Apps sold in the platform are developed by a potentially large pool of app developers M both in country H and foreign country, labeled country F. Such app developers are assumed to supply one app and to be heterogeneous over fixed costs of developing apps including maintenance costs, f_S. Following Rasch and Wenzel (2013), an app developer expects ϕ of the gross profit per capita and equivalently an expected price net of variable costs of apps, which is regarded as producer-side network externality. The network externality, for example, captures a better online algorithms or technology to match consumers and apps well based on individuals' consumption or search histories which are beneficial to predict their preference on apps. Therefore, a larger ϕ is interpreted as another different measure of digitization from α. In addition, app developers need to pay commission fee, R, to the platformer to sell their app in the platform. We allow R to be positive or negative and regards a negative R as a subsidy from the platformer to app developers.[15] The analysis below derives the following reduced-form function: suppose that participating providers earn the amount proportional to $m_1 > 0$ of the aggregate gross profits. The total number of app providers m can be written as:

$$m = m_1(\tau, \phi q) - R m_2(\tau, \phi q, R),$$

where m_2 is the value proportional to the number of participating firms.

A specific micro-founded model is as follows. Tax liability is different based on the location where app developers operate. Before the tax reform is conducted, app developers in country H needs to pay VAT whereas those in country F can avoid such payments because tax authority in country H has no rights to collect or penalize those foreign firms. After the tax reform is in force, home app suppliers are still subject to tax liability whereas tax liability for foreign app suppliers is on the platformer instead of foreign app developers. Let τ and η be VAT rate in country H and a binary function which takes zero under pre-tax reform and unity under post-tax reform. Then,

[14] In the last two decades, the percentage of individuals using the internet has grown: It was 7% in 2000 and 67% in 2023. See `https://data.worldbank.org/indicator/IT.NET.USER.ZS`, accessed 2025 February 5th.

[15] A negative R can be interpreted as a non-pecuniary subsidy such as technical supports to app developers by providing constructions kit. For example, Apple allows app developers to apply for an Apple vision pro developer kit (see `https://developer.apple.com/visionos/developer-kit/`, accessed 2025 February 5th).

the entry condition with respect to (expected) post-tax profits of app developers in each country are written as,

$$\pi_{SH} = \phi q - R - \tau\phi q \geq f_S \equiv \overline{f}_{SH}, \tag{2}$$

$$\pi_{SF} = \phi q - R - \eta\tau\phi q \geq f_S \equiv \overline{f}_{SF}, \tag{3}$$

In Regime O, only the domestic app producer pays the VAT, and the foreign app producer earns the tax-inclusive value ϕq without paying the VAT. In Regime T, the foreign app producer charges the VAT-inclusive price, and the VAT amount is remitted to the platformer in addition to the commission fee R. Assuming that f_S is uniformly distributed between zero and $\overline{f}$, these yield the following entrances of app developers,

$$m_H = \left(\frac{\overline{f}_{SH}}{\overline{f}}\right) M = \frac{M[(1-\tau)\phi q - R]}{\overline{f}}, \tag{4}$$

$$m_F = \left(\frac{\overline{f}_{SF}}{\overline{f}}\right) M = \frac{M\left[(1-\eta\tau)\,\phi q - R\right]}{\overline{f}}, \tag{5}$$

where the first parenthesis shows the entry rate. By summing up the entries, we have the total number of apps in the platform, $m = m_H + m_F$. The reduced-form specification above is a generalized model, where $m_1 = \frac{M}{\overline{f}}(2-\tau)\phi q$ (before tax reform) and $m_2 = 2\frac{M}{\overline{f}}$. Writing the model this way would clarify an important parameter at work in our stylized model.

Note that demands of the good and the number of app developers are associated through network externalities. By solving eqs. (1), (4) and (5) for three unknowns q, m_H and m_F, we can derive them as functions of p, R and τ as follows:

$$q(p,R) = \frac{\overline{f}(\nu - p) - 2\alpha MR}{\overline{f} - \alpha M\phi\{2-(1+\eta)\tau\}}, \tag{1'}$$

$$m_H(p,R) = \frac{M\left[\{1-\tau\}\,\phi q(p,R) - R\right]}{\overline{f}}, \tag{4'}$$

$$m_F(p,R) = \frac{M\left[\{1-\eta\tau\}\,\phi q(p,R) - R\right]}{\overline{f}}, \tag{5'}$$

The above expressions show that $m_H - m_F \leq 0$ due to $q > 0$, which means that the number of app developers in country H is fewer than that in F before the tax reform occurs whereas the tax reform equates the number across countries. This is intuitive because, before the tax reform, the asymmetry between home and foreign countries exists in tax liability for app developers. Thus, more foreign app developers enter the online platform, and this asymmetry is eliminated after the tax reform is conducted.

With the above setup about consumers and app developers, the platformer decides a price of the network good and a commission fee. Regarding cost structure of the platformer, we assume that the platformer produces the good with a constant marginal cost c of producing the goods and zero marginal costs of operating the online platform. Thus, the post-tax profits of the platformer is

$$\pi_P = (p - c)q + R(m_H + m_F) \tag{6}$$

where q, m_H and m_F follow eqs. (1), (4′) and (5′). In Regime T, the platformer collects the VAT from the foreign app producer $\tau\phi q m_F$ and remits them to the home tax authority. Therefore, the net amounts to receive from the app providers are $R(m_H + m_F)$, where R, m_H and m_F are regime-dependent. In the benchmark scenario, we assume that VAT is levied only on the use of the apps. In Section 5.1, we confirm that all our basic results continue to hold when the network good is also taxed.

Throughout the analysis, we have the following assumption to secure interior solution See eq.(11) in the next section).

Assumption 1. $\frac{\overline{f}}{M}$ is sufficiently high to satisfy

$$\frac{\overline{f}}{M} \geq \frac{\{2\alpha + \phi(2 - \tau)\}^2}{8} + \frac{(2\alpha + 2\phi + \tau\phi)(\nu - c)}{8M} \equiv A(\alpha, \phi, \tau, \nu - c, M). \tag{A-1}$$

The first part in the expression of (A-1), $\frac{\overline{f}}{M} > \frac{\{2\alpha+\phi(2-\tau)\}^2}{8}$, warrants that the induced demand function (1′) is downward-sloping in p (see "Meaning of the SOCs" in Appendix B). The part related to $\frac{\nu-c}{M}$ is that the potential number of app providers M is sufficient to absorb the market demand arising from the net market size $\nu - c$. In the next section, we will solve the optimal pricing strategies, (p, R), for the platformer in the absence and presence of the tax reform, respectively.

3 Equilibrium

3.1 Without the tax-reform ($\eta = 0$)

Let us begin our analysis with the case without the tax reform, which we use "O" for the superscript identifying the case without the tax reform. By differentiating $\pi_P^O = (p^O - c)q^O + R^O(m_H^O + m_F^O)$ with respect to p and R, and taking into account (1′), (4′) and (5′), the first-order condition (FOC)

$\frac{\partial \pi_P^O}{\partial p} = 0$ yields (see Appendix B for the derivation),

$$\frac{\partial \pi_P^O}{\partial p}\left(\frac{\overline{f} - \alpha M\phi(2-\tau)}{2\overline{f}}\right) = -p + c + \frac{\nu - c}{2} - \frac{\{2\alpha + (2-\tau)\phi\}MR}{2\overline{f}} \equiv FOC_p^O = 0,$$
$$\iff p^O = c + \frac{\nu - c}{2} - \frac{\{2\alpha + (2-\tau)\phi\}MR^O}{2\overline{f}} \tag{7}$$

In the above formula, the price is composed of two mechanisms: the market power and the network externality. Without network externality, the price is set above the marginal cost by the monopoly markup, which is reflected in the second term of the right-hand side. If the commission fee is positive, the last term on p^O lowers the equilibrium price because less app suppliers due to network externality reduce the platformer's profits from the app suppliers. Through the opposite reason, the product's price increases when $R^O < 0$.

In Appendix B, we use a general model mentioned in the previous section to show that p^O and R^O are linked in platformer's pricing strategy, with the coefficient $-\frac{\alpha m_2/(2\gamma)+(1-0.5(1+\eta)\tau)\phi|\partial m/\partial p|}{\rho}$ ($\gamma \equiv 1 - \alpha(2-(1+\eta)\tau)\phi\frac{\partial m_1}{\partial \Phi}$ and $\rho > 0$ is a variable related to the slope of consumers' demand curve). In the general model, (i) m's sensitivity to p ($\frac{\partial m}{\partial q} = \frac{M}{\overline{f}}(2-(1+\eta)\tau)\phi$, which is increasing in responsiveness of the app supplies from the number of users and decreasing in firm heterogeneity $\overline{f}$) matters for production side, and (ii) the number of app producers ($\alpha\frac{M}{\overline{f}}$ increasing in M) matters for consumption side. From this perspective, hereafter we call the corresponding parameter $\frac{M}{\overline{f}}$ as *elasticity of entry*, and its inverse, $\frac{\overline{f}}{M}$, as *inverse elasticity of entry*.

Turning to the first-order condition for R,

$$\frac{\partial \pi_P^O}{\partial R}\left(\frac{\overline{f} - \alpha M\phi(2-\tau)}{M}\right) = -4R + (2-\tau)\phi(\nu - p) - 2\alpha(p - c) \equiv FOC_R^O = 0. \tag{8}$$
$$\iff R^O = \frac{\overline{f}(\nu - c)(2\phi - \tau\phi - 2\alpha)}{8\overline{f} - M\{2\alpha + \phi(2-\tau)\}^2} \gtreqless 0 \Leftrightarrow \phi \gtreqless \frac{2\alpha}{2-\tau}$$

where the Assumption 1 warrants $8\overline{f} - M\{2\alpha + \phi(2-\tau)\}^2 > 0$. As explained above, whether the commission fee is positive or negative depends on the sizes network externality. If the producer-side network externality is strong and $\phi > \frac{2\alpha}{2-\tau}$, the important source of profits for the platformer is app developers. Therefore, the equilibrium commission fee is positive. Alternatively, if consumer-side network externality is strong or $\alpha > \frac{(2-\tau)\phi}{2}$ holds, selling the network good makes a large profits and the equilibrium commission fee is negative or a subsidy to expand the demand for the good. Subsequently, such commission fee influences the channel of network externality for the equilibrium price shown in eq.(7). Under a large producer side network externality $\phi > \frac{2\alpha}{2-\tau}$, the platformer decreases the equilibrium price for the good due to shrinking demands for the good. Otherwise, the equilibrium price for the good increases more than the monopoly markup. These features are preserved in a generalized model (Appendix B).

By substituting the equilibrium price of the good and commission fee, we have,

$$q^O = \frac{4\overline{f}(\nu - c)}{\left[8\overline{f} - M\{2\alpha + \phi(2-\tau)\}^2\right]} \tag{9}$$

$$m_H^O = \frac{M(\nu - c)(2\alpha + 2\phi - 3\tau\phi)}{\left[8\overline{f} - M\{2\alpha + \phi(2-\tau)\}^2\right]} < \frac{M(\nu - c)(2\alpha + 2\phi + \tau\phi)}{\left[8\overline{f} - M\{2\alpha + \phi(2-\tau)\}^2\right]} = m_F^O \ (\leq M) \tag{10}$$

where $m_F^O \leq M$ implies:

$$\frac{\overline{f}}{M} - \frac{\{2\alpha + \phi(2-\tau)\}^2}{8} \geq \frac{(2\alpha + 2\phi + \tau\phi)(\nu - c)}{8M}, \tag{11}$$

which is Assumption 1. To secure a positive number of app developers in H, we need $2\alpha + 2\phi - 3\tau\phi > 0$ or $\tau < \frac{2}{3} + \frac{2\alpha}{3\phi}$.

As mentioned before, electric devices getting access to online platform require are often characterized as a knowledge intensive industry, firms are sometimes criticized of using its high market power and setting their high prices.[16] In the present context, the platformer's sales corresponding to the extra part in pricing in (7) would cancel out with the commission fee in (8) and (10). Namely, from $p^O - c = \frac{\nu - c}{2} - \frac{\{2\alpha + (2-\tau)\phi\}MR^O}{2\overline{f}}$ and $R^O(m_H^O + m_F^O) = R^O \frac{M}{\overline{f}}\{(1-0.5\tau)\phi + \alpha\}q^O$:

$$\pi_P^O = (\frac{\nu - c}{2} - \frac{\{2\alpha + (2-\tau)\phi\}MR^O}{2\overline{f}})q^O + \frac{M}{\overline{f}}\{(1-0.5\tau)\phi + \alpha\}R^O q^O = \frac{\nu - c}{2}q^O. \tag{12}$$

3.2 With the tax-reform $(\eta = 1)$

Now, we introduce the tax-reform that the platformer is in charge of tax liability from sales of online apps instead of app developers, and we use the superscript "T" for the case.

The post-tax profits of the platformer are reformulated as $\pi_p^T = (p - c)q^T + R(m_H^T + m_F^T)$. Using

[16] For example, the U.S. department of Justice accused Apple of monopolizing Smartphone market. See `https://www.reuters.com/legal/us-takes-apple-antitrust-lawsuit-2024-03-21/`, accessed 2025 February 5th. European Union has the digital market act in 2023 to ensure for all businesses, contestable and fair markets in the digital sector. Inspired by the digital market act, Japan also enacted so called the Smartphone act to stop large companies such as Google and Apple from taking advantage of their position to give their own products "a competitive advantage" and from "imposing disadvantages on business users". See `https://eu-renew.eu/is-the-eus-digital-markets-act-going-global-how-japan-is-crafting-its-own-version-of-digital-regulation-with-the-smartphone-act/`, accessed 2025 February 5th.

eqs.(7) and (8) in the previous subsection, the FOCs, $\frac{\partial \pi_P^T}{\partial p} = 0$ and $\frac{\partial \pi_P^T}{\partial R} = 0$, yield,

$$\frac{\partial \pi_P^T}{\partial p}\left(\frac{\overline{f} - \alpha M\phi(2-2\tau)}{2\overline{f}}\right) = 0 \Rightarrow$$

$$p^T = p^O + \frac{\{\alpha + (1-\tau)\phi\}M}{\overline{f}}(R^O - R^T) + \frac{0.5\tau\phi M}{\overline{f}}R^O. \tag{7'}$$

$$\frac{\partial \pi_P^T}{\partial R}\left(\frac{\overline{f} - \alpha M\phi(2-2\tau)}{M}\right) = FOC_R^O - \tau\phi(\nu - p) = 0. \tag{8'}$$

When $R^O \geq 0$, the tax reform raises price and lower commission fee. More specifically, the following formula for reduction of the commission fee is obtained. For $* = O,\ T$ for $\eta = 0,\ 1$, let $den^* = 2 - (\alpha + \phi - 0.5(1+\eta)\tau\phi)^2\frac{M}{\overline{f}} > 0$ be the value that appears in the denominator of R^*,

$$R^* = \frac{(\nu - c)(2\phi - (1+\eta)\tau\phi - 2\alpha)}{4den^*} \Rightarrow$$

$$R^O - R^T = \frac{(\nu - c)}{4den^T}\{\tau\phi + \frac{(2\phi - \tau\phi - 2\alpha)(den^T - den^O)}{den^O}\} \tag{13}$$

Intuitively, tax reform prevents some foreign app suppliers from entering the platform due to the newly incurred tax burdens so that platformer reduces its profit-maximizing commission fee ($R^T < R^O$). In (13), apart from $den^T > 0$, the difference of the commission fee $R^O - R^T$ can be divided into the term related to the difference in the numerator of R^*, $0.25\tau\phi(\nu - c)$, and $\frac{(\phi - 0.5\tau\phi - \alpha)(\nu - c)(den^T - den^O)}{2den^O} = \frac{\tau\phi(\nu - c)}{2den^O}\frac{\{(2-\tau)\phi - 2\alpha\}\{4\alpha + (4-3\tau)\phi\}}{8}\frac{M}{\overline{f}}$ which relates to entry elasticity $\frac{M}{\overline{f}}$ defined in the previous section. The second term of (13) is positive when $2\phi - \tau\phi - 2\alpha \propto R^O \geq 0$, and (13) is still positive when $\frac{M}{\overline{f}}$ is sufficiently low. Intuitively, a large heterogeneity ($\overline{f}$) and a small number of potential entrants (M) mean that app suppliers' entry decision is less sensitive to price changes and, therefore, after the tax reform, the increase of app suppliers' entry when $R^O < 0$ is moderate. Referring to (A-1), the larger net market size $\nu - c$ also confirms $R^T < R^O$ and $p^T > p^O$.

