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Together or Apart? Eco-friendly Location under Fiscal Competition*

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Abstract

Parallel to governments' fiscal policy competition to attract a foreign firm, countries' attention to environmental damages grows. This paper analyzes fiscal competition between two asymmetric-sized countries under production-based pollution. An indigenous local firm exists in a large country, and two countries design a lump-sum fiscal policy for a multinational enterprise (MNE) outside the region. We find that fiscal competition changes the equilibrium location of an MNE from the large country to the small country when interregional trade costs are sufficiently small. Moreover, we show that whether a change in the MNE's location due to fiscal competition leads to eco-friendly location depends on how superior clean technology the MNE owns. Besides, we find that fiscal competition can improve welfare in competing countries simultaneously: the small country successfully attracts the MNE with a tax because the counteroffer by the large government has a heavier tax whereas a large country benefits from losing the MNE through less environmental damages.

Keywords: Fiscal competition, Pollution, Foreign direct investment
JEL classification: F15, F23, H25, Q56

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1 Introduction

Given the progress of globalization and mobility of firms, one of the important policy designs is to attract multinational enterprises (MNEs).[1] From the viewpoint of host countries, having MNEs' production is beneficial in some ways, such as having more supplies due to no transportation costs. In attracting FDI, countries often use fiscal policies, such as tax credits and subsidies for a few years, to compete for one target MNE rather than changing a statutory corporate tax rate. The extant literature calls this situation "bidding for firms." For example, in 2021, Hungary offered a HUF 4.5 billion grant and successfully attracted Seiren, a Japanese textile manufacturer, that raised Poland and the Czech Republic for its potential FDI destinations as well as Hungary.

From the perspective of a country, designing fiscal policies to attract an MNE is essential from the viewpoint of a country; however, such policy competition is often criticized as harmful.[2] The location may be inefficient if fiscal policies influence the location preferences of an MNE. On the contrary, even if such policies do not affect the location choice of an MNE, providing subsidies to lure an MNE reduces tax revenues and public goods provision in the host country. In practice, the European Economic and Social Committee pays attention to harmful fiscal competition, calling on the European Commission (which decides to approve state aid offered by a European country) to focus on preventing the distortion of competition.[3] Therefore, careful evaluation is indispensable to avoid harmful fiscal policy competition and many researchers investigated this issue as we introduce the related literature later.

As an essential but overlooked aspect, concern about environmental problems, such as air pollution, has been rising. Furthermore, governments care about the potential impacts of FDI inflows on environmental damages when luring an MNE.[4] In the above example of Seiren's FDI

[1] In the international economics literature, several factors, such as the size of local markets and fiscal policies such as tax credits and subsidies, are known to influence the location choices of MNEs. See Greenaway and Kneller (2007) for a survey about firms' choices to supply goods to foreign countries including export-platform foreign direct investment (FDI). Some factors outside our model include better access to country-specific input advantages, such as cheap labor and abundant natural resources. See Tokunaga and Iwasaki (2017) for a meta-analysis of FDI determinants in transition countries.

[2] The Organisation for Economic Cooperation and Development raised this concern in its 1998 report. (https://www.oecd-ilibrary.org/taxation/harmful-tax-competition_9789264162945-en)

[3] See https://www.eesc.europa.eu/en/news-media/news/eesc-calls-simpler-and-fair-taxation-eu-and-beyond and https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52023AE2810.

[4] Several papers have examined the effect of competition among jurisdictions on capital/corporate tax and environmental policies under perfect competition (Eichner and Pethig 2018; Ogawa 2021; Madiès et al. 2022) and Sanna-Randaccio and Sestini 2012; Sanna-Randaccio et al. 2017 international duopoly.

in Hungary, the Ministry of Foreign Affairs and Trade, Péter Szijjártó, stated that "[t]he plant will produce some 2.5 million metres of seat cover for Europe's car market in an eco-friendly technology.[5]" Another recent example of the international fiscal competition for eco-friendly FDI is the competition for Tesla's Electric Vehicle plants in Asia and North America.[6] As manufacturing is tightly associated with pollution and MNEs production is less carbon-intensive, governments' willingness to attract an MNE seems largely influenced by environmental damages after receiving FDI.[7]

Importantly, how pollution changes government incentives to have FDI is not obvious.[8] On a positive aspect, because MNEs have cleaner technology than domestic firms, attracting an MNE can improve environmental damage in a host country. On a negative aspect, attracting firms intensifies market competition and increases total production. Empirical findings reflect these conflicting driving forces, showing mixed results on the impacts of FDI on total emissions in host countries Ren et al. 2014; Pazienza 2019; Demena and Afesorgbor 2020. For example, Demena and Afesorgbor (2020) found that 54% of the previous research reported negative impacts while 46% found positive effects. If we focus on results with significant signs, 29% and 25% of the literature show negative and positive effects, respectively. Their meta-analysis found a negative relationship between FDI and emission while considering heterogeneity in the previous studies. As the magnitude of these impacts is determined by market competition, several factors shaping the extent of market competition, such as the degree of trade liberalization, seem to play a core role.[9] Despite the complexities above, the literature has ignored the negative effects of production-based pollution regarding fiscal competition for FDI; thus, an MNE's location choice under fiscal

[5]See `https://www.nikkei.com/article/DGXZQOUC215670R20C21A5000000/` and `https://dailynewshungary.com/seirens-huf-15-bn-investment-to-create-170-new-jobs-in-sw-hungary/`.

[6]See `https://www.reuters.com/business/autos-transportation/president-jokowi-confident-tesla-will-invest-indonesia-2023-02-01/`.

[7]See `https://unctad.org/news/blog-how-tackle-pollution-fuelled-manufacturing-developing-countries` for production-based pollution and `https://thedocs.worldbank.org/en/doc/9a1339eeb35c11e262439bbda817a083-0430012023/original/MNEs-and-Climate-Change-summary-220523.pdf` for evidence on differences of carbon-intensive production.

[8]Note that MNE location decisions are not as simple as it might initially seem. Various factors, including the strategic relationships between host countries' governments, local firms, and MNEs, influence the choice. For example, many papers concluded that strict environmental regulations discourage inward FDI, which aligns with expectations. Conversely, Dijkstra et al. (2011) analyzed per-unit emission taxes in a two-country duopoly setting, showing that a foreign firm may be located in a strictly regulated home county because locating in the country similar to the home firm increases pollution damage and induces a higher emission tax on the home firm.

[9]Hu et al. (2023) empirically showed that market competition affects firms' green mergers and acquisitions.

competition is worth analyzing.[10]

Given the above importance of the topic, this paper addresses the following questions. How does pollution affect an MNE's location under fiscal competition? Does fiscal competition changing an MNE's location preferences mitigate global environmental damages? Does fiscal competition always reduce welfare in competing countries? Addressing these questions has important policy implications because trade costs are one key element for answers and deepened trade liberalization at present may cause different outcomes from the previous literature.

1.1 Results and literature

We construct an international duopoly model with two asymmetric countries in a region that compete for an MNE outside the region by incorporating production-based pollution. The MNE seeks to enter one of the two countries as a production location to supply goods to the host country and the other country via exports with regional trade costs. The two countries offer their lump-sum tax/subsidy for the MNE and are heterogeneous in two aspects: market size and an indigenous local firm in the large country. Firms have different production technologies: the MNE has cleaner technologies than the local firm, which is in line with the World Bank's finding mentioned in footnote 7.

Consistent with the literature on fiscal competition for FDI, our model shows regional trade costs play a key role in predicting the MNE's location. Without fiscal competition, the MNE's location choice is based on a trade-off between a market size advantage and fewer competition gains. As larger trade costs segregate the two countries, the latter gains are dominant and the MNE locates in the small but less-competitive-market country when trade costs are large. However, as small trade costs weaken competition gains, the MNE prefers locating in the large country when trade costs are sufficiently small.

In the presence of pollution effects, we find that fiscal competition changes the MNE's location preferences from a larger country to a smaller country under a sufficiently *small* trade cost. In this situation, the small country offers more generous policies than the large country because the local firm's production increases the marginal pollution damage, and the large country has a weak

[10] Additionally, pollution is a transboundary problem to some extent; thus, environmental damage from FDI affects countries differently depending on the degree of pollution transboundary. We begin with the simplest model to understand the main mechanisms and then consider this feature in our robustness discussion in section 4.3.

incentive to attract the MNE's production. The result sharply contrasts the extant literature, which shows that low trade costs induce an MNE to locate in the large country without pollution and zero trade costs make the MNE indifferent to its location.

Although pollution effects generally encourage a smaller country to host the MNE, it can induce a larger country to attract it more likely when the MNE's clean technology is very superior. The reason is that, because keeping the MNE together with the local firm in a large country relocates production from the dirtier local firm to the cleaner MNE and environmental damage is mitigated, the larger government's willingness to attract the MNE is larger than the case without pollution effects. Hence, whether pollution effects work in favor of a small or large country depends on how clean technology the MNE uses.

Due to the hesitation of a large country in attracting the MNE to protect its local firm and mitigate environmental damages, the general effect of fiscal competition is to induce the MNE in a small country. Our analysis shows whether such location changes lead to eco-friendly locations depending on the MNE's clean technology level. If the MNE uses similarly dirty technology, the vital way to mitigate global environmental damages is to reduce firms' total production by separating MNEs from local firms, thereby weakening worldwide market competition. Hence, fiscal competition that affects the MNE's location improves global environmental damage. Alternatively, if the MNE's technology is sufficiently superior, keeping the MNE with the local firm induces production relocation from the dirty local firm to the clean MNE. Therefore, fiscal competition leading to the MNE's location in a small country increases the severity of environmental damage.

