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Ramsey Taxation in the Global Economy

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Abstract

We study cooperative optimal Ramsey equilibria in the open economy, addressing classic policy questions: Should restrictions be placed to free trade and capital mobility? Should capital income be taxed? Should goods be taxed based on origin or destination? What are desirable border adjustments? How can a Ramsey allocation be implemented with residence-based taxes on assets? We characterize optimal wedges and analyse alternative policy implementations.

Keywords: Capital income tax; free trade; value-added taxes; border adjustment; origin- and destination-based taxation; production efficiency

JEL Codes: E60; E61; E62

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1 Introduction

In this paper we study cooperative Ramsey equilibria in the open economy, addressing classic policy questions such as: Should restrictions be placed on free trade and capital mobility? Should capital income be taxed? Should goods be taxed based on origin or destination? What are desirable border adjustments? How can the Ramsey equilibrium be implemented with residence-based taxation of asset income?

We take the Ramsey approach to optimal taxation, in that the tax system is exogenously given. We consider taxes widely used in practice in developed economies. Those include consumption and labor income taxes, taxes on capital income, equity returns, and returns on foreign assets, as well as value-added taxes with and without border adjustments. As is well known, many tax policies yield the same distortions, and the theory pins down those distortions in choices. Following the public finance literature, we refer to these distortions as wedges.

The first main question we address is, what are the optimal wedges? In particular, we ask whether the Ramsey equilibrium yields intertemporal wedges. If it does, we say that future capital is taxed. If it does not, we say that future capital is not taxed. No intertemporal wedges implies that intratemporal wedges are constant over time. This means that uniform taxation is optimal. We also ask whether the Ramsey allocations distort conditions for production efficiency associated with free trade. The second main question addressed in this paper is, how can the optimal wedges be implemented? We consider implementations that, we believe, are of interest to policy design.

The model is a neoclassical growth model with two countries with intermediate goods that are traded internationally, as in Backus, Kehoe, and Kydland (1994). A useful feature of the model is that it nests the closed economy neoclassical growth model. We characterize the optimal cooperative Ramsey allocations and determine what are optimal inter- and intratemporal wedges as well as wedges on the movement of goods across borders. We determine the minimal set of fiscal instruments that implement those allocations and study alternative sets of instruments that implement those same allocations.

For general preferences, capital should not be taxed in the steady state, and there is no presumption that it ought to be taxed along the transition. A subsidy may be optimal. Another main result is that free trade, required for production efficiency, is also optimal. In addition, for standard macro preferences with constant elasticities, it is not optimal to ever impose intertemporal wedges, meaning that it is not optimal to tax capital. This result holds for the steady state but also for the transition.

A minimal set of instruments to implement the Ramsey allocation are consumption and labor income taxes. There is no need for taxes on income from assets.[1] For standard macro preferences, only a constant tax on either labor or consumption, possibly different across countries, is necessary to implement the Ramsey allocation.

We move on to study alternative implementations in which assets are taxed. We construct a residence-based tax system with capital income taxes on firms and a country-specific, common tax on equity returns and returns from foreign assets. These taxes, together with either a labor income tax or a consumption tax, implement the Ramsey allocation. Capital income taxes are optimally set to zero. We also consider alternative ways of taxing goods, in particular, value-added taxes with and without border adjustments. A tax system with value-added taxes with border adjustments is equivalent to the system with consumption taxes. However, a value-added tax without border adjustment in general would distort the allocation of capital across countries. Compensating, time-varying tariffs can undo those distortions. We discuss the implications of these results for the desirability of origin- versus destination-based taxation of consumption.

There is a literature on value-added taxes with and without border adjustments.[2] Grossman (1980), and Feldstein and Krugman (1990) show in static models that border adjustments are irrelevant.[3] Barbiero, Farhi, Gopinath, and Itskhoki (2017) make the same point in a dynamic model with labor only. In our model with capital, border adjustments matter.

Because the neoclassical growth model is nested in the open economy model we study, the results on intertemporal and intratemporal wedges also apply in the closed economy model. So in the closed economy there is also no presumption that capital income should be taxed, not only in the steady state but also along the transition. This result is in contrast with influential results in the literature on the optimal taxation of capital. Chamley (1986) and Judd (1985) show that capital should be taxed at its maximum level initially and for a number of periods. Bassetto and Benhabib (2006)

[1]This does not mean that capital is not taxed, since intertemporal distortions may be optimal along the transition for general preferences.

[2]See Auerbach, Devereux, Keen, and Vella (2017) for a policy evaluation of the recent destination-based cash flow tax proposal.

[3]See also Dixit (1985).

and Straub and Werning (2015) show that full taxation of capital can last forever.[4] This literature leads to the presumption that capital taxes should be high at least for some time. Two assumptions are important for the contrasting results. The first assumption concerns the confiscation of initial wealth. We assume, in line with Armenter (2008), that confiscation is restricted both directly and indirectly through valuation effects. The literature instead only restricts direct confiscation. The second assumption is on the available instruments. In contrast with the literature, we allow for a rich set of fiscal instruments.[5] The contrasting results are explained in detail in a companion paper on capital taxation in the closed economy by Chari, Nicolini and Teles (2016).

Chari et al. (2016) also show, extending results in Werning (2007), that heterogeneity in initial endowments of capital does not affect the optimal wedges. They also relate the results on the optimal taxation of capital to the ones on uniform commodity taxation in Atkinson and Stiglitz (1972) and optimality of production efficiency in Diamond and Mirrlees (1971).

The paper is organized as follows. In Section 2, we present the two-country economy model with consumption and labor income taxes. We compute optimal Ramsey allocations, show that trade should not be restricted, and show that, for standard macro preferences, capital should never be taxed. In Section 3, we consider alternative tax systems that implement the same Ramsey optimal allocation. We first consider a common tax on income from domestic equity and from foreign assets, together with a profit tax (Section 3.1). We also discuss alternative ways of taxing consumption through value-added taxes with and without border adjustment (Sections 3.2 and 3.3). Section 4 concludes.

2 A two-country economy

There are two countries in this economy indexed by $i = 1, 2$. The preferences of a representative household in each country are over consumption c_{it} and labor n_{it},

$$U^i = \sum_{t=0}^{\infty} \beta^t u^i \left(c_{it}, n_{it}\right), \tag{1}$$

[4] Other relevant literature includes Chari, Christiano, Kehoe (1994), Atkeson, Chari and Kehoe (1999), Coleman (2000), Judd (1999, 2002), and Lucas and Stokey (1983).

[5] With a rich set of instruments, if indirect confiscation through valuation effects was allowed for, it would distort capital accumulation in the first period only.

satisfying the usual properties.

Following Backus, Kehoe and Kydland (1994) only intermediate goods are traded. Final goods are not traded.

Each country, $i = 1, 2$, produces a country specific intermediate good, y_{it}, according to a production technology given by

$$y_{i1t} + y_{i2t} = y_{it} = F^i\left(k_{it}, n_{it}\right), \tag{2}$$

where y_{ijt} denotes the quantity of intermediate goods produced in country i and used in country $j = 1, 2$, k_{it} is the capital stock, n_{it} is labor input and F^i is constant returns to scale. The intermediate goods produced by each country are used to produce a country specific final good that can be used for private consumption, c_{it}, public consumption, g_{it}, and investment, x_{it}, according to

$$c_{it} + g_{it} + x_{it} \leq G^i\left(y_{1it}, y_{2it}\right), \tag{3}$$

where G^i is constant returns to scale. Capital accumulates according to the law of motion

$$x_{it} = k_{it+1} - (1 - \delta)\, k_{it}. \tag{4}$$

If lump sum taxes and transfers across countries are available, the allocations on the Pareto frontier satisfy the following efficiency: conditions,

$$-\frac{u^i_{ct}}{u^i_{nt}} = \frac{1}{G^i_{i,t} F^i_{nt}},\ i = 1, 2 \tag{5}$$

$$\frac{u^i_{c,t}}{\beta u^i_{c,t+1}} = 1 - \delta + G^i_{i,t+1} F^i_{kt+1},\ i = 1, 2 \tag{6}$$

$$\frac{G^1_{j,t}}{G^1_{j,t+1}}\left[G^1_{1,t+1} F^1_{k,t+1} + 1 - \delta\right] = \frac{G^2_{j,t}}{G^2_{j,t+1}}\left[G^2_{2,t+1} F^2_{k,t+1} + 1 - \delta\right],\ j = 1, 2 \tag{7}$$

$$\frac{G^1_{1,t}}{G^2_{1,t}} = \frac{G^1_{2,t}}{G^2_{2,t}}, \tag{8}$$

which, together with the resource constraints, characterize the Pareto frontier.