The foreign firms' tax-inclusive commission fee to pay to the platformer (the last two terms of (3), as the sum of the commission fee and the VAT payment) has the following structure of tax incidence shown in Appendix C. The platformer gives twice the increase in the tax-inclusive fee than the decrease in its own receipt ($R^T + \tau\phi q^T - R^O \approx (2+1)(R^O - R^T)$ when $\frac{M}{\overline{f}}$ is small). In addition, a higher value of $(2-\tau)\phi - 2\alpha$ (in the numerator of R^O and the second term of (13), the value indicating a charge to producing firms) implies larger decrease of the commission fee.

(7′) shows the cross-market pass through to the rise of the network-good's price ($p^T > p^O$) since the last term of (7) increases after tax reform due to $-R^T > -R^O$. The analysis in the next section shows the following regarding the profit of the monopoly platformer:

$$\pi_P^T = \frac{\nu - c}{2} q^T. \tag{12'}$$

The increase of the tax burden from tax reform occurs in *per-unit burden* and *the number of goods/apps*. We show in the next section that $q^T < q^O$, but (12) and (12′) show that the per-unit surplus of the platformer is invariant through tax reform. Namely, although the per-unit joint surplus $(\nu - p^*) + (p^* - c) = \nu - c$ and the seller's per-unit bookkeeping profits $\frac{\nu - c}{2}$ are unchanged, the consumers' net gain[17] decreases so $(\nu - p^T) - (\nu - p^O) = -(p^T - p^O) < 0$.

The incidence of $R^O - R^T$ vs $[R^T + \tau\phi q^T] - R^O$ tells us the share between consumers and foreign app producers' per-unit burden. By paying a portion related to R^* of the product's price p^*, consumers pay certain fraction of foreign app producers' tax-inclusive commission fee. In Appendix C we show the following:

$$\frac{(\nu - p^T) - (\nu - p^O)}{\tau\phi m_F^T} = -\frac{(R^T + \tau\phi q^T - R^O)}{\tau\phi q^T} \frac{2(\frac{den^O}{\alpha + (1-0.75\tau)\phi} + (2\phi - \tau\phi - 2\alpha)\frac{M}{f})}{3\frac{den^O}{\alpha + (1-0.75\tau)\phi} - (2\phi - \tau\phi - 2\alpha)\frac{M}{f}} - \frac{2\phi - \tau\phi - 2\alpha}{4(\phi - \tau\phi + \alpha)} < 0 \tag{14}$$

where the consumers' net gain is expressed per m_F^T which are newly taxed after reform. The above formula shows that the fraction of consumers' per-unit burden by tax reform is $\frac{2}{3+2}$ =40% of foreign producers' burden or even greater when $2\phi - \tau\phi - 2\alpha \propto R^O > 0$.

The above discussion shows the following proposition regarding the effects of the tax reform on the equilibrium price of the network good and commission fee to the platform.

Proposition 1. (i) Suppose that elasticity of entry (app suppliers' sensitivity of entry decision to prices, $\frac{M}{f}$) is sufficiently low, or the net market size defined as $\nu - c$ is sufficiently large. Then, the tax reform increases the price of the network good and reduces commission fee of the domestic app producers, and increases the tax-inclusive commission fee of the foreign app producers.

(ii) From tax reform, the monopoly seller's per-unit profit remains the same despite the fact that consumer's price and tax-inclusive commission fee increase.

(iii) From tax reform, consumers bear substantial fraction of the increase of foreign firms' tax-inclusive commission fee (in our benchmark model, greater than 40% if $R^O > 0$).

This result is in line with a standard discussion on a pass through of imposing VAT on prices. In our model, the platform is newly taxed and, therefore, a pass through for the commission fee

[17] $(b_k - p^*)$ for consumer k, but we abbreviate this with $\nu - p^*$.

arises. As foreign inefficient app suppliers captured by high fixed costs are eliminated by tax reform, the surviving producers can bear the tax burden. Taking advantage of these surviving firms, the platformer, as the mediator, chose to charge higher tax-inclusive commission fee from the formerly tax-evading firms.

Contrary to this standard effect for foreign suppliers, the proposition also shows two new mechanisms which are specific to our setup. First, because such a new tax burden for foreign app suppliers induces an exit from the platform, the platformer intends to encourage app suppliers not to exit further from the platform. Moreover, beyond the content market which is directly impacted with the tax reform, our result shows that such a pass through also spreads to the price of the network good for the access to the platform since the markets are two-sided, which is argued in Cui (2019).

At the first look, these pass through effects seem to hurt consumers and foreign app suppliers via an increase in price and tax-inclusive commission fee, but to benefit home app suppliers due to a reduction in commission fee. However, network externality makes these effects further complicated and we analyze such issues in the next section.

4 Welfare effects

Tax reform changes the platformer's pricing strategies. These affect the equilibrium consumption of the network good and the number of app developers. Although the tax reform is expected to increase tax revenues in home country as argued in Introduction, results in this section reveal concerns on consumers and home app suppliers. Thus, this section explores the welfare effects of the tax reform beyond tax revenues.

4.1 Cross-market effect and consumer surplus

To see the whole welfare effects, let us first show the decline of the equilibrium consumption of the network good. By substituting the equilibrium price of the good and commission fee, we have $q^* = \frac{v-c}{den^*}$ for $* = O,\ T$, for the equilibrium consumption of the network goods under each regime with $\frac{1}{den^O} > \frac{1}{den^T}$:

$$q^T - q^O = \frac{q^T(den^O - den^T)}{den^O} < 0. \tag{9'}$$

This implies that tax reform reduces the consumption and leads to the shrinkage of the product market. The lower multiplier relates not only to the increase in price of the good but also less attractive platform reflected in the less number of total apps.

Our specification yields the following consumer surplus:

$$CS = \int_{\underline{\nu}}^{\nu} (b_k + \alpha m - p)\, db_k = \frac{1}{2}(\nu^2 - \underline{\nu}^2) - \underline{\nu}(\nu - \underline{\nu}) = \frac{1}{2}(\nu - \underline{\nu})^2 = \frac{q^2}{2}. \tag{15}$$

As shown in eq. (9'), $q^T - q^O < 0$ secures $CS^T - CS^O = \frac{(q^T+q^O)(q^T-q^O)}{2} < 0$. Therefore, the tax reform unambiguously reduces consumer surplus in country H.

As mentioned in the last section, the loss of consumer surplus appears in its square term because the real burden of tax occurs in the number of goods/apps (the reduction of q^* in (9')) and per-unit burden (the decline of $b_k - \underline{\nu}$ in (15) per unit, as $\underline{\nu} = p - \alpha m$ is raised after tax reform). The large loss by consumers through increases the price in (14) and the loss of quantity for fair tax burden is a notable feature of the two-sided market with monopoly supplier. We see why, as it often happens in European and other countries, consumers oppose taxes on platformer, since the fair tax burden gives substantial reduction of consumer surplus of related online products.

4.2 Entry and exit of app producers and domestic producer surplus

Once we identify of the tax reform on the product markets, we see the decline of the whole sizes of the app market, from $m = \frac{M}{\overline{f}}\{(1 - 0.5(1+\eta)\tau)\phi + \alpha\}q$, as follows:

$$m^T - m^O = -0.5\tau\phi q^T \frac{M}{\overline{f}} + \{(1 - 0.5\tau)\phi + \alpha\}(q^T - q^O)\frac{M}{\overline{f}} < 0. \tag{16}$$

The negative first term corresponds to the direct negative effects on foreign app suppliers due to the new tax burden. In the platform, the difference in the number of the network device $q^O > q^T$ is aggravated by the fact that tax reform hinders foreign producer's entry. Therefore, as a result of the tax reform, both markets shrink in the sense of less consumption of the good and less apps. From (16), we have $R^T m^T = R^T \frac{M}{\overline{f}}\{(1-\tau)\phi + \alpha\}q^T$ and from (7') we have $p^T - c = \frac{\nu - c}{2} - \frac{\{\alpha + (1-\tau)\phi\}MR^T}{\overline{f}}$. We therefore have (12') in the last section.

We next identify the impacts of the tax reform on app suppliers in each country. We can derive the following equilibrium number of app producers;

$$m_H^T = m_F^T = \frac{(\alpha+\phi-\tau\phi)M/\overline{f}}{2}q^T = \frac{M(\nu-c)(\alpha+\phi-\tau\phi)}{2\left\{2\overline{f}-M\{\alpha+\phi(1-\tau)\}^2\right\}} < \frac{M(\nu-c)(\alpha+\phi+\frac{\tau\phi}{2})}{\left[4\overline{f}-M\frac{\{2\alpha+\phi(2-\tau)\}^2}{2}\right]} = m_F^O. \tag{10'}$$

Regarding the app suppliers in country F, the tax reform decreases the number of foreign app suppliers ($m_F^T < m_F^O$ in (10')) and equalizes it to that of the home app suppliers ($m_F^T = m_H^T$) due to the equalized tax burdens in Regime T. This result is intuitive because the tax reform eliminates unfair tax burden and location advantage of foreign apps as well as the less attractive platform as mentioned above. Both heavier commission fee ($R^T + \tau\phi q^T > R^O$) and shrinking market ($\phi q^T < \phi q^O$) clearly reduce profits of foreign surviving app suppliers. In other words, the producer surplus in country F clearly declines through both extensive (the number of foreign surviving suppliers) and intensive (per-firm profits) margin.[18]

Once we explore the impacts on app developers in H, such a concern related to competition can extend to app suppliers. Regarding producer surplus in each country H, we derive,

$$PS_H = \int_0^{\overline{f}_{SH}} \{(1-\tau)\phi q - R - f_S\}\frac{M}{\overline{f}}df_S = \frac{m_H^2\overline{f}}{2M}$$

and, thus, whether the tax reform increases producer surplus depends on the direction of a change in app producers of country H. Formally, $PS_H^T \gtreqless PS_H^O$ holds if and only if $m_H^T \gtreqless m_H^O$ holds, and equivalently, whether the incidence to the (lower) commission fee ($-R^T > -R^O$) is more dominant than the effect of the downsized number of users ($q^T < q^O$) or not.

Notably, although the tax reform appears to increase the number of home app suppliers and domestic producer surplus by eliminating the unfair tax burden between app suppliers in H and F, whether the tax reform induces more home app suppliers ambiguous. The reason is less app suppliers in country F causes the reduction of consumers' willingness to pay for the network good and the value of the platform from the viewpoint of the home app suppliers. One can decompose,

[18] Analogous to derivation of producer surplus in country H below, one can derive producer surplus of the foreign app suppliers. From (10) and (10'), $PS_F = \frac{m_F^2\overline{f}}{2M} \propto [\{\alpha+\phi+(0.5-1.5\eta)\tau\phi)\}q]^2$, so the tax reform reduces producer surplus since it reduces firm entry and the network use.

from $m_H = \frac{(\alpha+\phi-(1.5-0.5\eta)\tau\phi)M/\overline{f}}{2}q$:

$$m_H^T - m_H^O = \frac{0.5\tau\phi}{2}q^T - \frac{(\alpha+\phi-1.5\tau\phi)M/\overline{f}}{2}(q^O - q^T) \gtreqless 0 \tag{17}$$
$$\Leftrightarrow \frac{\overline{f}}{M} \gtreqless \frac{\{2\alpha+\phi(2-\tau)\}^2}{8} + \frac{(2\alpha+2\phi-3\tau\phi)(4\alpha+4\phi-3\tau\phi)}{8} \equiv K(\alpha,\phi,\tau),$$

because we have $-\frac{(\alpha+\phi-1.5\tau\phi)M/\overline{f}}{2}(q^O - q^T) = -\frac{0.5\tau\phi}{2}q^T\frac{M(\alpha+\phi-1.5\tau\phi)(\alpha+\phi-0.75\tau\phi)}{\overline{f}-M\{2\alpha+\phi(2-\tau)\}^2/8}$. Since $q^T = \frac{\nu-c}{den^T}$ in (9′), the first term of the right hand side of (17) is identical to $\frac{\nu-c}{4den^T}\tau\phi$ appearing in (13): the reduction of R after tax reform, $R^O - R^T > 0$ in Proposition 1.(i), encourages entry of domestic firms. The second term of the right hand side of (17) includes the second tern of (13) as we show in Appendix D.

Compared with the value of $\frac{\overline{f}}{M} \geq A(\alpha,\phi,\tau,\nu-c,M)\left(> \frac{\{2\alpha+\phi(2-\tau)\}^2}{8}\right)$, $K(\alpha,\phi,\tau) > \frac{\overline{f}}{M}$ holds when $A(\alpha,\phi,\tau,\nu-c,M)$ is sufficiently small (either $\frac{\overline{f}}{M}$ or $\nu-c$ is small), whereas the sign could be reversed otherwise. This equation means that, when $\frac{\overline{f}}{M}$ is high (app suppliers' sensitivity of entry decision to prices is low), the tax reform is likely to induce more entry of home app suppliers so $PS_H^T > PS_H^O$, whereas when when $\frac{\overline{f}}{M}$ is small, tax reform induces the exit of home app producers. Quite interestingly, the emergence of entry in (17) reveals a less proportional reduction of demand (low $\frac{q^O-q^T}{q^T}$), so the entry or exit of domestic firms is informative to see the welfare loss in the product's market. However, the effect on tax incidence in (14) is rather neutral. In (14), only how much the tax incidence goes above 40% relates to entry elasticity.