Finally, we conduct welfare analysis to examine whether fiscal competition benefits the competing countries. As known in the previous literature, fiscal competition changing the MNE's location does not simultaneously improve welfare in the competing countries, because it worsens welfare in a newly nonhost country. However, due to pollution effects, a newly nonhost country benefits from losing the MNE by mitigating environmental damages. As low trade costs make consumers' losses less critical and environmental gains dominate, fiscal competition betters both competing countries. Because lower trade costs are crucial for the Pareto-improving outcome, policies to facilitate economic integration by reducing trade costs are important to avoid harmful fiscal policy competition.

Our paper contributes to the literature on fiscal competition for FDI. Haufler and Wooton

(1999) analyzed fiscal competition with two governments of countries with asymmetric market sizes to attract an international monopoly MNE and showed that the large country wins the competition with a tax. Bjorvatn and Eckel (2006) extended Haufler and Wooton (1999) by incorporating a local firm in the large country and argued that fiscal competition is in favor of a small country because the large country's government is hesitant to attract the MNE to protect the local firm. Recent extensions include Amerighi and De Feo (2017), Ma and Wooton (2020), Okoshi and Thar (2023) and Mukunoki and Okoshi (2024) by analyzing the effects of a public firm, product differentiation, the role of foreign ownership restrictions, and network goods, respectively.

Notably, Ferrett and Gravino (2021) introduced technological differences between the local firm and the MNE, investigating the impact of technological spillovers and revealing that, if technological spillover happens under the same location of firms, fiscal competition switches the MNE's location from a country without local firms to the other country with a local firm because of varying governments' willingness to attract the MNE. Although many studies, such as Fumagalli (2003), showed that fiscal competition changing a target MNE's location preference hurts a newly nonhost country, Ferrett and Gravino (2021) concluded that such a fiscal competition may benefit a newly nonhost country. The reason is because technological spillover increases a local firm's productivity and may result in more supplies in a country without local firms when technological spillover is strong and trade costs are low enough to spur exports. However, none of these papers examined production pollution. Our paper considers heterogeneous firms in the sense of clean technologies and shows similar results to Ferrett and Gravino (2021). One exception is Stoschek (2009), which explored how corporate taxes and emission taxes are set in the framework of Haufler and Wooton (1999). Hence, the paper considers no interactions between firms, which is our paper's primary focus and contribution.[11]

The rest of the paper is organized as follows. Section 2 explains the model and derives the output decisions of firms. Section 3 explores the equilibrium location without and with fiscal competition, whereas section 4 analyzes the equilibrium fiscal policies and welfare effects, and discusses a more generalized case. Section 5 concludes.

[11]In the context of environmental policy, Elliott and Zhou (2013) incorporated a lump-sum permission as our model does.

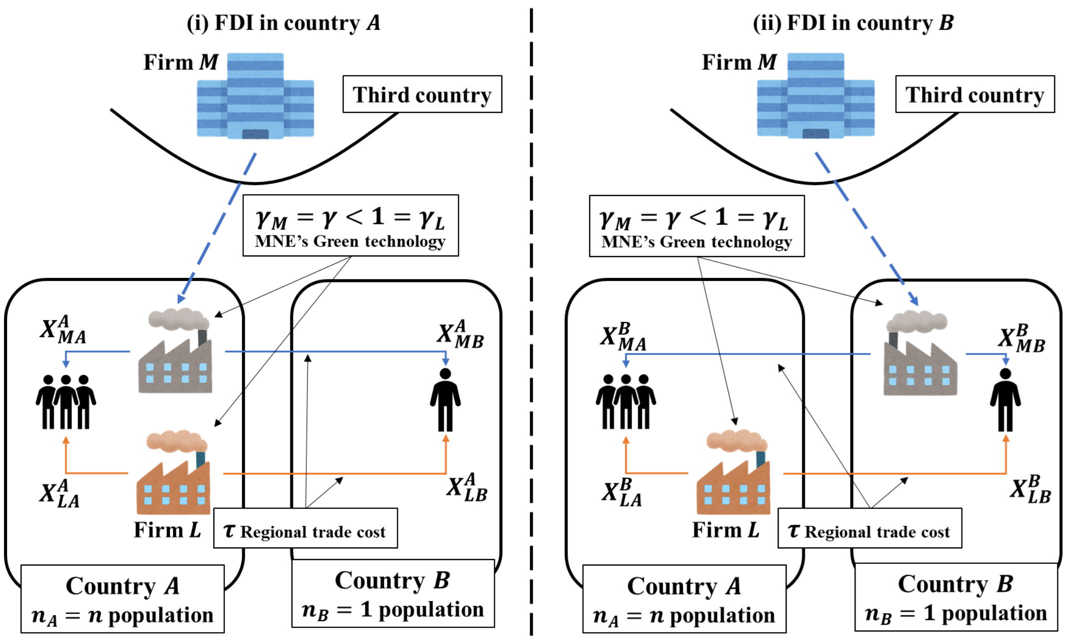

Figure 1: Model

2 Model

We consider the three-country model illustrated in Fig.1. Our analysis mainly focuses on the markets in a region composed of two countries, labeled A and B. The countries compete to attract a multinational firm, firm M, headquartered in a third country outside the region.

Firms We consider two sectors, X and Y. Sector Y is characterized by perfect competition and we regard it as a numéraire sector. The production of good Y generates no pollution and is characterized as a clean industry. Sector X is an imperfectly competitive sector. The production of goods generates pollution and, thus, is considered a dirty industry.

Homogeneous dirty goods are supplied to the markets in the region by firm M and a local firm in country A, firm L. Due to the prohibitive transportation costs between the third country and the region, firm M has to establish its production plant in the region. We assume that firm M cannot have two plants in the region due to the relatively high fixed costs of establishing a plant.

For simplicity, firms are assumed to have the same technology and produce the dirty good with zero marginal cost.[12] Besides, as the firms have only one plant in the region, they have to incur

[12]In the online appendix, we show our results are robust by considering a more general case, even if we incorporate positive and different marginal costs, $0 < c_M < c_L$.

intraregional trade costs τ to ship the goods abroad. To secure positive supplies by the firms, we assume $\tau < \tau^{max} \equiv a/2$. Therefore, given the firm M's location in j and a nonhost country $-j$, firms' profits are formally expressed as,

$$\pi_M^j = p_j^j X_{Mj}^j + (p_{-j}^j - \tau) X_{M-j}^j - t_j, \quad \text{and} \quad \pi_L^j = p_A^j X_{LA}^j + (p_B^j - \tau) X_{LB}^j,$$

where X_{Mi}^j and X_{Li}^j are the supplies to country i by firms M and L and p_i^j represents the price of the dirty goods in country i. Thus, we use superscripts for an index showing the host country. As explained later, t_i is the lump-sum fiscal policy designed by government i and the positive sign means a tax while the negative one does a subsidy.

Pollution is assumed to be production-based and nontransboundary.[13] Specifically, firms M and L generate γ_M and γ_L units of pollution by producing one unit of goods. In line with the empirical evidence from the World Bank, which showed that MNEs' production is less carbon intensive than that of domestic firms, firm M is assumed to have cleaner technology than firm L. Hence, by normalizing γ_L to unity, $0 \leq \gamma_M < \gamma_L = 1$ holds. Although firm M's clean technology is reflected in γ_M, we allow the possibility that firm M prefers not to perfectly transfer the cleanest technology to the subsidiary in a host country and uses less cleaner technology than the cleanest option for some reasons, e.g., to utilize loose environmental regulation there. However, as firms tend to care about corporate social responsibility, a foreign firm may realistically refrain from using worse technology than local firms. Thus, we assume that the actual technology that firm M uses for its production in the region is considerably cleaner than or equal to firm L's technology.[14] Hence, let $\gamma \in [\gamma_M, \gamma_L] \subset [0, 1]$ be the actual technology level that firm M uses in the region, and we refer γ to the degree of firm M's clean technology hereafter. Then, we formulate the pollution damage

[13] We will argue some features in a case that pollution is transboundary in section 4.3.

[14] Eskeland and Harrison (2003) showed that U.S. multinational firms in developing countries use cleaner technology than local firms.

function of country i given the firm M's location in j, d_i^j, as

$$d_A^A = \frac{\alpha}{2}\left(\sum_{k=\{A,B\}} \gamma X_{Mk}^A + X_{Lk}^A\right)^2, \qquad d_B^A = 0,$$
$$d_A^B = \frac{\alpha}{2}\left(\sum_{k=\{A,B\}} X_{Lk}^B\right)^2, \qquad d_B^B = \frac{\alpha}{2}\left(\sum_{k=\{A,B\}} \gamma X_{Mk}^B\right)^2,$$

where $\alpha(\geq 0)$ shows the parameter of pollution damages. The quadratic function indicates that the marginal environmental damage increases with production in the country, which is frequently used in the theoretical literature and supported with empirical evidence.[15]

Consumers The two countries have different population sizes. We assume that the population of country A is n times larger, and we normalize the population size in country B to unity. Specifically, let n_i be the market size in country $i \in \{A, B\}$, and then $n_A = n > 1 = n_B$ holds.