The conditions above mean that there are no intratemporal wedges (conditions (5)), no intertemporal wedges ((conditions (7)), and no production distortions (conditions

(6) and (8)). Conditions (5) set the marginal rate of substitution between consumption and labor equal to the marginal productivity in each country. Conditions (6) equate the intertemporal marginal rate of substitution to the marginal productivity of capital. Conditions (7) equate the marginal rates of transformation of the same intermediate good in the two countries, and conditions (8) equate the marginal rates of technical substitution for the two intermediate goods.

We can use the intratemporal and intertemporal conditions, (5) and (6), to write the intertemporal condition for labor,

$$\frac{u^i_{nt}}{\beta u^i_{n,t+1}} = \frac{G^i_{i,t} F^i_{nt}}{G^i_{i,t+1} F^i_{n,t+1}} \left[1 - \delta + G^i_{i,t+1} F^i_{kt+1}\right], \; i = 1, 2. \tag{9}$$

We explicitly characterize this intertemporal labor margin because are interested in understanding when it is optimal not to distort this margin.

Next we consider an economy with distorting taxes. Throughout we allow for transfers across governments.[6] We begin by considering only country-specific consumption and labor income taxes. We then include a richer tax system with alternative taxes and discuss alternative implementations.

2.1 Competitive equilibria with consumption and labor income taxes

We now describe a competitive equilibrium with taxes in which governments finance public consumption and initial debt with proportional taxes on consumption and labor income, τ^c_{it} and τ^n_{it}, as well as a tax on initial wealth, l_{i0}.

Each country has two types of firms. Given that the technologies are constant returns to scale, we assume, without loss of generality, that there are two types of representative firms. The *intermediate good firm* in each country uses the technology in (2) to produce the intermediate good using capital and labor, purchases investment goods, and accumulates capital according to (4). Let V_{i0} be the value of the firm in period zero after the dividend paid in that period, d_{i0}. The intermediate good firm

[6] We solve for the whole Pareto frontier. It can be shown that there are welfare weights such that transfers are zero.

maximizes the value of dividends

$$V_{i0} + d_{i0} = \sum_{t=0}^{\infty} Q_t \left[p_{it} \left(y_{i1t} + y_{i2t} \right) - w_{it} n_{it} - q_{it} x_{it} \right] \tag{10}$$

subject to (2) and (4), where p_{it} is the price of the intermediate good in units of a numeraire (or common money across countries) at t, w_{it} is the wage rate, and q_{it} is the price of investment, or equivalently of the final good, all in units of the same numeraire. Q_t is the intertemporal price of the common numeraire at time t in units of the numeraire at zero ($Q_0 = 1$). Because the intermediate goods are traded, and there are no tariffs, the prices of each of the intermediate goods are the same in the two countries.

If we define r_{t+1}^f to be the return on one period bonds in units of the numeraire between period t and $t+1$, then it must be the case that

$$\frac{Q_t}{Q_{t+1}} = 1 + r_{t+1}^f, \text{ for } t \geq 0. \tag{11a}$$

The *final goods firm* in each country uses the technology in (3) to produce the final good using foreign and domestically produced intermediate goods to maximize the value of dividends

$$\sum_{t=0}^{\infty} Q_t \left[q_{it} G^i \left(y_{1it}, y_{2it} \right) - p_{1t} y_{1it} - p_{2t} y_{2it} \right]. \tag{12}$$

This problem reduces to a sequence of static problems.

Household The household budget constraint in each country is

$$\sum_{t=0}^{\infty} Q_t \left[q_{it} \left(1 + \tau_{it}^c \right) c_{it} - \left(1 - \tau_{it}^n \right) w_{it} n_{it} \right] \leq \left(1 - l_{i0} \right) a_{i0}, \tag{13}$$

with

$$a_{i0} = V_{i0} + d_{i0} + Q_{-1} b_{i0} + \left(1 + r_0^f \right) f_{i0},$$

where a_{i0} denotes net holdings of assets by the household of country i, $Q_{-1} b_{i0}$ denotes holdings of domestic public debt in units of the numeraire, inclusive of interest, and $\left(1 + r_0^f \right) f_{i0}$ denotes holdings of claims on households in the other country, in units of the numeraire, also inclusive of interest. Without loss of generality, households within a country hold claims to the firms in that country as well as the public debt of the government of that country. There is an internationally traded bond.

The household's problem is to maximize utility (1) subject to (13).

Government The budget constraint of the government of each country is given by

$$\sum_{t=0}^{\infty} Q_t \left[\tau_{it}^c q_{it} c_{it} + \tau_{it}^n w_{it} n_{it} - q_{it} g_{it}\right] + l_{i0} a_{i0} = Q_{-1} b_{i0} - T_{i0}, \tag{14}$$

where T_{i0} denotes transfers received by the government of country i from other governments, so that

$$T_{10} + T_{20} = 0. \tag{15}$$

The budget constraints of the government and the household (with equality) in each country imply

$$\sum_{t=0}^{\infty} Q_t \left[p_{it} y_{it} - q_{it} \left(c_{it} + g_{it} + x_{it}\right)\right] = -\left(1 + r_0^f\right) f_{i0} - T_{i0}, \tag{16}$$

which can be written as the balance of payments condition

$$\sum_{t=0}^{\infty} Q_t \left[p_{it} y_{ijt} - p_{jt} y_{jit}\right] = -\left(1 + r_0^f\right) f_{i,0} - T_{i0} \tag{17}$$

with $\left(1 + r_0^f\right) f_{1,0} + \left(1 + r_0^f\right) f_{2,0} = 0$.

A *competitive equilibrium* for this economy consists of a set of allocations $\{c_{it}, n_{it}, y_{ijt}, k_{it+1}, x_{it}\}$ and d_{i0}, prices $\{q_{it}, p_{it}, w_{it}, Q_t, V_{i0}\}$, and policies $\{\tau_{it}^c, \tau_{it}^n, l_{i0}, T_{i0}\}$, given $\left\{k_{i0}, Q_{-1} b_{i0}, \left(1 + r_0^f\right) f_{i0}\right\}$ such that households maximize utility subject to their constraints, firms maximize value, the balance of payments conditions (17) hold, and markets clear in that (2), (3), and (4) together with (15) are satisfied.

Note that we have not explicitly specified the governments' budget constraints because they are implied by the other constraints.

We say that an allocation $\{c_{it}, n_{it}, y_{ijt}, k_{it+1}, x_{it}\}$ is *implementable* if it is part of a competitive equilibrium.

