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Corporate Tax Competition in the Presence of Unemployment

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Corporate Tax Competition in the Presence of Unemployment[1]

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Abstract

We analyze the corporate tax competition between two countries in a two-sector model in which one sector is an oligopoly and oligopolists can choose their location between the two countries. Importantly, our model considers imperfect labor markets, where the wage rates in both countries are fixed, causing unemployment to appear. Under such framework, we show that a unique and stable Nash equilibrium of corporate taxes exists and discuss the properties of the equilibrium tax rates. We also examine the relation between the wage rates and equilibrium tax rates as well as that between the share of equities for oligopoly profits and equilibrium tax rates.

Keywords: Corporate tax rate, Unemployment, Oligopoly
JEL classification: F16, H25, J64

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1 Introduction

The corporate tax rates in many OECD countries have been decreasing over the past two decades. For example, the corporate tax rate in Japan has fallen from 30% in 2000 to 23.4% in 2017 and that in the United Kingdom has dropped from 30% to 19% over the same period. In the United States, by contrast, the corporate tax rate has remained stable at 35%. However, U.S. President Trump is plannning to reduce the corporate tax rate to 15% to "make the United States more competitive". OECD countries have reduced their corporate tax rates to attract multinational firms to their countries and raise the employment. Bond et al. (2000), Devereux et al. (2002), and Griffith and Klemm (2004) investigate the declines in the corporate tax rates in OECD countries and show that one driver is a fall in the cost of income shifting and expansions in activities of multinational firms.

Further motivation for this study comes from the finding of recent empirical research. Mittermaier and Rincke (2013) show the relationship between the minimum wage and the corporate tax rate theoretically and empirically. By using the real compensation costs of 16 European countries, they find that an increase in the compensation cost lowers the statutory corporate tax rate. Ljungqvist and Smolyansky (2014) find that the corporate tax rate in the United States affects employment and income. These results suggest three questions, which are investigated in this study: Why have OECD countries reduced their corporate tax rates in recent decades? Why do countries set different corporate tax rates? And does a cut in the corporate tax rate reduce the unemployment rate?

To tackle these three questions, we construct a two-country model to analyze the effect of corporate tax competition on the unemployment rate and welfare. In our model, there is a competitive sector and an oligopolistic sector. The wage rate is assumed to be constant, meaning that unemployed agents exist in both countries. In the oligopolistic sector, there are a fixed number of oligopolists in the world and these firms can choose their location and output. The government in each country levies the corporate tax rate on the profits of those firms located in the domestic country to maximize its own welfare.

This study provides four main results. First, our model shows that there exists a unique and stable Nash equilibrium of corporate tax rates. Secondly, we can show that the country with the larger market sets a higher corporate tax rate at the Nash equilibrium. Thirds, we examine the relation between the wage level and the Nash equilibrium corporate tax rate. A rise in the wage rate in a country lowers the corporate tax rate. Since an increase in the wage rate in a country encourages some firms to relocate to the other country, the government reduces its corporate tax rate to attract firms. The last result concerns the effect of an increase in the share of equities for firms on the equilibrium corporate tax rate.[1] A rise in the share of equities owned by residents in a country lowers the

[1] Peralta and van Ypersel (2005) investigate the capital tax competition with asymmetric capital endowment. They show that capital importing country levies the positive unit capital tax rate and capital exporting country subsidizes capital.

corporate tax rate in that country and raises that in the other country. If the share of equities owned by domestic residents rises, profit becomes an important factor in welfare. Therefore, the government reduces its corporate tax rate.

We calibrate our model by using Japanese and U.S. data in 2014. To use the corporate tax rates in both countries in this year, we compute the key variables predicted in our model and investigate the effect of a 10% increase in the Japanese corporate tax rate. We find that a decrease in the corporate tax rate in Japan by 10%, with the corporate tax rate in the United States remaining constant, decreases employment in Japan by 1% and the number of firms in Japan by 0.6%. On the contrary, a decrease in the corporate tax rate in Japan by 10% reduces employment in the United States by 0.4% and increases the number of U.S. firms by 0.5%.

The remainder of this paper is structured as follows. In the next subsection, we describe the literature related to this study. We construct the model in Section 2. In Section 3, we show that there exists a unique equilibrium and describe some of the comparative statistics of this equilibrium. In section 4, we calibrate our model by using Japanese and U.S. data. Section 5 concludes.

1.1 Related Literature

Many researchers have investigated tax competition between countries, pioneered by the seminal studies of Zodorow and Mieszkowski (1986) and Wilson (1986). In these models, governments maximize the welfare levels in their country. Neglecting other countries' behavior, governments set an inefficiently low capital tax rate because of the fiscal externality, which suggests that an increase in the capital tax rate moves capital from one country to the other and thus increases the tax base in the other country. Bucovetsky (1991) and Wilson (1991) construct asymmetric country models to investigate the capital tax rate, showing that the larger country sets a higher capital tax rate. Haufler and Stähler (2013) construct a two-country model with firms that have different productivity level and show that the larger country sets a higher corporate tax rate, which in turn attracts lower productivity firms. On the contrary, a smaller country sets a lower corporate tax rate and attracts higher productivity firms. However, although the results of these studies are the same as those of our model, they do not consider unemployment, as we do herein.

In the literature on tax competition, some studies investigate the capital tax rate by considering imperfect labor markets. Fuest and Huber (1999), Ogawa, Sato, and Tamai (2006, 2016), and Sato (2009) describe the relationship between the capital tax rate and unemployment in a perfectly competitive market whereas Haufler and Mittermaier (2011), Egger and Seidel (2011), and Morita, Sawada, and Yamamoto (2016) construct models with imperfectly competitive market to examine the effect of the capital tax rate on the unemployment rate.[2]

[2] Fuest and Huber (1999) introduce a wage bargaining. Ogawa, Sato, and Tamai (2006) introduce a minimum wage. Egger and Seidel (2011) introduce a fair-wage. Haufler and Mittermaier (2011), Exbrayat, Gaigné, and Riou (2012), and Ogawa, Sato, and Tamai (2016) introduce labor unions. Sato (2009) and Morita, Sawada, and Yamamoto (2016) introduce

In particular, Exbrayat, Gaigné, and Riou (2012) and Mittermaier and Rincke (2013) are closely related to the present study. The former theoretically analyze the effect of wage rigidities on the tax competition between two countries, showing that a country whose union places a higher wage compared with the other country's union sets a higher capital tax rate and that the wage rate is lower. There are some differences between Exbrayat, Gaigné, and Riou (2012) and our study, however. Firstly, in their model, they assume that under Cournot competition in a sector, the marginal costs are zero and there exist fixed costs of capital and labor. Therefore, in their analysis, an output change does not affect employment. By contrast, we consider the general situation in which both firms' location and output affect employment. Secondly, they determine the wage rate based on the monopoly labor union maximizing its utility, whereas this study assumes that wage rates are fixed, meaning that unemployment exist in the market. Thus, we examine the extent to which a change in the wage rate affects various endogenous variables. Thirdly, in Exbrayat, Gaigné, and Riou (2012), the governments in both countries levy the capital tax rate in a unit form. By contrast, this study imposes a corporate tax on the profits of firms, (i.e., the tax is in an ad valorem form). While such an ad valorem form of tax complicates the analysis because it yields an indirect effect on the real tax rate through price changes, as indicated by Lockwood (2004) and Akai, Ogawa, and Ogawa (2011) it does make the analysis more realistic.