Individuals in the region share the same utility function,

$$u_i = ax_i - \frac{x_i^2}{2} + y_i,$$

where x_i and y_i represent the amount of consumption for sectors X and Y. This yields the willingness to pay for the dirty goods as $p_i = a - x_i$. As each country has n_i population, we derive the inverse demand function as,

$$X_i = n_i x_i = n_i(a - p_i) \rightarrow p_i = a - \frac{X_i}{n_i},$$

where X_i is the total amount of consumption.

Consumers maximize their utility given three incomes. First, individuals own exogenously given income I which secures positive amount of supplies in both goods. Second, individuals in country A equally own firm L, and, thus, the profits of firm L is distributed to them. Finally, if a host country successfully attracts firm M, the fiscal policy affects individuals' budget. If the fiscal policy is a tax $t_i > 0$, the tax revenue is equally distributed to the citizens. However, if the fiscal policy is

[15] See, for example, Marjit and Mukherjee (2023) for theoretical setup and Howard and Sterner (2017) for empirical support.

a subsidy $t_i < 0$, then the subsidy is collected from the citizens as a head tax. Let $T_i > 0$ ($T_i < 0$) be the tax distribution to (the head tax on) the citizens. Then, the budget constraint for each consumer is,

$$p_A x_A + y_A = I + \frac{\pi_L}{n} + \zeta \frac{T_A}{n} \quad \text{and} \quad p_B x_B + y_B = I + (1-\zeta)T_B,$$

where ζ is a binary function and takes unity if firm M locates in country A and zero otherwise.

Governments Governments design their lump-sum fiscal policy to maximize welfare: the sum of individuals' utility minus environmental damage. As mentioned above, the subsidy for firm M is financed with the head tax or the tax on firm M is distributed to the citizens, $t_i = T_i/n_i$ holds. Then, after solving the utility maximization problem, we derive the following welfare function,

$$\begin{aligned} W_A &= nu_A - d_A = \frac{n}{2}\left(\frac{X_A}{n}\right)^2 + \pi_L + \zeta t_A + nI - d_A, \\ W_B &= u_B - d_B = \frac{(X_B)^2}{2} + (1-\zeta)t_B + I - d_B. \end{aligned}$$

We solve the following three-stage game. In the first stage, governments simultaneously determine fiscal policy t_i. After observing t_i, firm M decides in which country to locate. Finally, firms compete in the markets in a Cournot fashion. The game is solved by backward induction.

2.1 Output decision and pollution

In the third stage, given firm M's location in j, firms M and L maximize their profits π_M^j and π_L^j by choosing their supplies. We derive the following supplies of firms under firm M's location in country A,

$$\widehat{X}_{MA}^A = \widehat{X}_{LA}^A = \frac{na}{3} \qquad \text{and} \qquad \widehat{X}_{MB}^A = \widehat{X}_{LB}^A = \frac{a-\tau}{3}$$

and those under firm M's location in country B,

$$\widehat{X}_{MA}^B = \frac{n(a-2\tau)}{3} < \frac{n(a+\tau)}{3} = \widehat{X}_{LA}^B \qquad \text{and} \qquad \widehat{X}_{MB}^B = \frac{a+\tau}{3} > \frac{a-2\tau}{3} = \widehat{X}_{LB}^B.$$

These equilibrium supplies yield the following firm profits,

$$\widehat{\pi}_M^j = n_j \left(\frac{\widehat{X}_{Mj}^j}{n_j} \right)^2 + n_{-j} \left(\frac{\widehat{X}_{M-j}^j}{n_{-j}} \right)^2 - t_j, \quad \text{and} \quad \widehat{\pi}_L^j = n \left(\frac{\widehat{X}_{LA}^j}{n} \right)^2 + \left(\widehat{X}_{LB}^j \right)^2.$$

Given the outputs, we identify the effect of hosting firm M on environmental damages in the host economy. Let $\Delta d_j \equiv d_j^j - d_j^{-j}$ be the pollution damages from inward FDI in country j. If the sign is negative (positive), attracting FDI improves (deteriorates) environmental damages in the country. Clearly, the sign in country B is positive, $\Delta d_B = d_B^B = \alpha\gamma^2\{n(a-2\tau)+(a+\tau)\}^2/18 > 0$, as pollution is production-based.

However, the sign in country A is ambiguous and depends on the degree of firm M's clean technology, γ. Specifically, we have

$$\begin{aligned} \Delta d_A &= \frac{\alpha\{\gamma(na+a-\tau)+2na+2a-3\tau\}}{18} \left\{ \underbrace{\gamma(na+a-\tau)}_{\text{Production attracting effect}} - \underbrace{(n-1)\tau}_{\text{Production relocation effect}} \right\} \\ &\gtreqless 0 \iff \gamma \gtreqless \gamma^{d_A} \equiv \frac{(n-1)\tau}{na+a-\tau} (< 1) \end{aligned}$$

On the one hand, likewise Δd_B, firm M's location in country A tends to increase pollution damage in country A, which is referred to as production attracting effect and it is always positive. On the other hand, having firm M reduces firm L's supply to market A more than an increase in its supply to market B due to the gap of country sizes. Therefore, the total production of firm L declines due to changes in market competition. Hence, if firm M has sufficiently superior clean technology captured by a smaller $\gamma < \gamma^{d_A}$, the latter negative (desirable) effect dominates the former positive (undesirable) effect; thus, attracting firm M reduces the environmental damage in A.

In addition, whether attracting firm M leads to globally less environmental damages also depends on γ. Specifically, we obtain a threshold of γ, γ^{d_W}, such that $d_W^A \equiv d_A^A + d_B^A = d_A^B + d_B^B \equiv d_W^B$ holds as follow,

$$d_W^A \gtreqless d_W^B \iff \gamma \gtreqless \gamma^{d_W} \equiv \frac{\sqrt{(na+a-\tau)^4 + 4(n-1)^2\tau^2(na+a-n\tau)(2na+2a+n\tau-3\tau)}}{4(n-1)(na+a-n\tau)\tau},$$

which means that firm M's location in a large country A results in globally eco-friendly if it uses

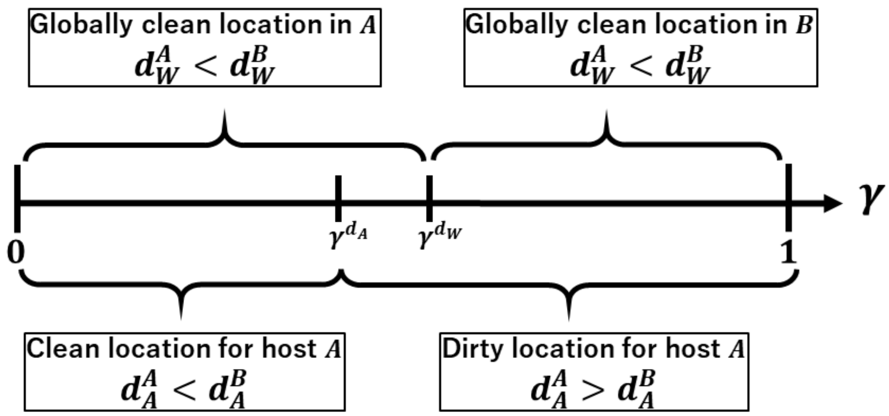

Figure 2: Environmental damages

sufficiently clean technology. Intuitively, attracting firm M in country A causes two opposing effects. As a negative side, total production is larger when the two firms locate in the same country, which tends to increase global environmental damages. However, as a positive aspect likewise Δd_A, the same locations of firms reduce production of the dirtier local firm. Therefore, when firm M's clean technology is superior enough, the global environmental damage under firm M's location in country A is less serious. As shown in appendix, we obtain $\gamma^{d_A} < \gamma^{d_W}$. This order holds because firm M's location in country A reduces environmental damages in nonhost country B even if it hurts country A.

We summarize the above result with the following proposition.

Proposition 1 *(i) Hosting an MNE in country B always increases pollution damages. (ii) However, hosting an MNE in country A reduces environmental damages for country A when $\gamma < \gamma^{d_A}$ holds, whereas it increases pollution damage when $\gamma^{d_A} < \gamma$ holds. (iii) Furthermore, globally eco-friendly location of the MNE is in a large country when $\gamma < \gamma^{d_W}$ holds whereas it is in a small country otherwise.*

It is worth stating that the second result is in line with empirical results and provides a new insight into whether attracting FDI generates severe pollution. As mentioned in Introduction, Demena and Afesorgbor (2020) pointed out that the impact of FDI on pollution is mixed. On the positive side, pollution-reducing FDI is due to MNE's cleaner technology and this is the case of small γ in our analysis. On the negative side, attracting FDI and production causes pollution and the impact is huge when MNEs' clean technology is similar to local firms, reflected by huge γ.

As in the proposition, production-based pollution always dampens country B's willingness to attract firm M, but whether it encourages or discourages country A to host firm M depends on firm M's clean technology, γ. We will investigate how these additional effects affect firm M's location in the next section.

3 Location choice

Given firms' production in the third stage, this section derives firm M's location decision. To clarify the effects of fiscal competition and pollution, we first investigate the case without fiscal competition, and then incorporate fiscal competition without and with pollution effects.

