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Fiscal competition and interindustry trade

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Neighboring economies – cities, states and provinces, countries – often are strongly linked through a large volume of interindustry trade The tax and expenditure policies chosen by one jurisdiction will affect its neighbors through these channels A model is developed of two jurisdictions, one of which is the upstream supplier of an intermediate input for the other's export industry Theoretical analysis shows how changes in tax policy in either jurisdiction affect wages and welfare for the residents of both jurisdictions, highlighting the fiscal interactions arising from the interindustry trade linkages With appropriate simplifying assumptions, predictions about the direction of these effects can be made More generally, however, the sign and magnitude of these interactions depend on a number of empirical parameters characterizing technology and trade Numerical calculations provide a first-order analysis of the impact of policy changes when specific values are assumed for these parameters

1. Introduction

The issue of capital taxation in open economies – countries, states, localities – has always been important, and presently is attracting increasing attention This is partly the consequence of increasing economic integration, both of capital and of goods markets The policy debate is full of conflicting arguments Sometimes it is argued that capital taxation – often the taxation of some export-oriented industry – enables a government to shift the burden of its taxes to non-residents, as firms pass on taxes in the form of higher output prices This phenomenon, referred to as 'tax exporting', suggests that governments might tax capital too heavily, particularly in certain industries,

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in an effort to exploit outsiders On the other hand, it is argued that the mobility of capital induces governments to provide lenient fiscal treatment of capital, again particularly in industries that are export-oriented It is argued that governments may cut capital tax rates or offer various other fiscal inducements as subsidies to attract and retain capital It is often suggested that this phenomenon, known as 'tax (or fiscal) competition', could result in taxes on capital that are too low Sometimes it is argued that while tax rates are not necessarily too high or too low overall, they are too *different* Tax differentials across industries and jurisdictions may be undesirable in themselves This type of argument often leads to suggestions for *tax harmonization*, i e a move toward greater uniformity in capital taxation In all of the above cases, there is concern that the decentralized setting of capital tax rates may result in undesirable outcomes, offering the prospect of welfare gains from tax 'coordination' [1] Although the potential for confusion is large, the general nature of the issues, in broad terms, is not difficult to understand Consider a system of open economies, such as those of the states in the United States or the countries of Europe The following questions are of interest (i) Taking into account the openness of these economies, what form of capital taxation is in the best interest of each taxing jurisdiction? (ii) Does the taxation of capital by one jurisdiction harm or help the other jurisdictions? (iii) In view of (i) and (ii), what form of coordination of tax policy is advantageous from the viewpoint of the system as a whole?

These questions cannot properly be answered outside of the context of a model of the fiscal interactions among governments The present paper suggests such a model, and explores the interjurisdictional impact of capital taxation within it This model is based on three stylized facts The first fact is that a large volume of trade between jurisdictions occurs in intermediate goods [2] Consider the figures on EEC trade in table 1, for instance While there might be some question about the definition of intermediate and final

[1]The literature on the above topics is enormous and widely scattered Just to give a few references for the interested reader Oates (1972, ch 4), Break (1980, ch 2), and Gramlich (1985) provide excellent introductions to the policy issues McLure (1967) is a classic reference on tax exporting The use of taxation to achieve terms-of-trade advantages is discussed in Arnott and Grieson (1981) Other discussions of tax exporting include McLure (1981), Kolstad and Wolak (1983), Wildasin (1987a,b), Morgan et al (1989), and Mutti et al (1989) and references therein On fiscal competition, see Mintz and Tulkens (1986, 1989), Wilson (1986, 1987, 1991), Oates and Schwab (1988), Wildasin (1988, 1989, 1991), Black and Hoyt (1989), Bond and Samuelson (1989), Bucovetsky (1991), Jensen and Toma (1991), and Bucovetsky and Wilson (1991), inter alia On harmonization and coordination, see Alworth (1985), Musgrave (1985), and Musgrave and Musgrave (1989) Gordon (1983) provides a general theoretical analysis of optimal taxation in an open economy setting Furthermore references to the literature can be found in Wildasin (1987c)

[2]Analyses of tax and trade policy by Bhatia (1981), Sanyal and Jones (1982), Markusen (1989), and Markusen and Wigle (1989) have stressed the importance of intermediate goods trade Bhatia (1988) analyzes the incidence of taxes in a model with intermediate goods, but restricts attention to the closed-economy case

Table 1

Selected uses of output, 8 EEC countries, 1980 (% shares)

	Denmark	West Germany	Spain	France	Italy	Netherlands	Portugal	United Kingdom
(1) Total intermediate output	38 6	44 4	44 0	39 7	44 3	38 0	44 7	44 7
(2) Exports to EC countries	6 9	5 4	2 7	5 2	4 4	14 9	5 3	4 9
(3) Exports to third countries	8 2	6 5	3 2	5 7	5 6	7 3	4 0	7 4
(4) Total exports [(2)+(3)]	15 2	11 9	6 0	10 9	10 0	22 2	9 3	12 3
(5) Total uses of output (incl consumption and other)	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0
(6) Intermediate output as proportion of domestic uses [(1) as % of (5) −(4)]	45 5	50 4	46 8	44 5	49 2	48 8	49 2	51 0
(7) Exports to EC countries as proportion of total exports [(2) as % of (4)]	45 3	45 3	45 0	47 7	44 0	67 1	56 9	39 8

Source Eurostat (1986, p 22)

goods, these data leave no doubt that intermediate goods trade among the EEC countries is very large – on the order of 40–50% – unless the composition of production for export (as between consumption and other uses) is drastically different from the composition of production for domestic use An accounting of trade between the United States and Canada or Mexico, among states in the United States, or within any state or metropolitan area, would also undoubtedly show a high volume of interindustry trade Of course, observed trade patterns are complex and diverse In some cases, natural resources are extracted or harvested in one country and processed in another, in other cases, manufactured goods are traded in both (or several) directions among two or more countries

The second stylized fact is that the volume of trade between 'neighboring' economies is high Important trading relationships between certain economies are observed to persist over long periods of time For example, in 1977, 50 1% of all EEC imports were from other EEC countries, in 1986, the corresponding figure was 57 8%[3] This pattern holds across all EEC member countries, as can be seen by referring, for example, to table 1 While the lowering of trade barriers within the EEC has undoubtedly increased intra-EEC trade relative to what it would have been, there is equally no doubt that the volume of intra-European trade by European countries has been high for long periods of time Trade between Canada and the United States tells a similar story each country has been a major trading partner of the other for many years, with Canada accounting for between 16% and 23% of U S imports and exports during the years 1975, 1980, and 1985, far out of proportion to its share of rest-of-the-world population or GNP[4] Although data on trade among states or among localities within states or metropolitan areas are not readily available, there can be no doubt that such trade flows are very large

A third fact of importance is that almost all countries and, a fortiori, subnational jurisdictions such as state, provincial, or local governments, are small and open relative to the world capital market Capital is increasingly mobile, and there are few instances where a single jurisdiction could expect to have a very significant effect on the world net return on capital[5]

In view of the above stylized facts, I construct a model of two jurisdictions that trade both with each other and with the rest of the world Both

[3]See Eurostat (1988, Table 6 1 1, p 189, and Table 6 1 4, p 192)

[4]See U S Department of Commerce (1987, Table 1345) These trade patterns motivate an interesting analysis of the implications of transportation costs for inter- and intra-national trade in Melvin (1985)

[5]The U S economy is the notable potential exception to this specification There has been some debate about whether the United States should be treated as open with respect to the world capital market and, if so, whether it should be treated as small [Summers (1988)] The capital market assumption used here is obviously an idealization, but it should be a reasonable one for many jurisdictions

jurisdictions are assumed to be small relative to the capital market in the rest of the world capital is freely mobile and the world net return on capital is taken as exogenously fixed in the model Furthermore, trade between these two jurisdictions is assumed to have a special structure one (the 'upstream' jurisdiction) is the sole supplier of an intermediate input used by the other (the 'downstream' jurisdiction) in the production of a traded good This is the simplest structure that can be used to capture our stylized facts

Section 2 spells out the notation and the formal structure of the model Section 3 presents the results of a general equilibrium comparative statics analysis of the model, showing how balanced-budget tax changes in one jurisdiction affect sectoral outputs and factor allocations, net wages, and welfare in both jurisdictions This analysis reveals that the economic linkage between the two jurisdictions through their intermediate goods trade can provide a channel for the propagation of policy impacts from one jurisdiction to the other Of course, the theoretical analysis cannot determine the *magnitude* of the interjurisdictional impact of capital taxation Section 4 therefore presents some illustrative calculations that show that these effects might well be quantitatively important They also illustrate the sensitivity of the results to various parameters The potential applications of the model to issues of tax coordination, harmonization, etc are discussed in the concluding section The details of the analysis are sketched in an appendix A full exposition of the analytical results is provided in Wildasin (1992), available on request

2. The model

The model focuses on the interactions between two jurisdictions, 1 and 2, that are open to the rest of the economy and that trade with each other Fig 1 presents a schematic presentation of the trading structure of the model In each jurisdiction, production occurs in two perfectly competitive industries, denoted x and y In both cases, x refers to a traded numéraire good whose price is fixed at unity For jurisdiction 1, good y_1 is a commodity that is sold on the external market but, for simplicity, is not purchased in either jurisdiction 1 or 2 Good y_2 is an intermediate good that is sold to jurisdiction 1 and possibly on the external market as well This intermediate input y_2 is used in jurisdiction 1 only in the production of good y_1, not in the production of good x Much of the analysis focuses on the implications of this special structure of interindustry trade [6]