Mittermaier and Rincke (2013) construct a two-country tax competition model and study the effect of wage differences on the capital tax rate. In their model, the wage rate is constant in one country, whereas the labor market in the other country is perfectly competitive. The production inputs are labor and capital, and capital is owned by the agents in the outside model. They find that a country in which the wage rate is larger than that of the other country levies a lower capital tax rate.

In contrast to both Exbrayat, Gaigné, and Riou (2012) and Mittermaier and Rincke (2013), the present study assumes that each household owns the same share of equity across all firms. Then, we allow an asymmetric equity share between countries. This study therefore examines the effects of these shares of equities on the Nash equilibrium tax rates and unemployment.

2 The Model

There are two countries, country 1 and 2, and two commodities. One production sector is perfectly competitive and the other is oligopolistic. Each oligopolist engages in Cournot competition. We assume that the commodity produced in the perfectly competitive sector is tradable between the two countries without trade costs and is chosen to be the numeraire. Both governments levy corporate tax on the firms located in their countries.

There are L_i workers in country i and each worker holds one unit of labor which she supplies inelastically. While workers are mobile between sectors, they

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are immobile between countries. The utility function of representative agent in country i is given by

$$U_i = z_i - \frac{\beta_i}{2}\tilde{X}_i^2 + \alpha_i \tilde{X}_i, \tag{1}$$

where z_i denotes the demand for the commodity produced in the perfectly competitive sector, $\tilde{X}_i$ the consumption of the oligopoly-produced commodity, and α_i and β_i are constant parameters. The budget constraint of each agent in country i is

$$z_i + p_i \tilde{X}_i = I_i,$$

where p_i denotes the price of the oligopoly-produced commodity in country i and I_i the income in country i.

We assume segmented markets for the oligopoly-produced commodity because of sufficiently high transportation costs. Thus, from the utility maximization problem, the inverse demand function of the oligopoly-produced commodity in country i becomes

$$p_i = \alpha_i - \beta_i \frac{X_i}{L_i}, \tag{2}$$

where $X_i (\equiv L_i \tilde{X}_i)$ represents total demand in country i. From (1) and (2), we obtain the indirect utility function, such as

$$U_i = \frac{\beta_i}{2}\left(\frac{X_i}{L_i}\right)^2 + I_i. \tag{3}$$

Here, we describe the production structure of both sectors. We assume that the production function of the competitive sector in country i is given by

$$z_i = B_i f_i(l_i^z),$$

where l_i^z is the labor employed in the competitive sector, B_i is the productivity of the sector in country i, and z_i is the output produced in country i. We assume that $f_i'(l_i^z) > 0$ and $f_i''(l_i^z) \leq 0$. The pre-tax profit of the competitive sector is

$$\pi_i^z = B_i f_i(l_i^z) - \bar{w}_i l_i^z, \tag{4}$$

where $\bar{w}_i$ is the minimum wage in country i. From the profit-maximization problem, labor demand in the competitive sector is given as the function of $\bar{w}_i$, that is,

$$l_i^z = l_i^z(\bar{w}_i). \tag{5}$$

As long as $\bar{w}_i$ is constant, labor demand in the competitive sector is unchanged. (4) and (5) imply that the profit in the perfectly competitive sector is also constant.

In the oligopolistic sector, there are an exogenous number of firms N and each firm can choose its location:

$$n_1 + n_2 = N, \tag{6}$$

where n_i is the number of firms located in country i. The firms in the oligopolistic sector are assumed to be symmetric. The pre-tax profit of the oligopolist located in country i is

$$\pi_i = p_i x_i - c_i x_i \bar{w}_i, \tag{7}$$

where π_i represents gross profit, x_i is output, and c_i is a unit of labor required to produce a unit of the commodity. Owing to the symmetric assumption, $y_i = X_i/n_i$. From (2), (7), and the profit maximization of the oligopolist, the demand function of the oligopoly-produced commodity and pre-tax profits are given by

$$x_i = \frac{L_i}{\beta_i} \frac{\alpha_i - c_i \bar{w}_i}{1 + n_i}, \tag{8}$$

$$\pi_i = \frac{L_i}{\beta_i} \left(\frac{\alpha_i - c_i \bar{w}_i}{1 + n_i} \right)^2. \tag{9}$$

Then, a rise in the number of firms lowers output and profit because the oligopoly market becomes more competitive. By using (2), (8), and the fact that $n_i x_i = X_i$, we obtain

$$p_i = \frac{\alpha_i + c_i n_i \bar{w}_i}{1 + n_i}.$$

An increase in n_i lowers the price in country i. Because oligopolists can move freely between countries, the after-tax profits are the same

$$(1 - t_1)\pi_1 = (1 - t_2)\pi_2, \tag{10}$$

where t_i is the corporate tax rate in country i. From (6), (9), and (10), the numbers of oligopolists in both countries are given by

$$n_1 = \frac{1 + N - A\phi}{1 + A\phi}, \qquad n_2 = \frac{A\phi(1 + N) - 1}{1 + A\phi}, \tag{11}$$

where $A = \sqrt{\frac{1-t_2}{1-t_1}}$ and $\phi = \frac{\alpha_2 - c_2 \bar{w}_2}{\alpha_1 - c_1 \bar{w}_1} \sqrt{\frac{L_2}{L_1}}$. If the countries are symmetric, $\phi = 1$, and they impose the same tax rate, $A = 1$; then, $n_1 = n_2 = 1/2$. From this, we find that an increase in N raises the number of oligopolists in both countries. From (11), $\partial n_1/\partial \phi = -\partial n_2/\partial \phi = -(2 + N)A/(1 + A\phi)^2 < 0$. This implies that an increase in α_1 and a decrease in c_1 increase the number of oligopolists in country 1. In addition, from (11), we immediately obtain

$$\frac{\partial n_i}{\partial t_i} = -\frac{(1 + n_i)(1 + n_j)}{2(1 - t_i)(2 + N)} < 0, \qquad \frac{\partial n_i}{\partial t_j} = \frac{(1 + n_i)(1 + n_j)}{2(1 - t_j)(2 + N)} > 0. \tag{12}$$

The intuition for this is clear. An increase in the corporate tax in country i lowers the after-tax profits of country i and hence induces some firms to move to country j. Therefore, an increase in the corporate tax rate in country i increases the number of firms in that country and decreases that in the other country.