3.1 Without fiscal competition

Suppose the governments have no policies to attract firm M, namely $t_A = t_B = 0$. In the second stage, firm M chooses its location for production by comparing its profits. By taking a difference between $\widehat{\pi}_M^A$ and $\widehat{\pi}_M^B$, we derive the fundamental location advantage of country A, denoted by $\Omega \equiv (\widehat{\pi}_M^A - \widehat{\pi}_M^B)\big|_{t_A=t_B}$, as,

$$\Omega = \frac{4\tau}{9}\left\{(n-1)a - n\tau\right\} \gtreqless 0 \iff \tau \lesseqgtr \frac{(n-1)a}{n} \equiv \overline{\tau}^{nfc}.$$

Therefore, firm M prefers locating in country A (country B) when trade costs are low (high). This is well-known result in the literature. On the one hand, firm M wants to locate in country A to pursue a larger market. On the other hand, locating in B may be beneficial due to mitigated market competition stemming from firms' separated location and the existence of firm L in country A discourages firm M from locating in country A. As the latter effect is dominant if the trade cost is large and locating in country B makes greater profits, firm M prefers locating in country B when τ is greater than $\overline{\tau}^{nfc}$. Otherwise, firm M establishes its subsidiary in country A with a large pool of consumers.

3.2 With fiscal competition

With fiscal competition, firm M's location decision also depends on government policies, and the MNE chooses its location by comparing their post-tax/subsidy profits, $\widehat{\pi}_M^A - \widehat{\pi}_M^B = \Omega - t_A + t_B$. As the difference in profits depends on fiscal policies, deriving the most generous fiscal policy $\underline{t}_i$ is essential for identifying a host country.

First, consider government A. As government A maximizes its welfare, it can choose any fiscal policy that satisfies the following to attract firm M,

$$W_A^A \geq W_A^B \iff t_A \geq \frac{\tau(3n\tau - 4a + 6\tau)}{18} + \Delta d_A \equiv \underline{t}_A.$$

Hence, $\underline{t}_A$ is the most generous fiscal policy to attract firm M. The first term shows a standard (dis)incentive of attracting firm M via consumer gains and local firm losses, and the sign of the first term is ambiguous. Moreover, the second term captures government A's additional consideration to attract firm M from the viewpoint of pollution. The sign of the second term is also ambiguous as discussed in section 2.1. If the sign of $\underline{t}_A$ is negative, hosting firm M is beneficial, and government A can offer a subsidy. If the sign of $\underline{t}_A$ is positive, hosting firm M is harmful, and government A's most generous offer remains a tax.

Similarly, we obtain the following most generous fiscal policy in country B as,

$$W_B^B \geq W_B^A \iff t_B \geq -\frac{\tau(4a - 3\tau)}{18} + \Delta d_B \equiv \underline{t}_B.$$

The first term is always negative, reflecting consumer gains from attracting FDI and government B can offer a subsidy. Additionally, the second term reflects a pollution effect, and its sign is positive. Hence, whether government B can offer a subsidy depends on the opposing two effects.

Recall that the second term of $\underline{t}_i$ is a pollution effect that disappears when $\alpha = 0$. Without pollution, country B can always offer a more attractive fiscal policy to firm M than country A as $\Omega^{MP} \equiv -\underline{t}_A + \underline{t}_B|_{\alpha=0} = -\tau^2(n+1)/6 < 0$ holds, where Ω^{MP} captures location advantage due to market-driven policy. This situation implies that fiscal competition without pollution effects

($\alpha = 0$) encourages country B to host firm M. Then, by using $\underline{t}_A$, $\underline{t}_B$ and $\alpha = 0$, we can compute,

$$\widehat{\pi}_M^A(\underline{t}_A) - \widehat{\pi}_M^B(\underline{t}_B)\big|_{\alpha=0} = \Omega + \Omega^{MP} = \frac{\tau\left\{8(n-1)a - (11n+3)\tau\right\}}{18} \geq 0$$
$$\iff \tau \leq \frac{8(n-1)a}{11n+3} \equiv \overline{\tau}_{\alpha=0}^{fc}\left(< \overline{\tau}^{nfc}\right).$$

Hence, if the governments do not care about pollution ($\alpha = 0$), firm M prefers locating in country A if $\tau < \overline{\tau}_{\alpha=0}^{fc}$ and locating in country B otherwise. This result aligns with previous literature, and the intuition is as follows. With fiscal competition, firm M's location choice is also affected by consumer gains and firm L's losses from inward FDI. As firm L is located in large country A, government A's fiscal policy is mixed with gains for consumers and protection of its local firm, whereas government B only considers consumer gains. This difference enables the small country to design a more generous fiscal policy and makes country B more attractive for firm M to enter.

To summarize location choice without pollution effects, the following lemma outlines firm M's location, which is not new in the literature such as Bjorvatn and Eckel (2006) but is important to highlight pollution effect on location choice that we will see next.

Lemma 1 *In the case of no production pollution, an MNE outside the region locates in the large country when $\tau < \overline{\tau}^{nfc}$ and $\tau < \overline{\tau}^{fc}\big|_{\alpha=0} (< \overline{\tau}^{nfc})$ holds without and with fiscal competition, respectively, and it locates in the small country otherwise. When the interregional trade cost is zero, an MNE is indifferent to its production location.*

3.2.1 Pollution effects

Hereafter, we consider the effect of pollution $\alpha > 0$. Recall that firm M's location choice is identified with the following equation,

$$\widehat{\pi}_M^A(\underline{t}_A) - \widehat{\pi}_M^B(\underline{t}_B) = \Omega + \Omega^{MP} - \Delta d_A + \Delta d_B.$$

The last two terms appear due to fiscal policies. As in proposition 1, ambiguous changes in pollution damages further complicate governments' incentives to attract firm M. Given the new mechanism via pollution effects, two new interesting features of fiscal competition arise.

First, although firm M's location without the pollution effect is in large country A under low transportation costs and indifferent across countries at $\tau = 0$ irrespective of fiscal competition, the pollution effect can induce firm M to locate in small country B. We can confirm this by substituting $\tau = 0$,

$$\widehat{\pi}_M^A - \widehat{\pi}_M^B|_{\tau=0} = \Delta d_A - \Delta d_B|_{\tau=0} = -\frac{\alpha\gamma(n+1)^2 a^2}{9} \leq 0.$$

This means that the equilibrium firm M's location under a sufficiently small τ is in country B if firm M's clean technology is imperfect $\gamma > 0$.

The intuition is as follows. At $\tau = 0$, firms' outputs do not depend on firm M's location, the fundamental location advantage, market-driven policy location advantage and the production relocation effect disappear. Moreover, although the production-attracting effect is still present in both countries, the size of the effect varies across countries. As firm L's production is fixed in country A, the production-attracting effect in country A is greater than country B due to our quadratic pollution damage function specification. Thus, government A offers a heavier tax than government B. As a special case, firm M's location is indifferent if firm M's clean technology is perfect ($\gamma = 0$) because the production-attracting effect disappears. Otherwise, firm M locates in small country B due to this difference in fiscal policies, $0 < \underline{t}_B|_{\tau=0} < \underline{t}_A|_{\tau=0}$. The next proposition summarizes the above result.

Proposition 2 *Suppose imperfect clean technology of firm M, $\gamma > 0$. At zero interregional trade costs, $\tau = 0$, the fiscal competition with pollution effect, $\alpha > 0$, induces firm M to locate in the smaller country.*

This feature is novel in the literature as lemma 1 shows that firm M is indifferent to locating in country A or B under no trade costs and prefers locating in A under a small trade cost. However, in our model, sufficiently low trade costs trigger firm M's location in small country B. As shown in Appendix A, there are two thresholds $\underline{\tau}^{fc}$ and $\overline{\tau}^{fc}$ between which country A hosts firm M, where

$$\underline{\tau}^{fc} \equiv \frac{4(n-1) - (n+1)\{(n-1)(2\gamma^2 - 1) - 2\gamma\}\alpha - \sqrt{\xi}}{(11n+3) - \{4(n-1)n\gamma^2 + 2\gamma - (n-3)(n-1)\}\alpha} \tag{1}$$

$$\overline{\tau}^{fc} \equiv \frac{4(n-1) - (n+1)\{(n-1)(2\gamma^2 - 1) - 2\gamma\}\alpha + \sqrt{\xi}}{(11n+3) - \{4(n-1)n\gamma^2 + 2\gamma - (n-3)(n-1)\}\alpha} \tag{2}$$

$$\text{and} \quad \xi \equiv (n-1)^2(n+1)^2(4\gamma^4 + 8\gamma^3 - 4\gamma^2 + 2\gamma + 1)\alpha^2 \\ - 2(n+1)\{8(n-1)^2\gamma^2 + (11n^2 + 6n + 11)\gamma - 4(n-1)^2\}\alpha + 16(n-1)^2.$$

This different location preferences clearly imply a new pattern of effects of trade liberalization on an MNE's location. If trade costs are sufficiently high, trade liberalization leading a reduction in trade costs from $\tau' > \overline{\tau}^{fc}$ to $\tau'' < \overline{\tau}^{fc}$ changes firm M's location preferences from country B to country A. However, only with pollution effects, a further reduction in trade costs from $\tau'' < \overline{\tau}^{fc}$ to $\tau''' < \underline{\tau}^{fc}$ triggers firm M to locate in country B.