[6]Since the model assumes an exogenously-fixed pattern of trade, it differs from international trade analyses whose objective is to *explain* the pattern of trade The spirit of the model here is closer to that of applied general equilibrium models of trade, for which, as a matter of realism, it is desirable not to have predicted trade patterns that are highly sensitive to small perturbations of prices, tastes, or technology Many authors working with applied general equilibrium trade models [e g Harris and Cox (1984), Whalley (1985), Markusen and Wigle (1989) and Deardorff

Both industries in both jurisdictions use capital and some fixed factor, called 'labor', as inputs Labor is inelastically supplied by households in each jurisdiction, 1 unit of labor per household, it is mobile across industries within each jurisdiction, but immobile across jurisdictions Let l_i denote the fixed amount of labor in jurisdiction i, and let l_{ix} and l_{iy} denote the amount employed in each industry The net wage in jurisdiction i is denoted by ω_i (labor mobility implies that this net wage must be the same in both industries) This differs from the gross wage w_i because of a proportional tax on earnings at rate τ_i $(1-\tau_i)w_i=\omega_i$

Capital is mobile across jurisdictions, and both jurisdictions are small and open relative to the external capital market, taking ρ, the net return on capital, as parametrically given Let k_{ix} and k_{iy} denote the amount of capital employed in each industry in jurisdiction i The gross return on capital in industry z $(=x,y)$ in jurisdiction i is denoted by r_{iz} This differs from the net return because of the presence of capital taxes or subsidies which may vary by industry Denoting tax rates by t_{iz}, the relationship between gross and net returns on capital is given by $(1-t_{iz})r_{iz}=\rho$

The x industry in each jurisdiction has a technology which shows strictly decreasing returns to scale in capital and labor, which are the only two variable inputs The assumption of decreasing returns reflects the presence of other fixed and immobile factors in the background, such as land, other natural resources, specialized labor inputs, entrepreneurship, patents, public infrastructure that is regarded as fixed for the time-frame of the analysis, etc As well shall see, the presence of this third factor enriches the analysis significantly It also helps rule out specialization in production, as discussed further below Let $\pi_x^i(w_i,r_{ix})\equiv\max_{\langle x_i\ l_{ix},k_{ix}\rangle} x_i-w_i l_{ix}-r_{ix}k_{ix}$ subject to $x_i=f_i(l_{ix},k_{ix})$ be the profit function for industry x in jurisdiction i, where f_i is the production function for the industry, twice continuously differentiable, strictly increasing in both arguments, and strictly concave By well-known properties of the profit function, the demand functions for labor and capital in the x industry are given by the negative of the derivatives of the profit function with respect to the gross factor prices $l_{ix}=-\partial\pi_x^i/\partial w_i$ and $k_{ix}=-\ \partial\pi_x^i/\partial r_{ix}$ The 'profit' π_x^i can be interpreted as the rent accruing to fixed inputs in (land, entrepreneurship, patients, etc) This profit or rent may be subject to tax, on a source basis, at the (percentage) rate θ_i Let s_i be the local ownership share of the profits of the x industry, $0\leqq s_i\leqq 1$ For simplicity, assume that there is no cross-ownership of these returns between jurisdictions 1 and 2, so that the share $1-s_i$ accrues to households elsewhere in the economy

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and Stern (1990)] exploit the assumption [identified with the name of Armington (1969)] that goods originating in different countries are differentiated products Imperfect substitutability across commodities insures that initial benchmark trade patterns will only be altered to a limited degree as policy or other model parameters change

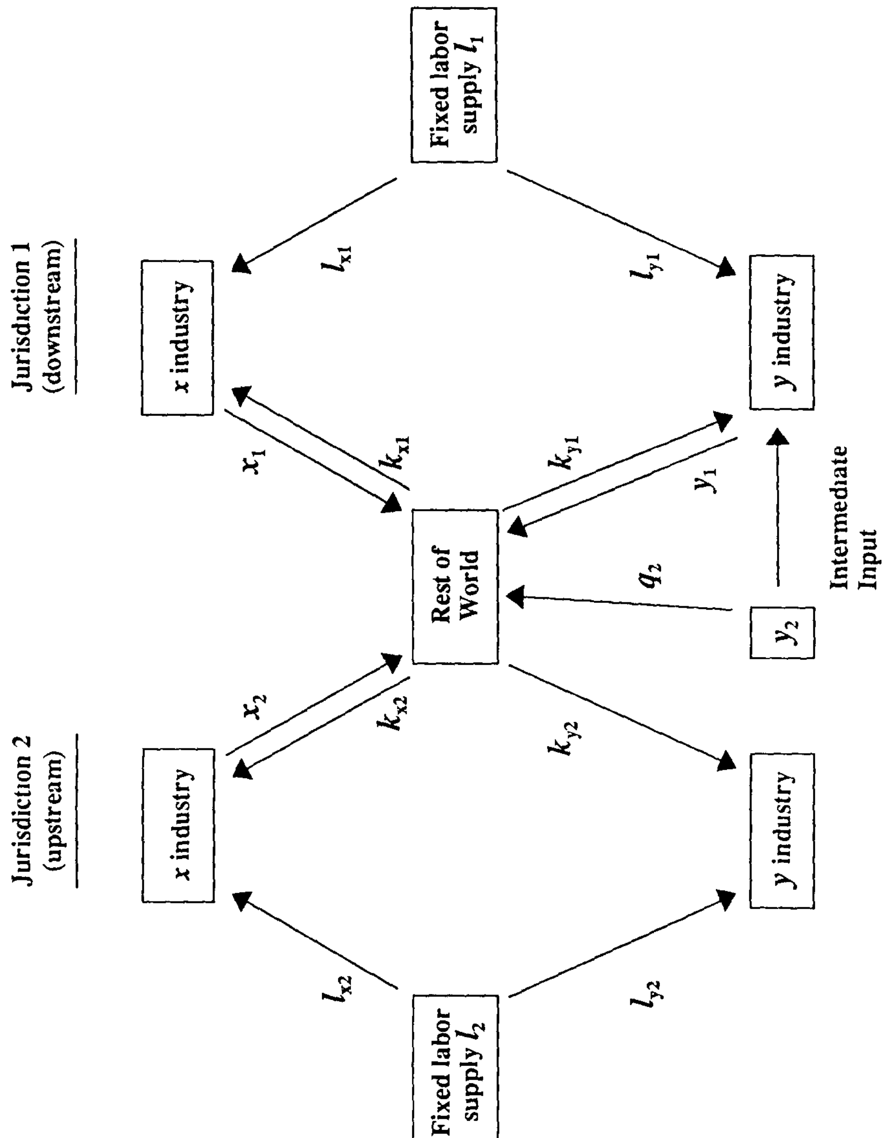
Jurisdiction 1
(downstream)
Jurisdiction 2
(upstream)
Fixed labor supply l_1
Fixed labor supply l_2
x industry
y industry
x industry
y industry
Rest of World
y_2
l_{x1}
l_{y1}
x_1
k_{x1}
k_{y1}
y_1
q_2
Intermediate Input
x_2
k_{x2}
k_{y2}
l_{x2}
l_{y2}

Fig 1

The production of good y_1 in jurisdiction 1 occurs under constant returns to scale using inputs of labor, capital, and the intermediate good y_2 Let p_2 be the price at which y_2 is sold, both to jurisdiction 1 on the external market The technology is described by the unit cost function $c_y^1(w_1, r_{1y}, p_2)$ with the usual properties it is twice continuously differentiable, strictly increasing in each argument, homogeneous of degree 1, and concave The assumption of a competitive constant-returns industry implies that profits in this industry are zero in equilibrium Letting p_1 denote the price at which y is sold on the external market, this equilibrium condition requires that $p_1 = c_y^1$ The *unit* demand functions for labor, capital, and the intermediate input are given by the derivatives of c_y^1 with respect to the input prices Letting Greek letters denote these unit inputs, we have $\lambda_1 = \partial c_y^1/\partial w_1$, $\kappa_1 = \partial c_y^1/\partial r_{1y}$, and $\mu_1 = \partial c_y^1/\partial p_2$ The *total* input demands are given by the product of the unit input demands and the level of output $l_{1y} = \lambda_1 y_1$, $k_{1y} = \kappa_1 y_1$, and $m_{1y} = \mu_1 y_1$, where m_{1y} denotes the level of intermediate input

Commodity y_2 is assumed to be produced under constant returns to scale using labor and capital as the only inputs Thus, the unit and input demands can be derived in the usual way from the unit cost function $c_y^2(w_2, r_{2y})$ The unit inputs of labor and capital in this industry are denoted by λ_2 and κ_2, respectively In equilibrium, profit are zero so that $p_2 = c_y^2$

Although production in both jurisdictions is assumed to be competitively organized, it is not assumed that the jurisdictions themselves are necessarily small relative to the external market for the commodities y_i In particular, $q_i(p_i)$ denotes the demand for good y_i on the external market as a function of its price, and $\varepsilon(q_i, p_i)$ is the elasticity of demand [For any variables x and y, $\varepsilon(x,y)$ will denote the elasticity of x with respect to y] As a special case, $\varepsilon(q_i, p_i) = -\infty$ (external price is taken as given)