Using (8), (9) and (12) yields

$$\frac{\partial y_i}{\partial t_i} = \frac{(1+n_j)x_i}{2(1-t_i)(2+N)} > 0, \qquad \frac{\partial y_i}{\partial t_j} = -\frac{(1+n_j)x_i}{2(1-t_j)(2+N)} < 0, \tag{13}$$

$$\frac{\partial \pi_i}{\partial t_i} = \frac{\beta_i(1+n_j)x_i^2}{L_i(1-t_i)(2+N)} > 0, \qquad \frac{\partial \pi_i}{\partial t_j} = -\frac{\beta_i(1+n_j)x_i^2}{L_i(1-t_j)(2+N)} < 0. \tag{14}$$

Raising the corporate tax rate increases output and pre-tax profits in the focal country and lowers output and pre-tax profits in the other country. This is because raising the tax rate in country j encourages some firms to relocate to the other country and hence market competition in country i becomes less severe. From (12) and (13), we obtain the following properties, which are used in the later analysis:

$$\frac{\partial X_i}{\partial t_i} = -\frac{(1+n_j)x_i}{2(1-t_i)(2+N)} < 0, \tag{15}$$

$$\frac{\partial((1-t_i)\pi_i)}{\partial t_i} = -\frac{\beta_i x_i^2}{L_i}\frac{1+n_i}{2+N} < 0. \tag{16}$$

In both countries, the government maximizes its own welfare by manipulating the corporate tax rate. Allowing for (3), the welfare function of country i is given by

$$W_i = L_i U_i = L_i \left[\frac{\beta_i}{2}\left(\frac{X_i}{L_i}\right)^2 + I_i\right]. \tag{17}$$

The first term in the brackets represents the consumer surplus in country i.

In this model, we assume that each household owns the same share of equities across all oligopolists. The equity share of households in country i is denoted by s_i. Tax revenues are paid to, and subsidy funds are collected from, each country's households as lump-sum amounts. The income in country i satisfies

$$I_i = l_i^z(\bar{w}_i)\bar{w}_i + c_i X_i \bar{w}_i + (1-t_i)\pi_i^z + s_i N(1-t_i)\pi_i + T_i, \tag{18}$$

where s_i denotes the share of total profits in country i and T_i the lump-sum transfer. The first and second terms on the right-hand side are the labor income obtained in the perfectly competitive and oligopolistic sectors, respectively. The third and forth terms represent the after-tax profits obtained in the perfectly competitive and oligopolistic sectors, respectively. The budget constraint of the government in country i is

$$T_i = t_i(n_i\pi_i + \pi_i^z). \tag{19}$$

Because unemployed agents in both countries exist in this model, we assume that the following inequality holds:

$$l_i^z(\bar{w}_i) + c_i n_i x_i \equiv L_i^E < L_i, \qquad i = 1, 2, \tag{20}$$

where L_i^E denotes the number of employees in country i. The left-hand side, $l_i^z + c_i n_i x_i$, represents labor demand. Since L_i is labor supply in country i, (20) implies unemployment in both countries. In this model, we assume that labor supply is larger than labor demand in both countries.

By using (18) and (19), (17) can be rewritten as

$$W_i = \frac{\beta_i X_i^2}{2L_i} + c_i \bar{w}_i X_i + s_i N(1 - t_i)\pi_i + t_i n_i \pi_i + l_i^z(\bar{w}_i)\bar{w}_i + \pi_i^z. \tag{21}$$

The first term describes the consumer surplus. The second to fourth terms are the labor income, profit income, and tax revenue obtained from the oligopolistic sector. The final two terms are the labor income and profit income in the perfectly competitive sector, which are constant as long as the wage rate is constant.

3 Nash Equilibrium Corporate Tax Rates

In both countries, the governments choose the corporate tax rate to maximize their own welfare. By differentiating (21) with respect to t_i, we obtain the following equation:

$$\frac{\partial W_i}{\partial t_i} = \frac{\beta_i X_i}{L_i}\frac{\partial X_i}{\partial t_i} + c_i \bar{w}_i \frac{\partial X_i}{\partial t_i} + s_i N \frac{\partial((1 - t_i)\pi_i)}{\partial t_i} + \frac{\partial(t_i n_i \pi_i)}{\partial t_i}. \tag{22}$$

From (15), raising the tax rate reduces the consumer surplus and labor demand in the oligopolistic sector. Therefore, the first two terms are negative. From (16), raising the tax rate reduces the after-tax profit and hence, the third term is also negative. Raising the tax rate increases tax revenue if the tax rate is sufficiently small.

3.1 Nash Equilibrium Tax Rates

In this subsection, we examine the properties of Nash equilibrium taxes. By substituting (12) and (14)–(16) into (22) and making use of (6), (9), and (11), we find that the optimal corporate tax rates of countries 1 and 2 satisfy, respectively,

$$F(t_1, t_2; \bar{w}_1, \bar{w}_2, s_1, s_2) = 0, \qquad G(t_1, t_2; \bar{w}_1, \bar{w}_2, s_1, s_2) = 0, \tag{23}$$

where

$$F(t_1, t_2) \equiv t_1 - \frac{(2 + A\phi)(1 + N - A\phi) - 2(1 + A\phi)s_1 N - (2 + N)A\phi\Psi_1}{2(1 + N) + A\phi N - 2(1 + A\phi)s_1 N}, \tag{24}$$

$$G(t_1, t_2) \equiv t_2 - \frac{(2A\phi + 1)\left[(1 + N - s_2 N)A\phi - 1\right] - A\phi\left[s_2 N + (2 + N)\Psi_2\right]}{A\phi\left[2A\phi(1 + N) + N - 2(1 + A\phi)s_2 N\right]},$$

$$\Psi_i = \frac{c_i \bar{w}_i}{\alpha_i - c_i \bar{w}_i} > 0. \tag{25}$$

The reaction function $t_1 = \varphi_1(t_2)$ obtains as a solution of the first condition of (23) and $t_2 = \varphi_2(t_1)$ as that of the second condition.

Because we consider a general model, deriving an analytical solution in our model is somewhat challenging. Thus, hereafter, we assume that $s_1 = s_2 = \frac{1}{2}$ initially holds to simplify for the analysis. This assumption allows us to avoid the effects of the distribution of profits on the Nash equilibrium taxes. Under this assumption, we obtain the following proposition (see the Appendix for the proof).

Proposition 1 *Suppose that $s_1 = s_2 = \frac{1}{2}$ and (20) hold. There exists a unique and stable equilibrium at which $t_1^* = \varphi_1(t_2^*)$ and $t_2^* = \varphi_2(t_1^*)$.*

Figure 1 depicts the reaction functions in both countries. The policy decisions of these two countries are strategic complements. The reaction function of country i is the convex function of the corporate tax rate in country j.[3] Hereafter, we focus on the case where the equilibrium corporate tax rates are positive in both countries.

Assumption 1 *The optimum corporate tax rate are positive in both countries.*

In the equilibrium, we investigate the effect of an increase in the relative population size on the corporate tax rate in both countries. In this study, we term the country that has the larger (smaller) population size the large (small) country. By totally differentiating (23), we obtain the following proposition (see the Appendix for the proof).