Note that we can derive the following effects of VAT rate on the thresholds:

$$\frac{\partial K(\alpha,\phi,\tau)}{\partial\tau} = -\frac{(11\alpha+11\phi-10\tau\phi)\phi}{4} < 0$$

When τ is relatively large (small), the tax reform increases (*reduces*) app supply and producer surplus in country H through $A(\alpha,\phi,\tau,\nu-c,M) \leq \frac{\overline{f}}{M} < K(\alpha,\phi,\tau)$. This result provides an important implication on the effects of the tax reform from the viewpoint of VAT rates. In general, European countries tend to impose a high VAT rate whereas a VAT rate in Asian countries are low,[19] and our result suggests that the reduction of app supply after tax reform tends to happen in countries with low VAT rate.

Proposition 2. (i) The tax reform unambiguously reduces the total number of apps and the number of foreign app developers. Additionally, it decreases (increases) home app developers if $\frac{\overline{f}}{M}$ <

[19]See `https://www.globalvatcompliance.com/globalvatnews/world-countries-vat-rates-2020/` for the list of VAT rates, accessed 2025 February 5th. For example, VAT rates in France and Germany in 2024 are 20% and 19% whereas those in Japan and Vietnam are 10% and 8%.

$K(\alpha, \phi, \tau)$ $\left(K(\alpha, \phi, \tau) < \frac{\bar{f}}{M}\right)$, or the net market size defined as $\nu - c$ is sufficiently small (large). Under a low VAT rate, the tax reform likely to discourage entry of home app suppliers.

(ii) The tax reform unambiguously reduces the consumption for the network good. The emergence of exit (entry) of domestic firms after tax reform reveals high (low) proportional shrinkage of the product market, but the entry or exit is independent of the baseline value of 40% of the tax incidence.

It is also worth noting that a smaller number of users after the tax reform ($q^T < q^O$) does not necessarily mean fewer home app producers. As Proposition 2 shows, more home app suppliers enter the platform when the VAT rate is sufficiently high because eliminating unfair tax burden is a dominant effect.

4.3 Tax revenue and welfare in country H

Although the above discussion casts some welfare effects of the tax reform due to the tax incidence, the reform is expected to increase tax revenues in H. As the tax revenues in each scheme are formulated as $TR^O = \tau\phi m_H^O q^O$ and $TR^T = \tau\phi(m_H^T + m_F^T)q^T$, we can compute the effects of the tax reform on tax revenue in country H is

$$TR^T - TR^O = \tau\phi\left(2m_H^T q^T - m_H^O q^O\right) \tag{18}$$

As shown above in proposition 2, $q^T < q^O$ holds and thus the tax reform has a negative channel for tax revenues through less consumers in the platform. However, as foreign app suppliers are subject to VAT payments indirectly through the platformer in the post-reform scheme, the tax reform also can increase tax revenues.[20] Online Appendix B.3 shows that $TR^T > TR^O$ under certain conditions.[21] Here, we show an alternative derivation.

As an extreme point, we have

$$\left.\frac{\partial\left(TR^T - TR^O\right)}{\partial\tau}\right|_{\tau=0} = \frac{M\bar{f}(\nu - c)^2\phi(\alpha+\phi)}{2\left\{2\bar{f} - M(\alpha+\phi)^2\right\}^2} > 0$$

[20]Under the post tax-reform, the total number of app suppliers subject to tax payments can increase from m_H^O to $m_H^T + m_F^T$ and one might expect that the tax reform can increase tax revenues in country H more than the amount of taxes avoided by foreign app suppliers. However, because $m_H^O + m_F^O > m_H^T + m_F^T$ and $q^O > q^T$ hold, we have

$$\tau\phi q^O(m_H^O + m_F^O) > \tau\phi q^T(m_H^T + m_F^T) = TR^T \iff \tau\phi q^O m_F^O > TR^T - \tau\phi q^O m_H^O = TR^T - TR^O$$

which means that the tax revenue gains are less than the amount of tax avoidance by foreign app suppliers under pre tax-reform.

[21]Specifically, $\tau < 0.3$ (a regular VAT) and $2\{\frac{\bar{f}}{M} - A(\alpha, \phi, \tau, \nu - c, M)\}/(\alpha + (1+0.5\tau)\phi) + (\nu - c)/(2M) \geq \phi$ (either the indicator of the inverse elasticity of entry or the net market size is sufficiently larger than the network externality).

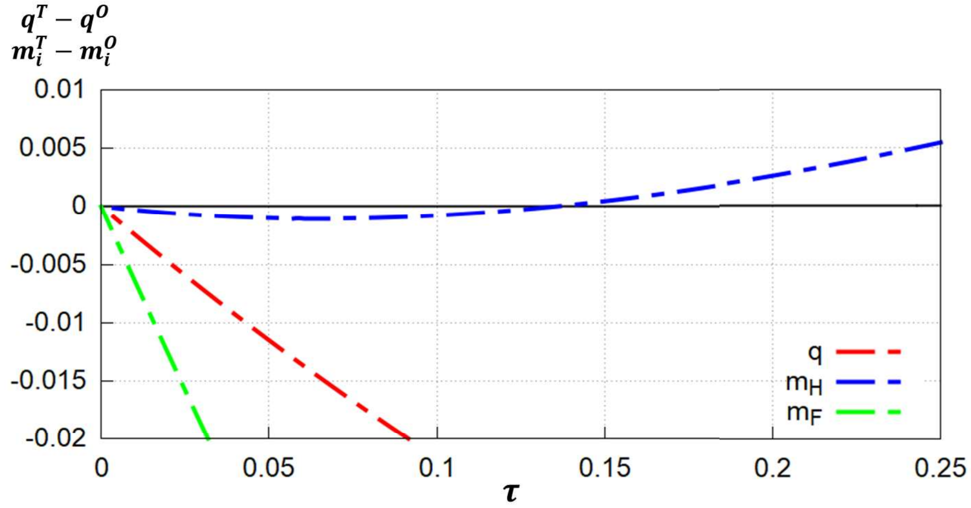


Figure 2: Effects of tax reform on q and m_i

which implies that the tax reform increases tax revenues in country H when the VAT is sufficiently small. Moreover, when the number of home app suppliers increases, because $2\frac{m_H^T}{m_H^O}q^T - q^O > 2q^T - q^O \propto 2\{2\overline{f} - M(\alpha+\phi)^2\} + M\phi^2\tau^2 > 0$ holds, eq.(18) means that tax revenue increases. Recall that Proposition 2 shows that an increase in the home app suppliers is likely to happen when τ is high. The recovery of tax revenues also seems to happen under a large τ as well.

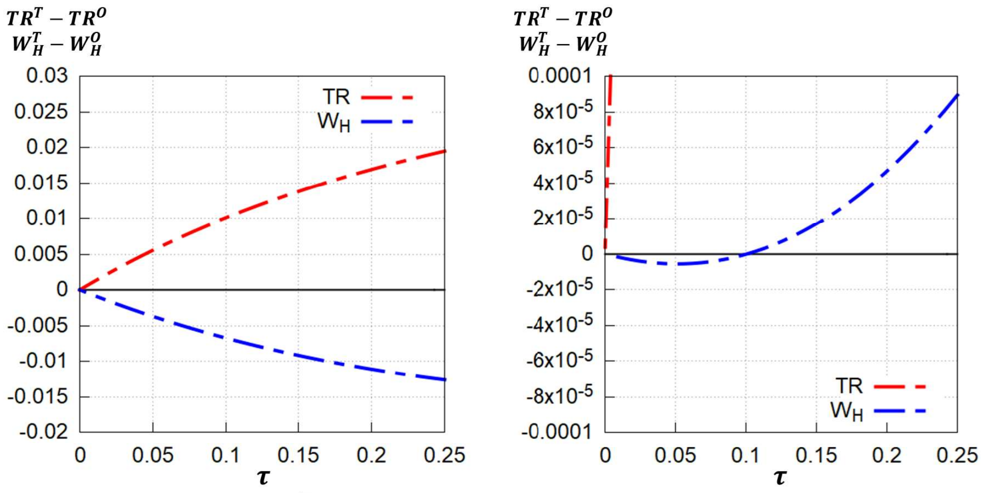
These welfare effects are summarized as the following proposition.

Proposition 3. Introduction of the tax reform tends to increase tax revenues in the home country under a low or high VAT rate.

As shown in Proposition 3, the tax reform generalizes both positive and negative effects in country H, and its total impacts are unclear. To see conditions for welfare deterioration, Fig.2 and Fig.3 draw numerical examples on the effects of the tax reform on entry of domestic firms and domestic welfare in country H defined as $W_H = CS + PS_H + TR$.

In Fig.2,[22] changes in q and m_i due to the tax reform are illustrated. The red and green curves capture reductions of consumption of the network good and foreign app suppliers in Proposition 2.(i) and (ii), respectively, after the tax reform. The blue curve depicting the change in home app suppliers shows non-monotonic effects of tax reform shown in Proposition 2.(i). Under a low tax rate, the dominant effect is the shrinkage of the network users and subsequently a decline in home app suppliers. Under a high VAT rate, however, the tax reform induces more entry of home app supplier. When the VAT rate is high, the equilibrium entrants of the home app producers are efficient ones who can bear tax burdens. The addition of the tax liability to the foreign app producers

[22]We use the following parameters: $\nu = 2$, $c = 0$, $M = 1$, $\alpha = \phi = 0.25$, and $\overline{f} = 0.33$.



(i) Small $\overline{f}$ (ii) Large $\overline{f}$

Figure 3: Effects of tax reform on TR and W_H

in Regime T eliminates unfair tax burden of the home app producers, and this effect allows the additional entries of the home app producers (as a replacement of the exit of inefficient foreign app producers).

In Figure 3, we use the same parameter for the left panel as used in Fig.2 whereas higher $\overline{f}(= 0.85)$ is used for the right panel. As we showed, lower entry elasticity $\frac{M}{\overline{f}}$ (the right panel) means that the reduction of q and m_H after tax reform will be less and in turn, country H's tax revenue increases greater than the case of higher $\frac{M}{\overline{f}}$ (the left panel). In each panel, tax revenues increased due to the tax reform and is moreover positive over greater VAT rate, which is in line with Proposition 3. However, because the tax reform reduces consumers surplus and potentially producer surplus in country H, the welfare effect (depicted with the blue curve) can be negative and decreasing in the VAT rate as in panel (i).

The above welfare analysis has a policy implication. As expected, the introduction of the tax reform increases tax revenue in a consumption country, and, thus, it seems one solution to the problem of international taxation in the digitalized world. However, in a wider scope of total welfare, the tax reform can deteriorate welfare in the country, because it generates negative network externalities driven by exits of foreign app suppliers. Because consumers lose in both product and app markets, evaluation of the tax reform only based on tax revenues is misleading. As we saw in (14), in two-sided markets, tax burdens caused by foreign suppliers shift to domestic consumers with high fraction.

Our analysis also shows that the tax reform decreases the number of home app suppliers under a low VAT rate, which indicates that the tax reform may hurt home app suppliers in countries such as Japan and Vietnam. In contrast, a high VAT rate as in European countries are essential for welfare improvement or mitigation of welfare losses.[23]

5 Issues for VAT and VAT reform

5.1 Tax incidence of VAT on the network good

So far, we have assumed that VAT is levied on the online apps. In this section, a more realistic scenario of the general sales tax, i.e., taxation on the network product, would further increase the share of consumers' per-unit burden. We assume that inverse elasticity of entry is sufficiently high so that $p^O > p^T$ holds (see Appendix E to see how Proposition 1 is extended).

The profit function of the platformer is modified as: $\pi_P = (p(1-\tau) - c)q + R(m_H + m_F)$. The cost cq, borne in the third country, is not deducible in the VAT in Country H.

A look to the consumers' net gain and the platformer's revenue reveals a structure of tax burdens that accrue to each party. For the tilde being the value divided by $\frac{1}{1-\tau}$, e.g., $\widetilde{\phi} \equiv \frac{\phi}{1-\tau}$, we have (see Appendix E):

$$\nu - p^* = \frac{\nu - \widetilde{c}}{2} + \{\alpha + (1 - 0.5(1+\eta)t)\widetilde{\phi}\}\frac{M}{\overline{f}}R^* \tag{7v}$$

$$\pi_P^* = \frac{\nu(1-\tau) - c}{2}q^* \tag{12v}$$

where the effects of the tax rate that already exist in the benchmark case are distinguished by t ($t = \tau$). As shown in (12), the correct reference of the real burden of the network-good supplier is the reduction of π_P^* from the benchmark case without tax on q. Effectively, it pays only part of the q–tax, and, importantly, tax reform does *not* increase the platformer's tax burden per unit of the good, even though the per-unit tax τp^* *increases* when $p^T > p^O$. This increase of the per-unit tax is entirely explained by the decrease of the last term of eq. (7v) since R^* decreases: as a result, *consumers entirely bear the increase of per-unit tax as a result of tax reform.*

Proposition 4. From the VAT of the network product, the monopoly seller bears only partly of the per-unit tax, which does not increase by tax reform. Out of the unit tax $\tau p^T - \tau p^O$, its increase is entirely born by consumers.

The structure of the tax burden is seen in the second term of the right-hand side of (7v). Its

[23]See `https://www.globalvatcompliance.com/globalvatnews/world-countries-vat-rates-2020/` for the list of VAT rates, accessed 2025 February 5th. For example, VAT rates in France and Germany in 2024 are 20% and 19% whereas those in Japan and Vietnam are 10% and 8%.

difference after tax reform has an equivalent expression to $p^T - p^O$ in (7′) where ϕ is replaced with $\frac{\phi}{1-\tau}$. The platformer uses this amount for its tax obligation.

Often, the MNE which conducts multiproducts' monopoly voluntarily offer the consumption tax payments to the host countries according to the destination principle. However, the platformer is willing to do this offer since, through its price setting power and interdependence in the multi-sided market, it makes *consumers* bear the increased tax duties.

Let us turn our analysis to tax revenue in this context to be written as

$$TR^T - TR^O = \tau\phi(2m_H^T q^T - m_H^O q^O) + \tau(p^T q^T - p^O q^O).$$

We confirm that the tax revenue increases even after taxation on the network good when $R^O \geq 0$, and $\frac{\overline{f}}{M}$ and $\nu - \frac{c}{1-\tau}$ are sufficiently high (see Online Appendix B.3). This is because, even with the reduced opportunity of earning profits, the taxable sales $p^* q^*$ does not decrease much after the tax reform since $p^T q^T(p^T, R^T) > p^O q^T(p^O, R^O)$,[24] a feature particular to the imperfect competition with cross market pass through.

