Labor Market Frictions, Capital, and Tax Competition *

(preliminary version)

by

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Abstract

This paper studies the role of capital in labor markets in a tax competition model with labor market frictions. Firms invest in capital to create vacancies and hire workers. Due to frictions, workers may not be employed, and firms may not fill vacancies. Attraction of capital to a jurisdiction enables more firms to create vacancies in the jurisdiction, but induces a firm to invest more to hire a worker. Attraction of capital thus may increase or decrease the employment rate, depending on the shapes of the production function and the matching function. Under reasonable conditions an increase in capital increases the employment rate and the wage. Unemployment insurance benefits are funded by the payroll tax imposed on employed labor, and firms' decisions to invest in capital and the returns to capital depend on the payroll taxes and on the capital taxes as well. Jurisdictions tend to tax capital either at a higher or lower rate than the efficient level, but to not tax labor when workers are risk neutral.

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1 Introduction

A large body of research has studied tax competition, and the literature is still growing.[1] Tax competition is an important topic not only in academic research, but also in policy circle (OECD, 1998, 2000), as jurisdictions tend to cut capital taxes in an inefficient manner in order to attract capital. The tax competition literature has naturally focused on capital, and labor markets rarely play any role in the analysis of tax competition. In particular, labor markets are typically assumed to be perfect, and wages are determined according to the marginal product of labor. However, this treatment of labor markets in the tax competition literature is unfortunate and unrealistic for two reasons.

First, unlike the classical labor market, labor markets in a real economy are characterized by unemployed workers and unfilled jobs (for example, Shimer, 2005; Diamond, 2011). This observation has spurred a good deal of research on search frictions in labor markets (McCall, 1970; Diamond, 1982; Mortensen, 1982; Mortensen and Pissarides, 1994; Moen, 1997; Pissarides, 2000; Rogerson et al., 2005). The basic idea of the literature is that workers search for jobs but are not necessarily employed due to frictions such as imperfect information about vacancies and the costs of applying for jobs. Likewise, firms post vacancies and attempt to hire workers, but vacancies are not necessarily filled again due to frictions such as the cost of hiring. The standard framework to study labor market frictions has been a matching technology that concerns the probability of workers finding jobs and that of firms filling vacancies. Building on matching functions, the literature has studied the determination of equilibrium employment and wages.

Second, the media and policymakers often mention tax incentives as a way of bringing jobs to their jurisdictions. In fact, states and cities have competed for capital and businesses to create more and better jobs by providing incentives such as tax cuts. Using data on business taxes and business incentives for 47 US cities in 33 states for 45 industries during a period of 26 years, 1990-2015, Bartik (2017) estimates that a present value of business incentives in 2015 amounts to about 30% of average state and local business taxes for new or expanding businesses in industries that sell their products outside the local area. This leads to a projection of \$45 billion in 2015 for the entire nation. Other estimates of business incentives range from \$65 billion per year (Thomas, 2011) to \$90 billion per year (Story, 2012). At a national

[1] The number of papers that survey the literature has also grown, and for recent surveys, see, for example, Wilson and Wildasin (2004), Devereux and Maffini (2007), Baskaran and Lopes da Fonseca (2013), and Karmakar and Martinez-Vazquez (2014).

level, for example, the US government has recently proposed corporate tax cuts in an attempt to encourage business investment and bring jobs to the U.S. (Bender et al., 2017). Despite these efforts of jurisdictions to use tax incentives to bring jobs, the tax competition literature cannot provide an analysis of the effect of attracting capital on jobs, because the literature assumes that the labor market is perfect and there is no unemployment.

Two reasons above motivate this research. In particular, this paper attempts to reflect recent research on labor market frictions and realism in policy making by considering a tax competition model with labor market frictions, thereby enabling an analysis of the effects of tax competition on labor markets and jobs.

In the model, the economy consists of a large number of jurisdictions. Each jurisdiction has a continuum of residents, and a continuum of firms. Residents/workers and firms of each jurisdiction attempt to form productive matches to produce output. In particular, as in the standard models of labor market frictions (Pissarides, 2000; Rogerson et al., 2005), a firm creates a vacancy and posts a wage by acquiring capital before employing a worker, and residents apply for jobs. Labor markets are not perfect, so a vacancy may not be filled, and a worker may not be employed. Once a match is formed and output is produced, the worker earns the wage and pays the payroll tax, and the firm enjoys the profit. In a labor market equilibrium of a jurisdiction, firms' investment in capital and wages and market tightness (the ratio of the number of vacancies to the number of workers searching for jobs) are determined in a way that the utility of workers and the profit of firms are maximized, so the marginal expected utility (a change in the expected utility resulting from a change in firm-level capital or market tightness) of a worker equals the marginal expected profit of a firm.

The key departure from the standard models of tax competition is that firm-level capital and jurisdiction-level capital have distinct roles. In the standard models of tax competition, the number of firms in a jurisdiction does not matter due to the constant-returns-to scale assumption, and a jurisdiction is typically assumed to have one jurisdictional production function. In the present model, jurisdictional-level capital enables firms to invest in capital in order to create vacancies and post wages. An increase in jurisdictional-level capital then directly increases the number of firms to create vacancies, given firm-level capital, directly increasing market tightness. However, an increase in market tightness alters the marginal job-finding rate of workers and the the marginal vacancy-filling rate of firms, altering the marginal expected utility of a worker and the marginal expected profit of a firm. To restore the equilibrium, the wage and the profit have to change. The wage and the profit come from a firm's output, and firms have to change firm-level capital, but the direction of a change in firm-level capital in response to a change in jurisdictional-level capital is ambiguous. Under empirically plausible conditions such as the diminishing returns of the job-finding rate with respect to market tightness, firms increase firm-level capital in response to an increase in jurisdictional-level capital in order to restore the equilibrium, because the marginal job-finding rate then falls due to an increase in market tightness caused by an increase in jurisdictional-level capital and the wage has to increase by increasing firm-level capital. This increase in firm-level capital decreases the number of firms opening vacancies, given jurisdictional-level capital, indirectly decreasing market tightness. Thus, attraction of capital to a jurisdiction in general may increase or decrease market tightness and hence the employment rate of the jurisdiction. However, for example, when the elasticity of the marginal product of firm-level capital is not too small, as is the case with empirically plausible parameter values, a firm's output and the wage of the firm increase enough to restore the equilibrium with a small increase in firm-level capital. The indirect effect of reducing market tightness due to a small increase in firm-level capital becomes then smaller, and the direct effect of increasing market tightness due to an increase in jurisdictional-level capital outweighs. As a result, an increase in jurisdictional-level capital increases market tightness and the employment rate. When the elasticity of the marginal product of firm-level capital is small, the opposite holds, and an increase in jurisdictional-level capital decreases the employment rate.

The effect of jurisdictional-level capital on employment is in general ambiguous and an empirical issue although jurisdictional-level capital has a positive effect on employment under plausible conditions. To the extent that jurisdictions differ in their elasticity of marginal product and other parameters, the effects of an increase in jurisdictional-level capital on employment would vary across jurisdictions, so more jurisdictional-level capital would increase employment in some jurisdictions but decrease it in others. In fact, available preliminary evidence indicates that business incentives such as tax cuts of a jurisdiction are not strongly correlated with employment of the jurisdiction (Bartik, 2017). Even within a jurisdiction, industries may differ in their production technologies, and the effects of attracting jurisdictional-level capital on employment may differ across industries in the jurisdiction. Likewise, sub-geographical units of a jurisdiction such as counties of a state in the U.S. may differ in production technologies and other parameters such as local matching frictions, and more jurisdictional-level capital may increase employment in some localities but decrease it in others. Regardless of the exact effects of jurisdictional-level capital on employment, this type of result shows that capital affects labor market outcomes unlike in the standard models where no unemployment exists and capital plays no role in labor markets due to the perfect labor market assumption.

To understand tax policies of jurisdictions, it is necessary to discuss the effects of the taxes on the return to capital net of the taxes. The utility of a worker depends on the expected wages, and both the wage and the profit come from a firm's output. Since workers earn the wages and pay the payroll taxes, the wages firms post and pay depend on the payroll taxes, because workers compare their utility from working and accepting the wage with that from not working. Firms' decisions to invest in capital and to create vacancies then depend in part on the payroll tax, so does the return to capital firms invest in. As capital moves freely between jurisdictions in order to maximize the return to capital net of the taxes, the allocation of capital between jurisdictions hinges on the payroll tax, in addition to the capital tax that directly decreases the net return to capital. An increase in the capital tax of a jurisdiction lowers the net return to capital or marginal product of capital, driving capital out of the jurisdiction. An increase in the payroll tax induces firms to invest more in firm-level capital and hence to increase the wage in order to compensate workers for the loss of the utility from a higher payroll tax, decreasing the marginal product of capital or the return to capital due to the diminishing marginal product of return. However, more investment in firm-level capital decreases market tightness and increases the vacancy-filling rate, increasing the expected profit or the return to capital. Due to these opposing effects, an increase in the payroll tax of a jurisdiction may drive capital out of or attract capital to the jurisdiction. The role of the payroll tax in attracting jurisdictional-level capital is thus ambiguous and an empirical issue although an increase in the payroll tax of a jurisdiction drives out capital under plausible conditions such as the elasticity of marginal product of capital being not too small. Irrespective of the exact effects of the payroll tax, the discussion above shows that the payroll tax also plays an important role in determining the allocation of capital between jurisdictions unlike in much of the standard models of tax competition without the payroll tax.

Policymakers of a jurisdiction select its taxes to maximize the well-being of its residents. The standard result in the literature states that the equilibrium capital tax is too low relative to the socially efficient level that takes into account the well-being of all jurisdictions. The reason is that an increase in the capital tax of a jurisdiction drives capital out to other jurisdictions and benefit them but the jurisdiction does not consider the external benefits it confers on other jurisdictions when selecting its capital tax. This standard result still holds in the present setup under some plausible conditions, mentioned above. Intuitively, in the present setup, first, an increase in the capital tax of a jurisdiction lowers the net return to capital, driving capital out to other jurisdictions. Second, more jurisdictional-level capital in other jurisdictions increases employment of those jurisdictions under some conditions, as noted above, and hence benefits them. These two observations lead to the same conclusion that the equilibrium capital tax is too low under some conditions, as the external effect of an increase in the capital tax of a jurisdiction works in the same manner.

As for the payroll tax, it is set at zero and jurisdictions do not tax labor for two reasons. First, an increase in the payroll tax drives capital out, decreasing firm-level capital and market tightness and hence decreasing the expected wage of a worker. Second, unlike the capital tax that finances the public good, the payroll tax finances unemployment insurance benefits, but unemployment insurance has no effect on the expected utility of a worker when the worker is risk neutral, as the expected payroll tax equals the expected benefit due to the unemployment insurance budget constraint. The result that no payroll tax is imposed in equilibrium is the standard result in models with labor market frictions and risk-neutral workers (Moen, 1997; Acemoglu and Shimer, 1999). This paper extends the same result to a tax competition model with mobile jurisdictional-level capital. However, when the worker is risk averse, unemployment insurance serves as insurance in the sense that it shifts income from the favorable state with employment to the unfavorable state with unemployment. As a result, the payroll tax is imposed on employed labor.

In terms of related literature, a large body of research has studied tax competition (Wilson, 1986; Zodrow and Mieszkowski, 1986; Wildasin, 1989; Brueckner 2000; survey papers noted earlier) without labor market frictions. The most important proposition in the literature states that jurisdictions tax mobile capital at a rate lower than the efficient level due to the externality noted above. This paper mainly concerns the effects of mobile capital on employment based on a matching model. To the best of my knowledge, tax competition has rarely been studied in a matching model. However, a few papers have considered tax competition with imperfect labor markets. Ogawa et al. (2006) extend the standard tax competition model to imperfect labor markets, and show that capital is taxed even in the presence of the head tax unlike in the standard model of tax competition (Zodrow and Mieszkowski, 1986). In their model, however, the wage is exogenously fixed. Aronsson and Wehke (2008) and Eichner and Upmann (2012) study tax competition with imperfect labor markets. In their models, unemployment is determined by bargaining between workers and unions. Aronsson and Wehke (2008) demonstrate that tax coordination among jurisdictions is welfare improving, and the overprovision of the public input good, as opposed to the public consumption good, may not occur. Eichner and Upmann (2012) show that the standard result of Zodrow and Mieszkowski (1986) is restored under efficient bargaining. Exbrayat et al. (2012) study the impact of labor market rigidities, characterized by unionization, on tax competition, and find that capital taxes increase in the country with less rigid labor market when both markets shift from a competitive market to a unionized market. The key difference is that these papers concern the effects of imperfect labor markets on capital taxes or public consumption goods or public input goods, as is the tradition of the tax competition literature, rather than on employment and jobs. In addition, labor market imperfections arise from labor unions in these papers rather than from matching frictions.