The first order conditions of the household's problem include

$$-\frac{u^i_{c,t}}{u^i_{n,t}} = \frac{(1+\tau^c_{it})\, q_{it}}{(1-\tau^n_{it})\, w_{it}}, \tag{18}$$

$$\frac{u^i_{c,t}}{(1+\tau^c_{it})} = \frac{Q_t q_{it}}{Q_{t+1} q_{it+1}} \frac{\beta u^i_{c,t+1}}{\left(1+\tau^c_{it+1}\right)}, \tag{19}$$

for all $t \geq 0$, where $u^i_{c,t}$ and $u^i_{n,t}$ denote the marginal utilities of consumption and labor in period t.

The first order conditions of the firms' problems are, for all $t \geq 0$,

$$p_{it} F^i_{n,t} = w_{it} \tag{20}$$

$$Q_t q_{it} = Q_{t+1} p_{it+1} F^i_{k,t+1} + Q_{t+1} q_{it+1} (1-\delta), \tag{21}$$

where $F^i_{n,t}$ and $F^i_{k,t}$ denote the marginal products of capital and labor in period t, together with

$$q_{it} G^i_{j,t} = p_{jt}. \tag{22}$$

By combining the household's and firm's equilibrium conditions, it can be shown that the value of the firm in (10) is

$$V_{i0} + d_{i0} = q_{i0} \left[1 - \delta + G^i_{i,0} F^i_{k,0}\right] k_{i0}. \tag{23}$$

The first order conditions can be rearranged as

$$-\frac{u^i_{c,t}}{u^i_{n,t}} = \frac{(1+\tau^c_{it})}{(1-\tau^n_{it})\, G^i_{i,t} F^i_{n,t}} \tag{24}$$

$$\frac{u^i_{c,t}}{\beta u^i_{c,t+1}} = \frac{(1+\tau^c_{it})}{\left(1+\tau^c_{it+1}\right)} \left[G^i_{i,t+1} F^i_{k,t+1} + 1 - \delta\right], \tag{25}$$

as well as (7) and (8), repeated here,

$$\frac{G^1_{j,t}}{G^1_{j,t+1}} \left[G^1_{1,t+1} F^1_{k,t+1} + 1 - \delta\right] = \frac{G^2_{j,t}}{G^2_{j,t+1}} \left[G^2_{2,t+1} F^2_{k,t+1} + 1 - \delta\right],\ j = 1, 2$$

$$\frac{G^1_{2,t}}{G^1_{1,t}} = \frac{G^2_{2,t}}{G^2_{1,t}}$$

for all $t \geq 0$.

Comparing these conditions with the ones for the Pareto frontier with lump sum taxation, (5), (6), (7), and (8), we have that the consumption and labor taxes create an intratemporal wedge in (24), and that time varying consumption taxes create intertemporal wedges in (25). Taxes do not affect the production efficiency conditions (7) and (8).

Using conditions (24) and (25), we can write

$$\frac{u^i_{n,t}}{\beta u^i_{n,t+1}} = \frac{(1-\tau^n_{it})}{\left(1-\tau^n_{it+1}\right)} \frac{G^i_{i,t} F^i_{n,t}}{G^i_{i,t+1} F^i_{n,t+1}} \left[G^i_{i,t+1} F^i_{k,t+1} + 1 - \delta\right], \tag{26}$$

which makes it clear how the taxes affect the labor intertemporal margin.

A competitive equilibrium has *no intertemporal distortions in consumption* from period s onward if the first order conditions (25) and (6) coincide for all $t \geq s$. Similarly, a competitive equilibrium has *no intertemporal distortions in labor* from period s onward if the first order conditions (26) and (9) coincide for all $t \geq s$. Finally, a competitive equilibrium has *no intertemporal distortions* from period s onward if it has no such distortions for both consumption and labor.

With the taxes that we consider here, it is not possible to create production distortions in the use of the traded goods, so that (7) and (8) always have to be satisfied. These marginal conditions will have to be imposed as restrictions to the Ramsey problem, but as we show below, they will not be binding at the Ramsey optimum.

2.1.1 Implementability

In order to characterize the Ramsey equilibrium, we begin by characterizing the set of implementable allocations. An allocation $\{c_{it}, n_{it}, y_{ijt}, k_{it+1}, x_{it}\}$ and period zero policies and prices, $\{l_{i0}, \tau^c_{i0}, T_{i0}, q_{i0}\}$, given $\{k_{i0}, b_{i0}, f_{i0}\}$ is implementable as a competitive equilibrium if and only if they satisfy the resource constraints (2), (3), (4), and the implementability conditions

$$\sum_{t=0}^{\infty} \left[\beta^t u^i_{c,t} c_{it} + \beta^t u^i_{n,t} n_{it}\right] = \mathcal{W}_{i0}, \tag{27}$$

where

$$\mathcal{W}_{i0} = (1 - l_{i0}) \frac{u^i_{c,0}}{(1 + \tau^c_{i0})} \left[\left(1 - \delta + G^i_{i,0} F^i_{k,0}\right) k_{i0} + Q_{-1} b_{i0} + \left(1 + r^f_0\right) \frac{f_{i,0}}{q_{i,0}} \right] \tag{28}$$

together with (7) and (8). The proposition follows.

Proposition 1 (Characterization of the implementable allocations): Any implementable allocation and period zero policies and prices satisfy the implementability constraints (27), together with (7) and (8), as well as the resource constraints (2), (3), (4). Furthermore, if an allocation satisfies these conditions for some period zero policies and prices, then it is implementable by a tax system with consumption and labor income taxes.

2.2 Cooperative Ramsey equilibria

A *(cooperative) Ramsey equilibrium* is a competitive equilibrium that is not Pareto dominated by any other competitive equilibrium. The *Ramsey allocation* is the associated implementable allocation.

We say that the Ramsey planner is unrestricted if the planner can choose policies and allocations in all periods subject only to the constraint that the resulting allocations, prices, and policies constitute a competitive equilibrium.

Consider the following programming problem, referred to as the *unrestricted Ramsey problem*, which is to choose allocations and period zero policies to maximize a weighted sum of utilities of the households of the two countries,

$$\theta^1 U^1 + \theta^2 U^2 \tag{29}$$

with weights $\theta^i \in [0, 1]$, subject to the conditions (27) and the resource constraints.

Assume policies are unrestricted in the sense that for any allocation, l_{i0} (or any of the other initial taxes) can be chosen to satisfy (27). Then the unrestricted Ramsey problem reduces to maximizing welfare subject to the resource constraints, and therefore it immediately follows that it is possible to implement the lump-sum tax allocation as the Ramsey equilibrium.

2.2.1 Ramsey problem

Suppose now that policies and initial conditions are restricted in the sense that households in each country must be allowed to keep an exogenous value of initial wealth $\bar{\mathcal{W}}_i$, measured in units of utility. Specifically, we impose the following restriction on the Ramsey problem:

$$\mathcal{W}_{i0} = \bar{\mathcal{W}}_i, \tag{30}$$

which we refer to as the *wealth restriction in utility terms*. With this restriction, policies, including initial policies, can be chosen arbitrarily, but the household must receive a value of initial wealth in utility terms of $\bar{\mathcal{W}}_i$ (see Armenter (2008) for an analysis with such a restriction).[7]

The Ramsey problem is to maximize (29), subject to the resource constraints (2), together with (3) and (4), that are combined as

$$c_{it} + g_{it} + k_{it+1} - (1-\delta) k_{it} \leq G^1 (y_{1it}, y_{2it}), \tag{31}$$

together with the implementability conditions (27), the wealth restriction (30), (7) and (8) . Condition (28) does not restrict the problem since it is satisfied by the choices of the initial taxes. We are going to write the problem without imposing the conditions for production efficiency, (7) and (8). We will show that they are satisfied at the optimum.