For other analysis we have conducted, as an example here, in the share of the tax burden from tax reform discussed before, $\frac{R^T + t\phi q^T - R^O}{p^T - p^O}$ (formally given in (14) in the benchmark case), $\frac{\overline{f}}{M}$ and ϕ are divided by $1 - \tau$ so $(2-t)\phi - 2\alpha$ is replaced with $\frac{2-t}{1-\tau}\phi - 2\alpha$ (a parameter of incidence which appears in the corresponding cases of R^O); the incidence becomes less responsive to entry elasticity, and it becomes more responsive to production externality. Such modifications adjust the after-tax value of parameters for a suitable behavior of the general sales tax. Online Appendix B.1 shows that Proposition 2 is maintained. Our results are qualitatively maintained by adding q–tax.

5.2 The case of eliminating VAT threshold

As explained in Introduction, some countries use a platform tax for taxing unregistered small and medium enterprises (SMEs). The formulation of (4) and (5) is mostly equivalent to the case when a country eliminates the unfair treatment of the SMEs whose revenue is below the VAT threshold.

Suppose that the number of potential entrants is $2M$. Before tax reform, VAT-registered firms

[24] Let $q^T(p, R)$ be the value of q that satisfies (1′) when $\eta = 1$. From the first-order condition of the platformer $\frac{\partial m^T}{\partial p} = (2 - 2\tau)\phi \frac{M}{\overline{f}} \frac{\partial q^T}{\partial p}$ and $-\frac{\partial q^T}{\partial p} > 0$, we have $\frac{\partial p q^T}{\partial p} = \left(R^T(2-2\tau)\phi\frac{M}{\overline{f}} - c\right)\left(-\frac{\partial q^T}{\partial p}\right)$. The term of $R^T(2-2\tau)\phi\frac{M}{\overline{f}}$ is per the digit of the number of app developers m in (4) and (5) which may well be less than the marginal cost of the network good. Then p^T is below the revenue-maximizing level of $pq^T(p, R^T)$, and $p^T q^T(p^T, R^T) > p^O q^T(p^O, R^T) > p^O q^T(p^O, R^O)$ since $p^T > p^O$ and $R^O > R^T$ if $\overline{f}/M$ is sufficiently large.

(group r) need to earn $v > 0$[25] as the revenue (net of f_S) so that $m_r = \left(\frac{[(1-\tau)\phi q - R]}{\bar{f}}\right) 2M - \frac{2Mv}{\bar{f}}$.[26] The other group, group u, does not have such a requirement. $m_u = \frac{2M[(1-\eta\tau)\phi q - R]}{\bar{f}} - m_r$. With the notation of (5′), we have $m_r^O(p,R) + m_u^O(p,R) = 2m_F^O(p,R)$ with the VAT threshold. The tax reform removes this VAT threshold and every firm pays the VAT. $m^T = 2m_F^T$ after tax reform (see Online Appendix B.5). Eqs.(14) and (A-4) in Appendix C for consumers' burden are unchanged in their basic features. Regarding new tax burdens on the SMEs, critics often show concerns on the exits of the SMEs and the windfall gain on the VAT-registered firms before the reform. Our model enables to quantify the magnitude of these effects by entry elasticity.[27]

We replace the app producers to the sellers of the online services. With minor modifications applied to the pre-reform regime, the features of the analysis (with or without q–tax; in the following we state the case without q–tax) are unchanged so that we can conclude the following proposition:

Proposition 5. Consider a model where a country eliminates the VAT threshold.

From tax reform, the per-unit gains of trade remains as $\nu - c$ in total ($\frac{\nu-c}{2}$ for the platformer and $\frac{\nu-c}{2}$ for the total of the buyers of the network good and service suppliers), but the buyers of the network good bear substantial fraction of the increase of the SMEs' tax-inclusive commission fee through the increase of the price of the network good, which is 40% or greater when $R^O \geq 0$. The decrease (increase) of the profits of formerly registered firms after tax reform reveals high (low) proportional shrinkage of the network users and the exit of the SMEs. High (low) proportional exit of the SMEs happens with high (low) entry elasticity.

6 Evolution of externalities and tax planning in the digital era

The advent of online platforms creates new business opportunities via app markets and the interactions between the users of smartphone and app providers as we have analyzed. In the past, in contrast, the central benefit arises from the channels such as communication with friends (direct

[25]If the sales instead of the profit is the criterion for the VAT registration, then one can formulate firm heterogeneity by its sales $h\phi q$ with $h \in [0,1]$.

[26]Since our analysis is the effect of eliminating the VAT threshold, the firm distribution in Onji (2009) and Saez (2010) before tax reform is treated as given. The firms' reaction after reform does not accompany the choice of the firm size so the firm distribution is treated invariant in the present analysis. Incorporating non-uniformity of the firm distribution in practice does not affect the present analysis.

[27]In this setup, the decrease of the profit $(1-\tau)\phi q^* - R^*$ of the formerly-registered firms means that the profit of some inefficient firms becomes less than v, whereas its increase means that the profit of efficient unregistered firms becomes greater than v. The emergence (non-emergence) of this windfall gains to the formerly-registered firms reveals low (high) proportional shrinkage of the network users and the exit of the SMEs.

network externality or traditional network externality). Let us modify the demand function as,

$$q(p) = \nu + \alpha m + \alpha_D q_e - p.$$

where α_D represents a parameter of direct network externality and $q_e(= q)$ shows expected numbers of consumers in the equilibrium (Katz and Shapiro (1985) and Wu et al. (2023)).[28] Recent development of digitization increases α (digitalization externality) to the greater extent than α_D. Our results so far qualitatively hold by adding the direct network externality into the benchmark analysis. In the following, we discuss the transition from the society with traditional linkage to digitalized society as a decline in α_D and a rise in α on the entry of domestic producers and the platformer's tax planning.

For the entry of domestic app suppliers in (17), recall that the domestic entry is encouraged by the fair tax burden but deterred by the shrinkage of the product market. Consumption and direct externalities are both active in shrinking the app provision in the second term of (17). In Appendix F, we show that, when $m_H^T > m_H^O$ and entry elasticity is relatively small, the following holds:

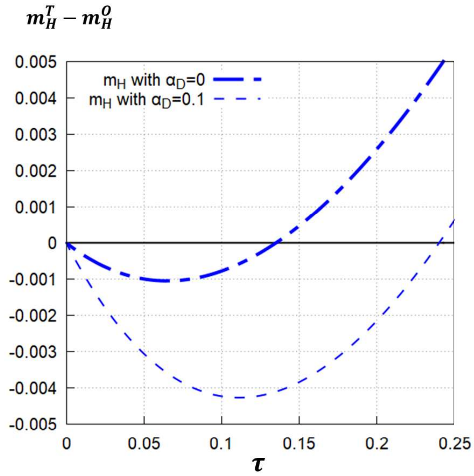
$$\frac{\partial(m_H^T - m_H^O)}{\partial\alpha_D} > \frac{\partial(m_H^T - m_H^O)}{\partial\alpha}$$

that is, less entry of the domestic app market from the tax reform occurs in the digitalized society. However, when $m_H^T < m_H^O$ and entry elasticity is relatively large, the above conclusion is reversed to $\frac{\partial(m_H^O - m_H^T)}{\partial\alpha} < \frac{\partial(m_H^O - m_H^T)}{\partial\alpha_D}$, since traditional channel increases the market-shrinkage effect in (17) through $\frac{\partial q^O}{\partial\alpha} < \frac{\partial q^O}{\partial\alpha_D}$.

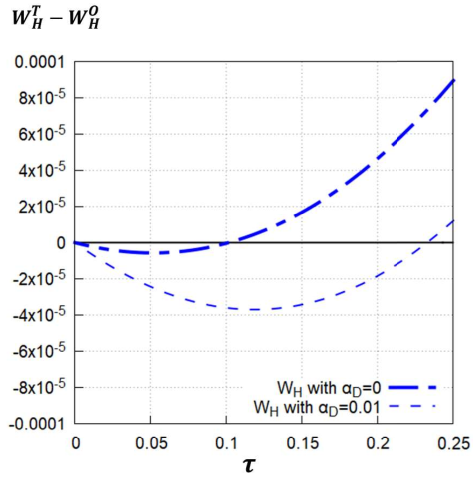
In the product market, the traditional channel works for q so $\frac{\partial q^*}{\partial\alpha_D} > \frac{\partial q^*}{\partial\alpha}$. For the total app provision m^* ($m^O > m^T$ as in the benchmark analysis), we show in Online Appendix B.2 that, for a parameter $0 < \beta < 1$: $(\frac{\partial\ln(q^O - q^T)}{\partial\alpha_D} - \frac{\partial\ln(q^O - q^T)}{\partial\alpha})\beta + \frac{1}{\alpha} < \frac{\partial\ln(m^O - m^T)}{\partial\alpha_D} - \frac{\partial\ln(m^O - m^T)}{\partial\alpha}$. Digitalization alleviates the shrinkage of the app market to the greater extent than the network-good market. For the product market to receive the same benefit of less reduction of the surplus, the consumption and production externalities need to be sufficiently strong on the one hand, and if the relative marginal productivity, $\frac{\partial q^*}{\partial\alpha}(\frac{\partial q^*}{\partial\alpha_D})^{-1}$, is not high (which happens under low entry elasticity), then digitalization makes less fall of consumer surplus.

Once the economy reaches the condition of $\frac{\partial\ln(q^O - q^T)}{\partial\alpha} < \frac{\partial\ln(q^O - q^T)}{\partial\alpha_D}$, greater digitalization also

[28]Following Katz and Shapiro (1985) and Wu et al. (2023), we assume that individuals make their purchase decision with an expected size of the direct network and the consumers' expectation would be fulfilled in the equilibrium, i.e., $q_e = q$ holds.



(i) Number of home app producers



(ii) Welfare in H under large $\overline{f}$

Figure 4: Effects of tax reform on m_H and W_H with direct network externality

works to reduce the entry fee $R^* = \frac{(1-0.5(1+\eta)\tau)\phi-\alpha}{2}q^*$ to promote consumption. As a result, when $R^T \geq 0$, digitalization reduces the extent of tax planning due to the tax reform, i.e., $\frac{\partial \ln(R^O-R^T)}{\partial \alpha} < \frac{\partial \ln(R^O-R^T)}{\partial \alpha_D}$ (Online Appendix B.2), and the same conclusion holds for the product's price.

Proposition 6. Suppose that $\{\alpha + \phi(1-0.5\tau)\}\frac{M}{\overline{f}} < 1$ holds.

(i) If fair-tax effect is dominant to increase the domestic app provision through the tax reform, and if $\alpha_D + \max\{\alpha, (1-0.5\tau)\phi\} \leq 1$ holds, then the increase of the domestic producer surplus through the tax reform is smaller with greater digitalization. If the market-shrinkage effect is dominant and entry elasticity is relatively high, the decrease of the domestic producer surplus through the tax reform may be smaller with greater digitalization.

(ii) Digitalization alleviates the shrinkage of consumer surplus ($\frac{\partial \ln(q^O-q^T)}{\partial \alpha} < \frac{\partial \ln(q^O-q^T)}{\partial \alpha_D}$) if α and ϕ are sufficiently high but traditional externality is more contributing to increase network users than digital externalities (specifically, $\min\{\alpha, (1-0.75\tau)\phi\}(2-1.5(\frac{\partial q^O}{\partial \alpha})(\frac{\partial q^O}{\partial \alpha_D})^{-1}) + 0.5\alpha_D \geq 0.5$). The opposite consequence holds if α and ϕ are low but entry elasticity is high.

(iii) If the externalities and entry elasticity allow $\frac{\partial \ln(q^O-q^T)}{\partial \alpha} < \frac{\partial \ln(q^O-q^T)}{\partial \alpha_D}$ to happen and $R^T \geq 0$, digitalization reduces the extent of tax planning on the fall of R and the rise of p due to the tax reform.

Exploring the impacts of α_D on home app producers and home country's welfare, we conducted a numerical example similar to Figs.2 and 3. Fig.4 illustrates with $\alpha_D = 0.1$ for the left panel and $\alpha_D = 0.01$ for the right panel. The left panel shows the impacts of tax reform on the number of home app producers whereas the right one draws those on domestic welfare in country H.[29] In each

[29]Under the values of externalities employed in the simulation, we have $-\frac{\partial \ln(q^O-q^T)}{\partial \alpha_D} > -\frac{\partial \ln(q^O-q^T)}{\partial \alpha}$ (the loss of

panel, the thick dot-dashed curve represents the case without direct network externalities, which corresponds to ones shown in Fig.2 and the right panels of Fig.3. The thin dashed curve depicts the change in the presence of the direct network externalities, and we can see the thin curves are below the thick curves. Since the product-shrinkage effect is more prominent through traditional externality, the turning point for the increase of $m_H^T - m_H^O$ in traditional society happens only with higher VAT rate than the case where digital externality is at work. The market size on the traditional channel hinges on the consumption of the network good and, hence, it magnifies the negative effects of tax reform and tends to cause more tax planning by the platformer.

7 Price ceiling: to app registration or to network good?

In the present model, consumers receive the direct benefit from the network good and app gives an indirect benefit. Producers give indirect benefit to consumers, and do (direct) payment R to the platformer. In this section, we discuss the following novel feature: the ceiling policy that benefits a party *in*directly (R for the consumer and p for the producer) will make "Pareto improvement":[30] consumer surplus, producer surplus, and the tax revenues all rise (Proposition 7). Hereafter we omit the q–tax for the VAT, but the conclusion with the q–tax is very straightforward.

We first consider the ceiling policy $\hat{R}$ in the neighborhood of R^*,

$$\hat{R} = R^* - \epsilon$$

with $\epsilon > 0$, and the platformer's commission fee is constrained by $R \leq \hat{R}$. Reflecting the nature of $R^T + \tau\phi q^T > R^O$ we found in the benchmark analysis, the commission-fee floor may be useful to alleviate the decrease of foreign providers' participation. In this sense, we conduct the analysis with Regime T.[31] In the following, we deal with the case of $(1-\tau)\phi > \alpha$ (so that the unregulated commission fee is $R^T > 0$) since the analysis is completely symmetric in the reverse case.

7.1 Commission-fee Ceiling

The first key point to understand is that the platformer re-optimizes against the commission-fee ceiling. Denoting all variables with the reaction of the ceiling policy by "hat", and in this section

consumer surplus becomes greater with digitalization) whose effect is included in the right panel.

[30]Other than the platformer.