A few papers have considered matching in tax competition models. Boadway et al. (2002) consider a matching model to study jurisdictional redistributive policies that assist disabled and unemployed individuals. In their model, entrepreneurs/firms move between jurisdictions to maximize profits, but no capital exists and labor is the only input. Boadway et al. (2004) consider a similar model to Boadway et al. (2002), but add agglomeration effects stemming from economies of scale in matching and production. The main focus is on the efficiency of government policies and firms' location decisions. Sato (2009) considers a matching model, and studies the efficiency of capital taxation in the presence of matching externalities. However, these papers have not studied the role of capital in labor market outcomes, the main concern of this paper.

The next section describes a simple model of imperfect labor markets. Section 3 studies the role of capital in labor markets in terms of the employment rate and the wage. Section 4 discusses the allocation of capital between jurisdictions, and considers the effects of the capital tax and the payroll tax on the allocation. Section 5 analyzes the effects of the taxes on the employment rate and the wage. Section 6 addresses the determination of the tax policies by the governments of jurisdictions. Section 7 considers alternative financing of unemployment insurance, and Section 8 extends the analysis to risk-averse workers. Section 9 analyzes heterogeneity in firms. Section 10 consider an economy consisting of a small number of jurisdictions, and the last section concludes.

2. The Model

Th simplest possible model is considered to study capital tax competition between jurisdictions in the presence of labor market frictions. To that end, the model here borrows from tax competition models (Wilson, 1986; Zodrow and Mieszkowski, 1986; Wildasin, 1989) and from search models of labor markets (Acemoglu and Shimer, 1999; Pissarides, 2000; Rogerson et al., 2005).

The economy consists of a large number of jurisdictions, indexed by subscripts $i = 1, 2, ...n$. Each jurisdiction has a continuum of identical residents with the number of residents normalized to one, and a continuum of identical firms with the number of firms less than one. Firms combine capital and labor to produce output that serves as a numeraire. In the standard models, the number of firms does not matter, and a jurisdiction is typically assumed to have one firm or one production function due to a constant-returns-to-scale assumption. The present setup departs from the standard models by distinguishing a firm from a jurisdiction, so that firm-level capital s and jurisdictional-level capital k differ. The relationship between s and k will be discussed later, and this section studies mainly firm-level capital s.

Residents/workers and firms of jurisdiction i attempt to form productive matches to produce output.[2] The approach to matching here closely follows Acemoglu and Shimer (1999) and Rogerson et al. (2005). The key difference is that both firm-level capital s and jurisdictional-level capital k are present and interact in this paper while only firm-level capital is modelled in the literature.[3] Until Section 5, the analysis focuses on a jurisdiction, and jurisdictional subscript i will be dropped. Firm j (of a jurisdiction) acquires capital s_j, and creates a vacancy and posts a wage w_j. Observing all wages, a worker (of the jurisdiction) decides which firm to apply for. Multiple firms may post a same wage w_j, and multiple workers may apply for a firm. Let q_j denote the ratio of the number of workers applying for firms posting w_j to the number of firms posting w_j, called the firms' expected queue length. Most of the literature on labor market frictions has used $\theta_j = 1/q_j$, called the firms' expected tightness, and henceforth θ_j will be used. Labor markets are not perfect, so a vacancy may not be filled, and a worker may not be employed. A worker applying for a firm posting a wage w_j is assumed to be hired with probability $\mu(\theta_j)$, and a firm posting a wage w_j is assumed to fill the vacancy with probability $\eta(\theta_j)$. As a firm's tightness increases or fewer workers apply for the firm, the probability of a worker being employed increases and the probability of a vacancy being filled decreases, so that

$$\mu'(\theta_j) > 0, \quad and \quad \eta'(\theta_j) < 0.$$

When a match between a firm posting w_j and a worker is created, the worker supplies one unit of labor inelastically, and using one unit of labor and capital s_j, the firm produces output $f(s_j)$, an increasing and concave production function. In that event, the worker earns the wage w_j and pays the payroll tax τ that may finance unemployment insurance or the public good, and the firm enjoys $f(s_j) - w_j$. When no match is created, the firm employes no worker and no output is produced, and a worker receives the unemployment insurance

[2] Residents and workers are used interchangeably.

[3] Even firm-level capital is present but not endogenously chosen in the literature, and Acemoglu and Shimer (1999) appears to be the only exception.

benefit b.[4] Regardless of whether a worker is employed or unemployed, she is also endowed with capital $\overline{k}$ and earns capital income $\rho\overline{k}$ with ρ denoting the return to capital net of taxes, and enjoys the public good z.[5] The the return to capital net of taxes and the public good will be discussed below. Since the probability of being employed is $\mu(\theta_j)$, the expected utility of a worker applying for a firm posting a wage w_j reads as

$$U_j = \mu(\theta_j)(w_j - \tau) + (1 - \mu(\theta_j))b + \rho\overline{k} + v(z).$$

The first three terms represent private good consumption, consisting of the expected wage net of the payroll tax, the expected unemployment insurance benefit, and capital income. The last term shows the utility of the public good with $v' > 0$ and $v'' < 0$. The utility function is linear in private good consumption, and risk neutrality is assumed for simplicity. Risk aversion will be considered later. A firm posting a wage w_j enjoys a profit

$$\pi_j = -Rs_j + \eta(\theta_j)[f(s_j) - w_j],$$

where R is the price of capital to be determined below.

Let $\overline{u}$ denote the highest expected utility a worker can enjoy by applying for a firm. Although $\overline{u}$ is endogenously determined in a labor market equilibrium, firms and workers take $\overline{u}$ as given when firms post a wage and workers apply for a firm. A worker will then apply for a firm posting a wage w_j only if $U_j \geq \overline{u}$. In equilibrium, the inequality is binding, because otherwise the firm will attract more job applicants and θ_j and hence $\mu(\theta_j)$ will decrease, decreasing U_j and equating U_j with $\overline{u}$. The inequality characterizes the relationship between w_j and θ_j, and a firm chooses w_j, along with s_j, to maximize its profits.

In equilibrium, all firms post the same wage w that leads to $\overline{u}$, resulting in the same θ and hence s. Acemoglu and Shimer (1999) show that a labor market equilibrium exists under reasonable regularity conditions, as stated below:

Proposition 0 *(Acemoglu and Shimer (1999)). A labor market equilibrium,* $(w^*, \theta^*, s^*, \overline{u}^*, R^*)$, *exists and is a solution to max* π *subject to* $U \geq \overline{u}$ *and* $\pi = 0$.

To study the properties of a labor market equilibrium, observe that it is a solution to[6]

$$max \;\; L \equiv \pi + \lambda[U - \overline{u}], \tag{1}$$

[4] She may also enjoy home production or leisure in addition to the unemployment insurance benefit, but the inclusion of home production turns out to play no role qualitatively in the subsequent analysis, and it will be henceforth ignored for notational simplicity.

[5] Free entry results in zero profits, and ownership of firms does not matter.

[6] In Acemoglu and Shimer (1999), U is maximized subject to $\pi \geq 0$. This alternative formulation is of course equivalent to (1), but it is standard to maximize π subject to $U \geq \overline{u}$.

where λ is a positive multiplier. The FOCs (first-order conditions) for an interior maximum of L are[7]

$$\frac{\partial L}{\partial \theta} = \eta'(f - w) + \lambda \mu'(w - \tau - b) = 0, \tag{2}$$

$$\frac{\partial L}{\partial w} = -\eta + \lambda \mu = 0, \tag{3}$$

$$\frac{\partial L}{\partial s} = -R + \eta f' = 0, \tag{4}$$

$$\frac{\partial L}{\partial \lambda} = U - \overline{u} = 0. \tag{5}$$

Free entry of firms results in zero profit, so that

$$\pi = -Rs + \eta(f - w) = 0. \tag{6}$$

To close the model, letting v and u denote the number of vacancies firms create and the number of workers who search for jobs, respectively, the market tightness equals

$$\theta = \frac{v}{u} = v,$$

as a unit mass of all residents are assumed to search, and $u = 1$. Each firm creates a vacancy, and there are v firms, so the demand for firm-level capital s by v firms of a jurisdiction equals sv. This demand must equal the total amount of capital available to the jurisdiction, namely jurisdictional-level capital k, so

$$sv = s\theta = k \implies \theta = \frac{k}{s}, \tag{7}$$

where use was made of $u = 1$ and hence $\theta = v$. Eq. (7) is the key difference from the standard models of matching, as they do not model firm-level capital s and jurisdictional-level capital k separately. Eq. (7) essentially determines the price of capital R, but in the standard model (Acemoglu and Shimer, 1999), R is exogenously determined by the capital market, outside the model.

Six Eqs., (2) through (7), determine six variables, $(w^*, \theta^*, s^*, \overline{u}^*, R^*, \lambda^*)$. Substitution of (4) into (6) gives

$$w^* = f(s^*) - s^* f'(s^*). \tag{8}$$

Substitution of w^* in (8) and $\lambda = \eta(\theta)/\mu(\theta)$ in (3) into (2) yields

$$\eta(\theta^*)\mu'(\theta^*)(f(s^*) - s^* f'(s^*) - \tau - b) + \mu(\theta^*)\eta'(\theta^*)s^* f'(s^*) = 0. \tag{9}$$

[7]A firm takes the government policy variables, (τ, b, ρ, z), as given when maximizing its profit.

(7) and (9) determine s^* and θ^* as functions of (k, τ, b). Then, R^* and $\overline{u}$ are determined by (4) and (5), respectively, while w^* is determined by (8).[8]

To relate b and τ, the unemployment insurance benefit b is assumed to be financed by the payroll tax $\tau \geq 0$,[9] and (b, τ) satisfies the budget constraint

$$b(1-\mu(\theta^*)) = \tau\mu(\theta^*) \implies b = \frac{\tau\mu(\theta^*)}{1-\mu(\theta^*)} \geq 0. \tag{10}$$

(9) becomes then

$$\eta(\theta^*)\mu'(\theta^*)[(1-\mu(\theta^*))(f(s^*) - s^*f'(s^*)) - \tau] + (1-\mu(\theta^*))\mu(\theta^*)\eta'(\theta^*)s^*f'(s^*) = 0. \tag{11}$$

For expositional simplicity, asterisks will be omitted and the arguments of functions such as s and θ will be dropped when discussing the properties of the equilibrium unless it is necessary to include them.

3. Capital and Labor Markets

Eq. (11) is the key to understanding the role of capital in labor markets. To simplify (11), it proves to be useful to relate $\mu(\theta)$ and $\eta(\theta)$, and let a matching function $M(u, v)$ represent the number of matches that are formed between workers and firms, so that

$$\mu(\theta) = \frac{M(u,v)}{u}, \ \ \textit{and} \ \ \eta(\theta) = \frac{M(u,v)}{v}.$$

u has been assumed to be one, but $\mu(\theta)$ and $\eta(\theta)$ above hold for any u. As $\theta = v/u$, the two functions above lead to

$$\mu(\theta) = \theta\eta(\theta). \tag{12}$$

Differentiation of (12) results in

$$\mu'(\theta) = \eta(\theta) + \theta\eta'(\theta) \implies \mu'(\theta) = \eta(\theta)[1 - \epsilon_\eta(\theta)], \tag{13}$$

where

$$\epsilon_\eta(\theta) \equiv \frac{-\theta\eta'(\theta)}{\eta(\theta)}$$

denotes the elasticity of the vacancy-filling rate, $\eta(\theta)$, with respect to market tightness θ. Substituting (12) and (13) into (11) and dropping θ as an argument of μ or η,

$$(1-\mu)[(1-\epsilon_\eta)f - sf'] - (1-\epsilon_\eta)\tau = 0. \tag{14}$$

[8] $\lambda^* = \eta(\theta^*)/\mu(\theta^*)$ by (3).

[9] Alternative financing will be discussed below.