Define

$$v^i \left(c_{it}, n_{it}; \varphi^i\right) = \theta u^i (c_{it}, n_{it}) + \varphi^i \left[u^i_{c,t} c_{it} + u^i_{n,t} n_{it}\right],$$

where φ^i is the multiplier of the implementability condition (27). We can now use the efficiency conditions for the case with lump-sum taxes, (5), (6), (7), and (8), replacing the marginal utilities of u^i by the derivatives of the function v^i. The solution of the Ramsey problem is given by

$$-\frac{v^i_{c,t}}{v^i_{n,t}} = \frac{1}{G^i_{i,t} F^i_{n,t}}, \; i = 1, 2 \tag{32}$$

[7]Chari et al. (2016) study equilibria with partial commitment in which the assumption in Armenter (2008) applies every period. The government in each period has partial commitment to one period returns on assets in utility terms. The Markov equilibrium coincides with the full commitment equilibrium with wealth restrictions in utility terms. Thus, partial commitment provides one rationalization for studying Ramsey equilibria with wealth restrictions in utility terms.

$$\frac{v^i_{c,t}}{\beta v^i_{c,t+1}} = 1 - \delta + G^i_{i,t+1} F^i_{kt+1},\ i = 1,2 \tag{33}$$

$$\frac{G^1_{j,t}}{G^1_{j,t+1}} \left[G^1_{1,t+1} F^1_{k,t+1} + 1 - \delta\right] = \frac{G^2_{j,t}}{G^2_{j,t+1}} \left[G^2_{2,t+1} F^2_{k,t+1} + 1 - \delta\right],\ j = 1,2 \tag{34}$$

$$\frac{G^1_{1,t}}{G^2_{1,t}} = \frac{G^1_{2,t}}{G^2_{2,t}}. \tag{35}$$

Every Ramsey solution must satisfy the production efficiency conditions, (7) and (8), even if the conditions were not imposed as a restriction to the problem. This means that if we had considered tariffs as possible instruments, they would not need to be used. The proposition follows.

Proposition 2 (Optimality of free trade): Unrestricted international trade is optimal.

In order to further characterize the optimal wedges, it is useful to write

$$v^i_{c,t} = u^i_{c,t}\left[\theta^i + \varphi^i\left[1 - \sigma^i_t - \sigma^{cni}_t\right]\right]$$

$$v^i_{n,t} = u^i_{n,t}\left[\theta^i + \varphi^i\left[1 + \sigma^{ni}_t - \sigma^{nci}_t\right]\right],$$

where

$$\sigma^i_t = -\frac{u^i_{cc,t} c_{it}}{u^i_{c,t}},\ \sigma^{ni}_t = \frac{u^i_{nn,t} n_{it}}{u^i_{n,t}},\ \sigma^{nci}_t = -\frac{u^i_{nc,t} c_{it}}{u^i_{n,t}},\ \sigma^{cni}_t = -\frac{u^i_{cn,t} n_{it}}{u^i_{c,t}}$$

are own and cross elasticities that are only functions of consumption and labor at time t.

Note also that if consumption and labor are constant over time, then the relevant elasticities are also constant, so $v^i_{c,t}$ and $v^i_{n,t}$ are proportional to $u^i_{c,t}$ and $u^i_{n,t}$, respectively. It then follows that it is optimal to have no intertemporal distortions. This observation leads to the following proposition.

Proposition 3 (No intertemporal distortions in the steady state): If the Ramsey equilibrium converges to a steady state, it is optimal to have no intertemporal distortions asymptotically.

For standard macro preferences,

$$U^i = \sum_{t=0}^{\infty} \beta^t \left[\frac{c_t^{1-\sigma^i} - 1}{1 - \sigma^i} - \eta_i \frac{n_t^{1+\sigma^{ni}}}{1 + \sigma^{ni}}\right], \tag{36}$$

the marginal conditions are

$$-\frac{u^i_{c,t}}{u^i_{n,t}} = \frac{\theta^i + \varphi^i \left(1+\sigma^{ni}\right)}{\theta^i + \varphi^i \left(1-\sigma^{i}\right)} \frac{1}{G^i_{i,t} F^i_{n,t}}, \tag{37}$$

together with the intertemporal efficiency conditions, (6), and the production efficiency conditions, (7) and (8). The proposition follows.

Proposition 4 (No intertemporal distortions ever): Suppose that preferences are given by (36). Then, the Ramsey solution has no intertemporal distortions for all $t \geq 0$.

Corollary: The Ramsey allocations can be implemented with consumption or labor taxes that are constant over time, but possibly different across countries.

The two-country model nests the closed economy neoclassical growth model for

$$G^i \left(y_{1it}, y_{2it}\right) = y_{iit}.$$

It follows that the results on the optimal taxation of capital also hold in the neoclassical growth model. This is in contrast with the influential results of Chamley (1986) and Judd (1985), which argue that capital should not be taxed in the steady state but should be heavily taxed along a transition. They are also in contrast with the results in the more recent literature, in Bassetto and Benhabib (2006) and Straub and Werning (2015), that it may be optimal to tax capital at the maximum rate forever.

To obtain our result that there is no presumption that capital ought to be taxed also along the transition, it is important that the initial confiscation be restricted not only directly, as is common to assume in the literature, but also indirectly through valuation effects, as proposed by Armenter (2008). This assumption is related to partial commitment to asset returns, as argued by Chari et al. (2016).

Another important assumption to shorten the transition of heavy capital taxation is that the tax system may be rich enough, in the sense that no taxes that are available in advanced economies may be left out if relevant for policy. We consider such a rich tax system, but that is not the common assumption in the literature. The assumptions that indirect confiscation is possible while direct confiscation is not, together with a restricted tax system, explain the contrasting results in the literature.

Note that the preferences considered in Proposition 4 are separable and homothetic in both consumption and labor. These properties are used in Chari et al. (2016) to provide intuition for the results on the optimal taxation of capital by relating them to results on uniform commodity taxation and production efficiency, as in Atkinson and Stiglitz (1972) and Diamond and Mirrlees (1971).

The Ramsey allocation characterized in Propositions 2 through 4 can be implemented in a variety of ways. The following sections describe alternative implementations.

3 Alternative implementations

In this section, we discuss a variety of other tax systems, including taxes on the income from different assets and alternative ways of taxing consumption. Our analysis is motivated by the observation that these alternative tax systems are widely used in practice. We show that no tax system can yield higher welfare than the tax system with only consumption and labor income taxes. We show that a variety of tax systems can implement the Ramsey allocation associated with those taxes. Furthermore, some tax systems do yield lower welfare.

3.1 Taxes on capital income, equity returns, and foreign assets

In this section, in addition to capital income taxes, we consider a common tax on the returns from foreign assets and on the equity returns including capital gains. This is a residence-based system where capital from different sources is treated the same. We assume that firms are residents of the country where they produce. For convenience, we keep both consumption and labor income taxes, but we discuss whether any of these will be made redundant.

We now describe the problems of the firms and the household in each country and define a competitive equilibrium. We maintain the assumption that ownership of firms is domestic, but we will see that this is without loss of generality.

Firm The representative intermediate good firm in each country produces and invests in order to maximize the present value of dividends, $V_{i0} + d_{i0} = \sum_{t=0}^{\infty} Q_t d_{it}$.

Dividends, in units of the numeraire, d_{it}, are given by

$$d_{it} = p_{it}F(k_{it}, n_{it}) - w_{it}n_{it} - \tau_{it}^k \left[p_{it}F(k_{it}, n_{it}) - w_{it}n_{it} - q_{it}\delta k_{it}\right] - q_{it}\left[k_{it+1} - (1-\delta)k_{it}\right], \tag{38}$$

where τ_{it}^k is the tax rate on capital income net of depreciation.