[31]The app producers increase the tax burden by $\tau\phi\frac{\{-\alpha+(1-\tau)\phi\}M}{f}\frac{\partial q}{\partial p}d\hat{R}$. For a sufficiently low demand elasticity, this value would be less than $d|\hat{R}|$.

we use superscript T only to represent the benchmark (unregulated) values, the new price $\hat{p}$ has its feature for $d\hat{p} = \hat{p} - p^T$ from (7) (or eq.(7A) in Appendix B):

$$\frac{\partial \pi_P(p, \hat{R})}{\partial p} = 0 \quad \Rightarrow \quad d\hat{p} = \epsilon(\alpha + (1-\tau)\phi)\frac{M}{\overline{f}}$$

With $\hat{R} < R^T$, the platformer re-optimize with the increase of the product's price. The second key point is that the following cross-market effect occurs: substituting these values into the numerator of $q(\hat{p}, \hat{R}) = \frac{\nu - \hat{p} - 2\alpha\hat{R}M/\overline{f}}{1-\alpha\phi\{2-2\tau\}M/\overline{f}}$ in (1') and subtracting it from the unconstrained equilibrium $q = q^T$:

$$dq(\hat{p}, \hat{R}) \propto -d\hat{p} - 2\alpha d\hat{R}\frac{M}{\overline{f}} < 0 \quad \text{if} \quad \{-\alpha + (1-\tau)\phi\}(-\epsilon)\frac{M}{\overline{f}} < 0 \quad (\, R^T > 0\,) \tag{19R}$$

Quite surprisingly, when the unconstrained commission-fee R^T is positive, the commission-fee ceiling decreases the consumption of the network good and the consumer surplus. This result is because, in the induced demand $q(p, R)$, the commission-fee's reduction counts by the order of $\alpha\frac{M}{\overline{f}}$, whereas this policy raises p by the order of $\frac{M}{\overline{f}}$ and lowers the number of network users.

As to the (domestic and foreign) producers, substitute these values to the numerator of the expression of $m_H = \frac{M}{\overline{f}}\frac{\left[\{1-\tau\}\phi(\nu-\hat{p})-\hat{R}\right]}{1-\alpha M\phi\{2-2\tau\}/\overline{f}}$,

$$dm_H(\hat{p}, \hat{R}) \quad \propto \quad \big(-\{1-\tau\}\phi\{\alpha + (1-\tau)\phi\}\frac{M}{\overline{f}} + 1\big)\epsilon \tag{19D}$$

The suppliers' net benefit is decreasing in the entry elasticity, and another factor that newly matters for its sign is $\frac{(1-\tau)\phi}{\alpha}$. Assumption 1 does not warrant its sign. We will come back to an implication of this formula later.

7.2 Indirect and direct benefits of policies

The fact that the commission-fee ceiling may not work for the consumers' welfare motivates us to examine another policy, which is *a price cap on p*.

If a price cap on p, denoted by "bar", is imposed as $\bar{p} = p^T - \delta$ ($\delta > 0$), the platformer re-optimizes the commission fee through the first-order condition on R: Again, another variable is raised. Substituting $\bar{p} = p^T - \delta$ and the platformer's revised commission fee (from (8) or eq.(8A) in Appendix C), $d\bar{R} = \{(0.5 - 0.5\tau)\phi + 0.5\alpha\}d\bar{p}$ into the numerator of $m_H(p, R)$ in (4'), we see for the increase or decrease of m_H by the price ceiling as:

$$dm_H(\bar{p}, \bar{R}) \propto \{1-\tau\}\,\phi(-d\bar{p}) - d\bar{R} > 0 \quad \text{if} \qquad (1-\tau)\phi - 0.5(1-\tau)\phi - 0.5\alpha > 0 \qquad (19p)$$

Interestingly and quite symmetrically with the case of the consumer surplus, the total number of apps and *the producer surplus* are increased by the price ceiling when $(1-\tau)\phi - \alpha > 0$. This in turn provides that *the increase of* m from the price ceiling warrants the increase of the consumption by $q = \nu + \alpha m - p$ in the demand function (1). Notice that, since q and $m^T = 2m_H^T$ increase, the tax revenue unambiguously increases.

Proposition 7. Suppose that the unregulated commission fee satisfies $R^T > 0$.

(i) The price ceiling brings the following welfare consequences. First, the policy increases the producer surplus. Second, $dm > 0$ and $-d\bar{p} > 0$ imply the increase of q. Third, the tax revenue increases.

(ii) If the entry elasticity $\frac{M}{f}$ or $\frac{(1-\tau)\phi}{\alpha}$ is sufficiently small, producers prefer R–ceiling that brings direct benefit to p–ceiling.

Part (ii) will be explained later. Part (i) is contrary to the initial impression. The commission-fee ceiling does not work for the consumers' welfare when $R^T > 0$ (in general, when the unconstrained commission fee is high reflecting the platformer's charging motive).[32] To the best of our knowledge, we do not hear this kind of policy choice in the public debate. Our novel view starts the argument from the variable that affects each party indirectly (R for the consumer and p for the producer) and sees that the strength of consumption's link (production's link for the producer) affects the consumer (producer) surplus. With the link through externalities, the profit of app providers through the ceiling of product's price in (19p) crucially depends on the strength of production externality, and, in case it is negative by $\alpha > (1-\tau)\phi$, we simply refer instead to (19R) to find that $-d\hat{R} > 0$ results in $d\hat{q} > 0$ and $dm_H(\hat{q}, \hat{R}) > 0$, so we can always find a Pareto-improving policy once policy makers identify the underlying parameters by the sign of magnitude of the unregulated commission fee R^T.

However, the party who receives direct benefit (R for producers) may prefer the policy that gives them direct benefit. We prove in Online Appendix B.6 that the increase of the profit is higher with a suitable commission-fee ceiling policy when: (1) $m_H^T > m_H^O$ or (2) $\max\{\frac{(1-\tau)\phi}{\alpha}, \frac{\alpha}{(1-\tau)\phi}\}$ is not much larger than 1. Still, in the first case (i.e., with low entry elasticity), the policymaker may choose a pro-consumer policy to alleviate the loss of consumers by tax reform ($q^T < q^O$ happens

[32]In a generalized model, $dq(\hat{p}, \hat{R}) \gtreqless 0$ if and only if $\alpha m_2 \gtreqless (1-\tau)\phi|\partial m/\partial p|$, and the same threshold implies $dm(\bar{p}, \bar{R}) \lesseqgtr 0$ if m_2 is constant.

$(1-\tau)\phi > \alpha$	CS	PS
$\hat{R} < R^*$	Eq.(19R); $(-)$ by the order of $\alpha - (1-\tau)\phi$	Eq.(19D); possibly larger than eq.(19p)
$\bar{p} < p^*$	increase (by $p \downarrow$ and $m \uparrow$)	Eq.(19p); $(+)$ by the order of $(1-\tau)\phi - \alpha$
Tax reform	decreases CS	may increase domestic PS

Table 1: Welfare effects of tax reform and price ceiling

unconditionally). The app producers and consumers face a conflict of interests when both got worse off by tax reform, between a policy that makes both parties better-off (price ceiling in Table 1) and the one which gives a bigger benefit to one party (commission-fee ceiling in Table 1).

8 Conclusion

The world has been digitalized and a growing concern on how countries collect VAT tax from foreign online firms is a central agenda in international taxation. In particular, it has been pointed out that countries face a hard time to tax some foreign app suppliers as they locate outside the countries and supply its contents remotely via an online platform. This paper theoretically investigated the impacts of tax reform which allows countries to collect VAT payments from an online platformer instead of foreign contents suppliers.

We find that the tax reform reduces both consumers of a network good which connects consumers with online apps and the number of apps in the platform. The reason is that the reform allows the platformer to increase the price of the network good and tax-inclusive commission fee, which is in line with the standard discussion of pass through of taxation. As the market are two-sided, the pass through of tax reform happening in app supplier side spreads to the market of the network good side. Due to the negative effects, the platform become less attractive for both individuals and app suppliers.

Interestingly, our model found that the tax reform can *hurt* home app suppliers, although it eliminates unfair tax burden across app suppliers. Because the reform reduces consumption of the network good and foreign app suppliers, the negative effects which magnified with network externality can dominate the positive effects from fair tax burden. Note that the positive effect is larger as the VAT rate is higher, which means that countries with a low VAT tend to hurt their domestic app suppliers.

Furthermore, our welfare analysis showed that the reform leads to an increase in tax revenue in the country, even if the network good is also taxed and its market was downsized. However, such tax gains arise at the expense of consumers and/or domestic app suppliers because of the shrinking market sizes. Notably, our numerical example provided a clue on the condition for the country to gain from the tax reform in the sense of total welfare: it tends to improve welfare when the degree of app suppliers response to changes in price of the network good and commission fee is low. If app suppliers are less sensitive to changes in those prices, higher price of the network good and commission fee does not reduce app suppliers much and the gains from tax revenues and possibly home app suppliers dominate consumers' losses. These results clearly imply the necessity of extended discussions on designs of international taxation rules by considering some cooperation between tax authority and competition department in a country.

Appendix

A. Derivation of (1)

Consumers are heterogeneous in their preference over the network good. Specifically, consumer k has the following net utility from purchasing the good,

$$u_k = b_k + \alpha m - p,$$

($u_k = b_k + \alpha m + \alpha_D q_e - p$ with direct externality in Section 6) where b_k is fundamental willingness to pay for the good and is assumed to be uniformly distributed, $b_k \in (-\infty, \nu]$ whereas the last term p is the price for the good. We assume that consumers decide to buy one unit of the good or not. This means that consumer k buys the good if $u_k \geq 0$ or equivalently $b_k \geq p - \alpha m \equiv \underline{\nu}$ holds, which implies that consumers having higher fundamental willingness to pay than $\underline{\nu}$ buy the good, leading to $q(p) = \int_{\underline{\nu}}^{\nu} 1 db_k = \nu - \underline{\nu}$, which is (1).

B. Derivation of FOCs (7), (7′), (8) and (8′) and SOCs

Begin with the platformer's FOC on p here. From (1′), we have $\frac{\partial q}{\partial p} = \frac{-\overline{f}}{\overline{f} - \alpha M \phi \{2-(1+\eta)\tau\}} \equiv -\frac{1}{\gamma} < 0$, $q = \frac{1}{\gamma}\left(\nu - p - \frac{2\alpha RM}{\overline{f}}\right)$ and from (4′) and (5′), we have $\frac{\partial m}{\partial p} = \{2 - (1+\eta)\tau\}\phi \frac{-1}{\gamma}\frac{M}{\overline{f}}$. Therefore, the FOC for p in the platformer's problem is written as:

$$\begin{aligned}\frac{\partial\Big((p-c)q + Rm\Big)}{\partial p}\gamma^{-1} &= -(p-c) + \left(\nu - p - \frac{2\alpha RM}{\overline{f}}\right) - R\frac{\{2-(1+\eta)\tau\}\phi M}{\overline{f}} = 0 \Rightarrow \qquad \text{(7A)}\\ p &= c + \frac{\nu - c}{2} - \frac{\{2\alpha + (2-(1+\eta)\tau)\phi\}MR}{2\overline{f}},\\ &\left(p = c + \frac{q_b}{\rho} - \frac{\alpha m_2/(2\gamma) + (1 - 0.5(1+\eta)\tau)\phi|\partial m/\partial p|}{\rho}R\right)\end{aligned}$$

which derives (7) and (7′).

The formula in the third line is obtained in a generalized setup mentioned in Section 2 where the provider's behavior corresponds to $m = m_1\big((2-(1+\eta)\tau)\phi q\big) - Rm_2\big((2-(1+\eta)\tau)\phi q, R\big)$ and the induced demand function is expanded through the mean value theorem of differentiation by $q\{1 - \alpha(2-(1+\eta)\tau)\phi\frac{\partial m_1}{\partial \Phi}\} \equiv q\gamma = q_a + q_1^{ar}p - \alpha m_2 R$ with $q_1^{ar} = \frac{\partial q_1^{mv}}{\partial p}$ representing an average reaction to p. In this formula, $\frac{q_a}{-q_1^{ar}} = \nu$ and $\rho = \frac{1}{2}\big(-\frac{\partial q}{\partial p} - \frac{q_1^{ar}}{\gamma}\big)$. The variable $\frac{q_b}{\rho}$ is related to $\nu - c$, and $(2-(1+\eta)\tau)\phi|\frac{\partial m}{\partial p}| \equiv \frac{\partial m}{\partial q}\frac{-\partial q}{\partial p}$.

For the commission fee, we have $\frac{\partial q}{\partial R} = 2\alpha\frac{M}{\overline{f}}\frac{-1}{\gamma}$, $m = \frac{M}{\overline{f}}\Big[\{2-(1+\eta)\tau\}\phi q(p,R) - 2R\Big]$

$=\frac{M}{\overline{f}}\frac{\{2-(1+\eta)\tau\}\phi\overline{f}(\nu-p)-2R\overline{f}}{\overline{f}-\alpha M\phi(2-(1+\eta)\tau)}$ and $\frac{\partial m}{\partial R} = -\frac{M(2-(1+\eta)\tau)\phi}{\overline{f}}\frac{2\alpha M}{\overline{f}-\alpha M\phi(2-(1+\eta)\tau)} + \frac{M(-2)}{\overline{f}} = -\frac{M}{\overline{f}}\frac{2\overline{f}}{\overline{f}-\alpha M\phi(2-(1+\eta)\tau)}$, so that:

$$\begin{aligned}\frac{\partial\Big((p-c)q+Rm\Big)}{\partial R}\gamma^{-1}\frac{\overline{f}}{M} &= \{2-(1+\eta)\tau\}\phi(\nu-p)-2R-2R-2\alpha(p-c) \qquad \text{(8A)}\\ &\equiv \; FOC_R^O-\eta\tau\phi(\nu-p)=0,\end{aligned}$$

which derives (8) and (8′). In the generalized entry function, for the mark-up $\frac{q_b}{\rho}$ that the platformer charges from consumers, we have $R^* \gtreqless 0 \Leftrightarrow \frac{q_b}{\rho}\frac{\alpha}{\gamma}m_2 \lesseqgtr (\nu-c-\frac{q_b}{\rho})\frac{\partial m_1}{\partial q}(-q_1^{ar})$ (Online Appendix B.4). The charging incentive relates to the consumers' net gain $\nu-c-\frac{q_b}{\rho}$, and the promotion incentive is through $\frac{m_2}{\gamma}>0$ in the induced demand function.

For the second-order condition, we have $\frac{\partial^2\pi_P}{\partial p\partial p}\gamma^{-1}=-2$, $\frac{\partial^2\pi_P}{\partial R\partial R}\gamma^{-1}=-4\frac{M}{\overline{f}}$, $\frac{\partial^2\pi_P}{\partial p\partial R}\gamma^{-1}=-\frac{2\alpha M}{\overline{f}}-\frac{\{2-(1+\eta)\tau\}\phi M}{\overline{f}}$. Therefore,

$$\overline{f}-\frac{M\left[2\alpha+\{2-(1+\eta)\tau\}\phi\right]^2}{8}>0.$$

Note that $\frac{M(2\alpha+2\phi-\tau\phi)^2}{8} > \frac{M(\alpha+\phi-\tau\phi)^2}{2}$ holds. Condition (A-1) subsumes the above condition, so Assumption 1 warrants the interior optimum of the benchmark model.