Since $\mu' > 0$ and hence $1 - \epsilon_\eta > 0$ in (13), and since $b \geq 0$ and hence $\tau \geq 0$, (14) implies

$$(1 - \epsilon_\eta) f - s f' \geq 0. \tag{15}$$

The results below hinge on (14), and it is useful to discuss the intuition of the condition (14). It can be rewritten as

$$\begin{aligned} & (1-\epsilon_\eta)[f - sf' - \frac{\tau}{(1-\mu)}] = \epsilon_\eta s f' \\ \Longrightarrow \quad & \frac{1}{\theta}\mu'[f - sf' - \frac{\tau}{(1-\mu)}] = -\eta' s f'. \end{aligned} \tag{14$'$}$$

The last expression comes from the definition of ϵ_η and $\theta = \mu/\eta$. The condition reflects the maximization of a worker's utility and the maximization of a firm's profit, and dictates that s and θ should satisfy the condition. On the RHS, $sf' = f - w$ due to $w = f - sf'$ in (8), and sf' is considered (operating) profit after capital s is sunk. Since an increase in θ decreases the probability of a vacancy being filled and hence that of a firm enjoying a profit, the RHS is the loss of expected profit resulting from an increase in θ. The expression inside the pair of square brackets of the LHS is $w - \tau - b$, given $b = \mu\tau/(1-\mu)$. Since an increase in θ increases the probability of a worker being employed and hence that of a worker enjoying a wage net of the payroll tax beyond the unemployment insurance benefit, $\mu'(w - \tau - b)$ is the gain of expected utility resulting from an increase in θ. The term $1/\theta$ is the weight placed on the utility of a worker when both the utility of a worker and the profit of a firm are maximized. In fact, $1/\theta = \eta/\mu = \lambda$ in (3). The condition, or equivalently Eq. (14), then states that in equilibrium, s and θ are chosen in a way that the marginal expected utility (a change in the expected utility resulting from a change in θ) of a worker equals the marginal expected profit of a firm.

(14), along with (7), determines s as a function of (τ, k). τ and k are treated as parameters, but will be endogenously determined below. Differentiation of (14) can show that

$$\frac{\partial s(\tau,k)}{\partial \tau} = \frac{1}{A}(1-\epsilon_\eta), \tag{16}$$

$$\frac{\partial s(\tau,k)}{\partial k} = \frac{1}{As}\{\mu'[(1-\epsilon_\eta)f - sf'] + \epsilon'_\eta[(1-\mu)f - \tau]\}, \tag{17}$$

where

$$A \equiv (1-\mu)[(1-\epsilon_\eta)f' - f' - sf''] + \mu'\frac{k}{s^2}[(1-\epsilon_\eta)f - sf'] + \epsilon'_\eta \frac{k}{s^2}[(1-\mu)f - \tau]. \tag{18}$$

The sign of A is in general ambiguous, but A can be signed using a stability condition. That is, for the comparative statics results in (16) and (17) to be stable, it must be that $A > 0$, as discussed below. However, the subsequent analysis considers a condition for $A > 0$. To that end, observe that substituting $\tau = (1-\mu)[(1-\epsilon_\eta)f - sf']/(1-\epsilon_\eta)$ from (14) into $(1-\mu)f - \tau$, the last term of (18) can be rewritten as

$$(1-\mu)f - \tau = \frac{1}{(1-\epsilon_\eta)}(1-\mu)sf' > 0. \tag{19}$$

In addition, the middle term of (18) is positive due to (15), so

$$\begin{aligned} A &> (1-\mu)[(1-\epsilon_\eta)f' - f' - sf''] + \epsilon'_\eta \frac{k}{s^2}\frac{1}{(1-\epsilon_\eta)}(1-\mu)sf' \\ &= (1-\mu)[-\epsilon_\eta f' + \epsilon_{f'} f'] + \epsilon'_\eta \frac{k}{s^2}\frac{1}{(1-\epsilon_\eta)}(1-\mu)sf' \\ &= (1-\mu)(\epsilon_{f'} - \epsilon_\eta)f' + \epsilon'_\eta \frac{k}{s^2}\frac{1}{(1-\epsilon_\eta)}(1-\mu)sf' \end{aligned} \tag{20}$$

with $\epsilon_{f'}$ denoting the elasticity of marginal product of capital, f', with respect to firm-level capital s

$$\epsilon_{f'} \equiv \frac{-sf''}{f'}.$$

Thus, $A > 0$ if

$$\epsilon_{f'} > \epsilon_\eta \;\; \textit{and} \;\; \epsilon'_\eta \geq 0. \tag{21}$$

Otherwise, A cannot be signed due to the inequality in (20). Since $(1-\epsilon_\eta) > 0$ and $(1-\epsilon_\eta)f - sf' \geq 0$ by (15), the signs of (16) and (17) are positive with (21), and the following result can be stated:

Lemma 1. *Assume $\epsilon_{f'} > \epsilon_\eta$ and $\epsilon'_\eta \geq 0$. $\partial s(\tau, k)/\partial\tau > 0$ and $\partial s(\tau, k)/\partial k > 0$ (an increase in the payroll tax or an increase in jurisdictional-level capital of a jurisdiction increases firm-level capital of the jurisdiction).*

To see the lemma intuitively, multiplying θ by (14′) and using the definition of ϵ_η, (14′) is rewritten as

$$\mu'[f - sf' - \frac{\tau}{(1-\mu)}] = \epsilon_\eta sf'. \tag{14''}$$

An increase in τ decreases the marginal expected utility on the LHS of (14″). To restore the equilibrium condition (14″), the LHS must increase and the RHS must decrease, or the LHS must increase more than the RHS increases, which requires an increase in s under the conditions in the lemma. The reasons for the increase in s are twofold. First, with holding θ (and hence μ' and ϵ_η) fixed, an increase in s changes the the marginal expected wage in the LHS by $-\mu' sf''$ and changes the marginal expected profit in the RHS by $\epsilon_\eta(f' + sf'')$. Second, an increase in s decreases θ by k/s^2, and changing the LHS by $[\mu''(f - sf' - \tau/(1-\mu)) - \mu'\tau/(1-$

$\mu)^2](k/s^2)$ and the RHS by $\epsilon'_\eta sf'(k/s^2)$. Using $\mu'' = (\mu')' = [\eta(1-\epsilon_\eta)]' = \eta'(1-\epsilon_\eta) - \eta\epsilon'_\eta$, it is straightforward to check that the sum of the two changes in the LHS, caused by an increase in s, exceeds that in the RHS under the conditions, or equivalently $A > 0$ in (18), so the equilibrium condition is restored. This condition is basically for the stability of the comparative statics results, $\partial s/\partial\tau > 0$, because the condition guarantees that a small change in τ starting from an equilibrium leads to another equilibrium. The conditions in the lemma can be seen more intuitively. An increase in s increases the LHS by $\mu'(-sf'') = \mu f'\epsilon_{f'}$ by the definition of $\epsilon_{f'}$, so the increase in s increases the LHS more and hence is more likely to restore the equilibrium when $\epsilon_{f'}$ is large such as $\epsilon_{f'} > \epsilon_\eta$. An increase in s decreases θ and hence decreases (increases) the RHS by $\epsilon'_\eta sf'$ when $\epsilon'_\eta \geq (\leq)\ 0$. Since the equilibrium is more likely to be restored when the increase in s decreases the RHS, the increase in s is more likely to restore the equilibrium when $\epsilon'_\eta \geq 0$. The other result, $\partial s/\partial k > 0$, can be understood in a similar manner.

To have a sense of plausibility of the conditions in the lemma, consider the production function $f(s) = s^\alpha$ with $\alpha \in (0,1)$. In this case, $\epsilon_{f'} = 1-\alpha$. Since α can be interpreted as the capital share of output, it is about $1/3 = 0.33$, so $\epsilon_{f'} = 1 - 0.33 = 0.67$. Empirical estimates of ϵ_η are known to be about 0.3 (Petrongolo and Pissarides, 2001). Thus, the condition, $\epsilon_{f'} > \epsilon_\eta$, appears reasonable. If $f(s) = ln\ (s), \epsilon_{f'} = 1$, so it is more likely that $\epsilon_{f'} > \epsilon_\eta$. As for the second condition $\epsilon'_\eta \geq 0$, $\epsilon'_\eta = 0$ when $\eta(\theta) = m\theta^{\delta-1}$ with $\delta \in (0,1)$ and $m > 0$ denoting the matching efficiency parameter, because $\epsilon_\eta = (1-\delta) =$ constant. As another example, if $\eta(\theta) = (1-e^{-\theta})/\theta$, as in Acemoglu and Shimer (1999), it can be shown that $\epsilon_\eta = 1 - [\theta e^{-\theta}/(1-e^{-\theta})]$ and the sign of ϵ'_η is the same as that of $(\theta - 1 + e^{-\theta})$, which is positive.[10] A third example is $\eta(\theta) = e^{-\theta}$. In this case, $\epsilon_\eta = \theta$, so $\epsilon'_\eta = 1 > 0$. For the remainder of the paper, the condition (21) will be assumed and not be mentioned for simplicity.

To see the role of jurisdictional-level capital in the labor market, it proves to be useful to discuss the effect of jurisdictional-level capital on market tightness. Using (17),

$$\frac{\partial\theta}{\partial k} = \frac{1}{s^2}[s - k\frac{\partial s}{\partial k}]$$

$$= \frac{1}{sA}(1-\mu)(\epsilon_{f'} - \epsilon_\eta)f' > 0 \tag{22}$$

with (21). This relationship between k and θ will be used in the subsequent analysis, and summarized as:

[10] It approaches zero as θ approaches zero, it approaches $e^{-1} > 0$ as θ approaches one, and it is increasing in θ. Thus, it is positive for all $\theta \in (0,1)$.

Lemma 2. $\partial\theta/\partial k > 0$ *(an increase in jurisdictional-level capital of a jurisdiction increases market tightness of the jurisdiction).*

An increase in capital has two opposing effects on market tightness. Given firm-level capital s, more jurisdictional-level capital k enables more firms to post vacancies, directly increasing market tightness. More jurisdictional-level capital k also induces firms to increase their firm-level capital s, as in Lemma 1, indirectly decreasing market tightness. Thus, the direct effect and the indirect effect work in opposite directions. However, the positive direct effect outweighs the negative indirect effect under the conditions in (21), and an increase in jurisdictional-level capital increases market tightness. Note that even if the first inequality in (21) is reversed and $\epsilon_{f'} \leq \epsilon_\eta$, it is not necessarily true that $\partial\theta/\partial k \leq 0$, because $\partial s/\partial k$ also depends on A in (18) and A may become negative when $\epsilon_{f'} \leq \epsilon_\eta$.

To see intuitively the implicit condition of Lemma 2, namely $\epsilon_{f'} > \epsilon_\eta$ in (21), observe that an increase in jurisdictional-level capital k induces firms to invest more in firm-level capital s, as in Lemma 1. If the elasticity of the marginal product of firm-level capital is large or $\epsilon_{f'} > \epsilon_\eta$, firm's output increases and the wage increases enough to compensate workers for the loss of the marginal expected utility arising from higher market tightness and hence to restore the equilibrium even with a small increase in firm-level capital s. The indirect effect of reducing market tightness due to a small increase in firm-level capital s becomes then smaller. In this case, the direct effect of increasing market tightness due to an increase in jurisdictional-level capital k dominates. As a result, an increase in jurisdictional-level capital increases market tightness. When the elasticity of the marginal product of firm-level capital is small, the opposite holds, and an increase in jurisdictional-level capital decreases market tightness if the stability condition holds and $A > 0$.

Using Lemma 2, the effects of jurisdictional-level capital k on labor market outcomes can be stated as follows:

Proposition 1. $\partial\mu/\partial k > 0$ *and* $\partial w/\partial k > 0$ *(an increase in jurisdictional-level capital of a jurisdiction increases the employment rate and the wage of the jurisdiction).*

To see the effect of capital on employment, note that $\partial\mu(\theta)/\partial k = \mu'(\theta)\ (\partial\theta/\partial k) > 0$ due to $\mu'(\theta) > 0$ and $\partial\theta/\partial k > 0$ by Lemma 2. Intuitively, since an increase in jurisdiction-level capital k increases market tightness θ, and since the employment rate $\mu(\theta)$ increases in θ, more capital increases the employment rate. As for the increase in the wage, an increase in k increases firm-level capital s by Lemma 1, increasing $w = f - sf'$, the wage in (8). Intuitively, more jurisdictional-level capital k induces firms to invest more in s, increasing output of a firm. Since the wage is part of the output, the wage increases.