Proposition 2 *At the Nash equilibrium, (i) the tax rate in the larger country is higher than that in the smaller country, and (ii) the number of workers in the larger country is less than that in the smaller country.*

The intuition is simple. It is beneficial for oligopolists to be located in a country with a large market. The large country has a larger tax base and hence imposes a higher tax rate. On the contrary, the small country levies a lower corporate tax rate to attract oligopolists in order to expand labor income and tax revenue. This result is consistent with the data as well as the results of Bucovetsky (1991) and Wilson (1991).

By investigating the effect of an increase in relative labor supply on the number of oligopolists and labor demand for the oligopoly-produced commodity, we obtain the following proposition (see the Appendix for the proof).

Proposition 3 *An increase in labor supply (L_i) in country i decreases the number of oligopolists and the number of workers and increases the unemployment rate in country i due to changes the optimum corporate tax rates in both countries.*

[3] When a country sets 100% corporate tax rate, the firms do not produce the commodity. Therefore, we need not to consider the case of 100% tax rate as an equilibrium.

According to Proposition 2, following rise in labor supply in country i, the government in country i sets a higher corporate tax rate and the government in the other country sets a lower corporate tax rate. Then, this induces oligopolists to relocate from country i to the other country and increases the unemployment rate in country i. From (15), a reduction in the corporate tax rate raises labor demand in commodity X and lowers the unemployment rate in the other country.

3.2 Minimum Wage and Equilibrium Tax Rates

Next, we examine the effect of an increase in the minimum wage on the corporate tax rates in the countries. By totally differentiating (23) with respect to t_i and w_i, we obtain the following proposition (see the Appendix for the proof).

Proposition 4 *A rise in the minimum wage rate in a country lowers the corporate tax rate in that country. An increase in the wage rate in country* 1 *increases (decreases) the corporate tax rate in country* 2 *if and only if* $N < (>) A\phi - 1$, *while an increase in the wage rate in country* 2 *decreases (increases) the corporate tax rate in country* 1 *if and only if* $N < (>) \frac{1-A\phi}{A\phi}$.

We explain this proposition intuitively. A rise in the wage rate in country i reduces the production of each oligopolist located in country i and induces some oligopolists to move to the other country. This decreases employment and the consumer surplus in country i. Then, the government in the focal country lowers the tax rate to withhold the oligopolists. On the contrary, the other country faces a lower tax rate than that country i but has a larger tax base because of relocation of some oligopolists from country i. Therefore, the direction of the change in the tax rate in the other country depends on the change in the tax base, which is related to the condition in Proposition 4.

By using the effect of the minimum wage rate on the corporate tax rate, we obtain the effect of the minimum wage on the unemployment rate as follows (see the Appendix for the proof).

Proposition 5 *An increase in the minimum wage rate in a country increases the number of oligopolists and that of workers in the oligopolistic sector as well as reduces the unemployment rate in its own country, while it decreases that of workers in the oligopolistic sector and increases the unemployment rate in the other country due to changes in the optimum corporate tax rates in both countries.*

An increase in the minimum wage rate in country i raises the marginal costs of firms in country i. Then, firms prefer to relocate to the other country because its relative marginal costs are cheaper. However, from the result of Proposition 4, the government in country i sets a lower corporate tax rate compared with that in the other country to retain commodity x producing firms. Then, because the latter effect is larger than the former, a rise in the minimum wage rate in country i raises the number of firms in country i. An increase in the number of firms in country i increases labor demand and this increases the number of workers in the oligopolistic sector in country i and thus reduces unemployment. On the contrary, a reduction in the number of firms in the other country lowers labor demand and this reduces the number of workers in the oligopolistic sector in the other country, which raises the unemployment rate.

3.3 Equity Holding and Equilibrium Tax Rates

Focusing on the symmetric equilibrium, we investigate the effect of an increase in the share of equities owned by country i on the corporate tax rates in both countries. In the symmetric equilibrium, $\phi = 1$, $\Psi_1 = \Psi_2 \equiv \Psi$, and $A = 1$ hold. By totally differentiating (23) with respect to t_i and s_i at the symmetric equilibrium, we obtain the following proposition (see the Appendix for the proof).

Proposition 6 *If the countries are initially symmetric, an increase in the share of equities owned by country i decreases the corporate tax rate in country i and increases that in the other country.*

An increase in the share of total profits in country i increases the negative effect of the corporate tax rate on profit income, which represents the third term in (22). In addition, from (10), a reduction in the corporate tax rate raises the after-tax profits of oligopolists. Therefore, the government in country i holding the share of equities lowers its corporate tax rate. On the contrary, because the large share of equities owned by the other country belongs to the agents in country i, the government in the other country levies a higher corporate tax rate.

By investigating the effect of the share of equities on the unemployment rate, we obtain the following proposition.

Proposition 7 *If the countries are initially symmetric, an increase in the share of equities owned by country i increases the number of firms in country i as well as the number of workers in the oligopolistic sector in country i due to changes in the optimum corporate tax rates in both countries.*

From Proposition 6, an increase in the share of total profits level in country i decreases the corporate tax rate in country i. Because of a fall in the corporate tax rate in country i, firms prefer to be located there, and this raises the number of firms in country i. Then, a rise in the number of firms raises labor demand, and the number of workers in the oligopolistic sector rises. On the contrary, from Proposition 6, the government in the other country sets the higher corporate tax rate and firms avoid relocating to the other country. Then, labor demand in the other country decreases.

4 Numerical Simulation

In this section, we present a numerical simulation to assess the effect of a reduction in corporate tax rate in a country. We use data on the statutory corporate tax rates and the number of workers in the United States and Japan in 2014. In 2014, the corporate tax rates of the United States and Japan were about 39% and 37%, respectively. We assume that the number of oligopolistic firms is $N = 100$, $c_1 = c_2 = 1$ and the production function of sector z is $B_i f_i(l_i^z) = \frac{1}{1000}(l_i^z)^{0.5}$. Then, by using the data on the statutory corporate tax rates and the number of workers, we estimate the unknown parameters of $(\alpha_1, \alpha_2, \bar{w}_1, \bar{w}_2)$ from the labor market equilibrium conditions and reaction functions in both countries.

Using these parameter values, we estimate two counterfactual examples. One is that the Japanese government cuts the corporate tax rate by 10%, (i.e., to 33%), while the U.S. corporate tax rate is constant. The other example is that the U.S. corporate tax rate becomes 15% from the statement of President Trump. We show that if the Japanese government cuts the corporate tax rate by 10%, this lowers the number of workers in Japan by 2% and increase that in United States by 0.1% because the costs in Japan rise by 4% and those in United States lowers by 0.2%. Moreover, the number of firms in Japan decreases by 0.2% and that in the United States increases by 0.2%. Next, if the U.S. government sets its statutory corporate tax rate at 15% and the Japanese corporate tax rate is constant, this raises the number of workers in Japan by 0.2% and lowers the number of worker in the United States by 14% because the costs in Japan decrease by 0.5% and those in the United States increase by 21%. In addition, the number of firms in Japan lowers by 0.4% and that in the United States rises by 0.3%.