The first order conditions of the firm's problem are now (20), together with

$$\frac{Q_t q_{it}}{Q_{t+1}q_{it+1}} = 1 + \left(1 - \tau_{it+1}^k\right)\left(\frac{p_{it+1}}{q_{it+1}}F_{k,t+1}^i - \delta\right). \tag{39}$$

Substituting for d_{it} from (38) and using (20) and (39), it is easy to show that the present value of the dividends at time zero in units of the numeraire is given by

$$V_{i0} + d_{i0} = \sum_{t=0}^{\infty} Q_t d_{it} = \left[1 + \left(1 - \tau_{i0}^k\right)\left(\frac{p_{i0}}{q_{i0}}F_{ik,0} - \delta\right)\right] p_{i0}k_{i0}. \tag{40}$$

The problem of the final good firm is as before. The first order conditions are given by (22) .

Households The flow of funds constraint in period t for the household in country i in units of the numeraire is given by

$$\begin{aligned} & b_{it+1} + V_{it}s_{it+1} + f_{it+1} \qquad (41a) \\ = \; & \frac{Q_{it-1}}{Q_{it}}b_{it} + \left(V_{it} + d_{it}\right)s_{it} - \tau_{it}\left(V_{it} - V_{it-1} + d_{it} - \frac{\left(q_{it} - q_{it-1}\right)V_{it-1}}{q_{it-1}}\right)s_{it} + \\ & \left(1 + r_t^f\right)f_{it} - \tau_{it}\left(r_t^f - \frac{q_{it} - q_{it-1}}{q_{it-1}}\right)f_{it} + \left(1 - \tau_{it}^n\right)w_{it}n_{it} - \left(1 + \tau_{it}^c\right)q_{it}c_{it}. \end{aligned}$$

In period 0, the constraint is

$$\begin{aligned} & b_{i1} + V_{i0}s_{i1} + f_{i1} \qquad (42) \\ = \; & (1 - l_{i0})\left[Q_{i-1}b_{i0} + \left(V_{i0} + d_{i0}\right)s_{i0} - \tau_{i0}\left(V_{i0} - V_{i-1} + d_{i0} - \frac{\left(q_{i0} - q_{i-1}\right)V_{i-1}}{q_{i-1}}\right)s_{i0}\right] + \\ & (1 - l_{i0})\left[1 + r_0^f - \tau_{i0}\left(r_0^f - \frac{q_{i0} - q_{i-1}}{q_{i-1}}\right)\right]f_{i0} + \left(1 - \tau_{i0}^n\right)w_{i0}n_{i0} - \left(1 + \tau_{i0}^c\right)q_{i0}c_{i0}. \end{aligned}$$

Dividends and capital gains are taxed at rate τ_{it} with an allowance for numeraire inflation. Returns on foreign assets are also taxed at the same rate, τ_{it}, also with an allowance for numeraire inflation. The returns on public debt, b_{it}, are country specific, $\frac{Q_{it-1}}{Q_{it}}$, because assets can be taxed at different rates in the different countries.

The household's problem is to maximize utility (1), subject to (41a), (42), and no-Ponzi-scheme conditions, $\lim_{T\to\infty} Q_{iT+1}b_{iT+1} \geq 0$, and $\lim_{T\to\infty} Q_{iT+1}f_{iT+1} \geq 0$.

The first order conditions of the household's problem in each country are, for $t \geq 0$, (18), and

$$\frac{u^i_{c,t}}{(1+\tau^c_{it})} = \frac{Q_{it}q_{it}}{Q_{it+1}q_{it+1}} \frac{\beta u^i_{c,t+1}}{\left(1+\tau^c_{it+1}\right)}, \tag{43}$$

together with

$$\frac{Q_{it}}{Q_{it+1}} = (1-\tau_{it+1})\left(1+r^f_{t+1}\right) + \tau_{it+1}\frac{q_{it+1}}{q_{it}} \text{ with } Q_{i0} = 1 \tag{44a}$$

and

$$\frac{Q_{it}}{Q_{it+1}} = \frac{(V_{it+1}+d_{it+1}) - \tau_{it+1}\left(V_{it+1} - V_{it} + d_{it+1} - \frac{q_{it+1}-q_{it}}{q_{it}}V_{it}\right)}{V_{it}}, \tag{45a}$$

which implies that

$$1 + r^f_{t+1} = \frac{V_{it+1}+d_{it+1}}{V_{it}}. \tag{46a}$$

This condition on the two returns can be written, using $1 + r^f_{t+1} = \frac{Q_t}{Q_{t+1}}$, as

$$Q_t V_{it} = Q_{t+1}V_{it+1} + Q_{t+1}d_{it+1}. \tag{47a}$$

Imposing that $\lim_{T\to\infty} Q_{T+1}V_{iT+1} = 0$, then

$$V_{it} = \sum_{s=0}^{\infty} \frac{Q_{t+1+s}}{Q_t} d_{it+1+s}.$$

The present value of dividends for the households of country i is a different expression from the expression above because they pay taxes on the asset income. Using (45a), we have that

$$V_{i0} = \sum_{t=0}^{\infty} \left(1-\hat{\tau}^a_{it+1}\right) Q_{it+1}d_{it+1},$$

where $1 - \hat{\tau}^a_{it+1} = \Pi^t_{s=0}\left(1-\hat{\tau}_{is+1}\right)$, and $1 - \hat{\tau}_{it+1} = \frac{(1-\tau_{it+1})}{\left(1-\tau_{it+1}\frac{q_{it+1}Q_{it+1}}{q_{it}Q_{it}}\right)}$. The values are the same since $\left(1-\hat{\tau}^a_{it+1}\right) Q_{it+1} = Q_{t+1}$. This condition is obtained from (44a).

The value of the firm for the households in country i including the dividends in period 0 is

$$V_{i0} + d_{i0} - \tau_{i0}\left(V_{i0} + d_{i0} - \frac{q_{i0}V_{i-1}}{q_{i-1}}\right) \tag{49}$$
$$= \left(1-\tau_{i0}\right)\left(V_{i0}+d_{i0}\right) + \tau_{i0}\frac{q_{i0}V_{i-1}}{q_{i-1}}.$$

Notice that the market price of the firm before dividends, $V_{i0} + d_{i0}$, is a linear function of the value for the firm for the households of each country, so that the solution of the maximization problem of the firm also maximizes shareholder value. That would also be the case if the stocks were held by the households of the foreign country. This means that the restriction that firms are owned by the domestic households is without loss of generality.

Using the no-Ponzi scheme condition, the budget constraints of the household, (41a) and (42), can be consolidated into the single budget constraint,

$$\sum_{t=0}^{\infty} Q_{it}\left[q_{it}\left(1+\tau_{it}^{c}\right)c_{it} - \left(1-\tau_{it}^{n}\right)w_{it}n_{it}\right] = \left(1-l_{i0}\right)a_{i0}, \tag{50}$$

where

$$a_{i0} = Q_{i-1}b_{i0} + \left(1-\tau_{i0}\right)\left(V_{i0}+d_{i0}\right) + \tau_{i0}\frac{q_{i0}V_{i-1}}{q_{i-1}} + \left[1 + r_0^f - \tau_{i0}\left(1 + r_0^f - \frac{q_{i0}}{q_{i-1}}\right)\right] f_{i0}. \tag{51}$$

Using (40) as well as $s_0 = 1$, the initial asset holdings in (51) can be written as

$$a_{i0} = Q_{i-1}b_{i0} + \left(1-\tau_{i0}\right)q_{i0}\left[k_0 + \left(1-\tau_{i0}^{k}\right)\left(G_{i,0}^{i}F_{ik,0} - \delta\right)k_{i0}\right] + \tau_{i0}\frac{q_{i0}V_{i-1}}{q_{i-1}}$$
$$+ \left[1 + r_0^f - \tau_{i0}\left(1 + r_0^f - \frac{q_{i0}}{q_{i-1}}\right)\right] f_{i0}$$