The consumption side of the model is very simple Each jurisdiction is inhabited by l_i identical and immobile households These households supply labor, and they may own some share of the profits in local industry They may also own some capital, which earns the exogenously-given rate of return ρ on the external capital market Let Y_i denote the capital income earned by each household in i, as well as any other exogenously-given income that they may receive Households consume only the numéraire private good, so that if ξ_i denotes per capita consumption of good x, the budget constraint facing a household in jurisdiction i is

$$\xi_i = \omega_i + \frac{s_i}{l_i}(l - \theta_i)\pi_x^i + Y_i \tag{1}$$

Since utility is monotonically increasing in x_i, the right-hand side of (1) may be regarded as the consumer's indirect utility function

Each government is constrained to set tax rates that balance its budget If

γ_i represents some arbitrarily-fixed level of public expenditure in jurisdiction i, then the government budget constraint is

$$\gamma_i = \tau_i w_i l_i + t_{ix} r_{ix} k_{ix} + t_{iy} r_{iy} k_{iy} + \theta_i \pi_x^i \tag{2}$$

The expenditure level γ_i is held constant in the analysis to follow It could therefore be regarded as already subsumed within preferences and technology and could therefore represent expenditures for the provision of public consumption goods or inputs

We can now describe the general equilibrium of the model in terms of a system of four fundamental equations The first two are the labor market equilibrium conditions for each jurisdiction, specifying that $l_i = l_{ix} + l_{iy}$, or, expressing l_{ix} and l_{iy} in terms of demand functions

$$l_1 = l_{1x}(w_1, r_{1x}) + y_1 \frac{\partial c_y^1(w_1, r_{1y}, c_y^2(\ ))}{\partial w_1}, \tag{3 1}$$

$$l_2 = l_{2x}(w_2, r_{2x}) + y_2 \frac{\partial c_y^2(w_2, r_{2y})}{\partial w_2} \tag{3 2}$$

(Note that the cost function c_y^1 is written as a function of c_y^2, reflecting the fact that the equilibrium price of the intermediate input must equal its marginal cost, i e $p_2 = c_y^2$) The other equilibrium conditions specify that supply equals demand in the y industries

$$y_1 = q_1(c_y^1[w_1, r_{1y}, c_{2y}(\ )]), \tag{4 1}$$

$$y_2 = q_2(c_y^2[w_2, r_{2y}]) + y_1 \frac{\partial c_y^1(\ )}{\partial c_y^2} \tag{4 2}$$

[Note that the external demand functions $q_i\ (p_i)$ are written here as functions of unit costs, $q_i(c_y^i)$, reflecting the competitive equilibrium conditions that $p_i = c_y^i$] Trade balance equations need not be included explicitly in describing the general equilibrium of the two jurisdictions, since that can be derived from the other equilibrium conditions and household and government budget constraints in the usual fashion

Writing the gross factor prices w_i and r_{iz} in terms of the net factor prices ω_i and ρ and tax policy parameters, (3) and (4) constitute a system of four equations that determine ω_1, ω_2, y_1, and y_2 endogenously in terms of the exogenous policy variables As shown in the appendix, this system can be implicitly differentiated to solve for the changes in the equilibrium values of wages and outputs as tax parameters change These results can in turn be used to compute the changes in the equilibrium levels of profits, employment, and tax revenue [7]

[7]A remark on the technical role of the decreasing-returns assumption in the x industries is in order here Suppose instead that we assumed constant returns to scale in labor and capital in

3. Some theoretical results

Consider now the effects of changes in capital taxation Suppose that the wage income tax rates in both jurisdictions adjust to maintain budget balance This differential tax analysis highlights the role of capital taxation with minimal complications from other sources [8]

The welfare and distributional effects of capital taxes are sensitive to the ownership of profits Assume initially that all profits are locally owned ($s_i = 1$), so that welfare in jurisdiction i is given by ξ_i This assumption is relaxed later The following two propositions present some results on the effects of capital taxation in the x and y industries, respectively

Proposition 1 Suppose that all capital tax rates are initially zero or sufficiently small, and that the elasticity of substitution in the y industry in each jurisdiction is zero or sufficiently small Let the cross-elasticity of demand for labor with respect to the cost of capital in the x industry in each jurisdiction be positive (zero) Then an increase in the rate of taxation on capital in the x industry in jurisdiction i raises (leaves unchanged) the gross and net wages and welfare in jurisdiction i, and lowers (leaves unchanged) the gross and net wages and welfare in jurisdiction j If the cross-elasticity of demand for labor with respect to the cost of capital in the x industry in each jurisdiction is negative, then an increase in the rate of taxation on capital in the x industry in jurisdiction i has an ambiguous effect on the net wage in jurisdiction i but lowers the gross wage and welfare there, and it raises gross and net wages and welfare in jurisdiction j

Proposition 2 Suppose that all capital tax rates are initially zero or sufficiently small, and that the elasticity of substitution in the y industry in each jurisdiction is zero or sufficiently small An increase in the rate of taxation on capital in the y industry in jurisdiction i has an ambiguous effect on the net wage there, but it lowers the gross wage and raises welfare It lowers gross and net wages and welfare in jurisdiction j

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these industries, and suppose that we then let $c^i_x(w_i, r_{ix})$ denote the unit cost functions in these industries Then the equilibrium zero-profit conditions in the x industries would require that

$$1 = c^i_x(w_i, r_{ix})$$

Since r_{ix} is exogenously determined, these two conditions would determine the equilibrium wage w_i in each jurisdiction Now suppose that the y industries are small relative to the external market, so that the prices p_i are exogenously fixed Then the zero-profit conditions for the y industries require that

$$p_i = c^i_y(w_i, r_{iy})$$

However, all of the variables in both of these equations are already determined Hence, there must either be specialization in production initially, or a small perturbation of policy would lead to specialization The assumption of increasing costs in the x industry (or, if one prefers, the assumption of a third fixed factor) obviates this problem

[8] It is possible to illustrate some of the following analysis diagrammatically See Wildasin (1992)

Proofs The proofs of these results are given in the appendix

Note that these results are symmetric with respect to the two jurisdictions, even though their trading relationship is asymmetric Thus, the impact of capital taxation is not critically dependent on whether the taxing jurisdiction is a supplier or a user of intermediate goods

The intuition behind Proposition 1 is as follows First, the effect of a tax on capital in the x industry on the demand for labor in the taxing jurisdiction depends on the cross-elasticity of demand with respect to the gross cost of capital in the industry, r_{ix} If this is positive, the tax induces substitution toward labor that is sufficiently strong to offset any reduction in the demand for labor resulting from reduction in industry output This puts upward pressure on the labor market, raising the gross wage Since workers receive the proceeds of the capital tax in the form of a reduction in the tax on wages, the net wage obviously rises The increase in the gross wage raises the cost of production in the y industry and reduces its equilibrium output This generates a favorable terms-of-trade effect (an increase in p_2 if $i=2$, a decrease if $i=1$) for the taxing jurisdiction, and welfare rises accordingly This harms the trading partner, so welfare there falls, the fall in output in the y industry in the trading partner reduces the demand for labor and thus the gross and net wage rates Obviously, the argument runs in reverse if the cross-elasticity of demand for labor in the x industries is negative In general, then, a tax on capital in the x industry causes welfare and gross wages to move in opposite directions in the two jurisdictions

The intuition behind Proposition 2 is equally clear A tax on capital in the y industry raises the cost of production there, and thus lowers the demand for labor The demand for labor might be increased by substitution away from capital toward labor, but we are assuming that this effect is small (low substitution elasticity in the y industry) Thus, the gross wage must fall The net wage could still rise, depending on the parameters of the model, because workers receive a tax cut The reduction in the output of the y industry exerts a favorable terms-of-trade effect that raises welfare in the taxing jurisdiction The same terms-of-trade effect lowers welfare in the trading partner The reduction in the output of the y industry reduces the demand for labor in the trading partner and thus the gross and net wage there It is interesting to note that although there is an asymmetry in the role of the two jurisdictions in the model (one upstream, one downstream), the effects of capital taxes are qualitatively the same in each This is because what matters is the effect of taxes on the *volume* of trade, and this is the same in both jurisdictions

Propositions 1 and 2 assume that capital tax rates are initially zero, or at least small The terms-of-trade effects on welfare are dominant in this case However, as is well known from the optimal tariff literature, this is only the case in general for 'incipient' taxes The first-order welfare loss from taxes in a zero-tax world is zero, but these losses eventually dominate the terms-of-trade effects as tax rates rise

The welfare analysis above has assumed that profits are locally owned ($s_i = 1$) The opposite assumption ($s_i = 0$) is easily considered In this case, the welfare of each jurisdiction is given by the net wage (plus a constant, Y_i), as is apparent from the consumer budget constraint (1) Propositions 1 and 2 have already described the effects of capital taxation on the net wage Note in particular that while the welfare effects of capital taxation may be positive when all profits are locally owned, this conclusion can be reversed in the opposite case Thus the ownership of fixed factors is in general of critical importance for welfare analysis

As discussed further below, the model could be reinterpreted so that the profits of the x industry represent a return to some specialized factor such as entrepreneurial skills We could suppose that the individuals receiving this income do reside in the jurisdiction, but are distinct from those receiving wage income In this case, the separate movements of net wages and of 'profits' are of independent interest from a distributional viewpoint Propositions 1 and 2 have shown that these variables need not move in the same direction