5 Conclusion

In this study, we have investigated the impacts of the wage rate and share of equity holdings on the corporate tax competition between asymmetric countries with imperfect labor markets. We have found that a unique equilibrium exists and that the corporate tax rate in the large country is higher than that in the small country. An increase in wages in a country decreases the corporate tax rate in that country and may decrease the corporate tax rate in the other country, too. We have also showed that an increase in the share of equity holdings in a country decreases its corporate tax rate and increases the corporate tax rate in the other country.

Appendix

Proof of Proposition 1

First, we investigate the shape of reaction functions in both countries. From (23), the slope of the reaction function in country 1 is given by

$$\frac{dt_1}{dt_2} = -\frac{F_2}{F_1} > 0,$$

where

$$F_1 \left(\equiv \frac{\partial F}{\partial t_1} \right) = 1 + \frac{A\phi}{2(1-t_1)} \left(\frac{1+2A\phi}{2+N} + \Psi_1 \right) > 0,$$

$$F_2 \left(\equiv \frac{\partial F}{\partial t_2} \right) = -\frac{A\phi}{2(1-t_2)} \left(\frac{1+2A\phi}{2+N} + \Psi_1 \right) < 0.$$

The reaction function in country 1 shows that t_1 is strategic complement to t_2. The curvature of the reaction function of country 1 satisfies

$$\begin{aligned} \frac{d\left(\frac{dt_1}{dt_2}\right)}{dt_2} &= \frac{\partial\left(-\frac{F_2}{F_1}\right)}{\partial t_1}\frac{dt_1}{dt_2} + \frac{\partial\left(-\frac{F_2}{F_1}\right)}{\partial t_2} \\ &= -\frac{F_{21}F_1 - F_{11}F_2}{F_1{}^2}\left(-\frac{F_2}{F_1}\right) - \frac{F_{22}F_1 - F_{12}F_2}{F_1{}^2} \\ &= -\frac{\Gamma_1}{F_1^3}, \end{aligned}$$

where

$$\Gamma_1 \equiv F_{11}F_2^2 - 2F_{12}F_1F_2 + F_{22}F_1^2.$$

Because $F_1 > 0$, the sign of $d\left(\frac{dt_1}{dt_2}\right)/dt_2$ depends on the sign of Γ_1. The second derivatives of F are given by

$$F_{11} \left(\equiv \frac{\partial F_1}{\partial t_1} \right) = \frac{A\phi}{4(1-t_1)^2} \left(\frac{3+8A\phi}{2+N} + 3\Psi_1 \right) > 0,$$

$$F_{22} \left(\equiv \frac{\partial F_2}{\partial t_2} \right) = -\frac{A\phi}{4(1-t_2)^2} \left(\frac{1}{2+N} + \Psi_1 \right) < 0,$$

$$F_{12} \left(\equiv \frac{\partial F_1}{\partial t_2} \right) = -\frac{A\phi}{4(1-t_1)(1-t_2)} \left(\frac{1+4A\phi}{2+N} + \Psi_1 \right) < 0.$$

By using $F_1 = 1 - A^2F_2$, we can rewrite Γ_1 as follows:

$$\Gamma_1 = -2F_2(F_{12} + A^2F_{22}) + F_{22} + F_2^2(A^4F_{22} + 2A^2F_{12} + F_{11}).$$

The third term of this equation is zero. Then, Γ_1 is given by

$$\Gamma_1 = -\frac{A^2\phi^2}{2(1-t_1)(1-t_2)^2} \left(\frac{1+2A\phi}{2+N} + \Psi_1 \right)^2 + F_{22} < 0.$$

Therefore, the sign of Γ_1 is negative and $d\left(\frac{dt_1}{dt_2}\right)/dt_2$ also has a positive value.

Next, we examine the slope of the reaction function in country 2. When $s_2 = 1/2$, From (23), the slope of the reaction function in country 2 is given by

$$\frac{dt_2}{dt_1} = -\frac{G_1}{G_2} > 0,$$

where

$$G_1 \left(\equiv \frac{\partial G}{\partial t_1} \right) = -\frac{1}{2(1-t_1)} \left[\frac{A\phi + 2}{(2+N)A^2\phi^2} + \frac{\Psi_2}{A\phi} \right] < 0,$$

$$G_2 \left(\equiv \frac{\partial G}{\partial t_2} \right) = 1 + \frac{1}{2(1-t_2)} \left[\frac{A\phi + 2}{(2+N)A^2\phi^2} + \frac{\Psi_2}{A\phi} \right] > 0.$$

The reaction function in country 2 shows that t_2 is a strategic complement to t_1. The curvature of the reaction function in country 2 satisfies

$$\begin{aligned} \frac{d\left(\frac{dt_2}{dt_1}\right)}{dt_1} &= \frac{\partial\left(-\frac{G_1}{G_2}\right)}{\partial t_1} + \frac{\partial\left(-\frac{G_1}{G_2}\right)}{\partial t_2}\frac{dt_2}{dt_1} \\ &= -\frac{G_{11}G_2 - G_{21}G_1}{G_2^2} + \frac{G_1}{G_2}\frac{G_{12}G_2 - G_{22}G_1}{G_2^2} \\ &= -\frac{\Gamma_2}{G_2^3}, \end{aligned}$$

where

$$\Gamma_2 \equiv G_{11}G_2^2 - 2G_{12}G_1G_2 + G_{22}G_1^2.$$

Because $G_2 > 0$, the sign of $d\left(\frac{dt_2}{dt_1}\right)/dt_1$ depends on the sign of Γ_2. The second derivatives of G are given by

$$G_{11} \left(\equiv \frac{\partial G_1}{\partial t_1} \right) = -\frac{1}{4(1-t_1)^2} \left[\frac{1}{(2+N)A\phi} + \frac{\Psi_2}{A\phi} \right] < 0,$$

$$G_{22} \left(\equiv \frac{\partial G_2}{\partial t_2} \right) = \frac{1}{4\left(1-t_2\right)^2} \left[\frac{8 + 3A\phi}{(2+N)A^2\phi^2} + \frac{3\Psi_2}{A\phi} \right] > 0,$$

$$G_{12} \left(\equiv \frac{\partial G_1}{\partial t_2} \right) = -\frac{1}{4(1-t_1)(1-t_2)} \left[\frac{4 + A\phi}{(2+N)A^2\phi^2} + \frac{\Psi_2}{A\phi} \right] < 0.$$

By using $G_2 = 1 - \frac{G_1}{A^2}$, we can rewrite Γ_2 as follows:

$$A^4\Gamma_2 = -2A^2G_1(A^2G_{12} + G_{11}) + A^4G_{11} + G_1^2(A^4G_{22} + 2A^2G_{12} + G_{11}).$$

The third term of this equation is zero. Then, the sign of Γ_2 is negative and $d\left(\frac{dt_1}{dt_2}\right)/dt_2$ also has a positive value.