The interest rate parity condition is obtained from

$$\frac{Q_t}{Q_{t+1}} = \frac{q_{it+1}}{q_{it}}\left[1 + \left(1-\tau_{it+1}^{k}\right)\left(\frac{p_{it+1}}{q_{it+1}}F_{k,t+1}^{i} - \delta\right)\right] \tag{52}$$

for $i = 1, 2$, or

$$\frac{q_{1t+1}}{q_{1t}}\left[1+\left(1-\tau^k_{1t+1}\right)\left(\frac{p_{1t+1}}{q_{1t+1}}F^1_{k,t+1}-\delta\right)\right]=\frac{q_{2t+1}}{q_{2t}}\left[1+\left(1-\tau^k_{2t+1}\right)\left(\frac{p_{2t+1}}{q_{2t+1}}F^2_{k,t+1}-\delta\right)\right]. \tag{53}$$

Using (22) to replace the relative prices of the intermediate and final goods, it follows that

$$\begin{aligned} & \frac{G^1_{j,t}}{G^1_{j,t+1}}\left[1+\left(1-\tau^k_{1t+1}\right)\left(G^1_{1,t+1}F^1_{k,t+1}-\delta\right)\right] \\ = & \frac{G^2_{j,t}}{G^2_{j,t+1}}\left[1+\left(1-\tau^k_{2t+1}\right)\left(G^2_{2,t+1}F^2_{k,t+1}-\delta\right)\right], \text{ for } j=1,2. \end{aligned} \tag{54}$$

To get production efficiency, that is, to satisfy (8), we need either to set the two tax rates to zero or to pick τ^k_{1t+1} and τ^k_{2t+1} according to

$$\begin{aligned} & \tau^k_{1t+1}\left(G^1_{1,t+1}F^1_{k,t+1}-\delta\right) \\ = & \tau^k_{2t+1}\left(G^1_{1,t+1}F^1_{k,t+1}-\delta-\left(\frac{G^1_{j,t+1}/G^2_{j,t+1}}{G^1_{j,t}/G^2_{j,t}}-1\right)\right), \text{ for } j=1,2. \end{aligned} \tag{55}$$

In order to ensure production efficiency, there has to be an adjustment to the movements in the real exchange rate. The tax revenue on the return on capital in the consumption of one country must be equal to the tax revenue on the return on capital in the consumption of the other country minus the proportionate change in the real exchange rate.

Using the intertemporal condition of the household (43), and

$$\frac{Q_{it}}{Q_{it+1}}=\left(1-\tau_{it+1}\right)\frac{Q_t}{Q_{t+1}}+\tau_{it+1}\frac{q_{it+1}}{q_{it}} \tag{56a}$$

obtained from (44a), together with $\frac{Q_t}{Q_{t+1}}=1+r^f_{t+1}$, and combining it with the firm's condition (39), together with (22), we obtain

$$\frac{u^i_{c,t}\left(1+\tau^c_{it+1}\right)}{\beta u^i_{c,t+1}\left(1+\tau^c_{it}\right)}=1+\left(1-\tau_{it+1}\right)\left(1-\tau^k_{it+1}\right)\left(G^i_{i,t+1}F^i_{k,t+1}-\delta\right). \tag{57}$$

The marginal conditions in this economy can be summarized by

$$-\frac{u^i_{c,t}}{u^i_{n,t}} = \frac{(1+\tau^c_{it})}{(1-\tau^n_{it})\, G^i_{i,t} F^i_{n,t}}, \tag{58}$$

the intertemporal condition (57), the interest rate parity condition (54), and condition (8), for all $t \geq 0$.

In this economy with a common tax on equity and foreign returns, it is possible to set to zero either the consumption tax or the labor income tax, but not both. The Ramsey allocation can be implemented with a (possibly time-varying) common tax on home and foreign assets. Capital income taxes in both countries either must be set to zero or must be set according to the difference in real returns in the goods of the two countries to ensure production efficiency. For standard macro preferences, all the taxes on assets are set to zero and the labor income tax is constant over time. In this economy with a common tax on domestic equity and foreign returns, firms use a common price to value dividends. If relaxed, the restriction that firms are owned by the domestic residents would not change the implementable allocations.

Consider the tax systems that do not tax either consumption or labor, but do have the other taxes. We refer to a tax system in which consumption taxes are set to zero as a *no-consumption* tax system, and similarly for the labor tax. The proposition follows. The proof is straightforward.

Proposition 5 (Common tax on domestic equity and foreign returns) : None of the tax systems considered here give higher welfare than the tax system with only consumption and labor income taxes. The Ramsey equilibrium under the no-consumption tax or the no-labor income tax system requires the taxation of domestic and foreign assets at the same rate. Capital income taxes can be set to zero. For standard macro preferences, only the consumption tax or the labor tax will be used, and it will be constant over time.

3.2 Border-adjusted value-added taxes and labor income taxes

Consider next an economy in which consumption taxes are replaced by value-added taxes levied on firms with border adjustment. Border adjustment means that firms in a country do not pay VAT taxes on exports and cannot deduct imports. Taxes on assets are set to zero, but labor income taxes are not. The value-added taxes are denoted by

τ_{it}^v. The setup is the same as in the economy with only consumption and labor income taxes, except that we distinguish prices in this economy with carets. Because taxes on assets are zero, there is a single intertemporal price of the numeraire.

The intermediate good firm now maximizes

$$\sum_{t=0}^{\infty} \hat{Q}_t \left[(\hat{p}_{i1t} y_{i1t} + \hat{p}_{i2t} y_{i2t}) - \hat{w}_{it} n_{it} - \hat{q}_{it} x_{it} \right] \\ - \sum_{t=0}^{\infty} \hat{Q}_t \tau_{it}^v \left[\hat{p}_{iit} y_{iit} - \hat{q}_{it} x_{it} \right] \tag{59}$$

subject to (2) and (4), where $\hat{p}_{ijt}$ is the price of the intermediate good produced in country i and sold in country j.

The final goods firm now maximizes

$$\sum_{t=0}^{\infty} \hat{Q}_t \left[\hat{q}_{it} G^i \left(y_{1it}, y_{2it} \right) - \hat{p}_{1it} y_{1it} - \hat{p}_{2it} y_{2it} \right] - \\ \sum_{t=0}^{\infty} \hat{Q}_t \tau_{it}^v \left[\hat{q}_{it} G^i \left(y_{1it}, y_{2it} \right) - \hat{p}_{iit} y_{iit} \right]. \tag{60}$$

The household problem is the same as above, except that the consumption taxes are set to zero.

The first order conditions of the household's problem now include

$$-\frac{u_{c,t}^i}{u_{n,t}^i} = \frac{\hat{q}_{it}}{\left(1 - \tau_{it}^n\right) \hat{w}_{it}},\ t \geq 0 \tag{61}$$

$$u_{c,t}^i = \frac{\hat{Q}_t \hat{q}_{it}}{\hat{Q}_{t+1} \hat{q}_{it+1}} \beta u_{c,t+1}^i,\ t \geq 0. \tag{62}$$

The first order conditions of the firms' problems for an interior solution are

$$\hat{p}_{iit} \left(1 - \tau_{it}^v\right) F_{n,t}^i = \hat{w}_{it} \tag{63}$$

$$\hat{Q}_t \hat{q}_{it} \left(1 - \tau_{it}^v\right) = \hat{Q}_{t+1} \hat{p}_{iit+1} \left(1 - \tau_{it+1}^v\right) F_{k,t+1}^i + \hat{Q}_{t+1} \hat{q}_{it+1} \left(1 - \tau_{it+1}^v\right) (1 - \delta)) \tag{64}$$

$$\hat{p}_{iit} \left(1 - \tau_{it}^v\right) = \hat{p}_{ijt} \tag{65}$$

$$\hat{q}_{it} G_{i,t}^i = \hat{p}_{iit} \tag{66}$$

$$\hat{q}_{it}\left(1-\tau_{it}^{v}\right)G_{j,t}^{i}=\hat{p}_{jit},\text{ for } j\neq i. \tag{67}$$