While the proposition is simple, it highlights a key difference from the standard tax competition models in terms of the effect of capital on labor markets. The standard models assume that labor markets are perfect and no unemployment exists. In particular, they assume that a jurisdiction has one firm and its production function $f(k, \ell)$ exhibits constant returns to scale with ℓ denoting labor, and $\ell = \overline{\ell}$ with $\overline{\ell}$ denoting the total labor supply. Factor market are competitive, and each factor is paid its marginal product and the wage equals $\partial f/\partial \ell = [f - k(\partial f/\partial k)]/\overline{\ell}$ due to the constant-returns-to-scale assumption. Thus, attraction of capital increases the wage, as $d[(f - k(\partial f/\partial k))/\overline{\ell})]/dk = -k(\partial^2 f/\partial k^2)/\overline{\ell} > 0$. However, it has no effect on employment, as $\ell = \overline{\ell}$. This is an irony, as the media and policymakers often mention that capital brings jobs and jobs are the reason for fierce competition for mobile capital. The model with labor market frictions here, by contrast, enables the analysis of the role of capital in employment. The result in the proposition shows that capital indeed brings jobs in the sense that it increases the employment rate $\mu(\theta)$ by influencing the number of vacancies and the magnitude of firm-level investment in capital. As for the effect of capital on the wage, $\partial w/\partial s > 0$, the standard models thus generate the same result as the model here. However, the wage increases in the standard models due to the complementarity between labor and capital. That is, more capital increases the marginal product of labor due to the complementarity between capital and labor . By contrast, in the present model, an increase in capital results in an increase in firm-level capital due to the properties of labor market equilibrium resulting from the maximization of a worker's utility and the maximization of a firm's profits, and the increase in firm-level capital increases output and hence the wages.

Recalling that all results above have assumed (21), those results may not necessarily hold in general. For instance, attraction of capital to a jurisdiction in general may not necessarily increase the employment rate or the wage of the jurisdiction without the condition in (21). The key reason for this ambiguity is that attraction of capital does not necessarily increase firm-level capital s and hence not necessarily market tightness. Given that the condition in (21) depends on the shape of the production function $f(s)$ and the vacancy-filling rate $\eta(\theta)$, the effects of capital on labor market outcomes may vary across jurisdictions to the extent that the production function and the vacancy-filling rate differ among jurisdictions. Alternatively, if a jurisdiction consists of different industries and each industry is characterized by a different technology and a matching function, the effects of capital on labor market outcomes would differ across industries, as will be further discussed below in a model with firm heterogeneity.

While Proposition 1 is about the role of jurisdictional-level of capital in labor market outcomes, payroll taxes also affect labor market outcomes, as in the following proposition:

Proposition 2. *$\partial\mu/\partial\tau < 0$ and $\partial w/\partial\tau > 0$ (an increase in the payroll tax of a jurisdiction decreases the employment rate and increases the wage of the jurisdiction).*

To see the first part, observe that

$$\frac{\partial\mu(\theta)}{\partial\tau} = \mu'(\theta)\frac{\partial\theta}{\partial\tau} = \mu'(\theta)[-\frac{k}{s^2}\frac{\partial s}{\partial\tau}] < 0,$$

given $\partial s/\partial\tau > 0$ by Lemma 1. As for the second part, an increase in τ increases s, increasing output of a firm and hence the wage.

While not stated in Proposition 2, the effect of an increase in the payroll tax on the expected wage is ambiguous due to the opposing effects on the employment rate and on the wage. That is, given that $w = f - sf'$,

$$\begin{aligned}
\frac{\partial}{\partial\tau}[\mu(\theta)w] &= \mu'(\theta)\frac{\partial\theta}{\partial\tau}(f - sf') + \mu(\theta)(-sf'')\frac{\partial s}{\partial\tau} \\
&= \mu'(\theta)(-\frac{k}{s^2})\frac{\partial s}{\partial\tau}(f - sf') + \mu(\theta)(-sf'')\frac{\partial s}{\partial\tau} \\
&= [\mu'(\theta)(-\theta\frac{1}{s})(f - sf') + \mu(\theta)(-sf'')]\frac{\partial s}{\partial\tau} \\
&= \mu(\theta)\frac{1}{s}[\epsilon_{f'}sf' - (1-\epsilon_\eta)(f - sf')]\frac{\partial s}{\partial\tau} \\
&< \mu(\theta)\frac{1}{s}(\epsilon_{f'} - \epsilon_\eta)sf' > 0.
\end{aligned}$$

The third equality comes from $k/s = \theta$. The fourth equality uses $\mu' = \eta(1-\epsilon_\eta)$ in (13), along with $\theta\eta = \mu$. The first inequality comes from $(1-\epsilon_\eta)f \geq sf'$ in (15), and the next one follows from the condition, $\epsilon_{f'} > \epsilon_\eta$ in (21).

Proposition 2 also differs from the standard model of tax competition in that the payroll tax is typically not considered in the standard models in order to focus on capital and capital taxes. The payroll tax in the model with frictions here affects the firm's decision to invest in capital s and hence market tightness and the employment rate even if jurisdiction-level capital k remains the same. This finding is sensible, as payroll taxes are expected to alter the labor market equilibrium.

4. Taxes and Capital Allocation

The economy has a fixed supply of capital $n\bar{k}$ with n denoting a large number of jurisdictions. The case with a small number of jurisdictions will be considered later. While $\bar{k}$ is fixed, k_i is jurisdictional-level capital employed in jurisdiction $i = 1, 2, ..., n$, and endogenously determined below. Capital moves freely between jurisdictions to maximize its return net of capital tax t_i, so that the net return ρ should be equalized between jurisdictions and

$$\rho = R_i - t_i = \eta_i(\theta_i)f_i'(s_i) - t_i, i = 1, 2, ..., n \tag{23}$$

where $R = \eta f'$ from (4).

Since s is a function of (τ, k) in (16) and (17) and $\theta = k/s$, k_i^* that satisfies the mobility condition (23) depends both on the capital tax t_i and the payroll tax τ_i of jurisdiction i. As a jurisdiction takes ρ as given when choosing its taxes (t_i, τ_i),[11] total differentiation of (23), along with (21), gives

$$\frac{\partial k_i^*}{\partial t_i} = \frac{1}{D} < 0,$$

$$\begin{aligned}\frac{\partial k_i^*}{\partial \tau_i} &= -\frac{1}{D}[\eta_i'(-\frac{k_i^*}{s_i^2})f_i' + \eta_i f_i'']\frac{\partial s_i}{\partial \tau_i} \\ &= -\frac{1}{D}\frac{\eta_i f_i'}{s_i}(\epsilon_{i\eta} - \epsilon_{if'})\frac{\partial s_i}{\partial \tau_i} < 0, \\ D &\equiv \eta_i'\frac{\partial \theta_i}{\partial k_i}f_i' + \eta_i f_i''\frac{\partial s_i}{\partial k_i} < 0. \end{aligned} \tag{24}$$

The expression of $\partial k_i^*/\partial \tau_i$ uses the definitions of ϵ_η and $\epsilon_{f'}$. The sign of $D < 0$ comes from $\eta' < 0$, $\partial s/\partial k > 0$ by Lemma 1, and $\partial \theta/\partial k > 0$ by Lemma 2. With the maintained assumption, $\epsilon_{f'} > \epsilon_\eta$ in (21), the following results can be stated:

Proposition 3. *$\partial k_i^*/\partial t_i < 0$ and $\partial k_i^*/\partial \tau_i < 0$ (an increase in the capital tax or the payroll tax of a jurisdiction decreases jurisdictional-level capital of the jurisdiction).*

The first result, $\partial k_i^*/\partial t_i < 0$, follows because an increase in the capital tax of jurisdiction i lowers the return to capital net of the tax located in jurisdiction i, driving out capital from the jurisdiction and decreasing k_i^*. The sign of the second result, $\partial k_i^*/\partial \tau_i$, is in general ambiguous and depends on the relationship between $\epsilon_{if'}$ and $\epsilon_{i\eta}$. Intuitively, an increase in τ_i increases firm-level capital s_i by Lemma 1, decreasing the return to capital due to the diminishing returns $f'' < 0$. At the same time, the increase in firm-level capital lowers market tightness θ_i, increasing the probability that the vacancies are filled and increasing the expected return to capital in jurisdiction i. As a result, if the first effect outweighs and $\epsilon_{if'} > \epsilon_{i\eta}$, an increase in the labor tax of jurisdiction i decreases the return to capital and moves capital from jurisdiction i, decreasing k_i^*. If $\epsilon_{if'} < \epsilon_{i\eta}$, an increase in the labor tax of jurisdiction i increases k_i^*.

The capital tax plays a crucial role in determining the allocation of mobile capital between jurisdictions, as in the literature. However, unlike in the literature on tax competition, the analysis has shown that the payroll tax also plays an important role. The reason is that the payroll tax affects firms' decisions to invest in firm-level capital s to create vacancies and

[11] With a small number of jurisdictions, each jurisdiction influences ρ by choosing its taxes, as will be discussed below.

the return to capital depends on firm-level capital via the production function $f(s)$. While the role of the payroll tax is new to the tax competition literature, a literature on multinational firms has shown that the payroll tax is indeed a determinant of their location decisions.

5. Taxes and Labor Markets

As jurisdictional-level capital k affects labor market outcomes in Section 3, and as capital moves in response to the difference in the taxes between jurisdictions in Section 4, labor market outcomes depend on tax policies. To relate tax policies to labor market outcomes, write jurisdictional-level capital and firm-level capital as functions of the taxes, $k_i(t_i, \tau_i)$ and $s_i(\tau_i, k_i(t_i, \tau_i))$, respectively, where recall that s is a function of τ and k from Lemma 1. The effects of the taxes on the employment rate and the wage of jurisdiction i are

$$\frac{d\mu_i(\theta_i)}{dt_i} = \mu_i'(\theta_i)\frac{\partial\theta_i}{\partial k_i}\,\frac{\partial k_i}{\partial t_i} < 0,$$

$$\frac{dw_i}{dt_i} = \frac{d}{dt_i}[f_i(s_i) - s_i f_i'(s_i)] = -s_i f_i''(s_i)\frac{\partial s_i}{\partial k_i}\,\frac{\partial k_i}{\partial t_i} < 0,$$

$$\frac{d\mu(\theta_i)}{d\tau_i} = \mu_i'(\theta_i)[\frac{\partial\theta_i}{\partial k_i}\,\frac{\partial k_i}{\partial \tau_i} - \frac{k_i}{s_i^2}\frac{\partial s_i}{\partial \tau_i}] < 0,$$

$$\frac{dw_i}{d\tau_i} = \frac{d}{d\tau_i}[f_i(s_i) - s_i f_i'(s_i)] = -s_i f_i''(s_i)[\frac{\partial s_i}{\partial k_i}\,\frac{\partial k_i}{\partial \tau_i} + \frac{\partial s_i}{\partial \tau_i}]. \tag{25}$$

The first inequality follows because $\partial\theta_i/\partial k_i > 0$ by Lemma 2 and $\partial k_i/\partial t_i < 0$ by Proposition 3. The second one comes from $\partial s_i/\partial k_i > 0$ by Lemma 1 and $\partial k_i/\partial t_i < 0$ by Proposition 3. The third one uses $\partial s_i/\partial k_i > 0$, $\partial k_i/\partial \tau_i < 0$ by Proposition 3, and $\partial s_i/\partial \tau_i > 0$ by Lemma 1. The last one cannot be unambiguously signed, as the first term inside the pair of square brackets is negative but the second term is positive. These results can be stated:

Proposition 4. *(i) $d\mu(\theta_i)/dt_i < 0$ and $d\mu(\theta_i)/d\tau_i < 0$, and (ii) $dw_i/dt_i < 0$ and $dw_i/d\tau_i > 0$ or < 0 (an increase in the capital tax or the payroll tax of a jurisdiction decreases the employment rate of the jurisdiction, and an increase in the capital tax of a jurisdiction decreases the wage of the jurisdiction but an increase in the payroll tax may decrease or increase the wage of the jurisdiction).*

The result has a simple intuition. An increase in the capital tax of a jurisdiction drives capital out of the jurisdiction, reducing market tightness θ or the number of vacancies and hence decreasing the employment rate of the jurisdiction. An increase in the payroll tax of a jurisdiction drives capital out of the jurisdiction and leads to the same result. The increase in the payroll tax has an additional effect, as it increases firm-level capital s and decreases market tightness, represented by the term $-(k_i/s_i^2)\,(\partial s_i/\partial\tau_i) < 0$ in the expression of $d\mu(\theta_i)/d\tau_i$. The additional effect thus reinforces the initial effect of driving capital out of the jurisdiction, and the increase in the payroll tax decreases the employment rate more than the increase in the capital tax does.