By comparing the slopes of the reaction functions when $s_1 = s_2 = \frac{1}{2}$, the following equation can be obtained:

$$\left(\frac{F_2}{F_1}\right) / \left(\frac{G_2}{G_1}\right) = \frac{F_2G_1}{1 - A^2F_2 - \frac{G_1}{A^2} + F_2G_1} < 1, \tag{A-1}$$

because $F_1 = 1 - A^2F_2$, and $G_2 = 1 - \frac{G_1}{A^2}$. Then, $\frac{F_2}{F_1} < \frac{G_2}{G_1}$ holds. Therefore, the equilibrium at which $t_1^* = \varphi_1(t_2^*)$ and $t_2^* = \varphi_2(t_1^*)$ is stable.

Proof of Propositions 2 and 3

Here, we investigate the effect of the relative market size of $\frac{L_2}{L_1}$ on the corporate tax rates in both countries. By totally differentiating (23), the following equation can be obtained:

$$\begin{pmatrix} F_1 & F_2 \\ G_1 & G_2 \end{pmatrix} \begin{pmatrix} \frac{dt_1}{d(L_2/L_1)} \\ \frac{dt_2}{d(L_2/L_1)} \end{pmatrix} = \begin{pmatrix} -\frac{dF}{d(L_2/L_1)} \\ -\frac{dG}{d(L_2/L_1)} \end{pmatrix}.$$

$\frac{dF}{d(L_2/L_1)}$ and $\frac{dG}{d(L_2/L_1)}$ are given by

$$\frac{dF}{d\left(L_2/L_1\right)} = \left[\frac{A(1+2A\phi)}{2+N} + A\Psi_1\right] \frac{\partial \phi}{\partial \left(L_2/L_1\right)} > 0,$$

$$\frac{dG}{d\left(L_2/L_1\right)} = -\left[\frac{2+A\phi}{(2+N)A^2\phi^3} + \frac{\Psi_2}{A\phi^2}\right] \frac{\partial \phi}{\partial \left(L_2/L_1\right)} < 0,$$

where

$$\frac{\partial \phi}{\partial \left(L_2/L_1\right)} = \frac{\phi}{2(L_2/L_1)} > 0.$$

By using Cramer's rule, we obtain the following equations:

$$\frac{dt_1}{d\left(L_2/L_1\right)} = \frac{-G_2 \frac{dF}{d(L_2/L_1)} + F_2 \frac{dG}{d(L_2/L_1)}}{F_1G_2 - G_1F_2},$$

$$\frac{dt_2}{d\left(L_2/L_1\right)} = \frac{-F_1 \frac{dG}{d(L_2/L_1)} + G_1 \frac{dF}{d(L_2/L_1)}}{F_1G_2 - G_1F_2}.$$

The denominators of these equations are positive from (A-1). The numerators of these equations are

$$-G_2 \frac{dF}{d\left(L_2/L_1\right)} + F_2 \frac{dG}{d\left(L_2/L_1\right)} = -\frac{dF}{d\left(L_2/L_1\right)} < 0,$$

$$-F_1 \frac{dG}{d\left(L_2/L_1\right)} + G_1 \frac{dF}{d\left(L_2/L_1\right)} = -\frac{dG}{d\left(L_2/L_1\right)} > 0.$$

Therefore, an increase in $\frac{L_2}{L_1}$ decreases the corporate tax rate in country 1 and increases the corporate tax rate in country 2.

The effects of an increase in $\frac{L_2}{L_1}$ on the number of firms in both countries are given by

$$\begin{aligned} \frac{dn_1}{d\left(L_2/L_1\right)} &= \frac{\partial n_1}{\partial A}\left[\frac{\partial A}{\partial t_1}\frac{dt_1}{d\left(L_2/L_1\right)} + \frac{\partial A}{\partial t_2}\frac{dt_2}{d\left(L_2/L_1\right)}\right] > 0, \\ \frac{dn_2}{d\left(L_2/L_1\right)} &= \frac{\partial n_2}{\partial A}\left[\frac{\partial A}{\partial t_1}\frac{dt_1}{d\left(L_2/L_1\right)} + \frac{\partial A}{\partial t_2}\frac{dt_2}{d\left(L_2/L_1\right)}\right] < 0, \end{aligned}$$

because $\frac{\partial n_1}{\partial A} < 0$, $\frac{\partial A}{\partial t_1} > 0$, and $\frac{\partial A}{\partial t_2} < 0$. An increase in labor supply in country 2 increases the number of firms in country 1 and decreases that in country 2.

By differentiating labor demand in commodity x with respect to the relative market size, we obtain the following equation:

$$\begin{aligned}\frac{d(c_1X_1)}{d\left(L_2/L_1\right)} &= \frac{\partial(c_1X_1)}{\partial t_1}\frac{dt_1}{\partial\left(L_2/L_1\right)}+\frac{\partial(c_1X_1)}{\partial t_2}\frac{dt_2}{d\left(L_2/L_1\right)}>0,\\ \frac{d(c_2X_2)}{d\left(L_2/L_1\right)} &= \frac{\partial(c_2X_2)}{\partial t_1}\frac{dt_2}{d\left(L_2/L_1\right)}+\frac{\partial(c_2X_2)}{\partial t_2}\frac{dt_2}{d\left(L_2/L_1\right)}<0,\end{aligned}$$

because (15). An increase in $\frac{L_2}{L_1}$ increases (decreases) labor demand for commodity x in country 1 (2).

Proof of Propositions 4 and 5

We show the effect of an increase in the wage rate in country i on the corporate tax rate in both countries. By totally differentiating (23), the following equation can be obtained:

$$\begin{pmatrix} F_1 & F_2 \\ G_1 & G_2 \end{pmatrix}\begin{pmatrix} \frac{dt_1}{d\bar{w}_i} \\ \frac{dt_2}{d\bar{w}_i} \end{pmatrix}=\begin{pmatrix} -\frac{dF}{d\bar{w}_i} \\ -\frac{dG}{d\bar{w}_i} \end{pmatrix}.$$