In order to show equivalence between these two tax systems, consider the following prices with value-added taxes. Let

$$\hat{q}_{it}\left(1-\tau_{it}^{v}\right)=q_{it} \tag{68}$$

$$\hat{p}_{iit}\left(1-\tau_{it}^{v}\right)=p_{it} \tag{69}$$

$$\hat{p}_{ijt}=p_{it},\ j\neq i,\ \hat{w}_{it}=w_{it},\ \hat{Q}_{t}=Q_{t}. \tag{70}$$

Replacing the prices with caret in the first order conditions in the economy with value-added taxes, we get

$$-\frac{u_{c,t}^{i}}{u_{n,t}^{i}}=\frac{q_{it}}{\left(1-\tau_{it}^{v}\right)\left(1-\tau_{it}^{n}\right)w_{it}},\ t\geq 0 \tag{71}$$

$$u_{c,t}^{i}=\frac{Q_{t}q_{it}}{Q_{t+1}q_{it+1}}\frac{\left(1-\tau_{it+1}^{v}\right)}{\left(1-\tau_{it}^{v}\right)}\beta u_{c,t+1}^{i},\ t\geq 0 \tag{72}$$

$$p_{it}F_{n,t}^{i}=w_{it} \tag{73}$$

$$p_{it}=p_{it} \tag{74}$$

$$Q_{t}q_{it}=Q_{t+1}p_{it+1}F_{k,t+1}^{i}+Q_{t+1}q_{it+1}\left(1-\delta\right)) \tag{75}$$

$$q_{it}G_{j,t}^{i}=p_{jt}. \tag{76}$$

These are the same conditions as in the economy with consumption taxes with

$$1-\tau_{it}^{v}=\frac{1}{1+\tau_{it}^{c}}. \tag{77}$$

The budget constraints of households in the two cases are (13) and

$$\sum_{t=0}^{\infty}\hat{Q}_{t}\left[\hat{q}_{it}c_{it}-\left(1-\tau_{it}^{n}\right)\hat{w}_{it}n_{it}\right]\leq\left(1-l_{i0}\right)a_{i,0}, \tag{78}$$

where

$$a_{i,0}=\hat{q}_{i0}\left(1-\tau_{i0}^{v}\right)\left[1-\delta+G_{i,0}^{i}F_{k,0}^{i}\right]k_{i0}+Q_{i,-1}b_{i0}+\left(1+r_{i0}^{f}\right)f_{i,0}.$$

Using the condition establishing the equivalence between the prices in the two economies, (68) and (70), it follows that the budget constraint in the value-added economy (78) becomes (13).

The budget constraints of the governments in the value-added economy are given by

$$\begin{aligned} & \sum_{t=0}^{\infty} \hat{Q}_t \left[\tau_{it}^v \left[\hat{p}_{iit} y_{iit} - \hat{q}_{it} x_{it} \right] + \tau_{it}^v \left[\hat{q}_{it} G^i \left(y_{1it}, y_{2it} \right) - \hat{p}_{iit} y_{iit} \right] + \left[\tau_{it}^n \hat{w}_{it} n_{it} - q_{it} g_{it} \right] \right] \\ = \ & -l_{i0} a_{i0} + Q_{i,-1} b_{i0} - T_{i0}. \end{aligned} \tag{79}$$

The balance of payments conditions are

$$\sum_{t=0}^{\infty} \hat{Q}_t \left[\hat{p}_{ijt} y_{ijt} - \hat{p}_{jit} y_{jit} \right] = -\left(1 + r_{i0}^f \right) f_{i,0} - T_{i0}, \tag{80}$$

where $\left(1 + r_{10}^f\right) f_{1,0} + \left(1 + r_{20}^f\right) f_{2,0} = 0$.

Since $\hat{p}_{ijt} = p_{it}$, for $j \neq i$, the balance of payments condition coincides with the one with consumption and labor income taxes.

The two economies are equivalent. This is stated in the following proposition.

Proposition 6 (Value-added taxes with border adjustment): Competitive equilibrium allocations in the economies with consumption and value-added taxes coincide if the taxes in the two systems satisfy (77).

3.3 Value-added taxes without border adjustment: The role of tariffs

Consider next an economy just like the one in the previous section, except that value-added taxes are levied on firms without border adjustment. This means that the taxation of intermediate goods will be source based. We will also consider tariffs.

The tariff levied by country j on the good imported from the other country i is denoted by τ_{ijt}^y. The value-added taxes in country i are denoted by τ_{it}^v. The intermediate goods firm now maximizes

$$\sum_{t=0}^{\infty} \hat{Q}_t \left[\left(1 - \tau_{it}^v\right) \left(\hat{p}_{i1t} y_{i1t} + \hat{p}_{i2t} y_{i2t} - \hat{q}_{it} x_{it} \right) - \hat{w}_{it} n_{it} \right] \tag{81}$$

subject to (2) and (4), where $\hat{p}_{ijt}$ is the price of the intermediate good produced in country i and sold in country j.

The final goods firm in country 1 now maximizes

$$\sum_{t=0}^{\infty} \hat{Q}_t \left(1-\tau_{1t}^{v}\right) \left[\hat{q}_{1t} G^1 \left(y_{11t}, y_{21t}\right) - \hat{p}_{11t} y_{11t} - \left(1+\tau_{21t}^{y}\right) \hat{p}_{21t} y_{21t}\right] \tag{82}$$

and similarly for country 2.

The household problem is the same as above, except that the consumption taxes are set to zero.

The first order conditions of the household's problem are

$$-\frac{u_{c,t}^{i}}{u_{n,t}^{i}} = \frac{\hat{q}_{it}}{\left(1-\tau_{it}^{n}\right)\left(1-\tau_{it}^{v}\right) \hat{p}_{iit} F_{n,t}^{i}},\ t \geq 0 \tag{83}$$

$$u_{c,t}^{i} = \frac{\hat{Q}_t \hat{q}_{it}}{\hat{Q}_{t+1} \hat{q}_{it+1}} \beta u_{c,t+1}^{i},\ t \geq 0. \tag{84}$$

The first order conditions of the firms' problems for an interior solution are

$$\hat{p}_{iit} \left(1-\tau_{it}^{v}\right) F_{n,t}^{i} = \hat{w}_{it} \tag{85}$$

$$\hat{Q}_t \hat{q}_{it} \left(1-\tau_{it}^{v}\right) = \hat{Q}_{t+1} \hat{p}_{iit+1} \left(1-\tau_{it+1}^{v}\right) F_{k,t+1}^{i} + \hat{Q}_{t+1} \hat{q}_{it+1} \left(1-\tau_{it+1}^{v}\right) (1-\delta)) \tag{86}$$

$$\hat{p}_{iit} = \hat{p}_{ijt} \equiv \hat{p}_{it} \tag{87}$$

$$\hat{q}_{it} G_{i,t}^{i} = \hat{p}_{iit},\ i = 1, 2 \tag{88}$$

$$\hat{q}_{it} G_{j,t}^{i} = \left(1+\tau_{jit}^{y}\right) \hat{p}_{jit},\ \text{for } i \neq j. \tag{89}$$

We can rearrange the first order conditions as

$$-\frac{u_{c,t}^{i}}{u_{n,t}^{i}} = \frac{1}{\left(1-\tau_{it}^{n}\right)\left(1-\tau_{it}^{v}\right) G_{i,t}^{i} F_{n,t}^{i}},\ t \geq 0 \tag{90}$$

$$u_{c,t}^{i} \left(1-\tau_{it}^{v}\right) = \left(1-\tau_{it+1}^{v}\right) \beta u_{c,t+1}^{i} \left[G_{i,t+1}^{i} F_{k,t+1}^{i} + 1 - \delta\right].$$