Meaning of the SOCs

Surrounding the benchmark gains-of-trade value of $\frac{\nu-c}{2}=\nu-p^O|_{R=0}$ in (7), one can equate (9) with the function before platformer's optimization (1′) as: $q^O=\frac{\overline{f}(\nu-c)/2}{\overline{f}-M\frac{\{2\alpha+\phi(2-\tau)\}^2}{8}}=\frac{\overline{f}(\nu-p)-2\alpha MR}{\overline{f}-\alpha M\phi\{2-\tau\}}$. Intuitively, utilizing externalities for pricing, the multiplier (self-enforcing) effect of the product's demand with respect to the retained benefit $\nu-p$ or $\frac{\nu-c}{2}$ is stronger in the optimized demand function than the effect in the price-taker's induced demand. $\frac{\{2\alpha+\phi(2-\tau)\}^2}{8}>\alpha\phi(2-\tau)$ when $R^O\neq 0$.

C. Proof of Proposition 1

The formula (9′) and the formula of R^T show that $R^T + \tau\phi q^T = \frac{\overline{f}(\nu-c)(\phi+\tau\phi-\alpha)}{2\{2\overline{f}-M\{\alpha+\phi(1-\tau)\}^2\}}$. From the formula of R^* ($* = O,\ T$) and (7′), with $den^* = 2 - (\alpha + \phi - 0.5(1+\eta)\tau\phi)^2 \frac{M}{\overline{f}} > 0$ for $\eta = 0,\ 1$:

$$p^T - p^O = \frac{(\alpha + (1-\tau)\phi)(\nu - c)M}{4den^T\overline{f}}\tau\phi\{1 + \frac{(2\phi - \tau\phi - 2\alpha)(\alpha + (1-0.75\tau)\phi)M}{den^O\overline{f}}\}$$
$$+ 0.5\tau\phi\frac{(\nu - c)(\phi - 0.5\tau\phi - \alpha)M}{2den^O\overline{f}} \tag{A-2}$$
$$\Longleftrightarrow (1 - \frac{3}{4}\tau)\phi - \frac{\{(2\alpha)^2 - (2-\tau)^2\phi^2\}\{\alpha + (1-0.75\tau)\phi\}}{4den^O}\frac{M}{\overline{f}} > 0,$$
$$R^T + \tau\phi q^T - R^O = \frac{\tau\phi(\nu - c)}{4den^T}\left\{3 + \frac{\{2\alpha - (2-\tau)\phi\}\{\alpha + (1-0.75\tau)\phi\}}{den^O}\frac{M}{\overline{f}}\right\}. \tag{A-3}$$

The signs of eqs.(A-2) and (A-3) depend on the last term of the numerator $2\alpha - 2\phi + \tau\phi$. From (13) and (A-2) , $2\alpha - 2\phi + \tau\phi \le 0$ or $p^T > p^O$ implies $R^O > R^T$. Therefore, Assumption 1 secures $p^T > p^O$ and $R^T < R^O < R^T + \tau\phi q^T$ if

$$\frac{8\{\overline{f} - MA(\alpha, \phi, \tau, \nu - c, M)\}}{2\alpha + 2\phi + \tau\phi} + \nu - c \ge \frac{M(4\alpha + 4\phi - 3\tau\phi)(-2\alpha + 2\phi - \tau\phi)}{3(2\alpha + 2\phi + \tau\phi)} \quad \text{when } -2\alpha + 2\phi - \tau\phi \ge 0,$$
$$\frac{8\{\overline{f} - MA(\alpha, \phi, \tau, \nu - c, M)\}}{2\alpha + 2\phi + \tau\phi} + \nu - c \ge \frac{M(4\alpha + 4\phi - 3\tau\phi)((2\alpha)^2 - (2-\tau)^2\phi^2)}{(2\alpha + 2\phi + \tau)(4 - 3\tau)\phi} \quad \text{when } 2\alpha - 2\phi + \tau\phi \ge 0,$$

holds.

The structure of tax incidence is as follows. Its implication is described in the main text.

$$\frac{R^T + \tau\phi q^T - R^O}{R^O - R^T} = \frac{3\frac{den^O}{\alpha + (1-0.75\tau)\phi} - (2\phi - \tau\phi - 2\alpha)\frac{M}{\overline{f}}}{\frac{den^O}{\alpha + (1-0.75\tau)\phi} + (2\phi - \tau\phi - 2\alpha)\frac{M}{\overline{f}}} \tag{A-4}$$

Apply (7′) for consumers' gains of trade and also apply (9′) and (10′) to have $m_H^T = \{(1-\tau)\phi + \alpha\}\frac{M}{2\overline{f}}q^T$. Substituting (A-4) into (A-2), we have (14).

D. Entry and exit in the general model

In (13), we decompose $(R^T - R^O) \cdot den^T$ between $\Delta r_b \equiv \frac{(\phi - 0.5\tau\phi - \alpha)(\nu - c)(den^O - den^T)}{2den^O}$ and $\Delta r_a \equiv (R^T - R^O) \cdot den^T - \Delta r_b$. In Online Appendix B.4, we show that we can do this decomposition in the general model. Δr_b relates to the entry elasticity since $den^O - den^T = -\tau\phi(\alpha + \phi - 0.75\tau\phi)\frac{M}{\overline{f}}$. In the linear model, it also relates to $(\nu - c)\frac{(den^O - den^T)}{den^O} = (q^T - q^O) \cdot den^T$ in (9′) since the denominator of q^* relates to that of R^*. $\Delta r_a (= -0.25\tau\phi(\nu - c))$ relates to the platformer's reduced charge after tax leak is prevented, and it is negative. For $\Delta R_a \equiv \frac{\Delta r_a}{den^T}$ and $\Delta R_b \equiv \frac{\Delta r_b}{den^T}$, the general expression of (17) for $m_H(q, R)$ is:

$$m_H^T - m_H^O = \frac{\partial m_H}{\partial R}\Delta R_a - \{\frac{\partial m_H}{\partial q}(q^O - q^T) - \frac{\partial m_H}{\partial R}\Delta R_b\} \gtreqless 0 \quad \text{with weak/strong entry elasticity,} \tag{17g}$$

where the derivative is identified by the mean value theorem of differentiation. The first term is generally positive since reduction of the commission fee encourages the entry. The effect of ΔR_b is, whether it is positive or negative, weaker than that of production, so the second term is negative in general.

Denoting $m((2-(1+\eta)\tau)\phi, R)$, we have $m^T - m^O = (-\tau\phi q^T \frac{\partial m}{\partial \Phi} + \frac{\partial m}{\partial R}\Delta R_a) - \{(2-(1+\eta)\tau)\phi\frac{\partial m}{\partial \Phi}(q^O - q^T) - \frac{\partial m}{\partial R}\Delta R_b\} \equiv \Delta m_a - \{(2-(1+\eta)\tau)\phi\frac{\partial m}{\partial \Phi}(q^O - q^T) - \frac{\partial m}{\partial R}\Delta R_b\}$ with $\eta \in [0,1]$.[33] For robustness, one can express $q = q_1(p) + \alpha m$ as:

$$(q^T - q^O)\{1 - \alpha(2-(1+\eta)\tau)\phi\frac{\partial m}{\partial \Phi} + \alpha\frac{\partial m}{\partial R}\frac{\Delta R_b}{q^T - q^O}\} = \frac{\partial q_1}{\partial p}\Delta p + \alpha\Delta m_a.$$

$$(q^T - q^O)\{1 - \alpha(2-(1+\eta)\tau)\phi\frac{\partial m}{\partial \Phi}\} = \frac{\partial q_1}{\partial p}\Delta p + \alpha\Delta m_a - \alpha\frac{\partial m}{\partial R}\Delta R_b.$$

When ΔR_b is negative (positive), we apply the first (second) formula. Within the range of $p^T - p^O > 0$, the right-hand side of each formula is positive (footnote 33) and decreasing in entry elasticity, and the term in the curly bracket in the left-hand side of each formula is positive and decreasing in entry elasticity. Therefore, q decreases after tax reform, and the market shrinkage is greater with greater entry elasticity. We therefore confirmed Proposition 2 in the general model.

E. Proof of Proposition 4

When the network good is subject to the VAT (Section 5.1), for the tilde being the value divided by $\frac{1}{1-\tau}$, e.g., $\widetilde{\phi} \equiv \frac{\phi}{1-\tau}$, we have (Online Appendix B.1):

$$p^*(1-\tau) - c = \frac{\nu(1-\tau) - c}{2} - \{\alpha + (1 - 0.5(1+\eta)t)\widetilde{\phi}\}\frac{(1-\tau)M}{\overline{f}}R^* \tag{A-6}$$

$$\nu - p^* = \frac{\nu - \widetilde{c}}{2} + \{\alpha + (1 - 0.5(1+\eta)t)\widetilde{\phi}\}R^*\frac{M}{\overline{f}} \tag{7v}$$

[33] $\Delta m_a = (-\tau\phi q^T\frac{\partial m}{\partial \Phi} + \frac{\partial m}{\partial R}\Delta R_a)$ is negative as it is in the first term of (16). In the first term of (16), the decline of $\frac{\partial m}{\partial q}$ from $\frac{M}{\overline{f}}(2-\tau)\phi$ in Regime O to $\frac{M}{\overline{f}}(2-2\tau)\phi$ after the tax reform dominates the positive part in (17) accruing in H and F ($-0.5 = -1 + 0.5$). The second term is negative as in the text. The domestic producers do not have the first term since they pay VAT since Regime O.

We have $\pi_P^* = \frac{v(1-\tau)-c}{2} q^*$ with q–tax, so comparing with the surplus in (12), out of the gains of trade $v - c = v - p^* + p^*(1-\tau) + \tau p^* - c$, the platformer bears the amount $\frac{\tau v}{2}$ per unit of the good.

Online Appendix B.1 shows that the new commission fee is: $R^* = (v(1-\tau)-c)\big((2-(1+\eta)t)\frac{\phi}{1-\tau} - 2\alpha\big)(4den_B^*)^{-1} = (1-\tau)R_B^*(\widetilde{\phi},(1-\tau)\frac{M}{\overline{f}},\widetilde{c},\alpha,t)$ (where R_B^* and den_B^* are the ones in (8′) where ϕ, $\frac{\overline{f}}{M}$ and c are divided by $1-\tau$). As the sum of (7v) and (A-6) is $v - c - \tau p^*$, the amount

$$\begin{aligned}\tau p^* - \frac{\tau v}{2} &= p^* - \frac{v+c}{2} + \{\alpha + (1-0.5(1+\eta)t)\widetilde{\phi}\}\frac{(1-\tau)M}{\overline{f}}R^* \\ &= \frac{\tau}{2}\frac{c}{1-\tau} - \tau(1-\tau)\{\alpha + (1-0.5(1+\eta)t)\widetilde{\phi}\}R_B^*\frac{M}{\overline{f}}\end{aligned}$$

is the per-unit tax burden attributed to the consumers. Therefore, taking the difference of the above value by tax reform, $\tau\Delta p^* = \tau(1-\tau)\frac{M}{\overline{f}}\Delta\left[\{\alpha + (1-0.5(1+\eta)t)\widetilde{\phi}\}(-R_B^*)\right]$ is positive (see below for $R_B^O > R_B^T$), and this amount is born by consumers. *Q.E.D.*

Tax incidence of the commission fee and price

In $R^T - R^O = (v - \frac{c}{1-\tau})\Delta\left[\big(\phi\{1-0.5(1+\eta)t\} - \alpha(1-\tau)\big)(2den_B^*)^{-1}\right]$, there is an increase of the fee by $\tau\alpha$ which dominates a reduction of the fee related to c (assuming, as it is reasonable, that $v - \frac{c}{1-\tau}$ is greater than $\phi\{1-0.5(1+\eta)t\} - \alpha(1-\tau)$). For the denominator we have $\frac{\partial}{\partial\tau}\{(den_B^*)^{-1}\} \propto \{-(\sqrt{1-\tau})^{-1}\alpha\frac{M}{\overline{f}} + (\sqrt{1-\tau})^{-1}\frac{1-0.5(1+\eta)t}{1-\tau}\phi\frac{M}{\overline{f}}\}$ that is positive and lower when $\eta = 1$. So when $R^* > 0$, q–tax *increases* the commission fee, and the reduction of the commission fee after tax reform is robust. Given t, q^* in (9) has a decrease in numerator by the factor of $\tilde{c} - c$ and the increase in $(den^*)^{-1}$ as explained above. The decrease in the numerator would be more significant if entry elasticity is sufficiently small. The incidence of these is $m^* = \frac{M}{\overline{f}}\{(1-0.5(1+\eta)t)\phi + \alpha(1-\tau)\}q^*$ in the subtraction of $\alpha\tau$ (since consumption is now taxed) and the shrinkage of network users q^*.

Regarding the price, denoting the condition for $p_B^T > p_B^O$ in the second line of (A-2) as $G(\alpha,\phi,\frac{M}{\overline{f}},\tau) > 0$, we have $G(\alpha,\widetilde{\phi},\frac{(1-\tau)M}{\overline{f}},\tau) > 0$ for $p^T > p^O$ in the present case. As in the benchmark case, this warrants $R_B^T < R_B^O$.

F. The Case with Two Externalities

When there is direct externality α_D (Section 6), the first line of (17) becomes $m_H^T - m_H^O = \frac{0.5\tau\phi}{2}\frac{v-c}{den^T} - \frac{0.5\tau\phi(\alpha+\phi-1.5\tau\phi)M/\overline{f}}{2}\frac{(\alpha+\phi-0.75\tau\phi)}{\overline{f}(1-\alpha_D)-M\{2\alpha+\phi(2-\tau)\}^2/8}\frac{v-c}{den^T}$ with $den^* = 2(1-\alpha_D) - (\alpha+\phi-0.5(1+\eta)\phi)^2 M/\overline{f}$, so for $\delta \in (0, 0.75)$ we have:

$$\frac{\partial(m_H^T - m_H^O)}{\partial \alpha_D} - \frac{\partial(m_H^T - m_H^O)}{\partial \alpha} \propto (1 - \frac{M(\alpha+\phi-1.5\tau\phi)(\alpha+\phi-0.75\tau\phi)}{\overline{f}(1-\alpha_D) - M\{2\alpha+\phi(2-\tau)\}^2/8})\frac{2}{den^T}(1 - \{\alpha+\phi(1-0.5\tau)\}M/\overline{f})$$
$$-(\frac{M\{\alpha+\phi-(1.5+0.75)\tau\phi/2\}}{\overline{f}(1-\alpha_D) - M\{2\alpha+\phi(2-\tau)\}^2/8})\times$$
$$\frac{-2(1-\alpha_D) + (\alpha+\phi-(0.75+\delta)\tau\phi) + (0.25+\delta)\tau\phi\{\alpha+\phi(1-0.5\tau)\}M/\overline{f}}{den^T}$$

The first term in the right-hand side is positive if $m_H^T > m_H^O$ and $\{\alpha+\phi(1-0.5\tau)\}\frac{M}{\overline{f}} < 1$. The latter is a natural extension of Assumption 1.[34] The last term is positive if $\alpha_D + \max\{\alpha, (1-0.75\tau)\phi\} \leq 1$. The first term becomes negative if $m_H^T < m_H^O$, and, maintaining $\{\alpha+\phi(1-0.5\tau)\}\frac{M}{\overline{f}} < 1$, the second term decreases in entry elasticity.