Second, although the above result implies that pollution effect induces firm M to locate in a smaller country, pollution effect can encourage firm M to establish its subsidiary in a larger country. We can confirm this by considering the marginal pollution effect at $\alpha = 0$. Specifically, we can derive the marginal impact of pollution effect as follows,

$$
\begin{aligned}
\left.\frac{\partial \underline{\tau}^{fc}}{\partial \alpha}\right|_{\alpha=0} &= \frac{a(n+1)^2\gamma}{4(n-1)} \geq 0 \\
\left.\frac{\partial \overline{\tau}^{fc}}{\partial \alpha}\right|_{\alpha=0} &= \frac{-16(n-1)^2(3n^2+22n+3)\gamma^2 - (11n^2+6n+11)^2\gamma + 8(n-1)^2(15n^2-2n+15)}{4(n-1)(11n+3)^2} \gtreqless 0 \\
\iff \gamma &\lesseqgtr \gamma^{\alpha} \equiv \frac{-(11n^2+6n+11)^2 + \sqrt{7\Xi}}{32(n-1)^2(3n^2+22n+3)}, \\
\text{where} \quad \Xi &\equiv 5383(n^8+1) + 15096(n^7+n) - 59580(n^6+n^2) + 154312(n^5+n^3) - 142614n^4.
\end{aligned}
$$

Therefore, if firm M has very clean technology than firm L, it is possible that pollution effect results in firm M's location in a larger country more likely compared to the case with fiscal competition without pollution concerns. This is because government A offers a more attractive fiscal policy to decrease dirtier production of firm L. As hosting firm M cause production attracting effect, the outcome that pollution effect encourages firm M to enter country A is possible only when $\gamma < \gamma^{\alpha}$ holds. The following proposition summarizes the above patterns of firm M's location.

Proposition 3 *The marginal pollution effect from the state under no pollution concerns, $\alpha = 0$, always increases $\underline{\tau}^{fc}$ whereas it decreases $\overline{\tau}^{fc}$ under $\gamma > \gamma^{\alpha}$. Under $\gamma < \gamma^{\alpha}$, it increases $\overline{\tau}^{fc}$.*

The above location patterns described in propositions 2 and 3 are illustrated in Fig.3 with different levels of γ. In the figure, four hump-shaped curves depict location gains in country A over country B. The gray curves show the cases without pollution effects: the dashed- and solid-curves represent the case without and with fiscal competition, respectively. As shown in lemma 1, the two gray vertical lines are the two thresholds of $\overline{\tau}^{nfc}$ and $\overline{\tau}^{fc}_{\alpha=0}$, and firm M chooses country A below

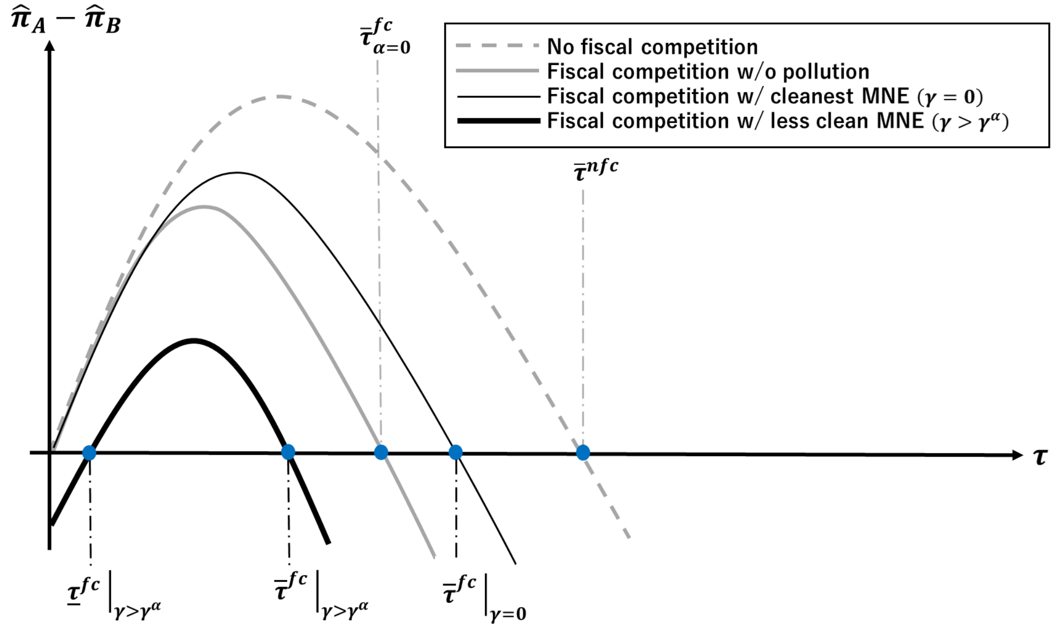

Figure 3: Location choice in the equilibrium

them. Thus, in the absence of pollution effect, firm M chooses to locate in country A (country B) when $\tau < \overline{\tau}^{fc}_{\alpha}$ ($\tau > \overline{\tau}^{nfc}$) holds irrespective of fiscal competition, whereas fiscal competition influences firm M from country A to country B.

Besides, Fig.3 shows two black hump-shaped curves, indicating the location gains in a large country A with pollution effects. The thin curve represents the case in which firm M has the cleanest technology and emits no pollution ($\gamma = 0$); the thick curve shows the less clean MNE with $\gamma > \gamma^{\alpha}$. As the proposition 2 states, a positive γ under $\tau = 0$ generates a negative location gain in country A, incentivizing firm M to locate in a small country B. Moreover, if $\gamma > 0$ holds, two thresholds arise between which firm M locates in country A. Especially, a new range of $\tau \in [0, \underline{\tau}^{fc}]$ that fiscal competition affects firm M's location arises due to country A's hesitation to welcome the firm because of the existing local firm and growing pollution damage.

Furthermore, as proposition 3 mentions, pollution effects induce country A to host firm M more likely, which is drawn with the thin curve. With $\gamma = 0$, the figure provides $\overline{\tau}^{fc}_{\alpha=0} < \overline{\tau}^{fc}$ and firm M's location choice under fiscal competition is not in country B but in country A in the presence of pollution effect under $\overline{\tau}^{fc}_{\alpha=0} < \tau < \overline{\tau}^{fc}$. Therefore, fiscal competition under pollution effects generally looks for a small country to be a host for firm M; however, it can encourage a large country to host firm M if the firm's clean technology is sufficiently superior. Attracting firm M

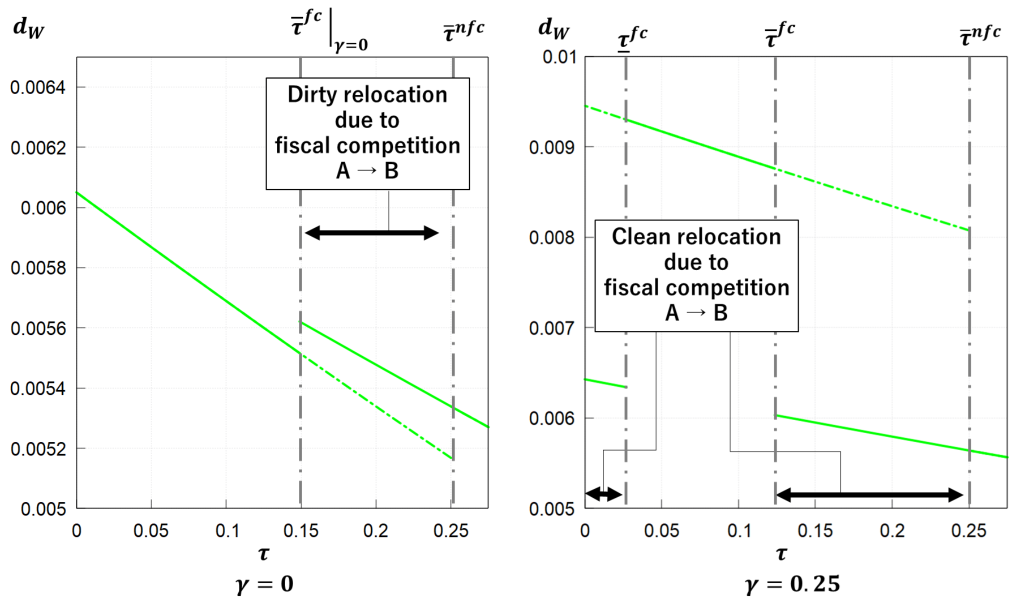

Figure 4: Environmental damages

does not generate much pollution damage, and production relocation from firm L also contributes less to pollution damage.

As fiscal competition with pollution effects impacts firm M's location in several ways, it is important to examine whether it leads to eco-friendly location or not. By using different γ, Fig.4 provides numerical examples and shows that whether recognizing pollution damages leads to globally clean or dirty relocation of firm M depends on how clean technology the MNE owns.[16] The solid curves draw the equilibrium global environmental damages in the presence of fiscal competition, and the dash-dot curves show them under no fiscal competition. In the left figure with $\gamma = 0$, location distortion occurs due to fiscal competition under $\tau \in [\overline{\tau}^{fc}\big|_{\gamma=0}, \overline{\tau}^{nfc}]$. It lends to larger global environmental damages because reducing the production of dirtier firm L by inducing firm M to locate in country A is crucial to decrease pollution damages; therefore, fiscal competition leads to dirty location of firm M.

However, as depicted in the right figure, we observe the opposite result under a large γ. In this case, although attracting firm M in country A arises gains from production relocation from firm L to firm M, the total volume of production increases due to fierce market competition in a large country, and the latter effect dominates the former effect. Therefore, when $\tau < \underline{\tau}^{fc}$ or

[16]We set the following parameters: $a = 1.5$, $n = 1.2$, and $\alpha = 0.01$. Furthermore, $\gamma = 0$ and $\gamma = 0.25$ are used in the left and right figures, respectively.