Propositions 1 and 2 provide some basic insight into the workings of the model, showing how capital taxes in either industry can affect intermediate goods trade and thus generate terms-of-trade effects with respect to the trading partner and, perhaps, the rest of the world Despite the fact that both jurisdictions are small relative to the world capital market, capital taxes in one cause spillover effects in the other Sometimes these spillovers are harmful, but sometimes they are beneficial

At this point, further analysis can proceed in two directions One possibility is to investigate what tax policies would be optimal for each jurisdiction acting independently, a task that might naturally be approached by investigating the Nash non-cooperative equilibria of a tax-setting game One could examine the welfare properties of such an equilibrium and the possible gains from policy coordination or harmonization This approach, however, raises numerous technical questions which go beyond the scope of the present analysis (and hence leave an interesting topic for future research) [9]

In the remainder of this paper, we proceed in a different direction Leaving

[9]Another question that one might raise is whether jurisdictions would even wish to use capital taxes at all, if other tax instruments (such as output taxes) were available Although this is a very interesting question, the motivation for the analysis here is somewhat different We begin instead by observing that capital taxes (and subsidies, which can be viewed as negative taxes) are important in practice, whether optimized or not, and it is therefore worth investigating what would happen if these taxes were altered in some way

aside the question of optimal policy for either jurisdiction, we can consider instead the issue of piecemeal policy changes Suppose that each jurisdiction's tax rates are fixed at some initial values Starting from that point, what are the effects of policy perturbations? Are welfare and wages locally increasing or decreasing functions of tax rates? If policies are initially uniform (harmonized), is it unilaterally advantageous to depart from uniformity? Do competitive pressures favor reductions in tax rates?

All of these questions can be investigated using comparative statics methods which are rather straightforward and do not require special assumptions of the type that would likely be needed to guarantee the existence of Nash equilibria

4. Interjurisdictional incidence of capital taxes: Quantitative estimates

The theoretical analysis of section 3 has shed some light on some of the possible effects of taxation on equilibrium prices, quantities, and income This section reports the results of a series of calculations showing how tax policy affects important endogenous variables given various assumed numerical values for the parameters of the model The goal is to see when and whether various tax effects are likely to be important, and to see what parameters have the largest impact on the results [10] Comparing the results in different cases also provides an opportunity to explain the interactions occurring within the model in an intuitive way

In order to calculate the numerical values for such variables as the elasticity of the net wage with respect to t_{1y}, it is necessary to specify numerical values for all of the parameters that determine it As detailed in the appendix, these include factor shares, substitution elasticities, tax rates, and so on The calculations presented here highlight the role of production technology, tax rates, and the elasticity of demand for the output of the y industries on the external market [11]

Two different sets of factor demand elasticities in the x industries are considered The first set corresponds to a three-factor Cobb–Douglas production function $x_i = l_{ix}^{\gamma} k_{ix}^{\delta} T_i^{(1-\gamma-\delta)}$, where T_i is interpreted as a fixed factor

[10] The analytical results underlying the calculations are sketched in the appendix It should be noted that the model is not a CGE model in the spirit of, say, Kimbell and Harrison (1984) The theoretical analysis in the appendix derives the *first-order* effects of tax policy changes for *general* production technologies, in the tradition of Harberger (1962)–Jones (1965) general equilibrium analysis This type of analysis has both advantages and limitations as compared with CGE models

[11] The values of all parameters in the model can in principle take on a wide range of values, varying across jurisdictions and industries The general analytical framework developed here, and the computer programs on which the numerical results are based, can accommodate whatever alternative assumptions one might wish to explore The values chosen for the calculations in this section are intended to be typical of those commonly used in the literature, and thus helpful in illustrating the basic properties of the model

('land') giving decreasing returns in labor and capital alone The second set of elasticities corresponds to a three-factor CES-type production function, $x_i=(g_{il}l_{ix}^{\rho}+g_{ik}k_{ix}^{\rho}+g_{iT}T_i^{\rho})^{1/\rho}$ Parameters are chosen in each case so that the factor shares of labor, capital, and the fixed factor (land of profits) are 0 6, 0 3, and 0 1, respectively This yields the factor demand elasticities

$$\varepsilon(l_{ix},w_i)=-7\,(-3\ 5),\qquad \varepsilon(l_{ix},r_{ix})=6\,(-1\ 5),$$

$$\varepsilon(k_{ix},w_i)=3\,(-3),\qquad \varepsilon(k_{ix},r_{ix})=-4(-2)$$

where the first number is the Cobb–Douglas elasticity and the second number (in parentheses) is the CES elasticity [12] It is to be noted that the cross-elasticities are positive in the Cobb–Douglas case but negative in the CES case Under CES, the output effects of factor price changes (with decreasing returns, output falls as factor prices rise) dominate the cross-substitution effects due to greater factor complementarity This difference between the two cases has a significant impact on the results, as already suggested in the theoretical discussion [13]

Next, consider the technology specification for the y industries To begin with, the value shares of labor, capital, and the intermediate input in jurisdiction 1 are assumed to be 0 6, 0 25, and 0 15, respectively, while the labor and capital shares in jurisdiction 2 will be 0 75 and 0 25 Two different sets of parameter values were considered for the unit input demand elasticities The first, corresponding to the special case discussed in Propositions 1 and 2, assumes perfect complementarity, so that all of these elasticities are zero The second corresponds to a Cobb–Douglas technology with the value share parameters given above The numerical results turn out not to differ very much between these cases, however, so only the results for the Leontief case are reported here

Two different tax rate specifications are considered In the first, all tax rates are initially zero in both jurisdictions, in the second, they are all initially 20% These bracket a range of interesting cases, and provide substantial variation for comparative purposes [14] The external demand

[12]For the CES case, one sets $\rho=-1$, $g_{il}=5/3$, and $g_{ik}=10/3$ CES production function approximates a two-factor CES production function with constant returns to scale and a substitution elasticity of 0 5 (the above production function reduces to the standard two-factor form as $T_i\to 0$) These derivations and calculations were performed using MACSYMA, a symbolic manipulation program developed at the MIT Laboratory for Computer Science and supported since 1982 by Symbolics, Inc of Burlington, MA

[13]There is no need to restrict attention to the Cobb–Douglas and CES cases The general model does *not* assume that production functions have this form The elasticities of factor demand could take on almost any values, and we consider the Cobb–Douglas and CES cases here merely to provide some guidance for parameter choice

[14]Uniformity of tax rates across and within jurisdictions is assumed merely for convenience, as with all of the other parameters of the model, it is straightforward to carry out calculations under different assumptions as desired

Table 2

Effects of changes in capital taxation

Cobb–Douglas technology in X, Leontief in Y

Tax changes in industry X

Parameters		Changes in net wage and net income							
Output demand	Tax rates	$\frac{d\omega_1 l_1}{dR_{1x}}$	$\frac{d\xi_1 l_1}{dR_{1x}}$	$\frac{d\omega_2 l_2}{dR_{1x}}$	$\frac{d\xi_2 l_2}{dR_{1x}}$	$\frac{d\omega_1 l_1}{dR_{2x}}$	$\frac{d\xi_1 l_1}{dR_{2x}}$	$\frac{d\omega_2 l_2}{dR_{2x}}$	$\frac{d\xi_2 l_2}{dR_{2x}}$
Low (−5)	Low (0)	2.765	0.152	−0.015	−0.001	−0.072	−0.006	2.823	0.157
	High (0.2)	3.726	0.846	−0.033	−0.016	−0.204	−0.120	3.537	0.864
High (−10)	Low (0)	2.690	0.146	−0.029	−0.002	−0.141	−0.012	2.801	0.155
	High (0.2)	4.013	0.817	−0.072	−0.034	−0.398	−0.235	3.593	0.856

Tax changes in industry Y

Parameters		Changes in net wage and net income							
Output demand	Tax rates	$\frac{d\omega_1 l_1}{dR_{1y}}$	$\frac{d\xi_1 l_1}{dR_{1y}}$	$\frac{d\omega_2 l_2}{dR_{1y}}$	$\frac{d\xi_2 l_2}{dR_{1y}}$	$\frac{d\omega_1 l_1}{dR_{2y}}$	$\frac{d\xi_1 l_1}{dR_{2y}}$	$\frac{d\omega_2 l_2}{dR_{2y}}$	$\frac{d\xi_2 l_2}{dR_{2y}}$
Low (−5)	Low (0)	0.549	0.825	−0.084	−0.007	−0.403	−0.035	0.866	0.852
	High (0.2)	0.226	0.481	−0.138	−0.066	−0.425	−0.200	0.688	0.650
High (−10)	Low (0)	0.143	0.790	−0.159	−0.014	−0.762	−0.066	0.741	0.841
	High (0.2)	−1.529	−0.162	−0.555	−0.265	−0.812	−0.347	0.576	0.609

elasticities for the outputs of the y industries are allowed to take two different values, −5 and −10. In the former case, the two jurisdictions have a considerable degree of market power in the national or international market, whereas the latter more closely approximates the 'small' jurisdiction assumption.[15]

The results of some of the numerical computations are displayed in tables 2 and 3, corresponding, respectively, to the Cobb–Douglas and CES technologies in the x industries. These calculations show the effect of changes in capital tax rates on net wages and welfare (assuming full local profit ownership, $s_i = 1$) in each jurisdiction. It is assumed that each capital tax rate is raised by enough to generate one additional dollar of revenue, and that the wage income tax rates in both jurisdictions are adjusted to offset this so

[15]To limit the analysis, the share of wage income in total income in each jurisdiction is held fixed at 0.75 for both jurisdictions and the share of the output of the upstream y industry sold to purchasers other than firms in jurisdiction 1, e, is fixed at 1. The share of workers employed in the x industry is fixed at 0.9 for both jurisdictions.