In Online Appendix B.2, we show part (ii) and part (iii) of the proposition. The condition that digitalization aggravates the shrinkage of the number of users is $\max\{\alpha, (1-0.75\tau)\phi\}(2 - 1.5(\frac{\partial q^T}{\partial \alpha})(\frac{\partial q^T}{\partial \alpha_D})^{-1})$ $+0.5\alpha_D \leq 0.5$ and $(\frac{\partial q^*}{\partial \alpha})(\frac{\partial q^*}{\partial \alpha_D})^{-1} = \alpha + \phi(1 - 0.5(1+\eta)\tau)\}\frac{M}{\overline{f}}$.

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[34] Assumption 1 is now $1 \geq (\frac{(\alpha+\phi-0.5\tau\phi)}{2(1-\alpha_D)} + \frac{(\alpha+\phi+0.5\tau\phi)(v-c)}{(\alpha+\phi-0.5\tau\phi)4M(1-\alpha_D)})(\alpha+\phi-0.5\tau\phi)\frac{M}{\overline{f}}$. So $\alpha_D + \max\{\alpha, (1-0.5\tau)\phi\} \leq 1$, or sufficiently high net market size, will warrant this assumption.

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Online Appendix for

"Tax Reform on Monopoly Platformer in Borderless Economy: The Incidence on Prices and Efficiency Consequences"

Shigeo Morita Yukihiro Nishimura Hirofumi Okoshi

B.1. Equilibrium values of two extension models

When there is direct externality α_D (Section 6), the induced demand function is now $q(p,R) = \frac{\overline{f}(\nu-p)-2\alpha MR}{\overline{f}(1-\alpha_D)-\alpha M\phi\{2-(1+\eta)\tau\}}$. With this modification, (7A) is unchanged but (8A) is changed to:

$$\frac{\partial \pi_P}{\partial R}\left(-\frac{\partial q}{\partial p}\right)^{-1}\frac{\overline{f}}{M} = (2-(1+\eta)\tau)\phi(\nu-p) - 2R(1-\alpha_D) - 2R(1-\alpha_D) - 2\alpha(p-c) = 0,$$

which corresponds to the benchmark formula where R and $\overline{f}$ are multiplied by $1-\alpha_D$, so $R^* = \frac{\overline{f}(\nu-c)((1-0.5(1+\eta)\tau)\phi-\alpha)}{4(1-\alpha_D)\overline{f}-2M\{\alpha+\phi(1-0.5(1+\eta)\tau)\}^2} = \frac{R_B^*(\overline{f}(1-\alpha_D))}{1-\alpha_D}$ to be written with the benchmark value R_B^* in (8′) as a function of $\overline{f}$. Substituting this and (7A) (with $R=R^*$) into the new demand system, we have $q^* = \frac{q_b^*(\overline{f}(1-\alpha_D))}{1-\alpha_D}$. In turn, we have $m_H^* = \frac{M\left[\{1-\tau\}\phi\frac{q_b^*(\overline{f}(1-\alpha_D))}{1-\alpha_D} - \frac{R_B^*(\overline{f}(1-\alpha_D))}{1-\alpha_D}\right]}{\overline{f}} = m_H^*(\overline{f}(1-\alpha_D))$. Assumption 1 is replaced with $\frac{\overline{f}}{M}(1-\alpha_D) \geq A(\alpha,\phi,\tau,\nu-c,M)$.

When the network good is subject to the VAT (Section 5.1), for the tilde being the value divided by $\frac{1}{1-\tau}$, e.g., $\widetilde{\phi} \equiv \frac{\phi}{1-\tau}$ we have:

$$\frac{\partial \pi_P}{\partial p}\left(-\frac{\partial q}{\partial p}\right)^{-1} = -(p(1-\tau)-c) + (1-\tau)(\nu-p) - \frac{2\alpha R(1-\tau)M}{\overline{f}} - R\frac{[2-(1+\eta)\tau]\widetilde{\phi}(1-\tau)M}{\overline{f}} = 0$$
$$\frac{\partial \pi_P}{\partial R}\left(-\frac{\partial q}{\partial p}\right)^{-1}\frac{\overline{f}}{M} = (2-(1+\eta)\tau)\widetilde{\phi}(1-\tau)(\nu-p) - 4R - 2\alpha(p(1-\tau)-c) = 0.$$

Therefore, the obtained formula corresponds to the benchmark counterpart where ϕ and $\overline{f}$ are divided by $1-\tau$ and ν and p are multiplied by $1-\tau$ (or, equivalently, ϕ, $\overline{f}$, c, and R are divided by $1-\tau$). From the above two equations, we have $R^* = (1-\tau)R_B^*(\widetilde{\phi},(1-\tau)\frac{M}{\overline{f}},\widetilde{c},\alpha,t)$ (where R_B^* is the one in (8′) where ϕ, $\frac{\overline{f}}{M}$ and c are divided by $1-\tau$) and $\nu-p^*$ in (7v) for $*=O,\ T$ for $\eta=0$ and 1, respectively.

Substituting these equations into (1′), we have $q^* = q_B^*(\widetilde{\phi},(1-\tau)\frac{M}{\overline{f}},\widetilde{c},\alpha,t)$. Substituting these into (4′) brings $m^*_H = m^*_{H,B}(\widetilde{\phi}, (1-\tau)\frac{M}{\overline{f}}, \widetilde{c}, \alpha, t)$. Therefore, we have

$$m^T_H \gtreqless m^O_H \Leftrightarrow \overline{f} \gtreqless (1-\tau)MK\big(\alpha, \frac{\phi}{1-\tau}, t\big)$$

with $t = \tau$. The meaning of this formula is basically the same as Proposition 2. The threshold inverse elasticity decreases since the platformer takes into account that firm entry is taxed when it comes to consumption of the network good. High VAT rate makes the increase of the entry even more likely to occur than in the benchmark model. This is because $\frac{d\{(1-\tau)K\left(\alpha,\frac{\phi}{1-\tau},\tau\right)\}}{d\tau} = (1-\tau)\frac{\partial K\left(\alpha,\frac{\phi}{1-\tau},t\right)}{\partial\tau} - K\big(\alpha, \frac{\phi}{1-\tau}, \tau\big) + k\big(\alpha, \frac{\phi}{1-\tau}, \tau\big)$, for a function k such that $k\big(\alpha, \frac{\phi}{1-\tau}, \tau\big) < K\big(\alpha, \frac{\phi}{1-\tau}, \tau\big)$, so we have $\frac{d\{(1-\tau)K\left(\alpha,\frac{\phi}{1-\tau},\tau\right)\}}{d\tau} < (1-\tau)\frac{\partial K\left(\alpha,\frac{\phi}{1-t},\tau\right)}{\partial\tau}|_{t=\tau}$.

B.2. The Case with Two Externalities

The traditional channel works for q and $\frac{\partial q^*}{\partial\alpha} < \frac{\partial q^*}{\partial\alpha_D}$ if, as a natural extension of Assumption 1, $\{\alpha + \phi(1-0.5\tau)\}\frac{M}{\overline{f}} < 1$ (see Appendix F).

$q^O - q^T = \frac{(\nu-c)\tau\phi(\alpha+\phi-0.75\tau\phi)M/\overline{f}}{\left\{2(1-\alpha_D)-\{\alpha+\phi(1-\tau)\}^2M/\overline{f}\right\}\left\{2(1-\alpha_D)-\{\alpha+\phi(1-0.5\tau)\}^2M/\overline{f}\right\}}$ and $\frac{\partial\ln(q^O-q^T)}{\partial\alpha_D} - \frac{\partial\ln(q^O-q^T)}{\partial\alpha} \propto -1 + \frac{(1-\{\alpha+\phi(1-\tau)\}M/\overline{f})\{\alpha+\phi-0.75\tau\phi\}}{\left\{1-\alpha_D-\{\alpha+\phi(1-\tau)\}^2M/\{2\overline{f}\}\right\}} + \frac{(1-\{\alpha+\phi(1-0.5\tau)\}M/\overline{f})\{\alpha+\phi-0.75\tau\phi\}}{\left\{1-\alpha_D-\{\alpha+\phi(1-0.5\tau)\}^2M/\{2\overline{f}\}\right\}}$. The latter is positive when $(\alpha + (1-0.75\tau)\phi)(1-0.75(\alpha+(1-0.5\tau)\phi)M/\overline{f}) + 0.5\alpha_D \geq 0.5$ but negative when $(\alpha + (1-0.75\tau)\phi)(1-0.75(\alpha+(1-\tau)\phi)M/\overline{f}) + 0.5\alpha_D \leq 0.5$.

For the commission fee, when $(1-0.5(1+\eta)\tau)\phi - \alpha > 0$, we have $\frac{\partial R^*}{\partial\alpha_D} > \frac{\partial R^*}{\partial\alpha} = \frac{(1-0.5(1+\eta)\tau)\phi-\alpha}{2}\frac{\partial q^*}{\partial\alpha} - \frac{1}{2}q^*$.

Let $\tilde{R}^O = \frac{(1-\tau)\phi-\alpha}{2}q^O$ so $R^O - \tilde{R}^O = \frac{0.5\tau\phi}{2}q^O$ and $\tilde{R}^O - R^T = \frac{(1-\tau)\phi-\alpha}{2}(q^O - q^T)$. Let $\frac{\partial(R^O-R^T)}{\partial\alpha}|_{den} = \frac{(1-0.5(1+\eta)\tau)\phi-\alpha}{2}\frac{\partial q^*}{\partial\alpha}$. When $(1-0.5(1+\eta)\tau)\phi - \alpha > 0$, we have $-0.5(q^O - q^T) + \frac{\partial(R^O-R^T)}{\partial\alpha}|_{den} = \frac{\partial(R^O-R^T)}{\partial\alpha}$ and $\frac{\partial(R^O-R^T)}{\partial\alpha_D} = \frac{\partial(\tilde{R}^O-R^T)}{\partial\alpha_D} + \frac{\partial(R^O-\tilde{R}^O)}{\partial\alpha_D}$. Therefore, if $\frac{\partial\ln(q^O-q^T)}{\partial\alpha_D} > \frac{\partial\ln(q^O-q^T)}{\partial\alpha}$ and $R^T \geq 0$, then $\frac{\partial(R^O-R^T)}{\partial\alpha} < \frac{\partial(R^O-R^T)}{\partial\alpha_D}$. Likewise, we can show $\frac{\partial(p^T-p^O)}{\partial\alpha} < \frac{\partial(p^T-p^O)}{\partial\alpha_D}$.

For the total app provision m^* ($m^O > m^T$ as in the benchmark analysis), we show below the following. For a parameter $0 < \beta < 1$:

$$\Big(\frac{\partial\ln(q^O-q^T)}{\partial\alpha_D} - \frac{\partial\ln(q^O-q^T)}{\partial\alpha}\Big)\beta + \frac{1}{\alpha} < \frac{\partial\ln(m^O-m^T)}{\partial\alpha_D} - \frac{\partial\ln(m^O-m^T)}{\partial\alpha} \qquad (16d)$$

Digitalization alleviates the shrinkage of the app market to the greater extent than the network-good market.

Let $p^* = c + \frac{\nu - c}{2} - d^* q^*$ where $d^* = \frac{M(-\alpha^2 + \{(1-0.5(1+\eta)\tau)\phi\}^2)}{2\bar{f}}$ and $d^O - d^T > 0$. For total number of app producers, from $\alpha m = q - p$ we have

$$\alpha \frac{\partial(m^O - m^T)}{\partial \alpha} - (d^O - d^T)\frac{\partial q^T}{\partial \alpha_D} = -(m^O - m^T) - \frac{M\alpha}{\bar{f}}(q^O - q^T) + (1 + d^O)\frac{\partial(q^O - q^T)}{\partial \alpha}$$
$$+ (d^O - d^T)(\frac{\partial q^T}{\partial \alpha} - \frac{\partial q^T}{\partial \alpha_D}).$$

The additional term in the left-hand side of the above formula is present to compare this value with $\alpha \frac{\partial(m^O - m^T)}{\partial \alpha_D} - (d^O - d^T)\frac{\partial q^T}{\partial \alpha_D}$. $1 + d^O \propto \frac{\bar{f}}{M} + \frac{(-\alpha^2 + \{(1-0.5\tau)\phi\}^2)}{2}$ which is positive by Assumption 1 in the present context, and $(1 + d^O)\frac{\partial(q^O - q^T)}{\partial \alpha_D} = \alpha \frac{\partial(m^O - m^T)}{\partial \alpha_D} - (d^O - d^T)\frac{\partial q^T}{\partial \alpha_D}$. Dividing both sides of the above formula by $\alpha(m^O - m^T)$ and $\beta = \frac{(1+d^O)(q^O - q^T)}{\alpha(m^O - m^T)}$, we have (16$d$).

B.3 Increase of tax revenue

A comparison of TR^O and TR^T is done in the following way.

$$TR^T - TR^O = \tau\phi(2m_H^T q^T - m_H^O q^O) + \tau p^O(q^T - q^O) + \tau(p^T - p^O)q^T$$

When $R^O \geq 0$, a variant of (A-2) holds to induce $p^T > p^O$ and $R^T < R^O$. For the difference in the VAT revenue from the network good, we broke it down into parts. The last term is positive. Now we show that the sum of the first and second terms is positive if: (i) $R^O \geq 0$ (the production-side externalities are dominant for the commission fee), (ii) $0.30 > \tau$, (iii) $\frac{\bar{f}}{M}$ is sufficiently large so that $q^T/q^O \geq 0.75$ or $q^T/q^O \leq 0.5$, and (iv) the market size with distorted marginal cost is still large: $(1-\tau)(\nu - \frac{c}{1-\tau})/(2M) \geq \phi$ and $0.5(\nu - \frac{c}{1-\tau}) > \frac{c}{1-\tau}$.