$\frac{dF}{d\bar{w}_1}$ and $\frac{dG}{d\bar{w}_1}$ are given by

$$\frac{dF}{d\bar{w}_1}=\left[\frac{A(1+2A\phi)}{2+N}+A\Psi_1\right]\frac{\partial\phi}{\partial\bar{w}_1}+A\phi\frac{\partial\Psi_1}{\partial\bar{w}_1}>0,$$

$$\frac{dF}{d\bar{w}_2}=\left[\frac{A(1+2A\phi)}{2+N}+A\Psi_1\right]\frac{\partial\phi}{\partial\bar{w}_2}<0,$$

$$\frac{dG}{d\bar{w}_1}=-\left[\frac{2+A\phi}{(2+N)A^2\phi^3}+\frac{\Psi_2}{A\phi^2}\right]\frac{\partial\phi}{\partial\bar{w}_1}<0,$$

$$\frac{dG}{d\bar{w}_2}=-\left[\frac{2+A\phi}{(2+N)A^2\phi^3}+\frac{\Psi_2}{A\phi^2}\right]\frac{\partial\phi}{\partial\bar{w}_2}+\frac{1}{A\phi}\frac{\partial\Psi_2}{\partial\bar{w}_2}>0,$$

where

$$\frac{\partial\phi}{\partial\bar{w}_1}=\frac{c_1\phi}{2(\alpha_1-c_1\bar{w}_1)}>0,\qquad \frac{\partial\phi}{\partial\bar{w}_2}=-\frac{c_2\phi}{2(\alpha_2-c_2\bar{w}_2)}<0,$$

$$\frac{\partial\Psi_i}{\partial\bar{w}_i}=\frac{\alpha_i\Psi_i}{\bar{w}_i(\alpha_i-c_i\bar{w}_i)}>0.$$

By using Cramer's rule, we can obtain the following equations:

$$\frac{dt_1}{d\bar{w}_i}=\frac{-G_2\frac{dF}{d\bar{w}_i}+F_2\frac{dG}{d\bar{w}_i}}{F_1G_2-G_1F_2},$$

$$\frac{dt_2}{d\bar{w}_i}=\frac{-F_1\frac{dG}{d\bar{w}_i}+G_1\frac{dF}{d\bar{w}_i}}{F_1G_2-G_1F_2}.$$

The denominators of these equations are positive. The numerators of these equations are

$$-G_2\frac{dF}{d\bar{w}_1}+F_2\frac{dG}{d\bar{w}_1}=-A\left(\frac{1+2A\phi}{N+2}+\Psi_1\right)\frac{\partial\phi}{\partial\bar{w}_1}-G_2A\phi\frac{\partial\Psi_1}{\partial\bar{w}_1}<0,$$

$$-F_1\frac{dG}{d\bar{w}_1}+G_1\frac{dF}{d\bar{w}_1}=\left[\frac{2+A\phi}{(2+N)A^2\phi^2}+\frac{\Psi_2}{A\phi}\right]\left[\frac{1}{\phi}\frac{\partial\phi}{\partial\bar{w}_1}-\frac{A\phi}{2(1-t_1)}\frac{\partial\Psi_1}{\partial\bar{w}_1}\right],$$

$$-G_2\frac{dF}{d\bar{w}_2}+F_2\frac{dG}{d\bar{w}_2}=-\left(\frac{1+2A\phi}{2+N}+\Psi_1\right)\left[A\frac{\partial\phi}{\partial\bar{w}_2}+\frac{1}{2(1-t_2)}\frac{\partial\Psi_2}{\partial\bar{w}_2}\right],$$

$$-F_1\frac{dG}{d\bar{w}_2}+G_1\frac{dF}{d\bar{w}_2}=\left[\frac{2+A\phi}{(2+N)\,A^2\phi^3}+\frac{\Psi_2}{A\phi^2}\right]\frac{\partial\phi}{\partial\bar{w}_2}-\frac{F_1}{A\phi}\frac{\partial\Psi_2}{\partial\bar{w}_2}<0.$$

Therefore, an increase in $\bar{w}_i$ decreases the corporate tax rate in country i. The sign of $\frac{dt_2}{d\bar{w}_1}$ depends on the sign of the second parentheses of the above equation. When $N<(>)A\phi-1\equiv\hat{N}_1$, the numerator of $\frac{dt_2}{d\bar{w}_1}$ is positive (negative) and $\frac{dt_2}{d\bar{w}_1}$ is positive (negative). When $N<(>)\frac{1-A\phi}{A\phi}\equiv\hat{N}_2$, the numerator of $\frac{dt_1}{d\bar{w}_2}$ is negative (positive) and $\frac{dt_1}{d\bar{w}_2}$ is negative (positive).

Next, we investigate the effect of an increase in $\bar{w}_i$ on the number of firms and number of workers engaged in the commodity x sector. From (11), by differentiating the number of firms in country i with respect to $\bar{w}_i$, the following equation can be obtained:

$$\begin{aligned}\frac{\partial n_i}{\partial\bar{w}_i} &= \frac{\partial n_i}{\partial A}\left(\frac{\partial A}{\partial t_1}\frac{dt_1}{d\bar{w}_i}+\frac{\partial A}{\partial t_2}\frac{dt_2}{d\bar{w}_i}\right)\\ &= \frac{\partial n_i}{\partial A}\frac{A\left[(A^2G_2+G_1)\frac{dF}{d\bar{w}_i}-(A^2F_2+F_1)\frac{dG}{d\bar{w}_i}\right]}{2(1-t_2)(F_1G_2-G_1F_2)}.\end{aligned}$$

By using F_1, F_2, G_1, and G_2, $A^2G_2+G_1=A^2$ and $A^2F_2+F_1=1$ hold. Then, above equation becomes

$$\frac{\partial n_i}{\partial\bar{w}_i}=-\frac{\partial n_i}{\partial A}\frac{A\left(A^2\frac{dF}{d\bar{w}_i}-\frac{dG}{d\bar{w}_i}\right)}{2(1-t_2)(F_1G_2-G_1F_2)}>0.$$

Therefore, an increase in $\bar{w}_i$ increases the number of firms in country i.

We differentiate the number of workers engaged in the commodity x sector with respect to $\bar{w}_1$ in countries 1 and 2 as follows:

$$\frac{\partial(c_1X_1)}{\partial\bar{w}_1}=\frac{c_1x_1(1+n_2)\left(A^2\frac{dF}{d\bar{w}_1}-\frac{dG}{d\bar{w}_1}\right)}{2(1-t_2)(2+N)(F_1G_2-G_1F_2)}>0,$$

$$\frac{\partial(c_2X_2)}{\partial\bar{w}_1}=-\frac{c_2(1+n_1)x_2\left(A^2\frac{dF}{d\bar{w}_1}-\frac{dG}{d\bar{w}_1}\right)}{2(1-t_2)(2+N)(F_1G_2-G_1F_2)}<0.$$

Then, an increase in the wage rate in country 1 increases the number of workers engaged in the commodity x sector in country 1 and decreases that in country 2.