Table A 1

Computation of customs union and Common Market equilibria

		Customs Union		Common Market
Domestic prices	P_1, P_2	1 7567,	9	1, 9
World prices	Q_1, Q_2	1,	9	1, 9
Production	Y_1, Y_2	0 15,	9	1, 1
Labor allocation	L_1, L_2	0 15,	9 85	1, 9
Consumption	G_1, G_2	8 15,	0 3105	9, 1
Union exports (good 2)		8/9		8/9
Union imports (good 1)		8		8
Common external tariff on good 1		0 7567		0
Utility		11 6420		11 1111

$$\frac{Q_1}{Q_2} < MRS < MRT$$

Thus, given the trade flows with the rest of the world, it follows that union welfare rises if and only if production of good 2 rises This is also easily seen in fig 1, where consumption moves from X^u into the preferred region along l^{MRT} if and only if production on the production possibilities frontier moves to the south-east

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2 Moving down successive rows shows the same calculations for different combinations of demand elasticities and pre-existing tax rates The lower panel shows the same calculations when one considers a change in taxation in the y industry

Since the interindustry trade linkage between the two jurisdictions is so important for the analysis, let us focus on the impact of changes in capital taxation in the y industries The qualitative results are similar in both tables, the discussion is limited to table 2 for brevity

The first point to note is that when tax rates are initially zero, each jurisdiction has something to gain by introducing a tax on capital in its y industry, in accordance with Proposition 2 For instance, a tax on capital in the y industry in jurisdiction 1 would raise total net income there by \$0 825 per dollar increase in tax revenue when the external demand elasticities are relatively low (-5), and by \$0 790 when these elasticities are high The last column in the lower panel shows that the same effects operate, only more strongly, for jurisdiction 2 here the welfare gains are 85% and 84% of the first dollar of revenue raised from taxation of capital in the intermediate good industry, depending on the elasticity of external demand While the signs of these entries in the table come as no surprise, in view of Propositions 1 and 2, the magnitudes are here revealed to be quite substantial These welfare gains arise from exploitation of terms-of-trade advantages both with respect to the external market and with respect to the other jurisdiction Taxation of the y industries also yields benefits strictly from the viewpoint of workers alone (or, equivalently, from the viewpoint of total net income in the community in the case where all profits accrue to non-residents), as shown by the changes in net wages As one might have anticipated, for both jurisdictions (especially for the downstream jurisdiction 1) the gains from taxation of these industries are smaller when the elasticity on external markets is higher and when the rate of taxation is higher Indeed, jurisdiction 1 actually suffers a loss of wage and total income by further taxation of the intermediate goods industry when tax rates are initially at 20%

While each jurisdiction has some incentive to tax capital in the intermediate good industry, Proposition 2 suggests that this will work to the disadvantage of its neighbor The middle columns of the lower panel of the table not only confirm this, but show that the cross-effects of capital taxation in the y industries on wages in the neighboring jurisdiction can be substantial For instance, with low demand elasticities and tax rates initially 0, net wages in jurisdiction 1 fall by \$0 40 for the first dollar of capital taxation in the upsteam jurisdiction 2 Welfare always moves in the same direction as net wages, but the cross-effect on welfare is generally much smaller than the effect on wages (Thus, the above-mentioned \$0 40 loss of wages corresponds to a loss of only \$0 03 in welfare) This is because the gross wage rate falls, thus increasing profits in the x industry Thus, the interjurisdictional incidence of capital taxation is very uneven wages in the trading partner are hurt badly, while the net return to the fixed factor rises considerably Of course, to the extent that the fixed factor is owned by non-residents, the change in net wages is indicative of the change in total net income for the neighboring juisdiction, and, as we have seen, that impact can be strongly negative

In general, the interjurisdictional spillover effects of capital taxation are more strongly negative the higher are the initial tax rates and the higher the demand elasticities for the intermediate goods The explanation for the latter result is that 'smallness' implies a reduced ability to shift the burden of adverse intermediate good price fluctuations to agents external to the system For instance, if the upstream supplier taxes its y industry, this puts upward pressure on the costs of the downstream jurisdiction, if this downstream industry has little ability to shift this along to external demanders in the form of higher prices, the increase in the price of the intermediate good will cause a greater reduction in the equilibrium output of the y industry and more shifting of labor to the x industry, with a correspondingly larger reduction in the net wage there

So far, then, we have seen that each jurisdiction may enjoy some substantial gain from the taxation of capital in its y industry, but that such taxation can have a significant negative impact on its neighbor, at least in terms of net wages Thus, the hypothesized trade linkage between the two jurisdictions creates an important linkage as well in terms of the welfare effects of policy changes – a linkage that may lead to divergent interests between at least some groups of agents in the two economies

Consider now the implications of taxation of capital in the x industries Here the results are sensitive to the assumed production technology in the x industry As noted above, the Cobb–Douglas technology in the x industry implies that the cross-elasticities of factor demands are positive According to Proposition 1, this implies that the own-welfare effect of a tax on capital in the x industry must be positive and that the cross-effect must be negative This is confirmed in the upper panel of table 2 The positive own effects on net wages are very strong, but there are large offsets in the return to the fixed factor so that welfare changes by much less than net wages It is of interest to note that the own effects diminish as the external demand elasticity increases, when tax rates are held at 0

In the CES case, the cross-elasticities of factor demands in the x industries are negative The first and third rows of the upper panel of table 3 confirm the theoretical finding of Proposition 1 that the cross-effect of taxation of capital in the x industry on welfare on the other jurisdiction should be positive, and that the effect on net welfare in the taxing jurisdiction is negative The fact that the cross-effects of taxation in the x industry are positive illustrates the important possibility that a jurisdiction may gain as well as lose from increases in capital taxation by its neighbors, depending on the industry and particular circumstances in question

5. Conclusion

We may now return to the basic policy questions raised at the outset The calculations in tables 2 and 3 form the basis for the discussion of what can happen under different hypothesized circumstances

5 1 *Tax competition*

Suppose that both jurisdictions start with equal tax on capital in both industries, equal to 20% Given the other jurisdiction's tax policy, would either have an incentive to offer tax breaks on capital? If so, in which industry? If these tax breaks are offered, how do they affect welfare in the other jurisdiction?

According to table 2, jurisdiction 1 would not wish to lower its tax on capital in the x industry, but it would lower the tax on capital in the y industry, if the output demand elasticities are high This would *improve* welfare and wages in jurisdiction 2 Jurisdiction 2 itself would not wish to lower the tax on capital in either industry In the conditions corresponding to table 3, by comparison, *both* jurisdictions would cut the tax on capital in the x industry Such actions are harmful to one's trading partner A tax cut in the y industry is not welfare-improving for either jurisdiction under the conditions assumed in table 3 These results indicate that 'tax competition' may occur with respect to particular industries, not necessarily across the board, and when it occurs it may be harmful to trading partners In the illustrative calculations, however, both jurisdictions would typically wish to *raise* their rates on capital above 20% What is striking is that in doing so, they would *lower* welfare for their trading partner Thus, from the social viewpoint, jurisdictions will often tend to tax capital *too* heavily, even though capital is freely mobile This runs counter to the conventional wisdom that mobile capital results in excessive tax competition and tax rates that are too low Here, if anything, there is too *little* tax competition

5 2 *Tax exporting*

Suppose both jurisdictions start out with zero tax rates on capital This outcome is socially efficient in the model, because labor is inelastically supplied so that taxation of labor is distortionless However, each jurisdiction might find it in its self-interest to deviate from this efficient policy Given the other jurisdiction's tax policy, does either jurisdiction have an incentive to introduce a positive tax on capital, and if so, in which industries and with what impact on the trading partner?

From table 2, it is clear that both jurisdictions can raise both welfare and net wages by introducing taxes on capital in either jurisdiction Thus, there is a tendency for socially excessive taxation of capital Though individually rational, these taxes hurt trading partners [17] Under the conditions assumed in table 3, by contrast, while both jurisdictions would find it advantageous to tax capital in the y industry, they find it better to *subsidize* capital in the x industry The reason is that this distorts the terms of trade in favor of the jurisdiction providing the subsidy Thus, the interindustry trade relationship might offer an incentive not for excessive *taxation* of an industry, but for excessive *subsidy* of an industry

5 3 *Tax harmonization*

0 Is it welfare-improving for the two jurisdictions to harmonize their capital tax structures, by bringing tax rates on capital closer to each other? There are really two questions here First, should each jurisdiction move toward uniform taxation of capital across industries? And second, should tax rates across jurisdictions be brought into uniformity? To put these questions differently, suppose that the two jurisdictions begin with a fully harmonized structure, such as one of those portrayed in tables 2 or 3 Is there any potential gain to be had by moving toward a differentiated structure?