$\overline{\tau}^{fc} < \tau < \overline{\tau}^{nfc}$ hold and fiscal competition inducing firm M's location change from country A to B mitigates environmental damage by making market competition less fierce and reducing total productions.[17]

4 Equilibrium policy, welfare, and discussion

Thus far, we have seen the impact of fiscal competition on how pollution affects MNE location choice. This section discusses the equilibrium fiscal policy and provides additional welfare analysis. Particularly, given the development of trade liberalization, one important question is whether trade liberalization leads to fiercer fiscal competition and a "race to the bottom."[18] As fiscal policies include pollution considerations in our setting, this section explores how trade cost impacts on the equilibrium fiscal policy to determine the importance of pollution effects.

4.1 Equilibrium fiscal policy

Although $\underline{t}_i$ is critical to identify the condition in which country is the host, it is not the equilibrium fiscal policy when country i hosts firm M. Specifically, the equilibrium fiscal policy, t_i^* is such that $\widehat{\pi}_M^j - t_j^* = \widehat{\pi}_M^{-j} - \underline{t}_{-j}$ given firm M's location in j. This means that it is enough for the host country to offer a slightly more attractive fiscal policy than the sum of the fundamental location advantages and its rival government's best fiscal policy. More precisely, we have

$$t_A^* = \Omega + \underline{t}_B, \quad \text{where} \quad t_B^* = -\Omega + \underline{t}_A.$$

As the most generous fiscal policy reflects a consideration of pollution, the impact of trade liberalization on the equilibrium policy is in its rival's fiscal offer. Notably, smaller trade costs decrease the fundamental location advantage across countries and relatively strengthen governments' attention to pollution damage. Thus, especially when τ is sufficiently small, the impact of trade liberalization on the equilibrium policy may be different from the previous literature, which shows

[17] Once we investigate environmental damages in each country, we find mixed results of hosting FDI on environmental damage which is in line with the observed fact mentioned in Introduction. Thus, our model provides one rationale for the mixed results of effects of hosting a foreign firm on environmental damages.

[18] Note that the "race to the bottom" is used in several contexts. In terms of environmental regulation, it means inefficiently low levels of environmental regulation, including low emission taxes (see for example Davies and Naughton (2014)). In the context of fiscal competition, the term refers to inefficiently low fiscal policies to attract inward FDI (see, for example Abbas and Klemm (2013)). In the following, we use the phrase in the latter sense.

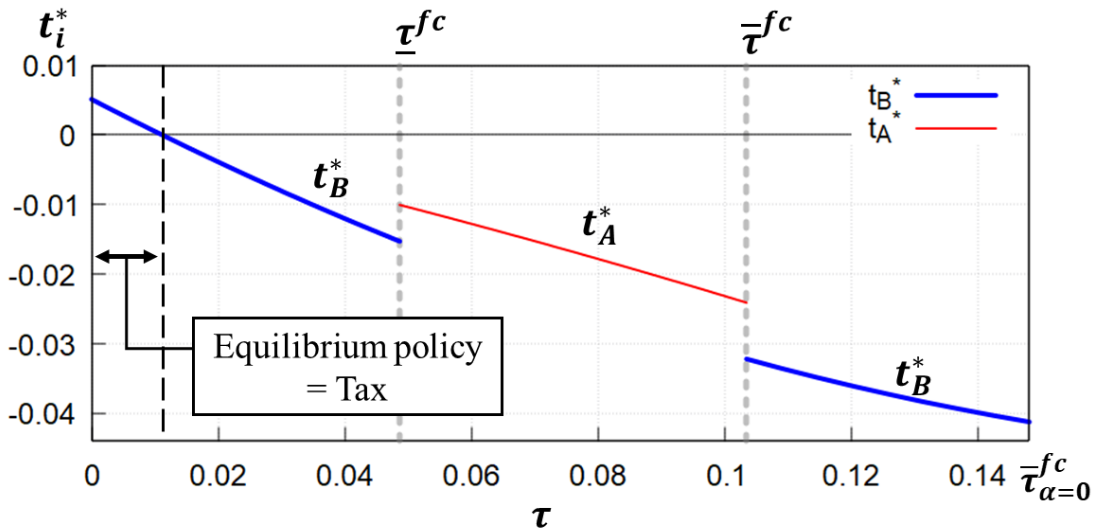

Figure 5: Equilibrium fiscal policy ($\gamma = 0.25$)

trade liberalization results in larger t_B^* and t_A^*. By noting proposition 2, country B hosts firm M at $\tau = 0$, and we have the following corollary.

Corollary 1 *When $\tau = 0$ and $\gamma > 0$ hold, a smaller country attracts the MNE by imposing a tax.*

Recall that, at $\tau = 0$, lemma 1 states there is no fundamental location advantage, $\Omega = 0$, but country A's most generous fiscal policy is a tax, $\underline{t}_A = \Delta d_A > 0$, due to production attracting effect. This means that country B can host firm M by imposing a tax instead of providing a subsidy, which sharply contrasts with the findings of the previous literature.

By focusing on the range of $\tau \in [0, \overline{\tau}^{fc}_{\alpha=0}]$ where the new location patterns of firm M due to pollution effects happen, Fig.5 illustrates the equilibrium fiscal policies in a host country with $\gamma = 0.25$.[19] In the figures, the red curve represents the equilibrium fiscal policy in country A whereas the blue ones show those in country B when each country is the host.

Under such a range of $\tau \in [0, \overline{\tau}^{fc}_{\alpha=0}]$, a downward sloping curves are depicted. The reason is that a low trade cost makes consumers gains are the more important than location advantage and government A's concern to protect its local firm. Therefore, the equilibrium policy under τ close to $\overline{\tau}^{fc}_{\alpha=0}$ is a subsidy and trade liberalization reduces the equilibrium subsidy. A further trade liberalization resulting in τ close to zero makes it possible that country B can impose a tax and successfully attract firm M. In such a case, the most important factor is the concern

[19]We set the following parameters: $a = 1.5$, $n = 1.2$, and $\alpha = 0.015$. These parameters are also used for Fig.6.

on environmental damages and country A's counteroffer reflects strong hesitation to attract the MNE to avoid production attracting effect and a tax. Due to the less attractive counteroffer by country A, we observe a range of τ that fiscal competition results in a tax as the equilibrium fiscal policy. This is another new result in the literature which showed that the equilibrium fiscal policy converges to zero $t_A^*|_{\alpha=0} = 0$ as τ approaches zero.

Therefore, under sufficiently low trade costs, trade liberalization in the form of a reduction in τ is crucial to prevent a "race to the bottom" outcome.

4.2 Welfare analysis

Although fiscal competition affects firm M's location and environmental damages, it always leads to an efficient location in the sense of global welfare, consistent with the previous literature.[20] However, fiscal competition leading to an efficient location from the global viewpoint does not necessarily mean that all the countries in the region are better off, because a host country pays a subsidy to the MNE. Especially, welfare in a newly nonhost country clearly declines although a newly host country may benefit from fiscal competition.

However, pollution effects generate an additional desirable impact on a newly nonhost country but provide an additional harmful impact on a new host country via production changes. Therefore, it is unclear whether fiscal competition increases welfare in one country at the expense of another. Herein, we conduct welfare analysis by focusing on the range of τ under which fiscal competition results in location changes from country A to country B.

Formally, welfare changes in country A and B are written as,

$$W_A^B - W_A^A\big|_{t_A=0} = \underbrace{-(CS_A^A - CS_A^B)}_{-}\underbrace{-(\pi_L^A - \pi_L^A)}_{+} + \underbrace{\Delta d_A}_{+},$$

$$W_B^B\big|_{t_B=t_B^*} - W_B^A = t_B^* - \underbrace{\left\{\left(CS_B^B - CS_B^A\right) - \Delta d_B\right\}}_{=\underline{t}_B} > 0.$$

[20]Let global welfare be defined as $WW^j = W_A^i + W_B^j + \widehat{\pi}_M^j$. We have

$$\begin{aligned} WW^A - WW^B &= \widehat{\pi}_M^A - (W_A^B - W_A^A) - \left\{\widehat{\pi}_M^B - (W_B^A - W_B^B)\right\} \\ &= \widehat{\pi}_M^A - (\underline{t}_A - t_A) - \left\{\widehat{\pi}_M^B - (\underline{t}_B - t_B)\right\} = \widehat{\pi}_M^A(\underline{t}_A) - \widehat{\pi}_M^B(\underline{t}_B) \gtreqless 0. \end{aligned}$$

As the countries compete over one MNE and their fiscal policies reflect their welfare, which was ignored by the MNE's consideration, fiscal competition internalizes such overlooked aspects.