As for the effects on the wage, an increase in the capital tax of a jurisdiction decreases capital of the jurisdiction, inducing firms of the jurisdiction to decrease firm-level capital s. Such a decrease in firm-level capital in turn decreases output $f(s)$ of a firm. Since the wage is a part of the output, the wage decreases. An increase in the payroll tax of a jurisdiction drives capital out of the jurisdiction and leads to the same result. The increase in the payroll tax has an additional effect, as it increases firm-level capital s. The additional effect is represented by the term $\partial s_i/\partial \tau_i > 0$ in the expression of $dw_i/d\tau_i$. The output of a firm then increases, increasing the wage. The additional effect and the initial effect thus move in opposite directions, making ambiguous the effect of the payroll tax on the wage, as in the last comparative statics results of (25).

The standard models of tax competition have demonstrated that jurisdictions attempt to attract capital by lowering the capital tax. However, the standard models focus on the effects of attracting capital on the public goods, but not on jobs or employment. The reason is that the models assume that labor markets are perfect and there is no unemployment. The present setup with imperfect labor markets, by contrast, can relate the tax policies of jurisdictions to employment. In particular, Proposition 4 shows that a decrease in the capital tax increases the employment rate, justifying attempts to undercut capital taxes and to attract capital to the extent that the policymakers of jurisdictions care about jobs. As noted earlier, the standard models show that an increase in capital increases the wage, namely the marginal product of labor, so a decrease in the capital tax attracts capital and increases the wage. The standard models thus generate the same result as the model here as far as the effect of the capital tax on the wage is concerned. However, the wage increases in the standard models due to the complementarity between labor and capital. That is, an increase in capital by a decrease in the capital tax increases the marginal product of labor. By contrast, in the present model, an increase in capital results in an increase in firm-level capital, increasing output and hence the wages.

In the standard models of tax competition, payroll taxes do not play any role in labor market outcomes. However, in the present model, the payroll tax also affects labor market outcomes, as in the proposition. In particular, a decrease in the payroll tax increases the employment rate, but does not necessarily increase the wage.

6. Determination of Taxes

This section considers the determination of tax policies. The government of jurisdiction

i sets the capital tax t_i and the payroll tax τ_i to maximize the utility of its resident $\overline{u}$ in Section 2. The utility can be rewritten as

$$U_i = \mu_i(\theta_i)[f_i(s_i) - s_i f_i'(s_i)] + \rho\overline{k} + v(z_i), \tag{26}$$

because the wage equals $f - sf'$ in (8), and the payroll tax τ and unemployment insurance benefit b cancel out due to the budget constraint (10). The payroll tax finances the unemployment insurance benefits, and the capital tax finances the public good z, so by assuming that one unit of the private good can be transformed into one unit of the public good,

$$z_i = t_i k_i. \tag{27}$$

For the subsequent analysis, it is assumed that $t_i > 0$, because otherwise no public good is provided.[12]

The government of jurisdiction i chooses t_i and τ_i. The FOCs for an interior maximum of U_i are

$$\begin{aligned} \frac{\partial U_i}{\partial t_i} &= v_i'[k_i + t_i \frac{\partial k_i}{\partial t_i}] \\ &+\mu_i(-s_i f_i'') \frac{\partial s_i}{\partial k_i} \frac{\partial k_i}{\partial t_i} \\ &+\mu_i'(f_i - s_i f_i') \frac{\partial \theta_i}{\partial k_i} \frac{\partial k_i}{\partial t_i} = 0, \end{aligned} \tag{28}$$

$$\begin{aligned} \frac{\partial U_i}{\partial \tau_i} &= v_i' t_i \frac{\partial k_i}{\partial \tau_i} \\ &+\mu_i(-s_i f_i'') (\frac{\partial s_i}{\partial k_i} \frac{\partial k_i}{\partial \tau_i} + \frac{\partial s_i}{\partial \tau_i}) \\ &+\mu_i'(f_i - s_i f_i') (\frac{\partial \theta_i}{\partial k_i} \frac{\partial k_i}{\partial \tau_i} + (-\frac{k_i}{s_i^2})\frac{\partial s_i}{\partial \tau_i}) = 0. \end{aligned} \tag{29}$$

The FOC (28) consists of three terms. The first one in the first line is the change in the public good. An increase in the capital tax increases the public good at a given level of capital k_i, but it also drives capital out and decreases the public good. The second line represents the effect of an increase in the capital tax on the wage arising from a reduction in jurisdictional-level capital k_i and hence firm-level capital s_i. The last term shows the effect of an increase in the capital tax on the job-finding rate arising from a reduction in jurisdictional-level capital k_i and hence market tightness θ_i. The interpretation of the FOC (29) is analogous to that of (28), except that an increase in the payroll tax does not directly reduce the public good level

[12] This turns out to be the case, for example, if $v(z)$ is assumed to satisfy the Inada condition, $lim_{z\to 0} v'(z) = \infty$.

while it directly affects firm-level capital s.

There are two differences from the standard models of tax competition in terms of the effects of the taxes on the utility of the resident. First, the effect of the taxes on the wage depends on the job-finding rate $\mu_i(\theta_i)$. The resident earns the wage only when employed, and the employment rate or the job-finding rate depends on capital and hence taxes. This difference reflects the assumption that labor markets are imperfect, so workers may not be employed. Second, the payroll tax affects the wage, as it alters the allocation of jurisdictional-level capital k between jurisdictions and alters the behavior of firms in an attempt to re-maximize profits in response to a change in the payroll tax.

To study the properties of the taxes, observe that if the public good is efficiently provided, $v' = 1$, as one unit of the private good can be transformed into one unit of the public good. However, using the FOC (28), it can be shown that $v' > 1$. Given $v_i'' < 0$, the inequality implies that the public good is inefficiently underprovided in the tax competition equilibrium. In addition, it can be shown that all terms of FOC (29) are negative, so $\tau_i^* = 0$. These results can be stated as:

Proposition 5. *At a tax competition equilibrium, $v_i' > 1$ and $\tau_i^* = 0$ (the public good is inefficiently underprovided, and labor is not taxed).*

The proof is in the appendix. The result has a simple intuition. If a jurisdiction increases its capital tax, it drives out capital to other jurisdictions and hence benefits them, because more capital increases the employment rate and the wages in addition to the tax revenues in other jurisdictions. However, the jurisdiction does not consider the external benefit it confers on other jurisdictions when setting its capital tax. As a result, the equilibrium capital tax is too low. This result is standard in the literature, and labor market frictions do not alter the standard conclusion. However, the results differ in two respects. The external benefits include an increase in the employment rate of other jurisdictions due to imperfect labor markets, but the standard models do not include such external benefits. In addition, the same conclusion that the public good is underprovided hinges on the conditions in (21). In particular, without the conditions, an increase in the capital tax of a jurisdiction may not drive out capital to other jurisdictions, given that the sign of $\partial k_i^*/\partial t_i = 1/D$ depends on the signs of $\partial \theta_i/\partial k_i$ and $\partial s_i/\partial k_i$ and hence on the conditions in (21).

Turning to the second result, the payroll tax has no direct effect on the utility of the resident due to the budget constraint (10), namely the expected payroll tax equal to the expected unemployment insurance benefit. An increase in the payroll tax drives capital out, decreasing the public good and the employment rate and the wage. It encourages firms to invest more in s, as in Lemma 1, increasing the wage but decreasing the employment rate due to lower market tightness caused by higher firm-level investment s. Thus, an increase in the payroll tax decreases the employment rate both through a loss of jurisdictional-level capital k and through an increase in firm-level capital s and hence a decrease in market tightness θ. It decreases the wage through a loss of jurisdictional capital k but increases the wage through an increase in firm-level capital s. However, the negative effects on the employment rate outweigh the last positive effect on the wage, and an increase in the payroll tax decreases the utility of the resident. Thus, the government of a jurisdiction that cares about the well-being of its residents sets the payroll tax at zero.

This result that the payroll tax is zero in equilibrium is standard in the literature (Moen, 1997; Acemoglu and Shimer, 1999). Proposition 5 shows that the standard conclusion holds even with the public good and jurisdictional-level capital k. In addition, the same conclusion again hinges on the conditions in (21). Regardless of the differences from the standard models of labor market frictions, a key reason for no payroll tax is risk neutrality. As will be discussed below, the payroll tax serves as insurance when the resident is risk averse, and the equilibrium payroll tax does not have to be set at zero.

The payroll tax was chosen to maximize the utility of the resident. Suppose alternatively that the payroll tax is chosen to maximize output. A firm produces ηf. Since there are v or θ firms in a jurisdiction, output of the jurisdiction equals $y = v\eta f = \theta\eta f = \mu f$. Consider first the case without the mobility of jurisdictional-level capital k between jurisdictions. The effect of an increase in the payroll tax τ on output is

$$\begin{aligned}\frac{\partial}{\partial\tau}y &= [\mu'(-\frac{k}{s^2})f + \mu f']\,\frac{\partial s}{\partial\tau}\\ &= [-\mu'\theta\frac{1}{s}f + \mu f']\,\frac{\partial s}{\partial\tau}\\ &= \frac{\mu}{s}[-(1-\epsilon_\eta)f + sf']\,\frac{\partial s}{\partial\tau} \leq 0.\end{aligned}$$

The last equality uses (13), and the inequality comes from (15). The inequality shows that the payroll tax would be set at zero even if the goal is to maximize output. With mobile capital, an increase in the payroll tax results in the additional effect on output y,

$$[\mu'\frac{\partial\theta}{\partial k}f + \mu f'\frac{\partial s}{\partial k}]\,\frac{\partial k}{\partial\tau} < 0,$$

because $\partial\theta/\partial k > 0, \partial s/\partial k > 0$ and $\partial k/\partial\tau < 0$. As a result, the mobility of jurisdictional-level capital k reinforces the argument that the payroll tax is set at zero when output is to be maximized.

7. Alternative Financing of Unemployment Insurance

7-A. Employer-Paid Payroll Tax

This section considers different ways of financing unemployment insurance. First, assume that employers or firms, not workers, pay the payroll taxes τ to finance unemployment insurance benefits b. This assumption is realistic, as employers pay the taxes under the US unemployment insurance system.

The profit of a firm and the utility of a worker are modified as

$$\pi = -Rs + \eta(\theta)[f(s) - w - \tau],$$

$$U = \mu(\theta)w + (1 - \mu(\theta))b + \rho\bar{k} + v(z).$$

The FOC (2) and the free-entry condition (6) become

$$\frac{\partial L}{\partial \theta} = \eta'(f - w - \tau) + \lambda\mu'(w - b) = 0,$$

$$-Rs + \eta(f - w - \tau) = 0.$$

The wage equals then

$$w = f - sf' - \tau. \tag{30}$$

Substitution of w in (30) and $\lambda = \eta(\theta)/\mu(\theta)$ into $\partial L/\partial\theta = 0$ gives

$$\eta\mu'(f - sf' - \tau - b) + \mu\eta' sf' = 0,$$

the same result as (9).

As for the unemployment insurance budget constraint, a firm hires a worker and pays the payroll tax τ with probability $\eta(\theta)$. Since there are v or θ firms, the total payroll tax revenues equal $\theta\eta(\theta)\tau = \mu(\theta)\tau$. Thus, the budget constraint (10) continues to hold. All the results in Section 3 then continue to hold, except the second part of Proposition 2. That is, the wage w was $f - sf'$ in (8), but it includes the additional term $-\tau$. Since $\partial w/\partial\tau > 0$ in Proposition 2, and since $\partial w/\partial\tau > 0$ now includes the negative term, -1, the sign of $\partial w/\partial\tau$ is now ambiguous. For the same reason, $dw_i/d\tau_i$ is still ambiguous in part (ii) of Proposition 4. In Section 6, the utility function remains the same as (26), because the addition term $-\tau$ in the wage and the unemployment insurance benefit cancel out. That is, the first term of (26) becomes $\mu_i(f_i - s_if_i' - \tau_i) + (1 - \mu_i)b = \mu_i(f_i - s_if_i')$ due to the budget constraint (10).