Because tables 2 and 3 assume that the jurisdictions are symmetric in many respects (tax rates, technologies, demand elasticities, factor shares, etc) they make the case for harmonization more appealing than it would be in general But even here it is easy to see how harmonization would break down To take just one example, suppose that the technology in industry x is CES (table 3), that the tax rates on capital in both industries and jurisdictions are initially completely equal at 20%, and that the external demand elasticities for the y goods are low Let each jurisdiction lower its tax on capital in the x industry by \$1, and raise the tax in the y industry by \$1 The welfare change for jurisdiction 1 that results from this differentiation of the tax structure is \$0 388 (increase in R_{1x}) $-0\,033$ (increase in R_{2x}) $+0\,439$ (increase in R_{1y}) $-0\,066$ (increase in R_{2y}) $=$\$0 728, which is to say that 1 gains A similar calculation indicates that 2 gains as well It is not difficult to find other examples of this type Thus, in general harmonization

[17]Note that the two jurisdictions taken together might gain on balance, that is, the gains to one might outweigh the losses to the other This is because the two together are reaping welfare gains at the expense of the rest of the world

of taxes – meaning a move toward uniformity in tax structure – is not optimal policy (Of course, there might be policitical economy or other arguments in favor of harmonization that are not considered here)

The model has many other potential applications For example, suppose that the upstream jurisdiction is an LDC, whose traditional argicultural sector is designated as the x industry, and whose y industry is a more advanced sector that exports some 'primary' commodity (for example, oil, minerals, or electronic or other manufacturing components) to a downstream developed country In this case the 'profits' of the x industry represent the returns to landowners (e g family farms) whereas the wage in the x industry refers to the wage of hired workers As we have seen, tax interventions will often affect these groups within the LDC in quite different ways For instance, taxation of capital in the y industry of the downstream DC often has quite a strong negative impact on wages in the LDC, but this loss is often almost completely offset by increases in the returns to landowners Thus, aside from the overall effect on 'aggregate income', tax changes in the DC can have substantial effects on the distribution of income in the LDC For example, the lower panel of table 2 illustrate cases where, starting with uniform 20% tax rates, a \$1 increase in taxation of capital in the y industry of the DC can lower net wages in the LDC by \$0 14 to \$0 55, while raising net income to landowners by \$0 08 to \$0 29, depending on the output demand elasticity These are surprisingly large impacts

The model presented here is distinguished by its two-sector structure, by its assumptions about the pattern of trade, and by its assumptions about the capital market The role of these key features of the model should be emphasized

First, many models of tax competition assume only one industry in each jurisdiction This means that they cannot be used to study differential taxation by industry, a crucial limitation if we are interested in selective interventions of the type that are frequently used in practice Second, virtually all models that incorporate mobile capital have assumed either that the jurisdictions are large in all markets, including the capital market, or small in all markets, including any output markets For present purposes, however, both of these polar alternatives have serious drawbacks In the small open case, problems of tax harmonization and coordination among a small number of jurisdictions simply do not warrant analysis since, in such a world, the capital tax policy of any one jurisdiction is irrelevant to the output, factor prices, and welfare of any other single jurisdiction For example, if the Benelux countries or the states of New England are truly small and open with respect to all markets, the policies undertaken by one would be of no significance to the others Thus, some degree of 'largeness' on the part of some jurisdictions is a sine qua non for models designed to deal with policy coordination questions in a non-trivial way At the other polar extreme, one could assume that the jurisdictions in question are large relative to the capital market But many jurisdictions are arguably both quite small and quite open with respect to the world capital market

In the light of these observations, and in the light of the basic data mentioned in the introduction, a model that emphasizes intermediate goods trade between neighboring jurisdictions has some appeal The volume of intermediate goods trade is very large And it is reasonable to argue that 'transportation costs', broadly defined to include the cost of acquisition of information about markets, legal institutions, language, etc endow 'neighboring' jurisdictions with some non-trivial degree of influence over each other's terms of trade [18] These essential ingredients of the model developed above allow jurisdictions to have significant impacts on the terms of trade for some commodities while having no impact on the world capital market, thus avoiding an undesirable dichotomization between jurisdictions which are small in all respects and those that are large in all respects As we have seen, this yields a structure in which issues of capital tax interactions are non-degenerate without requiring jurisdictions to be large enough to influence the world net return to capital

It is appropriate to conclude on a cautionary note Although the foregoing analysis has identified situations in which one jurisdiction may find it advantageous to institute industry-specific tax cuts or subsidies (financed by increases in wage taxation), it has also shown that such policies are not always welfare-improving Although special tax preferences of the type that are so popular with policy-makers may conceivably achieve positive economic benefits, popular policy debates on this issue have not focused on determining and verifying the conditions under which such *selective* interventions would be more attractive than alternative policies, such as more broad-based reforms of the capital tax structure The two-sector model developed here does provide potential support for selective interventions (from the narrow perspective of welfare in a single jurisdiction) insofar as it provides a framework within which the alleged benefits of these policies can actually arise (in contrast, for instance, to a one-sector small-open model in which the problem cannot even be posed) On the other hand, a particular configuration of circumstances must be met for selective interventions to be beneficial, and careless application of such policies could easily harm rather than help the jurisdiction undertaking them Finally, the model used here could be generalized in several directions, for example by allowing two-way intermediate goods trade The extent to which results from the present

[18]Indeed, the economic benefits of the large internal market of the United States have been widely recognized Similarly, 'transportation costs in a broad sense undoubtedly provide the main economic (as opposed to political) impetus for regionally-based international trade agreements (the EEC, LAFTA, EFTA, the Canada–U S free trade agreement)

analysis may generalize is obviously an open question, and additional investigation would be of considerable value

Appendix: Derivations of selected analytical results

This appendix does not show all of the detailed derivations of the theoretical results that are used in the theoretical and numerical analysis in the paper, since they are quite lengthy It provides a sample of the derivations so that the reader can understand better the nature of the formal analysis underlying the results in the text In many cases, expressions are presented showing the effect on some endogenous variable of a particular tax rate, whereas the full analysis requires that comparable expressions be developed for changes with respect to other tax rates, for the change in the corresponding endogenous variable in the other jurisdiction, etc Phrases such as 'for instance' or 'expressions such as' are used below to signal the deletion of all but a representative member of such a system of equations The proofs of Propositions 1 and 2 are found in (A 4), (A 15), and (A 16)

The four-equation system (3) and (4) lies at the heart of the analysis The first task is to explain how that system can be used to solve for the changes in net wage rates and outputs in the y industries in terms of exogenous tax parameters

To begin with, the notation $\varepsilon(x,y)$ generally refers to the elasticity of a variable x with respect to y – i e $(y/x)(\partial x/\partial y)$ For elasticities with respect to tax rates, the meaning is slightly different the elasticity of a variable x with respect to some tax rate t is denoted $\varepsilon(x,t)$ and is defined to be $[(1-t)/x](\partial x/\partial t)$ For the constant-returns industries in each jurisdiction i (the y industries), α^i_{yl} and α^i_{yk} refer to the share of labor and capital in total factor cost For the downstream industry, α^1_{ym} denotes the factor share of the intermediate input In the x industry, α^i_{xk} and α^i_{xl} denote outlays for capital and labor as a proportion of total factor outlays (thus $\alpha^i_{xk}+\alpha^i_{xl}=1$) The share of workers employed in the x industry in jurisdiction i is denoted σ_i The share of the intermediate input sold on the external market (i e not sold to jurisdiction 1) is e

From differentiation of (4 1) and (4 2), one obtains the elasticities of y_1 and y_2 with respect to the gross factor prices

$$\varepsilon(y_1,w_1)=\varepsilon(q_1,p_1)\alpha^1_{yl}, \tag{A 1 1}$$

$$\varepsilon(y_1,r_{1y})=\varepsilon(q_1,p_1)\alpha^1_{yk}, \tag{A 1 2}$$

$$\varepsilon(y_1,w_2)=\varepsilon(q_1,p_1)\alpha^1_{ym}\alpha^2_{yl}, \tag{A 1 3}$$

$$\varepsilon(y_1,r_{2y})=\varepsilon(q_1,p_1)\alpha^1_{ym}\alpha^2_{yk}, \tag{A 1 4}$$

$$\varepsilon(y_2, w_1) = (1-e)[\varepsilon(q_1, p_1)\alpha_{yl}^1 + \varepsilon(\mu_1, w_1)], \tag{A 1 5}$$

$$\varepsilon(y_2, r_{1y}) = (1-e)[\varepsilon(q_1, p_1)\alpha_{yk}^1 + \varepsilon(\mu_1, r_{1y})], \tag{A 1 6}$$

$$\varepsilon(y_2, w_2) = e\varepsilon(q_2, p_2)\alpha_{yl}^2 + (1-e)[\varepsilon(q_1, p_1)\alpha_{ym}^1\alpha_{yl}^2 + \varepsilon(\mu_1, p_2)\alpha_{yl}^2], \tag{A 1 7}$$

$$\varepsilon(y_2, r_{2y}) = e\varepsilon(q_2, p_2)\alpha_{yk}^2 + (1-e)[\varepsilon(q_1, p_1)\alpha_{ym}^1\alpha_{yk}^2 + \varepsilon(\mu_1, p_2)\alpha_{yk}^2] \tag{A 1 8}$$