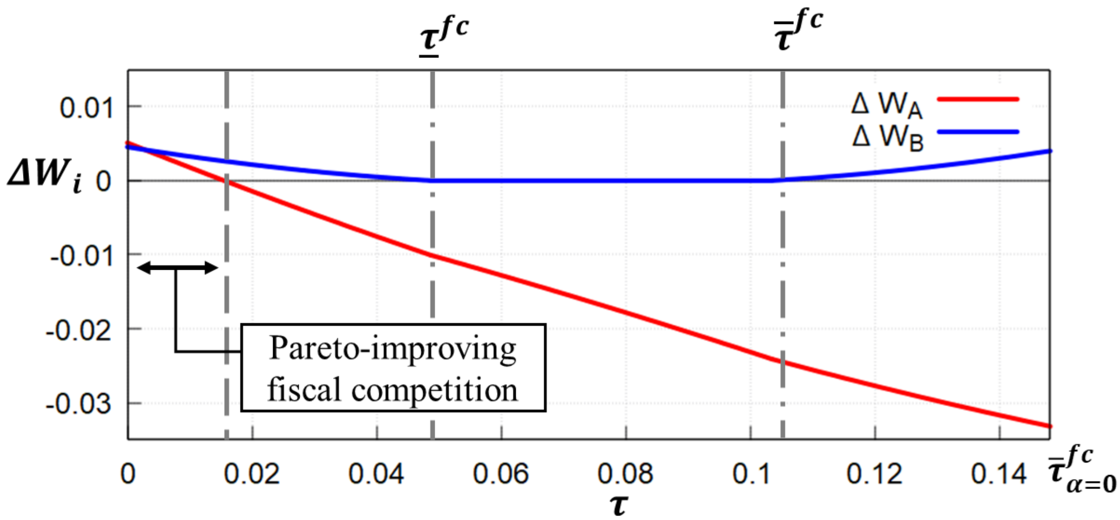

Figure 6: Welfare effect in each country ($\gamma = 0.25$)

Recall if government B attracts firm M, the equilibrium policy satisfies $t_B^* > \underline{t}_B$ to secure welfare improvement. Therefore, welfare in a newly host country B clearly increases due to fiscal competition changing location preferences of firm M. Regarding a newly nonhost country A, the sign of the total impacts is ambiguous because the first two terms are negative in total; however, the last term is positive. By evaluating at $\tau = 0$, the first two terms in the first line disappear; however, the last positive term remains, implying that when trade costs are sufficiently low, fiscal competition with pollution effects can simultaneously improve welfare in both competing countries. The following proposition summarizes this.[21]

Proposition 4 *When trade costs are sufficiently low, fiscal competition changing an MNE's location preference from a large country to a small country simultaneously improves welfare in the competing countries.*

Fig.6 illustrates the country-level welfare effects of fiscal competition, denoted by $\Delta W_i \equiv W_i^{fc} - W_i^{nfc}$, in the range of $\tau \in [0, \overline{\tau}^{fc}_{\alpha=0}]$ that pollution effects generate new patterns of location preferences. From the numerical analysis, we can see the above discussion on Pareto improvement under τ is low enough. Alternatively, if τ is an intermediate level, consumers losses due to firm M's location in B are crucial. Therefore, trade liberalization plays an important role not only for

[21] Suppose firm M's changes in location preferences increase regional welfare but reduce welfare in one of the two countries. In such a case, some financial transfers make fiscal competition beneficial for the whole region. We show this discussion in Appendix B.

preventing a race to the bottom outcome in the sense of tax revenues but also for welfare measure with environmental damages.

As mentioned in Introduction, the result that fiscal competition improves welfare in not only a newly host country but also a newly nonhost country is rare in the literature. One exception is that Ferrett and Gravino (2021) which introduced technological spillovers from a productive MNE to a less productive local firm if their location is the same and concluded that fiscal competition inducing the MNE to locate in a country with the local firm benefits both newly host and non-host country through a higher productivity of the local firm. From our result, fiscal competition changing an MNE's location preferences achieves Pareto improvement in another form of technological differences. This implies that technological differences play a core role for beneficial fiscal competition.

4.3 Discussions: More generalized case

Our model has provided several new results about the effects of fiscal competition in the presence of pollution effects on the MNE location choice, environmental damages and welfare. We finally argue about the robustness of our results by considering more generalized model which is provided in the online appendix. In the modified model, we incorporate differences in marginal costs, $c_M \leq c_L$, and transboundariness of pollution effect, and we find that the main results qualitatively hold.

Notably, if the degree of the transboundariness of pollution is large and the MNE's technology is sufficiently clean, our generalized model shows that fiscal competition induces firm M to locate in a large country more likely unlike the benchmark analysis. This result stems from the fact that both competing countries are eager to keep two firms in the same country because it relocates production from dirtier local firm to cleaner MNE, which is magnified by the production cost differences. Hence, their fiscal policies are designed to induce firm M to be in country A, and $\overline{\tau}^{nfc} < \overline{\tau}^{fc}$ is possible.

5 Conclusion

Parallel to fiscal competition between countries for an FDI, concerns on environmental problems such as air pollution, have also increased. Having an MNE influences environmental damages on top of gains from an FDI; however, it is not obvious how pollution affects governments' incentives to attract FDI. Following Bjorvatn and Eckel (2006), this study revisited the fiscal competition for an MNE to investigate the effects of pollution on an MNE's location choice and the welfare effects. Specifically, the model consists of two asymmetric-sized countries with one local firm in the large country by assuming that the MNE uses cleaner technology that the local firm.

The model showed that the interaction between the MNE and the local firm in a competing country plays an important role for environmental damages in the two competing countries. On the one hand, the MNE's location with the local firm may reduce environmental damages because the MNE has cleaner technology and, thus, production relocation from the local firm to the MNE decreases environmental damages. On the other hand, the MNE's location apart from the local firm can improve environmental damage because globally less fierce market competition reduces total production in the two countries. Therefore, how governments' incentives attract the MNE depends on the situation.

Our results has two notable features about the effects of fiscal competition on MNE's location choice which are new in the literature. First, fiscal competition with pollution concerns under low trade costs induces the MNE in the small country without a local firm. This is because low trade costs make the pollution consideration more important and a country with a local firm suffers from severe environmental damage and imposes a heavier tax than a country without local firms. As previous literature often stated that an MNE prefers locating in the larger country under sufficiently low trade costs, the result is a sharp contrast and an important finding especially under the development of trade liberalization.

Second, fiscal competition, which changes the MNE's location preferences, can improve welfare in both competing countries. Note that welfare in a newly nonhost country usually decreases due to fiscal competition. However, because losing the MNE benefits a competing country by a channel of less pollution damages, it is possible for a newly nonhost country to benefit from such fiscal competition influencing the MNE's location. This result provides a new insight into a positive side of fiscal competition instead of a negative one concerned with a "race to the bottom."

In addition to the above novel results, our study examined whether fiscal competition results in eco-friendly locations. The key variable determining eco-friendly location is how cleanly the MNE uses technology compared to a local firm. If the MNE's clean technology is similar to that of the local firm, reducing the total production of firms is essential, and keeping the MNE apart from the local firm is desirable. Alternatively, if the MNE uses sufficiently superior clean technology, reducing the production of the dirtier local firm is crucial to mitigate global environmental damages, and keeping the MNE together with the local firm reduces the environmental damage. Given the growing attention to environmental problems and developments of clean technologies, our result implies that the gap in clean technology between MNEs and local firms is a critical factor for the eco-friendly location.

Even though our model provided several new insights, potential extensions exist. First, although this paper considered environmental issues, it ignored regulations on production. As many countries aim at "net zero by 2050," exploring some restrictions should provide important policy implications. Additionally, increasing public concern on the environment inspires firms to invest more in research and development to obtain cleaner technology. As governments design new policies on such investments, e.g., subsidies for electric vehicles, combining firms' investment strategy with governments' other policies is an interesting examination. Finally, further empirical examination on this topic is vital.

Appendix A: Derivation of $\gamma^{d_A} < \gamma^{d_W}$.

We can compute the followings,

$$\begin{aligned}
d_W^A - d_W^B\big|_{\gamma=0} &= \frac{-(n-1)\alpha\tau(2an+2a+n\tau-3\tau)}{18} < 0 \\
d_W^A - d_W^B\big|_{\gamma=\gamma^{d_A}} &= \frac{-(n-1)^2\alpha\tau^2(an+a-2n\tau+\tau)}{18} < 0 \\
d_W^A - d_W^B\big|_{\gamma=1} &= \frac{\alpha\tau\left[2(a-2\tau)\{a+n(a-2\tau)+n^2\tau\}+n^2(2a^2-\tau^2)+(2a+\tau)(na-\tau)+3na\tau\right]}{18} > 0 \\
\frac{\partial\left(d_W^A-d_W^B\right)}{\partial\gamma} &= \frac{\alpha\left[(a-2\tau)\{a(1+n)+2n^2\gamma\tau\}+4a\tau\gamma(n^2-1)+\tau(\tau+2n^2a\gamma)+an(a+n)\right]}{9} > 0,
\end{aligned}$$

which means that there is a unique threshold of $\gamma = \gamma^{d_W}$ which is greater than γ^{d_A}.

Appendix B: Derivation of eqs.(1) and (2).

Firm M's location choice depends on the following equation,

$$\widehat{\pi}_M^A(\underline{t}_A) - \widehat{\pi}_M^B(\underline{t}_B) = \Omega + \Omega^{MP} - \Delta d_A + \Delta d_B = \frac{A_1\tau^2 + 2B_1 a\tau - 2(n+1)^2\gamma\alpha a^2}{18}$$

where $A_1 \equiv -(11n+3) + \{4n(n-1)\gamma^2 - 2\gamma + (n-1)(n-3)\}\alpha$

and $B_1 \equiv 4(n-1) + (n+1)\{(n-1)(1-2\gamma^2) + 2\gamma\}\alpha$.

Without pollution effects ($\alpha = 0$), a combination of $A_1 < 0$ and $B_1 > 0$ holds. With pollution effects, other combinations of the signs are possible as below. However, we focus on $A_1 > 0$ and $B_1 < 0$ for the sake of comparability with previous studies and we will derive conditions for the combination.