7-B. No Payroll Tax

Suppose that no payroll tax exists, and the capital tax finances both the public good and unemployment insurance. Indeed, the standard models of tax competition assume no payroll taxes. (9) is then modified as

$$\mu'(f - sf' - b) + \theta\eta' sf' = 0 \implies \mu'(f - b) - \eta sf' = 0, \tag{31}$$

In addition, (10) does not hold, as unemployment insurance is not financed by payroll taxes. Using (13), (31) can be rewritten as

$$(1 - \epsilon_\eta)(f - b) - sf' = 0. \tag{32}$$

Total differentiation of (32) leads to

$$\frac{\partial s(b,k)}{\partial b} = \frac{1}{A}(1 - \epsilon_\eta),$$
$$\frac{\partial s(b,k)}{\partial k} = \frac{1}{As}\epsilon'_\eta(f - b),$$

where[13]

$$A \equiv [(1 - \epsilon_\eta)f' - f' - sf''] + \epsilon'_\eta \frac{k}{s^2}(f - b)$$
$$= (\epsilon_{f'} - \epsilon_\eta)f' + \epsilon'_\eta \theta \frac{1}{s}(f - b).$$

The sign of A is still in general ambiguous even without the payroll tax τ. However, with the conditions in (21), $A > 0$, and hence $\partial s(b,k)/\partial b > 0$ and $\partial s(b,k)/\partial k > 0$, because $(f - b) = sf'/(1 - \epsilon_\eta) > 0$ from (32). Thus, the absence of the payroll tax does not alter the results qualitatively.

Lemma 2 extends, as

$$\frac{\partial \theta}{\partial k} = \frac{1}{s^2}[s - k\frac{\partial s}{\partial k}] = \frac{1}{sA}(\epsilon_{f'} - \epsilon_\eta)f' > 0.$$

Proposition 1 is based on Lemmas 1 and 2, and continues to hold. Since there is no payroll tax, Proposition 2 does not apply. However, it continues to hold with b replacing τ, so $\partial\mu/\partial b < 0$ and $\partial w/\partial b > 0$. The same comment applies to Propositions 3 and 4, so that they hold with b replacing τ.

As for Section 6, the utility in (26) is modified as

$$U_i = \mu_i(\theta_i)[f_i(s_i) - s_i f'_i(s_i)] + (1 - \mu_i(\theta_i))b_i + \rho\overline{k} + v(z_i),$$

with

$$z_i = t_i k_i - (1 - \mu_i(\theta_i))b_i.$$

[13]Since A was already used in Section 3, it is desirable to use a different notation, but the same A is kept to avoid cluttering up the notation.

The FOC for an interior maximum of U_i with respect to t_i is

$$\frac{\partial U_i}{\partial t_i} = v_i'[k_i + t_i\frac{\partial k_i}{\partial t_i} + \mu_i' b\,\frac{\partial \theta_i}{\partial k_i}\,\frac{\partial k_i}{\partial t_i}]$$

$$+\mu_i(-s_i f_i'')\,\frac{\partial s_i}{\partial k_i}\,\frac{\partial k_i}{\partial t_i}$$

$$+\mu_i'(f_i - s_i f_i' - b)\,\frac{\partial \theta_i}{\partial k_i}\,\frac{\partial k_i}{\partial t_i} = 0.$$

Using the steps to establish Proposition 5, it is straightforward to show that Proposition 5 continues to hold, so $v' > 1$ and the public good is inefficiently underprovided. The reason is that an increase in the capital tax of a jurisdiction moves capital out of the jurisdiction, which does not depend on whether unemployment insurance is financed by the payroll tax or the capital tax.

8. Risk Aversion

The analysis returns to the baseline model with the payroll tax τ paid by workers, and the utility function is modified as

$$U = \mu(\theta)u(w - \tau + \rho\overline{k}) + (1 - \mu(\theta))u(b + \rho\overline{k}) + v(z),$$

with $u' > 0$ and $u'' < 0$. The FOCs (2) and (3) become

$$\frac{\partial L}{\partial \theta} = \eta'(f - w) + \lambda\mu'(u_1 - u_2) = 0, \tag{33}$$

$$\frac{\partial L}{\partial w} = -\eta + \lambda\mu u_1' = 0, \tag{34}$$

where subscripts 1 and 2 in the utility functions denote the state with employment and the state with unemployment, respectively, so $u_1 = u(w - \tau + \rho\overline{k})$ and $u_2 = u(b + \rho\overline{k})$, and similarly for u_1' and u_2'.

Since firms continue to be risk neutral, (4) and (6) still hold, so does (8), $w = f - sf'$. Substitution of w and (34) into (33) gives

$$\mu'(u_1 - u_2) + \theta u_1'\eta' sf' = 0 \implies (1 - \epsilon_\eta)(u_1 - u_2) - \epsilon_\eta u_1' sf' = 0. \tag{35}$$

Differentiation of (35), along with $b = \mu\tau/(1 - \mu)$ in (10), can show that

$$\frac{\partial s(\tau, k)}{\partial \tau} = \frac{1}{A}[(1 - \epsilon_\eta)\,(u_1' + u_2'\frac{\mu}{(1 - \mu)}) - \epsilon_\eta u_1'' sf'],$$

$$\frac{\partial s(\tau, k)}{\partial k} = \frac{1}{A}[\mu'\frac{1}{s}(1 - \epsilon_\eta)\frac{1}{(1 - \mu)^2}\tau u_2' + \epsilon_\eta'\frac{1}{s}(u_1 - u_2 + u_1' sf')],$$

where

$$A \equiv (1-\epsilon_\eta)u_1'(-sf'') + (1-\epsilon_\eta)u_2'\frac{1}{(1-\mu)^2}\mu'\tau\frac{1}{s}\theta$$

$$-\epsilon_\eta u_1'(f'+sf'') + \epsilon_\eta u_1'' sf'(sf'') - \epsilon_\eta'(-\frac{k}{s^2})(u_1 - u_2 + u_1' sf')$$

$$= u_1' f'(\epsilon_{f'} - \epsilon_\eta) + \epsilon_\eta u_1'' s^2 f' f'' + u_2'\mu\frac{1}{s}(\frac{1-\epsilon_\eta}{1-\mu})^2\tau + \epsilon_\eta'\theta\frac{1}{s}(u_1 - u_2 + u_1' sf').$$

The sign of A is in general ambiguous, but $A > 0$ if $\epsilon_{f'} \geq \epsilon_\eta$ and $\epsilon_\eta' \geq 0$, as in (21), because $u_1'' < 0$ and $u_2' > 0$ and the remaining terms are all positive. As a result, $\partial s(\tau, k)/\partial\tau > 0$ and $\partial s(\tau, k)/\partial k > 0$. Lemma 1 thus extends to the risk-aversion case.

As for Lemma 2, using the expression of $\partial s(\tau, k)/\partial k$,

$$\frac{\partial\theta}{\partial k} = \frac{1}{s^2}[s - k\frac{\partial s}{\partial k}]$$

$$= \frac{1}{sA}[u_1'(\epsilon_{f'} - \epsilon_\eta)f' + \epsilon_\eta u_1'' s^2 f' f''] > 0$$

when $\epsilon_{f'} \geq \epsilon_\eta$. Thus, Lemma 2 also extends to the risk-aversion case. All the results in Sections 3 through 5 then continue to hold.

Turning to the tax policies in Section 6, the FOC for an interior maximum of U with respect to τ includes the term

$$(1-\mu)u_2'\frac{\partial b}{\partial\tau} - \mu u_1' = \mu u_2' - \mu u_1' > 0,$$

because $b = \mu\tau/(1-\mu)$ by (10) and $w - \tau > b$ and hence $u_1' < u_2'$. These positive terms reflect the fact that unemployment insurance serves as insurance for risk-averse workers by shifting income from the favorable state with employment to the unfavorable state with unemployment. Since unemployment insurance is actuarially fair, risk-averse workers desire to purchase insurance. This desire to have unemployment insurance counteracts the forces that lead to no payroll tax in Section 6, and the equilibrium payroll tax is in general positive.

9. Firm Heterogeneity

Firms of a jurisdiction are assumed to differ in their production function and their matching technology, so that the production function and the vacancy-filling rate of a type-ϕ firm are written as $f_\phi(s) \equiv f(s : \phi)$ and $\eta_\phi(\theta) \equiv \eta(\theta : \phi)$, respectively, $\phi = 1, 2, ...M$. Types may be interpreted as industries in a jurisdiction that have different technologies and hiring practices. For instance, manufacturing and service industries would differ in their production technologies and in their difficulty or complexity of filling their vacancies. Types may be alternatively interpreted as sub-geographical units of a jurisdiction. For example, states in the U.S. compete for jurisdictional capital that move among states, and types may be firms located in different counties in a state. The difference from the previous section lies in the allocation of workers and firms across types and in the allocation of jurisdictional-level capital k among types.

Type-ϕ firms post a wage w_ϕ, and the firms' tightness is θ_ϕ. In a manner analogous to (2) through (9), the same conditions hold for each type-ϕ firm, except that the total number of workers who search for jobs equals one as before, but the number of workers who apply for type-ϕ firms equals u_ϕ. Thus, $\theta_\phi = v_\phi/u_\phi$, and (7) becomes

$$v_\phi s_\phi = u_\phi \theta_\phi s_\phi = k_\phi \;\; for \;\; all \;\; \phi.$$

Unlike in the previous sections, u_ϕ must be endogenously determined. While firms differ in their production function and matching technologies, the price of capital they pay must be the same and the profit-maximizing choice of s results in

$$-R + \eta_\phi(\theta_\phi) f'_\phi(s_\phi) = 0 \implies \eta_\phi(\frac{k_\phi}{u_\phi s_\phi}) f'_\phi(s_\phi) = R \;\; for \;\; all \;\; \phi.$$

The number of all workers searching for jobs is unity, and

$$\sum_{\phi=1}^{M} u_\phi = 1.$$

The above conditions, along with (9) for all ϕ, determine $(s_\phi, \theta_\phi, u_\phi, R)$ in terms of k_ϕ.

To determine k_ϕ, letting U_ϕ denote the utility of a worker applying for a type-ϕ firm, and it must be that

$$U_\phi \equiv \mu_\phi(f_\phi - s_\phi f'_\phi - \tau) + \mu_\phi b + \rho \overline{k} + v(z) = \overline{u} \;\; for \;\; all \;\; \phi. \tag{36}$$

In addition, the demand for capital by all firms in a jurisdiction should equal the amount of capital available to the jurisdiction, k, and

$$\sum_{\phi=1}^{M} k_\phi = k.$$

The above conditions can be solved for k_ϕ and $\overline{u}$ in terms of k. If the unemployment insurance benefit is funded by the payroll tax imposed on employed labor, (τ, b) satisfies the budget constraint

$$\tau \sum_{\phi=1}^{M} [u_\phi \mu_\phi(\theta_\phi)] = b \sum_{\phi=1}^{M} [u_\phi(1 - \mu_\phi(\theta_\phi))].$$

The constraint, along with the two conditions above, should be then used to determine k_ϕ and $\overline{u}$ as a function of k.

The effect of attracting jurisdictional-capital k to a jurisdiction on the employment rate of type-ϕ firms reads as

$$\frac{d}{dk}[u_\phi \mu_\phi(\theta_\phi)] = [\frac{\partial u_\phi}{\partial k_\phi}\ \mu_\phi(\theta_\phi) + u_\phi\ \mu'_\phi(\theta_\phi)\ \frac{\partial \theta_\phi}{\partial k_\phi}]\ \frac{\partial k_\phi}{\partial k}.$$

The sign of $\partial\theta_\phi/\partial k_\phi$ depends on the relationship between $\epsilon_{\phi f'}$ and $\epsilon_{\phi\eta}$, as in the previous sections, and may be positive for some ϕs and negative for other ϕs. The sign of $\partial k_\phi/\partial k$ depends on the common-utility condition (36), and an increase in jurisdictional-level capital k may increase capital k_ϕ in some types of firms and may decrease it in others.

The main question concerns the effect of an increase in jurisdictional-level capital k on the jurisdiction-wide employment rate,

$$\sum_{\phi=1}^{M} \frac{d}{dk}[u_\phi \mu_\phi(\theta_\phi)],$$

which may be positive or negative, given the ambiguous sign of $d[u_\phi \mu_\phi(\theta_\phi)]/dk$. Thus, attraction of capital may not bring more jobs in the sense of increasing the employment rate of the jurisdiction. A key reason for this ambiguous effect of jurisdictional-level capital k on employment is that the allocation of capital among different types of firms in a jurisdiction is endogenously determined and an increase in jurisdictional-level capital k does not necessarily increase firm-level capital for all types of firms. The exact effect of jurisdictional-level capital k on employment depends on the shapes of the production function and the vacancy-filling rate, and an example considered below.