We first notice, since $q^* = \frac{\bar{f}(\nu - \frac{c}{1-\tau})}{2\bar{f} - (1-\tau)M\{\alpha + (1-0.5(1+\eta)\tau)\frac{\phi}{1-\tau}\}^2}$,

$$m_F^O \leq M \Leftrightarrow \frac{\bar{f}}{M} \geq (1-\tau)A(\alpha, \frac{\phi}{1-\tau}, \tau, \nu - \frac{c}{1-\tau}, M),$$
$$m_H^* = \frac{M(\nu - \frac{c}{1-\tau})\{(1-\tau)\alpha + \{1 - (1.5 - 0.5\eta)\tau\}\phi\}}{4\bar{f} - 2(1-\tau)M\{\alpha + (1-0.5(1+\eta)\tau)\frac{\phi}{1-\tau}\}^2},$$
$$q^O - q^T = \frac{\tau\phi(\nu - \frac{c}{1-\tau})(\alpha + (1-0.75\tau)\frac{\phi}{1-\tau})(1-\tau)M/\bar{f}}{\left\{2 - \{\alpha + \phi\}^2(1-\tau)M/\bar{f}\right\}\left\{2 - \{\alpha + (1-0.5\tau)\frac{\phi}{1-\tau}\}^2(1-\tau)M/\bar{f}\right\}} \quad (9'')$$

From the above formula and $m_F^T = m_H^T$ we have:

$$
\begin{aligned}
&(m_H^T + m_F^T)q^T - m_H^O q^O + p^O(q^T - q^O)/\phi \propto \\
&(\alpha+\phi)\left(1.7[2-\{(1-0.5\tau)\frac{\phi}{1-\tau}+\alpha\}^2(1-\tau)\frac{M}{\bar{f}}]^2 - [2-\{\phi+\alpha\}^2(1-\tau)\frac{M}{\bar{f}}]^2\right) \\
&+0.3(\alpha+\phi)[2-\{(1-0.5\tau)\frac{\phi}{1-\tau}+\alpha\}^2(1-\tau)\frac{M}{\bar{f}}]^2 + 0.5\tau\frac{\phi}{1-\tau}[2-\{\phi+\alpha\}^2(1-\tau)\frac{M}{\bar{f}}]^2 \\
&-\tau p^O(\nu - \frac{c}{1-\tau})(\alpha + (1-0.75\tau)\frac{\phi}{1-\tau})\times \\
&[2-\{\alpha+\phi\}^2(1-\tau)\frac{M}{\bar{f}}][2-\{\alpha+(1-0.5\tau)\frac{\phi}{1-\tau}\}^2(1-\tau)\frac{M}{\bar{f}}]/(\nu-\frac{c}{1-\tau})^2
\end{aligned}
$$

When there is no q–tax (Section 4.3), multiply $1-\tau$ to ϕ and $\frac{\bar{f}}{M}$ and omit the part with τp^O in the above formula. Then tax revenue increases if $\sqrt{2}-1 \approx 0.414 > \tau$ and $2\{\frac{\bar{f}}{M} - A(\alpha,\phi,\tau,\nu - c, M)\}/(\alpha+(1+0.5\tau)\phi) + (\nu-c)/(2M) \geq \phi$.

When there is q–tax, the first term in the RHS of the above formula is positive if $\sqrt{1.7}-1 \approx 0.30 > \tau$ and $\frac{\bar{f}}{M}$ or $\nu - \frac{c}{1-\tau}$ is sufficiently large ($2\left\{\frac{\bar{f}}{M} - (1-\tau)A(\alpha, \frac{\phi}{1-\tau}, \tau, \nu - \frac{c}{1-\tau}, M)\right\}/\{\alpha + (1+0.5\tau)\frac{\phi}{1-\tau}\} + (1-\tau)(\nu - \frac{c}{1-\tau})/(2M) \geq \phi$). For $s = q^T/q^O$ and $p^O \leq \frac{c}{1-\tau} + 0.5(\nu - \frac{c}{1-\tau})$ under $R^O \geq 0$, the rest of the term is positive if the following expression is positive:

$$
\begin{aligned}
&(\alpha+\phi)s^2 + 0.5\frac{\phi}{1-\tau} - p^O\left(\nu - \frac{c}{1-\tau}\right)^{-1}\left(\alpha + (1-0.75\tau)\frac{\phi}{1-\tau}\right)s \\
\geq &(\alpha+\phi)(s^2+0.25) + 0.25\tau\frac{1.5\phi}{1-\tau} + 0.25\left(\frac{1-0.5\tau}{1-\tau}\phi - \alpha\right) \\
&-\left\{0.5 + \frac{c}{1-\tau}\left(\nu - \frac{c}{1-\tau}\right)^{-1}\right\}s\left(\alpha+\phi+0.25\tau\frac{\phi}{1-\tau}\right) \qquad \text{(B-1)}
\end{aligned}
$$

Eq. (9″) shows that s can be arbitrarily close to 1 by $\frac{\bar{f}}{M}$ being sufficiently large. If $s^2 + 0.25 \geq s$ (say $s \geq 0.75$ or $s \leq 0.5$) and $\frac{c}{1-\tau} < 0.5(\nu - \frac{c}{1-\tau})$, then (B-1) is positive.

B.4. A general case

Suppose that participating providers earn the amount proportional m_1 of the aggregate gross profits, and suppose that the number of participating firms is written as $m = m_1\big((2-(1+\eta)\tau)\phi q\big) - Rm_2\big((2-(1+\eta)\tau)\phi q, R\big)$. Substituting this relation into the demand function and applying the mean value theorem of differentiation to have $q\{1-\alpha(2-(1+\eta)\tau)\phi\frac{\partial m_1}{\partial \Phi}\} \equiv q\gamma = q_a + q_1^{ar}p - \alpha m_2 R$ where $q_1^{ar} = \frac{\partial q_1^{mv}}{\partial p}$ represents an average reaction to p and $\frac{q_a}{\gamma}$ is an intercept of the demand function.

Revenue-maximizing prices

For $\gamma = 1 - \alpha\phi(2-(1+\eta)\tau)\frac{\partial m}{\partial \Phi}$ we have $\gamma\frac{\partial q}{\partial p} = \frac{\partial q_1}{\partial p}$, and we define $\gamma q^{ar} = q_1^{ar}$. $\frac{q_a/\gamma}{-q^{ar}} = \nu$ and $\frac{q_a/\gamma}{-q^{ar}} - p = \nu - p$ for the gains of trade. With

$$\rho \equiv \frac{1}{2}\big(-\frac{\partial q}{\partial p} - \frac{q_1^{ar}}{\gamma}\big), \quad \frac{\partial(Rm_2)}{\partial R} = m_2.$$

(the second formula is a simplifying assumption here), we have, for maximization of $\pi_P^O = (p-c)q + R(m_1 - Rm_2)$:

$$\frac{\partial \pi_P^O}{\partial p} = -p(-\frac{\partial q}{\partial p} - \frac{q_1^{ar}}{\gamma}) + c(-\frac{\partial q}{\partial p}) + \frac{q_a}{\gamma} - R(\alpha\frac{m_2}{\gamma} - (2-(1+\eta)\tau)\phi\frac{\partial m}{\partial p}) = 0 \qquad (7B)$$

$$\rightarrow \quad p^O = c + \frac{q_b}{\rho} - \frac{\alpha m_2/(2\gamma) + (1-0.5\tau)\phi|\partial m/\partial p|}{\rho}R^O,$$

$$\frac{\partial \pi_P^O}{\partial R}\Big|_{\frac{\partial \pi_P^O}{\partial p}=0}\frac{\gamma}{m_2} = -R^O\{2 - \frac{\alpha m_2/(2\gamma) + (1-0.5\tau)\phi|\partial m/\partial p|}{\rho}(\alpha + (1-0.5\tau)\phi\frac{\partial m_1/\partial \Phi}{m_2/(-2q_1^{ar})})\}$$
$$+ (1-0.5\tau)\phi h(\frac{q_b}{\rho})\frac{\partial m_1/\partial\Phi}{m_2/(-2q_1^{ar})} - \alpha\frac{q_b}{\rho} = 0,$$

where $\frac{q_b}{\rho} = (\frac{q_a}{\gamma} - c(-\frac{q_1^{ar}}{\gamma}))\frac{1}{2\rho} = \frac{\nu - c}{2}\frac{-q_1^{ar}}{\gamma\rho}$, and $h(\frac{q_b}{\rho}) = \nu - c - \frac{q_b}{\rho}$ is the consumers' share of the gains-of-trade. The correspondence between the first formula and (7) is apparent in that p^O and R^O are linked in platformer's pricing, with the coefficient $-\frac{\alpha m_2/(2\gamma)+(1-0.5\tau)\phi|\partial m/\partial p|}{\rho}$. In the linear model, $\frac{\alpha m_2}{2\gamma\rho} = \alpha\frac{\partial m/\partial R}{-2\partial q_1/\partial p}$. For the commission fee, we have $(p-c)\frac{\partial q}{\partial R} = (\frac{q_b}{\rho} - \frac{\alpha m_2/(2\gamma)+(1-0.5(1+\eta)\tau)\phi|\partial m/\partial p|}{\rho}R)\alpha\frac{-m_2}{\gamma}$ and $\frac{\partial m}{\partial R} = -(2-(1+\eta)\tau)\,\alpha\phi\frac{\partial m_1}{\partial \Phi}\frac{m_2}{\gamma} - m_2 = -\frac{m_2}{\gamma}$ and $m_1 - Rm_2 = (2-(1+\eta)\tau)\,\phi\frac{\partial m_1}{\partial\Phi}\frac{-q_1^{ar}}{\gamma}\;(h(\frac{q_b}{\rho}) + \frac{\alpha m_2/(2\gamma)+(1-0.5(1+\eta)\tau)\phi|\partial m/\partial p|}{\rho}R)\; - R\frac{m_2}{\gamma}$. In the second equation, the part in the curly bracket after R^O constitutes a multiplier. Therefore, the equilibrium commission fee is increasing in the entry elasticity, and also, the elasticity increases the rate of substitution between the two prices by monopoly platformer. The remaining two terms, $-\frac{q_b}{\rho}\alpha$ and $(1-0.5\tau)\phi h(\frac{q_b}{\rho})\frac{\partial m_1/\partial\Phi}{m_2/(-2q_1^{ar})} \approx h(\frac{q_b}{\rho})\frac{-\partial m_1/\partial q\cdot\partial q/\partial p}{-\partial(m/\gamma)/\partial R}$, correspond to the promotion/charging incentive of the commission fee we discussed in (8).

Tax reform and the separation of Δr_a and Δr_b

The decrease of R (when $R^O \geq 0$ or when entry elasticity is low) in (13) is generalized as the following formula being negative.[35] For the relative value of entry elasticity $n_1 =$

[35] As there is no prediction regarding the increase/decrease of other variables, e.g., markup and demand elasticity, we only consider taking the difference of the variables relevant for tax reform across regimes.

$|\frac{\partial m_1}{\partial p}|(\frac{m_2/2}{1-\alpha(2-2\tau)\phi\frac{\partial m}{\partial \Phi}})^{-1}$:

$$\begin{aligned}
&\Delta(\frac{\partial \pi_P}{\partial R}\frac{\gamma}{m_2})|_{\frac{\partial \pi_P}{\partial p}=0} \\
&= -R^O\frac{0.5\tau\phi|\partial m/\partial p|}{\rho}(\alpha+(1-0.5\tau)\phi n_1) - 0.5\tau\phi\{h(\frac{q_b}{\rho})n_1 + \frac{\alpha m_2/(2\gamma)+(1-\tau)\phi|\partial m/\partial p|}{\rho}R^O\} \\
\iff &(FOC_R^O - \tau\phi(\nu-p))|_{p=(7')} - FOC_R^O|_{p=(7)} \\
&= -2\alpha\frac{\{\tau\phi\}MR^O}{2\bar{f}} + (2-\tau)\phi\frac{\{-\tau\phi\}MR^O}{2\bar{f}} - \tau\phi(\frac{\nu-c}{2} + \frac{\{2\alpha+(2-2\tau)\phi\}MR^O}{2\bar{f}}) = -\tau\phi\frac{\nu-c}{2} + 2\Delta r_b
\end{aligned}$$

where $\Delta r_a = -\tau\phi\frac{\nu-c}{4} \propto -\tau\phi\cdot\frac{h\left(\frac{q_b}{\rho}\right)}{2}n_1 < 0$ is a factor that decreases R^* which is unrelated to entry elasticity. Δr_b is consistent with Appendix D.

B.5 (eliminating) VAT threshold

After the elimination of the threshold, $(1-\tau)\phi q - R - f_S \geq 0$ for the entry of firm S. To keep track of large (formerly registered) firms, we have $m_r^T = \left(\frac{[(1-\tau)\phi q^T - R^T]}{\bar{f}}\right)2M - \frac{2Mv}{\bar{f}}$. The decrease of $(1-\tau)\phi q^* - R^*$ of the formerly-registered firm means that the profit of some inefficient firms becomes less than v, whereas its increase means that the profit of efficient unregistered firms becomes greater than v. In either case, the total number of firms equals to $\left(\frac{\bar{f}_{Su}}{\bar{f}}\right)2M = \frac{2M[(1-\tau)\phi q - R]}{\bar{f}} = 2m_F^T$. Solving the equilibrium prices from $m_r^O(p,R) + m_u^O(p,R) = \frac{2M[\phi q - R]}{\bar{f}}$ in the text for maximization of $(p-c)q + R(m_r^O + m_u^O)$, the equilibrium number of the network users becomes $q = \frac{4\bar{f}(\nu-c)}{\left[8\bar{f} - M\{2\alpha+2\phi\}^2\right]} \equiv \hat{q} > q^O$ and the number of sellers becomes $m_r^O + m_u^O = \{\phi+\alpha\}\hat{q}$. From $m_r^T + m_u^T = 2m_T^F$, the number of sellers after reform $m_r^T + m_u^T = \{(1-\tau)\phi + \alpha\}q^T$ is invariant from the baseline model, so that $q^T < \hat{q}$.

Therefore, the exit of the sellers occurs by $(m_r^O + m_u^O) - (m_r^T + m_u^T) > 0$. $\hat{R} = \frac{\bar{f}(\nu-c)(2\phi-2\alpha)}{8\bar{f} - M\{2\alpha+2\phi\}^2\}}$, so eqs.(14) and (A-4) in Appendix C for consumers' burden are unchanged in their basic features. The key conclusions are invariant with q–tax.

B.6. Proof of Proposition 7.(ii)

By taking the ratio between the positive term and the negative term of (19p) and (19D), we conclude the following: for any $d\bar{p}$ chosen in (19p), the policymaker can choose a commission-fee ceiling policy with $dm(\hat{p},\hat{R}) > dm(\bar{p},\bar{R})$ if:

$$\frac{\{1-\tau\}\phi}{\alpha}\{1-\tau\}\phi\{\alpha+\{1-\tau\}\phi\} < \frac{\overline{f}}{M}$$

holds. To be more illustrative, $dm(\hat{p},\hat{R}) > dm(\bar{p},\bar{R})$ occurs if (a) $m_H^T > m_H^O$ in (17) or (b) $\frac{(1-\tau)\phi}{\alpha}$ is not much larger than 1. This is because, in the first case, with $\frac{(1-\tau)\phi}{\alpha} \equiv b > 1$, $\frac{\overline{f}}{M} > K(\alpha, \frac{b\alpha}{1-\tau}, \tau) > 1.5(1+b)^2\alpha^2 > b^2\{1+b\}\alpha^2 = \frac{\{1-\tau\}\phi}{\alpha}\{1-\tau\}\phi\{\alpha+\{1-\tau\}\phi\}$ since $1.5(1+b) > b$. In the second case, the condition of $\frac{\{1-\tau\}\phi}{\alpha}\{1-\tau\}\phi\{\alpha+\{1-\tau\}\phi\} < \frac{\overline{f}}{M}$ is satisfied by the second-order condition. *Q.E.D.*