Substitute eqs (4) into eqs (3), eliminating y_1 and y_2 This leaves a two-equation system in the variables w_1, w_2, r_{1x}, r_{1y}, r_{2x}, and r_{2y} – that is, the gross factor prices But the gross factor prices depend on tax rates and net factor prices Making this substitution, eqs (3) become a two-equation system that can be used to determine the equilibrium net wages in each jurisdiction as functions of the tax parameters Thus, differentiation of the system (3) yields

$$\begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix}\begin{pmatrix} \mathrm{d}\log\omega_1 \\ \mathrm{d}\log\omega_2 \end{pmatrix} = \begin{pmatrix} -a_{11} & -a_{12} \\ -a_{21} & -a_{22} \end{pmatrix}\begin{pmatrix} \dfrac{\mathrm{d}\tau_1}{1-\tau_1} \\ \dfrac{\mathrm{d}\tau_2}{1-\tau_2} \end{pmatrix} + \begin{pmatrix} b_{11} & b_{12} & b_{13} & b_{14} \\ b_{21} & b_{22} & b_{23} & b_{24} \end{pmatrix}\begin{pmatrix} \dfrac{\mathrm{d}t_{1x}}{1-t_{1x}} \\ \dfrac{\mathrm{d}t_{1y}}{1-t_{1y}} \\ \dfrac{\mathrm{d}t_{2x}}{1-t_{2x}} \\ \dfrac{\mathrm{d}t_{2y}}{1-t_{2y}} \end{pmatrix}, \tag{A 2}$$

where, letting $\sigma_i = l_{ix}/l_i$ denote the proportion of workers employed in industry x, jurisdiction i,

$$a_{11} = \sigma_1\varepsilon(l_{1x}, w_1) + (1-\sigma_1)[\varepsilon(y_1, w_1) + \varepsilon(\lambda_1, w_1)],$$

$$a_{12} = (1-\sigma_1)[\varepsilon(y_1, w_2) + \varepsilon(\lambda_1, p_2)\alpha_{yl}^2],$$

$$a_{21} = (1-\sigma_2)\varepsilon(y_2, w_1),$$

$$a_{22} = \sigma_2\varepsilon(l_{2x}, w_2) + (1-\sigma_2)[\varepsilon(y_2, w_2) + \varepsilon(\lambda_2, w_2)],$$

and where

$$b_{11} = -\sigma_1 \varepsilon(l_{1x}, r_{1x}), \qquad b_{21} = 0,$$

$$b_{12} = -(1-\sigma_1)[\varepsilon(y_1, r_{1y}) + \varepsilon(\lambda_1, r_{1y})], \qquad b_{22} = -(1-\sigma_2)\varepsilon(y_2, r_{1y}),$$

$$b_{13} = 0, \qquad b_{23} = -\sigma_2 \varepsilon(l_{2x}, r_{2x}),$$

$$b_{14} = -(1-\sigma_1)[\varepsilon(y_1, r_{2y}) + \varepsilon(\lambda_1, p_2)\alpha_{yk}^2],$$

$$b_{24} = -(1-\sigma_2)[\varepsilon(y_2, r_{2y}) + \varepsilon(\lambda_2, r_{2y})]$$

Let A denote the matrix on the left-hand side of (A 2) Assuming that $\varepsilon(q_i, p_i) < 0$, both i, $a_{11} < 0$ and $a_{22} < 0$ Both of the off-diagonal elements a_{12} and a_{21} are theoretically ambiguous in sign, since they involve the cross-effects of the intermediate input price on the demand for labor, and of the wage rate on the demand for the intermediate input, respectively If these off-diagonal elements are sufficiently small that they do not dominate the direct effects, which is a weak empirical restriction, it will be the case that $|A| > 0$ This condition will be assumed to hold henceforth Eqs (3) can then be solved implicitly for the equilibrium net wage rates in the neighborhood of some initial equilibrium

From (A 2) one can compute

$$\varepsilon(\omega_1, \tau_1) = \varepsilon(\omega_2, \tau_2) = -1, \tag{A 3 1}$$

$$\varepsilon(\omega_2, \tau_1) = \varepsilon(\omega_1, \tau_2) = 0 \tag{A 3 2}$$

and

$$\varepsilon(\omega_1, t_{1x}) = \frac{-\sigma_1 \varepsilon(l_{1x}, r_{1x}) a_{22}}{|A|}, \tag{A 4 1}$$

$$\varepsilon(\omega_2, t_{1x}) = \frac{\sigma_1 \varepsilon(l_{1x}, r_{1x}) a_{21}}{|A|}, \tag{A 4 2}$$

$$\begin{aligned}\varepsilon(\omega_1, t_{1y}) = |A|^{-1}[&-(1-\sigma_1)(\varepsilon(y_1, r_{1y}) + \varepsilon(\lambda_1, r_{1y}))a_{22} \\ &+ (1-\sigma_2)\varepsilon(y_2, r_{1y})(1-\sigma_1)(\varepsilon(y_1, w_2) + \varepsilon(\lambda_1, p_2)\alpha_{yl}^2)],\end{aligned} \tag{A 4 3}$$

$$\begin{aligned}\varepsilon(\omega_2, t_{1y}) = |A|^{-1}[&-\alpha_{11}(1-\sigma_2)\varepsilon(y_2, r_{1y}) \\ &+ (1-\sigma_2)\varepsilon(y_2, w_1)(1-\sigma_1)(\varepsilon(y_1, r_{1y}) + \varepsilon(\lambda_1, r_{1y}))]\end{aligned} \tag{A 4 4}$$

These elasticities are general equilibrium responses is that they are based on labor market clearing in both jurisdictions However, they ignore the changes in the tax rate on labor income that must occur to maintain government budget balance In view of (A 3), any adjustments of the labor tax rate will change the net wage but will leave the gross wage unchanged Thus, (A 4) show the general equilibrium changes in *gross* wages Note that the sign of the effect of a tax increase in the x industry on the gross wage is the same as the sign of $\varepsilon(l_{1x}, r_{1x})$ To obtain the net wage change for balanced-budget changes in tax policy requires further analysis

First, is necessary to calculate the impact of changes in t_{1x} and t_{1y} on y_1 and y_2, taking into account the changes in wages in each jurisdiction These elasticities are obtained by differentiation of (3) For instance,

$$\varepsilon(y_1, t_{1x}) = \varepsilon(y_1, w_1)\varepsilon(\omega_1, t_{1x}) + \varepsilon(y_1, w_2)t(\omega_2, t_{1x}) \tag{A 5}$$

It is also necessary to compute the effect of changes in t_{1x} and t_{1y} on the amount of capital in each industry and in each jurisdiction Differentiation of the factor demand functions yields expressions such as

$$\varepsilon(k_{1x}, t_{1x}) = \varepsilon(k_{1x}, w_1)\varepsilon(\omega_1, t_{1x}) + \varepsilon(k_{1x}, r_{1x}) \tag{A 6}$$

To determine the effect of capital taxes in jurisdiction 1 on profits in each jurisdiction, define $\beta^i_{xl} = w_i l_{ix}/\pi^i_x$ and $\beta^i_{xk} = r_{ix}k_{ix}/\pi^1_x$ Using basic properties of the profit function, one obtains expressions like

$$\varepsilon(\pi^1_x, t_{1x}) = -\beta^1_{xl}\varepsilon(\omega_1, t_{1x}) - \beta^1_{xk} \tag{A 7}$$

Assume now that the tax rates on labor income in each jurisdiction adjust so as to keep total revenue and thus expenditure constant Differentiating the government budget constraints [eqs (2) in the text] and solving for the labor income tax rates in terms of the capital income tax rates, one obtains expressions like

$$\begin{aligned} -\frac{(1-t_{1x})}{(1-\tau_1)}\frac{\partial \tau_1}{\partial t_{1x}} &= \tau_1\varepsilon(\omega_1, t_{1x}) \\ &\quad + \frac{\sigma_1\alpha^1_{xk}}{\alpha^1_{xl}}(1 + t_{1x}\varepsilon[k_{1x}, t_{1x}]) + t_{1y}\frac{(1-\sigma_1)\alpha^1_{yk}}{\alpha^1_{yl}}\varepsilon(k_{1y}, t_{1x}) \\ &\quad + \theta_1\frac{\sigma_1}{\beta^1_{xl}}\varepsilon(\pi^1_x, t_{1x}) \end{aligned} \tag{A 8 1}$$

and

$$\begin{aligned} -\frac{(1-t_{1y})}{(1-\tau_1)}\frac{\partial \tau_1}{\partial t_{1y}} &= \tau_1\varepsilon(\omega_1, t_{1y}) + t_{1x}\frac{\sigma_1\alpha^1_{xk}}{\alpha^1_{xl}}\varepsilon(k_{1x}, t_{1y}) \\ &\quad + \frac{(1-\sigma_1)\alpha^1_{yk}}{\alpha^1_{yl}}(1 + t_{1y}\varepsilon[k_{1y}, t_{1y}]) + \theta_1\frac{\sigma_1}{\beta^1_{xl}}\varepsilon(\pi^1_x, t_{1y}) \end{aligned} \tag{A 8 2}$$