Using (88) and (89), it follows that

$$\frac{\hat{q}_{1t}}{\hat{q}_{2t}} = \frac{\left(1+\tau_{21t}^{y}\right) G_{2,t}^{2}}{G_{2,t}^{1}} = \frac{G_{1,t}^{2}}{\left(1+\tau_{12t}^{y}\right) G_{1,t}^{1}}. \tag{91}$$

Using (86) and (88), we have that

$$\frac{1-\tau^v_{1t+1}}{1-\tau^v_{1t}}\frac{\hat{q}_{1t+1}}{\hat{q}_{1t}}\left[G^1_{1,t+1}F^1_{k,t+1}+1-\delta\right]=\frac{1-\tau^v_{2t+1}}{1-\tau^v_{2t}}\frac{\hat{q}_{2t+1}}{\hat{q}_{2t}}\left[G^2_{2,t+1}F^2_{k,t+1}+1-\delta\right]. \tag{92}$$

The marginal conditions are summarized by

$$-\frac{u^i_{c,t}}{u^i_{n,t}}=\frac{1}{\left(1-\tau^n_{it}\right)\left(1-\tau^v_{it}\right)G^i_{i,t}F^i_{n,t}} \tag{93}$$

$$u^i_{c,t}\left(1-\tau^v_{it}\right)=\left(1-\tau^v_{it+1}\right)\beta u^i_{c,t+1}\left[G^i_{i,t+1}F^i_{k,t+1}+1-\delta)\right] \tag{94}$$

$$\frac{\left(1-\tau^v_{1t+1}\right)\left(1-\tau^v_{2t}\right)\left(1+\tau^y_{21t+1}\right)}{\left(1-\tau^v_{2t+1}\right)\left(1-\tau^v_{1t}\right)\left(1+\tau^y_{21t}\right)}\frac{G^1_{2,t}}{G^1_{2,t+1}}\left[G^1_{1,t+1}F^1_{k,t+1}+1-\delta\right]=\frac{G^2_{2,t}}{G^2_{2,t+1}}\left[G^2_{2,t+1}F^2_{k,t+1}+1-\delta\right] \tag{95}$$

$$\frac{\left(1-\tau^v_{1t+1}\right)\left(1-\tau^v_{2t}\right)\left(1+\tau^y_{12t}\right)}{\left(1-\tau^v_{2t+1}\right)\left(1-\tau^v_{1t}\right)\left(1+\tau^y_{12t+1}\right)}\frac{G^1_{1,t}}{G^1_{1,t+1}}\left[G^1_{1,t+1}F^1_{k,t+1}+1-\delta\right]=\frac{G^2_{1,t}}{G^2_{1,t+1}}\left[G^2_{2,t+1}F^2_{k,t+1}+1-\delta\right] \tag{96}$$

$$\frac{G^1_{2,t}}{G^1_{1,t}}=\frac{\left(1+\tau^y_{21t}\right)\left(1+\tau^y_{12t}\right)G^2_{2,t}}{G^2_{1,t}}. \tag{97}$$

In order to have production efficiency, verifying (7) and (8), it must be that

$$\frac{\left(1-\tau^v_{1t+1}\right)\left(1-\tau^v_{2t}\right)}{\left(1-\tau^v_{1t}\right)\left(1-\tau^v_{2t+1}\right)}=\frac{1+\tau^y_{12t+1}}{1+\tau^y_{12t}}$$

and

$$\left(1+\tau^y_{12t+1}\right)\left(1+\tau^y_{21t+1}\right)=\left(1+\tau^y_{12t}\right)\left(1+\tau^y_{21t}\right)=1.$$

The Ramsey allocation in the economy with consumption taxes can be implemented in this economy with a VAT without border adjustment and tariffs. The tariffs have to compensate each other $1+\tau^y_{12t}=1/\left(1+\tau^y_{21t}\right)$, so that if the tariff is positive in one country, it must be negative in the other. The compensating tariffs must be time varying to undo the distortions imposed by the VAT taxes on the (dynamic) production efficiency condition, (7). The value-added taxes will have to move over time, differently in the two countries to implement the optimal intertemporal distortions, and the labor income tax will implement the optimal intratemporal distortion. Without tariffs, the Ramsey allocation in the economy with both consumption and labor income taxes cannot in general be achieved.

For standard macro preferences, there is no need for tariffs, and the Ramsey allocation can be achieved with VAT taxes that, in general, are different across countries but constant over time. Border tax adjustments in this case are irrelevant.

We state these results in the following proposition.

Proposition 7 (Value-added taxes without border adjustment): The Ramsey allocation can be implemented with consumption taxes replaced by value-added taxes without border adjustment and tariffs. The tariffs must compensate each other and have to be time varying to compensate value-added taxes that may move differently across time in the two countries. For standard macro preferences, the value-added tax rates are constant over time, and therefore there is no need for tariffs.

Corollary: In general, the Ramsey allocation cannot be implemented with a tax system with labor income taxes and value-added taxes without border adjustment.

Origin- versus destination-based taxation In order to discuss restrictions on tax systems based on origin and destination, we need to be clear about what we mean by a destination-based system and an origin-based system mean. One possible meaning is the following. A destination-based system is one in which taxes are set by the destination country; similarly, an origin-based system is one in which taxes are set by the country from where the goods originate. In such a destination-based system there is no reason to tax imports at the same rate as domestically produced goods. Similarly, in an origin-based system, there is no reason to tax exports at the same rate as domestically used goods. In such a system, whether destination-based or origin-based, there would be four tax rates that would allow to implement the Ramsey allocation. Under the destination based system, the Ramsey policy would set the rate on imports equal to the rate on domestically produced goods, and under the origin-based system, the rate on exports would be equal to the rate on the goods produced in the destination country.

Another interpretation of destination- versus source-based systems is more restrictive but is also closer to what most people have in mind. That is, a destination-based system is one where tax rates do not depend on origin, and an origin-based system is one where tax rates do not depend on destination. In this case, the VAT system with border adjustment would be a destination-based system, and the VAT system without border adjustment would be an origin based system. In the case of value-added taxes with border adjustment, the goods leave the country untaxed and are taxed in the destination country at the single value-added tax rate in the destination country. In the case with value-added taxes without border adjustments, however, goods are taxed at the single rate of the origin country. For this interpretation of destination- and origin-based systems, the destination-based system does not impose relevant restrictions on the set of implementable allocations, but the origin-based system, would in general impose such restrictions. Without tariffs, the destination-based system is superior, since in general it is not possible to implement the Ramsey allocation without tariffs when no border adjustments are made. Those restrictions would be undone by tariffs, but tariffs would convert an origin-based system into a destination-based one.

4 Concluding remarks

We characterize cooperative Ramsey allocations in the open economy. We show that free trade is also optimal in the second best Ramsey allocation and that for standard macro preferences, capital should never be taxed. For general preferences there is no presumption that capital should also be taxed along the transition. We study alternative implementations of the Ramsey allocation including residence-based taxation of equity returns, foreign asset returns and firms profits. We also consider value-added taxes with and without border adjustments. In these environments with capital accumulation, border adjustments matter for the optimal allocations. We discuss the desirability of destination- versus origin-based taxation of goods.

The results on the taxation of capital are related to the influential results of Chamley (1986) and Judd (1985) which argue that capital should not be taxed in the steady state but should be heavily taxed along a transition. They are also related to the more recent literature, in Bassetto and Benhabib (2006) and Straub and Werning (2015), that challenge the optimality of zero taxation of capital in the steady state. The contrasting results are explained in Chari et al. (2016).

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