10. Large Jurisdictions, Taxes and Capital Allocation

The economy consists of a small number of large jurisdictions, indexed by subscripts $i = 1, 2, ..N$. The difference from the small-jurisdiction case is that jurisdiction i influences the net return to capital ρ through its taxes (t_i, τ_i) rather than takes ρ as given. As before, capital moves freely between jurisdictions, and the net return ρ should be equalized and

$$\rho = R_i - t_i = \eta_i(\theta_i) f'_i(s_i) - t_i, i = 1, 2, ..., N.$$

Total differentiation of the net-return condition above gives

$$\frac{\partial k_i^*}{\partial t_i} = \frac{1}{E} < 0,$$

$$\frac{\partial k_i^*}{\partial \tau_i} = -\frac{1}{E}[\eta'_i(-\frac{k_i^*}{s_i^2}) f'_i + \eta_i f''_i]\frac{\partial s_i}{\partial \tau_i}$$

$$= -\frac{1}{E}\frac{\eta_i f'_i}{s_i}(\epsilon_{i\eta} - \epsilon_{if'})\frac{\partial s_i}{\partial \tau_i} < 0,$$

$$E \equiv \sum_{i=1}^{N}[\eta_i' \frac{\partial \theta_i}{\partial k_i} f_i' + \eta_i f_i'' \frac{\partial s_i}{\partial k_i}] < 0. \tag{37}$$

The comparative statics results in (37) are qualitatively the same as those in (24), and the results in Sections 4 and 5 continue to hold.

The difference lies in the determination of tax policies in Section 6. To see the property of equilibrium tax policies, it proves useful to consider the effects of the taxes on the net return ρ. Using (37),

$$\begin{aligned} \frac{d\rho}{dt_i} &= [\eta_i' \frac{\partial \theta_i}{\partial k_i} f_i' + \eta_i f_i'' \frac{\partial s_i}{\partial k_i}]\ \frac{\partial k_i}{\partial t_i} - 1 \\ &= -\frac{1}{E}\ \sum_{j\neq i}[\eta_j' \frac{\partial \theta_j}{\partial k_j} f_j' + \eta_j f_j'' \frac{\partial s_j}{\partial k_j}] < 0. \end{aligned} \tag{38}$$

The equality uses the expression of $\partial k_i/\partial t_i$ and that of E in (37). The inequality follows because all terms inside the pair of square brackets are negative and E is also negative. As for the effect of the payroll tax,

$$\begin{aligned} \frac{d\rho}{d\tau_i} &= [\eta_i' \frac{\partial \theta_i}{\partial k_i} f_i' + \eta_i f_i'' \frac{\partial s_i}{\partial k_i}]\ \frac{\partial k_i}{\partial \tau_i} + [\eta_i'(-\frac{k_i}{s_i^2}) f_i' + \eta_i f_i'']\ \frac{\partial s_i}{\partial \tau_i} \\ &= [\eta_i' \frac{\partial \theta_i}{\partial k_i} f_i' + \eta_i f_i'' \frac{\partial s_i}{\partial k_i}]\ [-\frac{1}{E}\frac{\eta_i f_i'}{s_i}(\epsilon_{i\eta} - \epsilon_{if'})\frac{\partial s_i}{\partial \tau_i}] + \frac{\eta_i f_i'}{s_i}(\epsilon_{i\eta} - \epsilon_{if'})\frac{\partial s_i}{\partial \tau_i} \\ &= \frac{1}{E}\ \frac{\eta_i f_i'}{s_i}(\epsilon_{i\eta} - \epsilon_{if'})\frac{\partial s_i}{\partial \tau_i}\ \sum_{j\neq i}[\eta_j' \frac{\partial \theta_j}{\partial k_j} f_j' + \eta_j f_j'' \frac{\partial s_j}{\partial k_j}] < 0. \end{aligned} \tag{39}$$

The second equality uses the expression of $\partial k_i/\partial \tau_i$ in (37), along with the definitions of $\epsilon_{i\eta}$ and $\epsilon_{if'}$. The next one uses the expression of E in (37). The inequality follows because all terms inside the pair of square brackets are negative and E is also negative, along with the condition $\epsilon_{i\eta} < \epsilon_{if'}$ in (21). Thus, an increase in ether the capital tax or the payroll tax reduce the net return to capital.

The government of jurisdiction i again chooses (t_i, τ_i) taking (t_j, τ_j) as given in order to maximize the utility (26). The FOCs for an interior maximum of U_i are

$$\begin{aligned} \frac{\partial U_i}{\partial t_i} &= v_i'[k_i + t_i \frac{\partial k_i}{\partial t_i}] + \mu_i(-s_i f_i'')\ \frac{\partial s_i}{\partial k_i}\ \frac{\partial k_i}{\partial t_i} \\ &+\mu_i'(f_i - s_i f_i')\ \frac{\partial \theta_i}{\partial k_i}\ \frac{\partial k_i}{\partial t_i} + \frac{d\rho}{dt_i}\ \overline{k} = 0, \end{aligned} \tag{40}$$

$$\begin{aligned} \frac{\partial U_i}{\partial \tau_i} &= v_i' t_i \frac{\partial k_i}{\partial \tau_i} + \mu_i(-s_i f_i'')\ (\frac{\partial s_i}{\partial k_i}\ \frac{\partial k_i}{\partial \tau_i} + \frac{\partial s_i}{\partial \tau_i}) \\ &+\mu_i'(f_i - s_i f_i')\ (\frac{\partial \theta_i}{\partial k_i}\ \frac{\partial k_i}{\partial \tau_i} + (-\frac{k_i}{s_i^2})\frac{\partial s_i}{\partial \tau_i}) + \frac{d\rho}{d\tau_i}\ \overline{k} = 0. \end{aligned} \tag{41}$$

These conditions differ from (28) and (29) in two respects, the last terms, $(d\rho/dt_i)\overline{k}$ and $(d\rho/dt_i)\overline{k}$, and the expressions of $\partial k_i/\partial t_i$ and $\partial k_i/\partial \tau_i$. Due to the differences, the first result of Proposition 5, $v' > 1$ and underprovision of the public good, in Section 6 does not extend to the case with a small number of jurisdictions in this section. The reason is that as a jurisdiction can influence the net return to capital, it creates an additional effect on the choice of tax policies, namely the terms-of-trade effect. That is, an increase in the capital tax of jurisdiction i lowers the net return to capital, benefiting jurisdiction i if $k_i \geq \overline{k}$ and hurting jurisdiction i if $k_i \leq \overline{k}$. Intuitively, when a jurisdiction employes capital more than its resident's endowment ($k_i \geq \overline{k}$), it imports capital and benefits from a lower net return to capital, so it has an incentive to increase the capital tax more than in the small-jurisdiction case. If a jurisdiction exports capital ($k_i \leq \overline{k}$), it benefits from a higher net return to capital, so it has an incentive to decrease the capital tax more than in the small-jurisdiction case. Thus, whether the additional terms-of-trade effect increases or decreases the capital tax depends on the relationship between $\overline{k}$ and k_i, and the public good may be still underprovided or overprovided. With symmetric jurisdictions, $\overline{k} = k_i, i = 1, 2, ...N$, the terms-of-trade effect vanishes, and the same result that $v' > 1$ and the public good is underprovided still holds, as shown in the Appendix. This is the standard conclusion in the literature. For the same reason, the second part of Proposition 5, $\tau = 0$, does not necessarily extend to this section with a small number of jurisdictions, but it does with symmetric jurisdictions, as shown in the Appendix.

11. Conclusion

The paper has considered tax competition for mobile capital when labor markets are not perfect. The analysis has shown that capital plays an important role in determining labor market outcomes, the employment rate and the wage. In particular, attraction of capital to a jurisdiction enables more firms to create vacancies and induces firms to alter their decisions to invest in firm-level capital and to create vacancies.

The tax competition literature has mainly studied the effects of competition for mobile capital among jurisdictions on the capital tax. In particular, the most important proposition is that jurisdictions tax capital too little and the public good is underprovided relative to the efficient level. This is a logical outcome of the standard model that focuses on mobile capital. However, in an attempt to focus on mobile capital, the literature has assumed that labor markets are perfect and no unemployment exists. As a result, the literature cannot provide any insights into the effects of tax competition on labor markets and jobs. However, considerable evidence shows that labor markets are not perfect and involuntary unemployment exists. In addition, policymakers of a jurisdiction are known to attempt to create more and better jobs by attracting capital and businesses to the jurisdiction. These two observations motivated this paper, so in this paper labor markets are characterized by search frictions, allowing for the possibility that workers may not be employed and firms may not fill vacancies. Such frictions enable the analysis of the role of capital in labor markets. While this paper is part of a small literature that takes into account imperfect labor markets, it warrants more research, given that a large literature in labor economics has devoted to labor market frictions.

Appendix

proof of Proposition 5

For simplicity, jurisdictional subscript i is omitted. It follows from (28) that

$$v' = -\frac{[\mu(-sf'')\,\frac{\partial s}{\partial k} + \mu'(f-sf')\,\frac{\partial \theta}{\partial k}]\,\frac{\partial k}{\partial t}}{k + t\frac{\partial k}{\partial t}}.$$

Since $v' > 0$, $\mu(-sf'')\,\frac{\partial s}{\partial k} > 0, \mu'(f-sf')\,\frac{\partial \theta}{\partial k} > 0$ and $\partial k/\partial t < 0$, it must that $k + t\frac{\partial k}{\partial t} > 0$. The sign of $v' - 1$ then coincides with that of

$$\begin{aligned}
v' - 1 &\cong -[\mu(-sf'')\,\frac{\partial s}{\partial k} + \mu'(f-sf')\,\frac{\partial \theta}{\partial k}]\,\frac{\partial k}{\partial t} - [k + t\frac{\partial k}{\partial t}] \\
&= -[\mu(-sf'')\,\frac{\partial s}{\partial k} + \mu'(f-sf')\,\frac{\partial \theta}{\partial k} + kD + t]\,\frac{\partial k}{\partial t} \\
&= -[\mu(-sf'')\,\frac{\partial s}{\partial k} + \mu'(f-sf')\,\frac{\partial \theta}{\partial k} + k(\eta'\frac{\partial \theta}{\partial k}f' + \eta f''\frac{\partial s}{\partial k}) + t]\,\frac{\partial k}{\partial t} \\
&= -[\mu'(f-sf')\,\frac{\partial \theta}{\partial k} + k\eta'\frac{\partial \theta}{\partial k}f' + t]\,\frac{\partial k}{\partial t} \\
&= -[\eta(1-\epsilon_\eta)(f-sf')\,\frac{\partial \theta}{\partial k} - s\eta\epsilon_\eta\frac{\partial \theta}{\partial k}f' + t]\,\frac{\partial k}{\partial t} \\
&= -[\eta((1-\epsilon_\eta)f - sf')\,\frac{\partial \theta}{\partial k} + t]\,\frac{\partial k}{\partial t} > 0.
\end{aligned}$$

The second equality uses $\partial k/\partial t = 1/D$ in (24), and the third equality uses the expression of D in (24). The fourth one comes from $k\eta = \theta s\eta = \mu s$. The fifth one uses (13) and the definition of ϵ_η. The last one follow from rearranging terms. The inequality holds because (15) and $t > 0$ due to the Inada condition, $\lim_{z\to 0} v'(z) = \infty$. The inequality establishes the first part of the proposition.