It is now possible to compute the impact of balanced-budget changes in capital taxation in jurisdiction 1 on net wages, by combining results from (A 4) with (A 3) and the total differentials of the revenue constraints Letting $(1-t_{1x})\,\mathrm{d}\log\omega_1/\mathrm{d}t_{1x}$ denote the *total* elasticity of ω_1 with respect to t_{1x} and similarly for the other derivatives, we have

$$\frac{(1-t_{1x})\,\mathrm{d}\log\omega_1}{\mathrm{d}t_{1x}}=\varepsilon(\omega_1,t_{1x})+(1-t_{1x})\frac{\partial\log\omega_1}{\partial\tau_1}\frac{\partial\tau_1}{\partial t_{1x}}$$

$$=\varepsilon(\omega_1,t_{1x})-\frac{(1-t_{1x})}{(1-\tau_1)}\frac{\partial\tau_1}{\partial t_{1x}},\tag{A 9}$$

and similarly for the change in net wages in each jurisdiction with respect to capital taxes in jurisdiction 1

The effect of changes in t_{1x} on total net income ξ_1 is given by

$$\varepsilon(\xi_1,t_{1x})=\frac{\omega_1}{\xi_1}(1-t_{1x})\frac{\mathrm{d}\log\omega_1}{\mathrm{d}t_{1x}}+\frac{s_1}{l_1}(1-\theta_1)\frac{\pi_x^1}{\xi_1}\varepsilon(\pi_x^1,t_{1x}),\tag{A 10}$$

similar expressions are obtained for the change in ξ_1 with respect to t_{1y}, and for the change in ξ_2 with respect to both tax rates in jurisdiction 1 The expressions in (A 9) and (A 10) can be written out in greater detail by repeated substitution from previous equations In general, they are complex and not easily evaluated from an a priori viewpoint It is straightforward to evaluate them numerically, however

Eqs (A 9) and (A 10), showing the *percentage* change in wages and income resulting from a given *percentage* change in tax rates, can be used to express the *dollar* amount of income change per *dollar* change in tax revenue using (A 8) Let R_{1x} denote the change in revenue in jurisdiction 1 from a 1 percent increase in t_{1x} Then the change in wage income in jurisdiction 1 per dollar of additional revenue collected by raising the capital income tax rate in industry x (taking general equilibrium effects on revenue into account) is

$$\frac{\mathrm{d}\omega_1 l_1/\mathrm{d}t_{1x}}{R_{1x}/(1-t_{1x})}=\frac{(1-\tau_1)w_1 l_1}{R_{1x}}\left[\frac{(1-r_{1x})\,\mathrm{d}\log\omega_1}{\mathrm{d}t_{1x}}\right]$$

$$=(1-\tau_1)\left[-\frac{(1-t_{1x})}{(1-\tau_1)}\frac{\partial\tau_1}{\partial t_{1x}}\right]^{-1}\left[\frac{(1-t_{1x})\,\mathrm{d}\log\omega_1}{\mathrm{d}t_{1x}}\right],\tag{A 11}$$

which can be calculated using (A 8) and (A 9) Similar expressions show the effect of changes in taxation of capital in industry y on net wage income in both jurisdictions

The change in total income per dollar change in revenue collected for the capital taxes in jurisdiction 1 is obtained in the same way from (A 10) and related equations, for instance,

$$\frac{\mathrm{d}\xi_1 l_1/\mathrm{d}t_{1x}}{R_{1x}/(1-t_{1x})}=\frac{\xi_1 l_1}{R_{1x}}\varepsilon(\xi_1,t_{1x})$$

$$=\left(\frac{R_{1x}}{w_1 l_1}\right)^{-1}\left((1-\tau_1)+s_1(1-\theta_1)\frac{\pi_x^1}{w_1 l_1}\right)\varepsilon(\xi_1,t_{1x})$$

$$=\left(-\frac{(1-t_{1x})}{(1-\tau_1)}\frac{\partial\tau_1}{\partial t_{1x}}\right)^{-1}\left((1-\tau_1)+s_1(1-\theta_1)\frac{\sigma_1}{\beta_{xl}^1}\right)\varepsilon(\xi_1,t_{1x}) \tag{A 12}$$

A special case Zero initial tax rates and perfect complementarity in the y industries

In the special case where all tax rates are initially zero, feedback effects of policy changes on tax revenue are negligible, and much of the analysis simplifies For example, eq (A 9) becomes

$$\frac{(1-t_{1x})\,\mathrm{d}\log\omega_1}{dt_{1x}}=\varepsilon(\omega_1,t_{1x})+\frac{\alpha_{xk}^1}{\alpha_{xl}^1}\sigma_1 \tag{A 13}$$

If all inputs are perfect complements in the y industries in both jurisdictions, all expressions such as $\varepsilon(\mu_1,r_{1y})$, $\varepsilon(\lambda_1,p_2)$, etc become zero In this case, (A 4 3) shows that taxation of the y industry lowers the gross wage in jurisdiction 1 Also,

$$|A|=\sigma_1\sigma_2\varepsilon(l_{1x},w_1)\varepsilon(l_{2x},w_2)+\sigma_1(1-\sigma_2)e\varepsilon(l_{1x},w_1)\varepsilon(q_2,p_2)\alpha_{yl}^2$$

$$+\sigma_1(1-\sigma_2)(1-e)\varepsilon(l_{1x},w_1)\varepsilon(q_1,p_1)\alpha_{ym}^1\alpha_{yl}^2$$

$$+(1-\sigma_1)\sigma_2\varepsilon(q_1,p_1)\varepsilon(l_{2x},w_2)\alpha_{yl}^1$$

$$+(1-\sigma_1)(1-\sigma_2)e\varepsilon(q_1,p_1)\varepsilon(q_2,p_2)\alpha_{yl}^1\alpha_{yl}^2 \tag{A 14}$$

The expressions for net wage change under our simplifying assumptions are obtained from equations like (A 9) After some manipulation, one can derive

$$\frac{(1-t_{1x})\,\mathrm{d}\log\omega_1}{\mathrm{d}t_{1x}} = -\sigma_1\varepsilon(l_{1x},r_{1x})[\sigma_2\varepsilon(l_{2x},w_2)+(1-\sigma_2)(e\varepsilon(q_2,p_2)\alpha_{yl}^2$$

$$+(1-e)\varepsilon(q_1,p_1)\alpha_{ym}^1\alpha_{yl}^2)]|A|^{-1}+\frac{\alpha_{xk}^1}{\alpha_{xl}^1}\sigma_1, \qquad \text{(A 15 1)}$$

$$\frac{(1-t_{1y})\,\mathrm{d}\log\omega_1}{\mathrm{d}t_{1y}} = \sigma_1(1-\sigma_1)\alpha_{yk}^1\Bigg[\frac{\varepsilon(l_{1x},w_1)}{\alpha_{yl}^1}(\sigma_2\varepsilon(l_{2x},w_2)$$

$$+(1-\sigma_2)\alpha_{yl}^2[e\varepsilon(q_2,p_2)+(1-e)\varepsilon(q_1,p_1)\alpha_{ym}^1])$$

$$-\varepsilon(q_1,p_1)(\sigma_2\varepsilon(l_{2x},w_2)+(1-\sigma_2)e\varepsilon(q_2,p_2)\alpha_{yl}^2)\Bigg]|A|^{-1},$$

$$\text{(A 15 2)}$$

$$\frac{(1-t_{1x})\,\mathrm{d}\log\omega_2}{\mathrm{d}t_{1x}} = \frac{\sigma_1\varepsilon(l_{1x},r_{1x})(1-\sigma_2)(1-e)\varepsilon(q_1,p_1)\alpha_{yl}^1}{|A|}, \qquad \text{(A 15 3)}$$

$$\frac{(1-t_{1y})\,\mathrm{d}\log\omega_2}{\mathrm{d}t_{1y}} = -(1-e)\varepsilon(q_1,p_1)\alpha_{yk}^1(1-\sigma_2)\sigma_1\varepsilon(l_{1x},w_1)|A|^{-1} \qquad \text{(A 15 4)}$$

The terms in these equations can be signed as asserted in Propositions 1 and 2

To see how a change in tax policy affects net income, one need only substitute into eqs (A 10) using (A 7) and (A 15) In the important special case where all profits (or returns to the fixed factor) accrue to local residents in each jurisdiction, one obtains

$$\varepsilon(\xi_1,t_{1x}) = \frac{\omega_1}{\xi_1}(1-\sigma_1)(-\sigma_1\varepsilon(l_{1x},r_{1x})[\sigma_2\varepsilon(l_{2x},\omega_2)+(1-\sigma_2)(e\varepsilon(q_2,p_2)\alpha_{yl}^2$$

$$+(1-e)\varepsilon(q_1,p_1)\alpha_{ym}^1\alpha_{yl}^2)]|A|^{-1}), \qquad \text{(A 16 1)}$$

$$\varepsilon(\xi_1,t_{1y}) = \frac{\omega_1}{\xi_1}\sigma_1\varepsilon(l_{1x},w_1)\frac{\alpha_{yk}^1}{\alpha_{yl}^1}[\sigma_2\varepsilon(l_{2x},w_2)$$

$$+(1-\sigma_2)\alpha_{yl}^2(e\varepsilon(q_2,p_2)+(1-e)\varepsilon(q_1,p_1)\alpha_{ym}^1)]|A|^{-1} \qquad \text{(A 16 2)}$$

The first of these expressions takes the same sign as $\varepsilon(l_{1x},r_{1x})$, whereas the second is unambiguously positive The direction of effect of tax rates in jurisdiction 1 on welfare in jurisdiction 2 must be the same as the direction of effect on net wages, since they only differ by a partial offset in profits

The analysis of the effects of changes in policy for the upstream jurisdiction parallels that for the downstream case, and none of the calculations for this case will be presented here

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