Proof of Proposition 6

Here, we show the effect of an increase in the share of total profits in country 1 on the corporate tax rate in the symmetric equilibrium. In the symmetric equilibrium, $\phi = 1$, $\Psi_1 = \Psi_2 \equiv \Psi$, and $A = 1$ hold. In this model, because total profits are perfectly allocated in both countries, $s_1 + s_2 = 1$ holds. By totally differentiating (23) at $s_1 = \frac{1}{2}$, the following equation can be obtained:

$$\begin{pmatrix} F_1|_{s_1=\frac{1}{2}} & F_2|_{s_1=\frac{1}{2}} \\ G_1|_{s_1=\frac{1}{2}} & G_2|_{s_1=\frac{1}{2}} \end{pmatrix} \begin{pmatrix} \frac{dt_1}{ds_1} \\ \frac{dt_2}{ds_1} \end{pmatrix} = \begin{pmatrix} -\left.\frac{dF}{ds_1}\right|_{s_1=\frac{1}{2}} \\ -\left.\frac{dG}{ds_1}\right|_{s_1=\frac{1}{2}} \end{pmatrix}.$$

$\left.\frac{dF}{ds_1}\right|_{s_1=\frac{1}{2}}$ and $\left.\frac{dG}{ds_1}\right|_{s_1=\frac{1}{2}}$ are given by

$$\left.\frac{dF}{ds_1}\right|_{s_1=\frac{1}{2}} = -\left.\frac{dG}{ds_1}\right|_{s_1=\frac{1}{2}} = \frac{4N\left[2+(2+N)\Psi\right]}{(2+N)^2}.$$

By using Cramer's rule, we obtain the following equations:

$$\frac{dt_1}{ds_1} = -\frac{dt_2}{ds_1} = -\frac{4N\left[2+(2+N)\Psi\right]^2}{(2+N)^2\left[5+(2+N)\Psi\right]} < 0.$$

Therefore, in the symmetric equilibrium, an increase in the share of total profits in country 1 decreases (increases) the corporate tax rate in country 1 (2).

By differentiating s_1 with respect to n_1 at $s_1 = \frac{1}{2}$, we obtain the following equation:

$$\left.\frac{\partial n_1}{\partial s_1}\right|_{s_1=\frac{1}{2}} = \left.\frac{\partial n_1}{\partial A}\right|_{s_1=\frac{1}{2}} \left(\left.\frac{\partial A}{\partial t_1}\right|_{s_1=\frac{1}{2}} \frac{dt_1}{ds_1} + \left.\frac{\partial A}{\partial t_2}\right|_{s_1=\frac{1}{2}} \frac{dt_2}{ds_2} \right) > 0,$$

because $\frac{\partial n_1}{\partial A} < 0$, $\frac{\partial A}{\partial t_1} > 0$, and $\frac{\partial A}{\partial t_2} < 0$. Then, a rise in the share of total profits in country 1 increases the number of firms in country 1. Next, we investigate the relationship between the share of total profits in country 1 and the number of workers engaged in the commodity x sector:

$$\begin{aligned} \left.\frac{d(c_1X_1)}{ds_1}\right|_{s_1=\frac{1}{2}} &= \frac{\partial(c_1X_1)}{\partial t_1}\frac{dt_1}{ds_1} + \frac{\partial(c_1X_1)}{\partial t_2}\frac{dt_2}{ds_1} > 0, \\ \left.\frac{d(c_2X_2)}{ds_1}\right|_{s_1=\frac{1}{2}} &= \frac{\partial(c_2X_2)}{\partial t_1}\frac{dt_2}{ds_1} + \frac{\partial(c_2X_2)}{\partial t_2}\frac{dt_2}{ds_1} < 0, \end{aligned}$$

because (15). An increase in s_1 increases (decreases) labor demand in the commodity x sector in country 1 (2).

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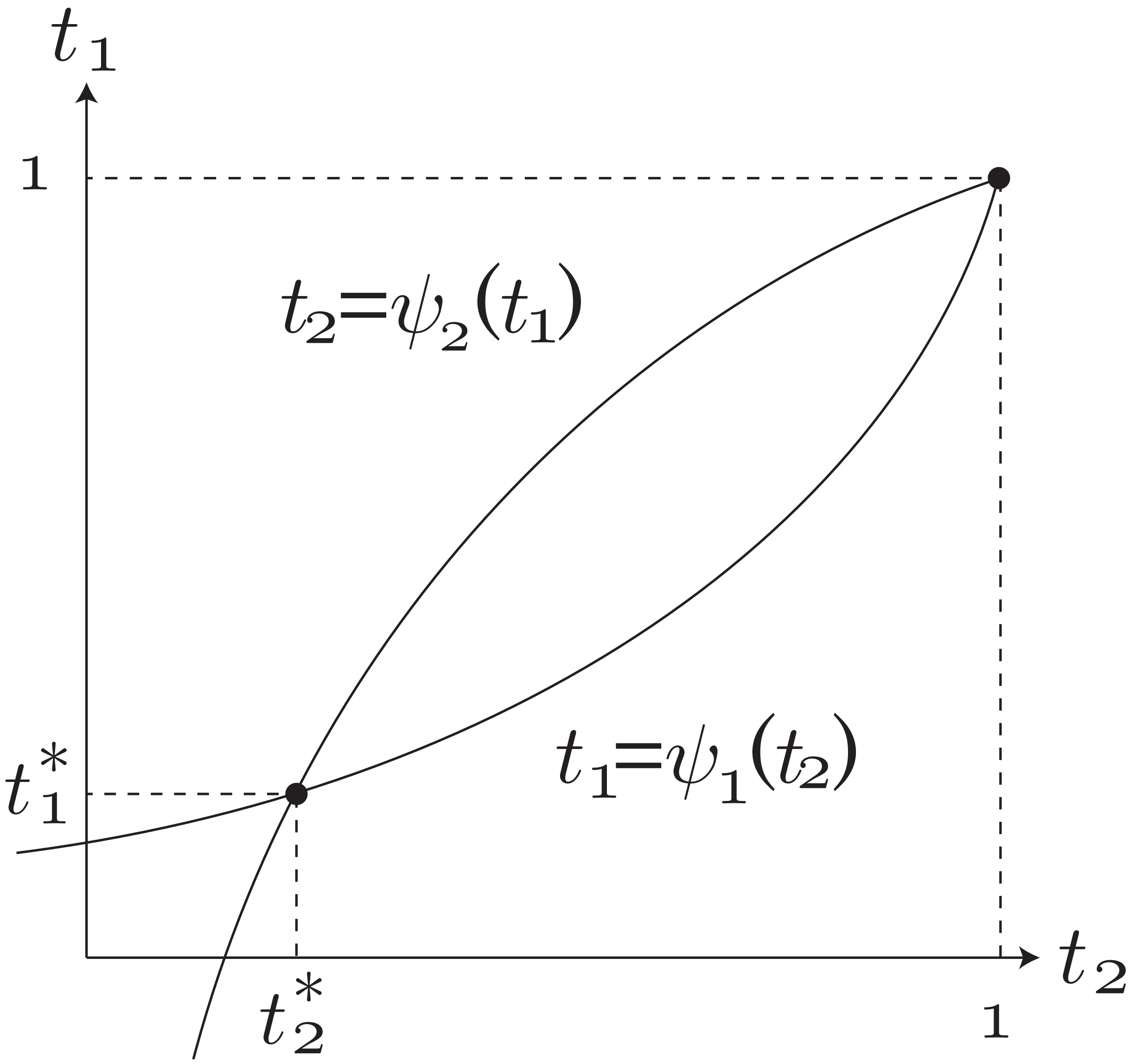

Figure 1: Reaction functions in both countries