As for the second part, since $t > 0$ and $\partial k/\partial \tau < 0$, it follows from (29) that

$$\begin{aligned}
\frac{\partial U}{\partial \tau} &< \mu(-sf'')\,(\frac{\partial s}{\partial k}\,\frac{\partial k}{\partial \tau} + \frac{\partial s}{\partial \tau}) \\
&+\mu'(f-sf')\,(\frac{\partial \theta}{\partial k}\,\frac{\partial k}{\partial \tau} + (-\frac{k}{s^2})\frac{\partial s}{\partial \tau}) \\
&= [\mu(-sf'') - \mu'(f-sf')\,\frac{k}{s^2}]\,\frac{\partial s}{\partial \tau} \\
&+[\mu(-sf'')\,\frac{\partial s}{\partial k} + \mu'(f-sf')\,\frac{\partial \theta}{\partial k}]\,\frac{\partial k}{\partial \tau} \\
&= \frac{1}{s}\mu[sf'\epsilon_{f'} - (1-\epsilon_\eta)(f-sf')]\,\frac{\partial s}{\partial \tau} \\
&+[\mu f'\epsilon_{f'}\frac{\partial s}{\partial k} + \mu'(f-sf')\,\frac{\partial \theta}{\partial k}]\,\frac{\partial k}{\partial \tau} \\
&= \{\frac{1}{s}\mu[sf'\epsilon_{f'} - (1-\epsilon_\eta)(f-sf')] - \frac{1}{D}\frac{\eta f'}{s}(\epsilon_\eta - \epsilon_{f'})[\mu f'\epsilon_{f'}\frac{\partial s}{\partial k} + \mu'(f-sf')\,\frac{\partial \theta}{\partial k}]\}\,\frac{\partial s}{\partial \tau}
\end{aligned}$$

$$
\begin{aligned}
&= -\frac{1}{D}\{\frac{1}{s}\mu[sf'\epsilon_{f'} - (1-\epsilon_\eta)(f-sf')](-\eta'\frac{\partial\theta}{\partial k}f' - \eta f''\frac{\partial s}{\partial k}) \\
&\quad +\frac{\eta f'}{s}(\epsilon_\eta - \epsilon_{f'})[\mu f'\epsilon_{f'}\frac{\partial s}{\partial k} + \mu'(f-sf')\ \frac{\partial\theta}{\partial k}]\}\ \frac{\partial s}{\partial\tau} \\
&\cong \frac{1}{s}f'\{\mu[sf'\epsilon_{f'} - (1-\epsilon_\eta)(f-sf')](-\eta') + \eta(\epsilon_\eta - \epsilon_{f'})\mu'(f-sf')\}\ \frac{\partial\theta}{\partial k} \\
&\quad +\frac{1}{s}\eta\mu\{[sf'\epsilon_{f'} - (1-\epsilon_\eta)(f-sf')](-f'') + f'(\epsilon_\eta - \epsilon_{f'})f'\epsilon_{f'}\}\ \frac{\partial s}{\partial k} \\
&= \frac{1}{s}f'\{[sf'\epsilon_{f'} - (1-\epsilon_\eta)(f-sf')](\eta^2\epsilon_\eta) + \eta^2(\epsilon_\eta - \epsilon_{f'})(1-\epsilon_\eta)(f-sf')\}\ \frac{\partial\theta}{\partial k} \\
&\quad +\frac{1}{s}\eta\mu\{[sf'\epsilon_{f'} - (1-\epsilon_\eta)(f-sf')](\frac{f'\epsilon_{f'}}{s}) + f'(\epsilon_\eta - \epsilon_{f'})f'\epsilon_{f'}\}\ \frac{\partial s}{\partial k} \\
&= \frac{1}{s}f'\{sf'\epsilon_{f'}\eta^2\epsilon_\eta - \eta^2\epsilon_{f'}(1-\epsilon_\eta)(f-sf')\}\ \frac{\partial\theta}{\partial k} \\
&\quad +\frac{1}{s}\eta\mu\{[-(1-\epsilon_\eta)(f-sf')](\frac{f'\epsilon_{f'}}{s}) + f'\epsilon_\eta f'\epsilon_{f'}\}\ \frac{\partial s}{\partial k} \\
&= \frac{1}{s}f'\{-\eta^2\epsilon_{f'}(1-\epsilon_\eta)f + \eta^2\epsilon_{f'}sf')\}\ \frac{\partial\theta}{\partial k} \\
&\quad +\frac{1}{s}\eta\mu\{[-(1-\epsilon_\eta)f(\frac{f'\epsilon_{f'}}{s}) + (f')^2\epsilon_{f'}\}\ \frac{\partial s}{\partial k} \\
&= -\frac{1}{s}f'\eta^2\epsilon_{f'}[(1-\epsilon_\eta)f - sf']\ \frac{\partial\theta}{\partial k} \\
&\quad -\frac{1}{s}\eta\mu\frac{f'\epsilon_{f'}}{s}[(1-\epsilon_\eta)f - sf']\ \frac{\partial s}{\partial k} \le 0.
\end{aligned}
$$

The first equality comes from rearranging terms. The second one uses (13) and the definition of $\epsilon_{f'}$. The third one uses the expression of $\partial k/\partial\tau$ in (24), and the fourth one comes from the expression of D in (24). The fifth one with $\cong$ (the same sign as above) follows because $-(1/D)(\partial s/\partial\tau) > 0$. The six one comes from the definitions of ϵ_η and $\epsilon_{f'}$. The remaining equalities result from simple rearrangement of terms. The inequality holds, as $(1-\epsilon_\eta)f - sf' \ge 0$ in (15), along with $\partial\theta/\partial k > 0$ and $\partial s/\partial k > 0$. The inequality establishes the second part of the proposition.

proof of $v' > 1$ and $\tau^* = 0$ in Section 10 with a small number of jurisdictions
Using (40),

$$
v' = -\frac{[\mu(-sf'')\ \frac{\partial s}{\partial k} + \mu'(f-sf')\ \frac{\partial\theta}{\partial k}]\ \frac{\partial k}{\partial t} + \frac{d\rho}{dt}\overline{k}}{k + t\frac{\partial k}{\partial t}}.
$$

Since $(d\rho/dt)\overline{k} < 0$, it must be that $k + t\frac{\partial k}{\partial t} > 0$ as before. The sign of $v' - 1$ then coincides with that of

$$
\begin{aligned}
v' - 1 &\cong -[\mu(-sf'')\ \frac{\partial s}{\partial k} + \mu'(f-sf')\ \frac{\partial\theta}{\partial k}]\ \frac{\partial k}{\partial t} - [k + t\frac{\partial k}{\partial t}] \\
&\quad -[(\eta'\frac{\partial\theta}{\partial k}f' + \eta f''\frac{\partial s}{\partial k})\ \frac{\partial k}{\partial t} - 1]\overline{k} \\
&= -[\mu(-sf'')\ \frac{\partial s}{\partial k} + \mu'(f-sf')\ \frac{\partial\theta}{\partial k} + (\eta'\frac{\partial\theta}{\partial k}f' + \eta f''\frac{\partial s}{\partial k})k + t]\ \frac{\partial k}{\partial t}
\end{aligned}
$$

$$= -[\mu'(f - sf')\frac{\partial \theta}{\partial k} + \eta' f' k \frac{\partial \theta}{\partial k} + t]\ \frac{\partial k}{\partial t}$$
$$= -[\eta(1-\epsilon_\eta)(f - sf')\frac{\partial \theta}{\partial k} - \eta\epsilon_\eta s f' \frac{\partial \theta}{\partial k} + t]\ \frac{\partial k}{\partial t}$$
$$= -[\eta((1-\epsilon_\eta)f - sf')\frac{\partial \theta}{\partial k} + t]\ \frac{\partial k}{\partial t} > 0.$$

The first equality uses the expression of $d\rho/dt$ in (38). The second equality comes from the symmetric-jurisdiction assumption, $\overline{k} = k_i = k$. The third equality uses $k\eta f'' = \theta s \eta f'' = \mu s f''$, so two terms involving $\partial s/\partial k$ cancel out. The fourth equality follows from (13) and the definition of ϵ_η. The last one is obtained by simplifying terms. The inequality holds due to (15) and $t > 0$.

As for $\tau^* = 0$, since $t > 0$ and $\partial k/\partial \tau < 0$, it follows from (41) that

$$\frac{\partial U}{\partial \tau} < \mu(-sf'')\ (\frac{\partial s}{\partial k}\ \frac{\partial k}{\partial \tau} + \frac{\partial s}{\partial \tau})$$
$$+\mu'(f - sf')\ (\frac{\partial \theta}{\partial k}\ \frac{\partial k}{\partial \tau} + (-\frac{k}{s^2})\frac{\partial s}{\partial \tau}) + \frac{d\rho}{d\tau}\overline{k}$$
$$= \frac{1}{s}\mu[sf'\epsilon_{f'} - (1-\epsilon_\eta)(f - sf')]\ \frac{\partial s}{\partial \tau}$$
$$+[\mu f' \epsilon_{f'} \frac{\partial s}{\partial k} + \mu'(f - sf')\ \frac{\partial \theta}{\partial k}]\ \frac{\partial k}{\partial \tau} + \frac{d\rho}{d\tau}\overline{k}$$
$$= \{\frac{1}{s}\mu[sf'\epsilon_{f'} - (1-\epsilon_\eta)(f - sf')] - \frac{1}{E}\frac{\eta f'}{s}(\epsilon_\eta - \epsilon_{f'})[\mu f'\epsilon_{f'}\frac{\partial s}{\partial k} + \mu'(f - sf')\ \frac{\partial \theta}{\partial k}]\}\ \frac{\partial s}{\partial \tau}$$
$$+\frac{1}{E}\frac{\eta f'}{s}(\epsilon_\eta - \epsilon_{f'})(N-1)(\eta'\frac{\partial \theta}{\partial k}f' + \eta f''\frac{\partial s}{\partial k})\ \frac{\partial s}{\partial \tau}\overline{k}$$
$$\cong \frac{1}{s}f'\{\mu[sf'\epsilon_{f'} - (1-\epsilon_\eta)(f - sf')]\ [-N(\eta'\frac{\partial \theta}{\partial k}f' + \eta f''\frac{\partial s}{\partial k})]$$
$$+\frac{\eta f'}{s}(\epsilon_\eta - \epsilon_{f'})[\mu f'\epsilon_{f'}\frac{\partial s}{\partial k} + \mu'(f - sf')]\ \frac{\partial \theta}{\partial k}$$
$$-\frac{\eta f'}{s}(\epsilon_\eta - \epsilon_{f'})(N-1)(\eta'\frac{\partial \theta}{\partial k}f' + \eta f''\frac{\partial s}{\partial k})\overline{k}$$
$$= \frac{1}{s}f'\{\mu[-(1-\epsilon_\eta)f + sf')]\ [-N(\eta'\frac{\partial \theta}{\partial k}f' + \eta f''\frac{\partial s}{\partial k})]$$
$$+\frac{\eta f'}{s}(\epsilon_\eta - \epsilon_{f'})[\mu f'\epsilon_{f'}\frac{\partial s}{\partial k} + \mu'(f - sf')]\ \frac{\partial \theta}{\partial k}$$
$$-\frac{\eta f'}{s}(\epsilon_\eta - \epsilon_{f'})(-N + N - 1)(\eta'\frac{\partial \theta}{\partial k}f' + \eta f''\frac{\partial s}{\partial k})\overline{k}$$
$$\leq \frac{\eta f'}{s}(\epsilon_\eta - \epsilon_{f'})[\mu f'\epsilon_{f'}\frac{\partial s}{\partial k} + \mu'(f - sf')]\ \frac{\partial \theta}{\partial k}$$
$$-\frac{\eta f'}{s}(\epsilon_\eta - \epsilon_{f'})(-N + N - 1)(\eta'\frac{\partial \theta}{\partial k}f' + \eta f''\frac{\partial s}{\partial k})\overline{k}$$

$$= \frac{\eta f'}{s}(\epsilon_\eta - \epsilon_{f'})[(\mu f' \epsilon_{f'} + \eta f'' k)\frac{\partial s}{\partial k} + (\mu'(f - sf') + \eta' f' k)\frac{\partial \theta}{\partial k}]$$

$$= \frac{\eta f'}{s}(\epsilon_\eta - \epsilon_{f'})\eta[(1-\epsilon_\eta)f - sf']\frac{\partial \theta}{\partial k} \leq 0.$$

The first equality comes from rearranging terms. The second one uses the expression of $\partial k/\partial \tau$ and $d\rho/d\tau$. The third one with $\cong$ (the same sign as above) follows from the expression of E and $-(1/E)(\partial s/\partial \tau) > 0$. The fourth one is obtained by simplifying terms. The next inequality follows because $(1-\epsilon_\eta)f - sf' \geq 0$ in (15). The next equality is obtained by simplifying terms. The last one uses the definition of $\epsilon_{f'}$ and ϵ_η, along with (13). The inequality holds due to (15), (21), and $\partial\theta/\partial k > 0$. The inequality establishes $\tau^* = 0$.

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