First, A_1 is positive when $4n(n-1)\gamma^2 - 2\gamma + (n-1)(n-3) > 0$ and $\alpha > (11n+3)/\{4n(n-1)\gamma^2 - 2\gamma + (n-1)(n-3)\}$ hold. The first equation is positive either if (i) $\gamma < \underline{\gamma}_{A_1}$ or $\overline{\gamma}_{A_1} < \gamma$ hold, where

$$\underline{\gamma}_{A_1} \equiv \frac{1 - \sqrt{1 + 4n(n+1)^2(3-n)}}{4n(n-1)}, \quad \text{and} \quad \overline{\gamma}_{A_1} \equiv \frac{1 + \sqrt{1 + 4n(n+1)^2(3-n)}}{4n(n-1)},$$

or (ii) if $n > 3.02028$ holds. Under the two cases, which are "Area II" and "Area III" in Figure 7, A_1 is positive when $\alpha > (11n+3)/\{4n(n-1)\gamma^2 - 2\gamma + (n-1)(n-3)\}$ holds. Otherwise, $A_1 < 0$ holds.

Next, $B_1 < 0$ holds when $(n-1)(1-2\gamma^2) + 2\gamma < 0$ and $\alpha > -4(n-1)/\{(n-1)(1-2\gamma^2) + 2\gamma\}$ hold. The first equation is negative if

$$\gamma < \gamma_{B_1} \equiv \frac{1 + \sqrt{1 + 2(n-1)^2}}{2(n-1)}$$

holds. Thus, as depicted in "Area III", $B_1 < 0$ holds when $\gamma < \gamma_{B_1}$ and $\alpha > -4(n-1)/\{(n-1)(1-2\gamma^2) + 2\gamma\}$ hold. Therefore, even in cases represented by "Area II" and "Area III," $A_1 < 0$ and $B_1 > 0$ is secured when

$$\alpha < \min\left\{\frac{11n+3}{4n(n-1)\gamma^2 - 2\gamma + (n-1)(n-3)}, \frac{4(n-1)}{(n-1)(1-2\gamma^2) + 2\gamma}\right\}$$

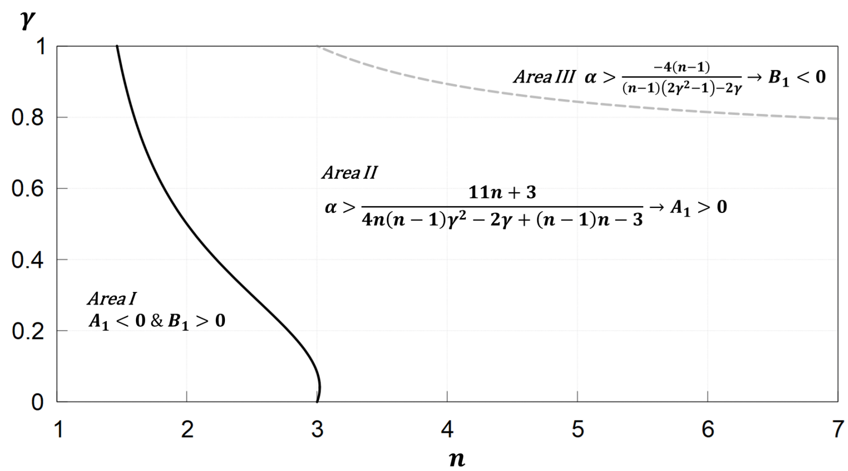

Figure 7: Signs of A_1 and B_1 in $n - \gamma$ axis

holds, which we assumed in the main text.

Given the above assumption, we can derive the following two thresholds $\underline{\tau}^{fc}$ and $\overline{\tau}^{fc}$ and firm M prefers locating in A under $\underline{\tau}^{fc} < \tau < \overline{\tau}^{fc}$ where,

$$\begin{aligned}
\underline{\tau}^{fc} &\equiv \frac{4(n-1) - (n+1)\{(n-1)(2\gamma^2-1) - 2\gamma\}\alpha - \sqrt{\xi}}{(11n+3) - \{4(n-1)n\gamma^2 + 2\gamma - (n-3)(n-1)\}\alpha} \\
\overline{\tau}^{fc} &\equiv \frac{4(n-1) - (n+1)\{(n-1)(2\gamma^2-1) - 2\gamma\}\alpha + \sqrt{\xi}}{(11n+3) - \{4(n-1)n\gamma^2 + 2\gamma - (n-3)(n-1)\}\alpha} \\
\text{and} \quad \xi &\equiv (n-1)^2(n+1)^2(4\gamma^4 + 8\gamma^3 - 4\gamma^2 + 2\gamma + 1)\alpha^2 \\
&\quad - 2(n+1)\{8(n-1)^2\gamma^2 + (11n^2 + 6n + 11)\gamma - 4(n-1)^2\}\alpha + 16(n-1)^2.
\end{aligned}$$

Appendix C: Joint welfare in the region

As fiscal competition occurs within the region, one interesting question is whether it hurts the region. If joint welfare increases due to fiscal competition, some kinds of transfers between countries can lead to Pareto improvement not only at the regional level but also at the global level. To see the joint welfare analysis, let us define $W_J^j = W_A^j + W_B^j$ as the joint welfare given firm M's location in country j. Our analysis is conducted in two steps: without and with firm M's relocation. Likewise the country level analysis, we focus on the case that fiscal competition induces firm M from country A to country B or keeps its location constant.

First, suppose that fiscal competition does not influence the location choice of firm M. In such

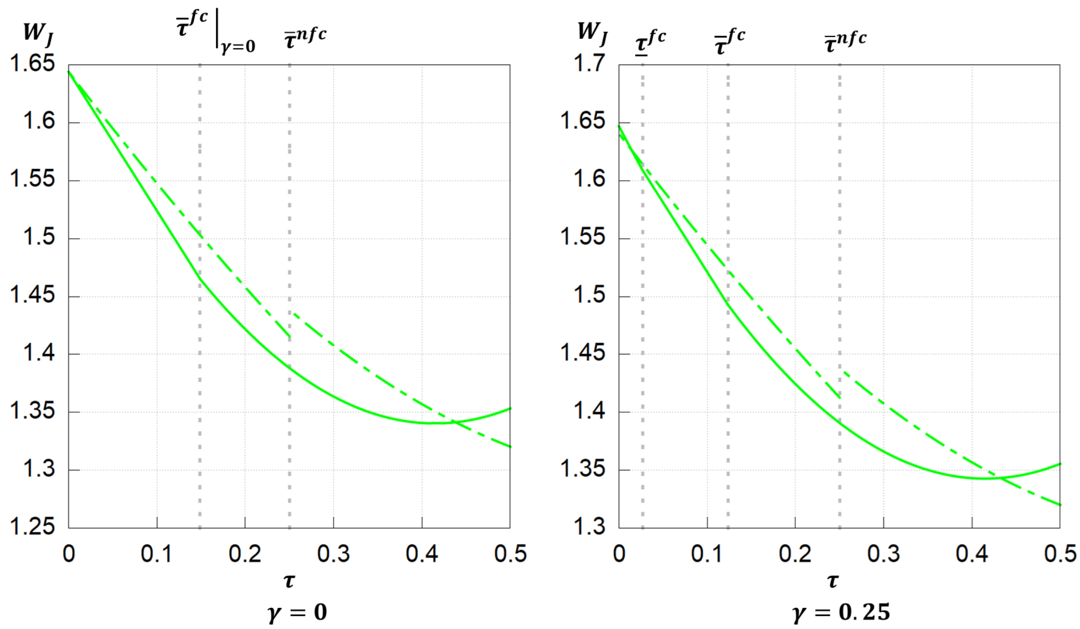

Figure 8: Regional joint welfare ($\gamma = 0$ for the left and $\gamma = 0.25$ for the right)

cases, the change in the joint welfare is via governments' fiscal policy, $\Delta W_J^j \equiv W_J^j\Big|_{t_j=t_j^*} - W_J^j\Big|_{t_A=0} = t_j^*$ because no location change keep consumers' gains and local firm's loss constant. Hence, the joint welfare increases when a host government imposes a tax but decreases when it provides a subsidy.

Second, suppose that fiscal competition changes firm M's location. Unlike the previous case, the change in the joint welfare also depends on changes in consumers' gains, local firm's loss, and environmental damages, and is expressed as

$$\begin{aligned}\Delta W_J^{AB} &\equiv W_J^B\big|_{t_B=t_B^*} - W_J^A\big|_{t_A=0} \\ &= CS_A^B + \pi_L^B + CS_B^B + t_B^* - d_A^B - d_B^B - \left(CS_A^A + \pi_L^A + CS_B^A - d_A^A - d_B^A\right).\end{aligned}$$

Fig. 8 is a numerical example showing the impacts of fiscal competition on the joint welfare. In the figure, dashed curves show cases without fiscal competition whereas solid curves draw cases with fiscal competition. Note that firm M's location is in country A below $\overline{\tau}^{nfc}$ without fiscal competition whereas it is inside the iso-profit curve of τ^{fc} with fiscal competition. Thus, fiscal competition does not affect firm M's location in country A inside the iso-profit curve and in country B above $\overline{\tau}^{nfc}$. As the equilibrium fiscal policy is a tax when trade costs are sufficiently high $t_B^* > 0$, such cases improve joint welfare.

Furthermore, fiscal competition changes firm M's location from country A to country B under $0 < \tau < \underline{\tau}^{fc}$ and $\overline{\tau} < \tau < \overline{\tau}^{nfc}$. In the region of $\tau \in [0, \underline{\tau}^{fc}]$, regional Pareto improvement is possible when $\gamma = 0.25$. As shown in Fig.6, regional Pareto improvement more likely occur compared to country-level Pareto improvement. Therefore, if some kinds of fiscal transfer is plausible, fiscal competition can better-off both competing countries.

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