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Global Public Goods, Fiscal Policy Coordination, and Welfare in the World Economy

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Abstract

A two-region endogenous growth model of the world economy with local and global public goods is used to study strategic interactions between national policymakers. Distortionary taxes are used to finance infrastructure investment at home and generate resources for vaccine production by a global fund. While the global public good is nonexcludable, it is partially rival. Optimal tax rates under cooperation and noncooperation are solved for analytically, under both financial autarky and openness, and numerical experiments are performed to evaluate the welfare gain from cooperation. Whether optimal levies are higher or lower under cooperation, and the magnitude of welfare gains, depend on the degree of integration of capital markets, the existence of a direct trade-off between expenditure components, and the nature of the tax base. When the health levy takes the form of a capital or wealth tax, cooperation is welfare-improving under both autarky and financial openness, but enforcement and collection costs may narrow the scope of taxation under all policy regimes.

JEL Classification Numbers: F43, H51, H87

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A global pandemic requires a world effort to end it. None of us will be safe until everyone is safe.

U. von der Leyen, President, European Commission
T. A. Ghevreyesus, Director General, World Health Organization
WHO Commentaries, September 30, 2020

If if we fail to learn the painful lessons [of the Covid-19 pandemic], we will pay dearly next time – and there *will* be a next time.

T. A. Ghevreyesus, Director General, World Health Organization
World Government Summit, February 13, 2022

There is now a strong... consensus on the need for an enhanced global health architecture for pandemic prevention, preparedness and response, with an empowered and sustainably financed WHO at its core, playing the leading, coordinating and normative role on which so many countries and partners depend.

T. A. Ghevreyesus, Director General, World Health Organization
Global Pandemic Preparedness Summit, March 8, 2022

1 Introduction

The COVID-19 pandemic has made it painfully clear that, in today's globalized world, national borders cannot stop the propagation of viruses and communicable diseases. The initial lack of progress in global vaccination entailed huge economic costs in the short run.[1] Equally worrying, going forward, is the fact that scientists have provided compelling evidence to suggest that the rate of emergence of new diseases, driven in part by the unprecedented loss and fragmentation of tropical forests, is accelerating, and that their adverse economic effects—not to mention their human toll—may well increase significantly in the future (Dobson et al. (2020)). According to the Coalition for Epidemic Preparedness Innovations, for instance, there are currently 260 viruses from 25 virus families, known to infect humans; however, over 1.6 million yet-to-be discovered viral species from these virus families are believed to exist in mammal and bird hosts. Any of these could be the source of the next pandemic.

Many observers have therefore advocated the implementation of a global strategy to promote the production and equitable distribution of vaccines, prevent the emergence of infectious diseases, and reduce the risk of pandemics. Indeed, there is growing consensus that, in an interconnected world, collective investment in prevention—including

[1] Çakmakli et al. (2021) argued that the global GDP loss due to the initial inoculation of the population in only some (mostly highly developed) countries, relative to a counterfactual of global vaccination, was substantially higher than the cost of manufacturing and distributing vaccines to all. Moreover, a significant portion of these costs were borne by advanced economies, as a result of trade linkages.

the preemptive stockpiling of vaccines and therapies, before viruses mutate, begin to spread, and become endemic—may well be in the future the only way to avoid catastrophic tolls in terms of human life and economic costs.[2] Fundamentally, this global strategy involves viewing health as a global public good, the provision of which requires collective action to overcome this particular form of market failure.[3] This raises a host of issues, including how the production of these goods should be financed if adequate fees cannot be imposed to cover costs, what type of institutional arrangements should be put in place to ensure fair access and distribution, and how to avoid free riding when benefits are nonexcludable.[4]

Also important in this context is the extent to which countries should coordinate their policy decisions on how to raise revenue, and how trade-offs in the provision of national and global public goods should be addressed in spending allocation. Microfounded, theoretical contributions to the literature on international fiscal policy coordination include Kehoe (1987, 1989), Turnovsky (1988), Chang (1990), Chari and Kehoe (1990), Devereux (1990, 1991), Ghosh (1991), Devereux and Mansoorian (1992), Sorensen (1996), Philippopoulos and Economides (2003), and Andersen (2007). Most of them focus on solving for welfare-maximizing tax and spending policies (including side payments) by benevolent governments, to achieve Pareto-efficient allocations. Kehoe (1987), for instance, considered a two-country world in which individuals live for two periods and the government produces a single utility-enhancing local public good, financed by a lump-sum tax. Under financial integration, changes in national tax rates have international repercussions through their impact on capital flows. A key result of his analysis is that, relative to outcomes under cooperation, optimal government spending and tax rates under decentralized policymaking can be either too high or too low, depending on the sign, and the magnitude, of the cross-border externality that reflects the net effect of each country's actions on the welfare of the other country's current and future generations. A similar outcome is obtained by Ghosh (1991), in a related model with distortionary taxation. Turnovsky (1988) compared cooperative

[2] See de Bolle (2021) for a more detailed discussion.

[3] Global public goods include also peace and political stability, protection and improvement of the natural environment, preservation of food security, eradication of hunger and poverty, and so on. Much of our discussion in this paper is actually relevant for these other goods as well, as noted in the conclusion.

[4] According to Wouters et al. (2021), as of June 2021 high-income countries (representing 16 percent of the global population) had struck pre-orders representing at least 70 percent of doses available in that year of five leading COVID-19 vaccines.

and noncooperative government expenditure policies and shows that the noncooperative equilibrium entails higher spending than the cooperative equilibrium. Devereux (1990) considered how the welfare properties of cooperative and noncooperative fiscal policies depend on the ability of governments to precommit to a given course of action.

In contrast to these contributions, Devereux and Mansoorian (1992) considered an endogenous growth setting.[5] In their model, households have infinite horizons, capital is perfectly mobile internationally, and governments choose taxes to provide two *local* public goods—a productive input, as in Barro (1990), and, as in some of the contributions referred to earlier, a utility-enhancing consumption good. Domestic and foreign goods are imperfect substitutes, and households in each country consume both of them. Tax rates affect the returns to investment and the rate of economic growth. Thus, their spillovers across countries consist of both level and growth effects, on both output and consumption. Regardless of whether governments act independently or cooperate, the choice of public productive inputs is always efficient. However, when countries act independently, this is not the case for tax rates. Depending upon household preferences (specifically, the degree of intertemporal substitution) taxes may be either higher or lower than under policy coordination—and so does the rate of economic growth.

This paper departs from the existing literature in several ways. To our knowledge, it is the first to analyze the welfare gains from tax policy coordination in an endogenous growth model that accounts for *both* local and global productive public goods. Specifically, we consider a two-region, endogenous growth model of the world economy in which a global health fund produces an international public good (vaccines) based on voluntary transfers by national governments. Resources transferred to the global fund are productive because health improves the productivity of all workers, wherever they are located. At the same time, health enhances utility because it is also valued in its own right. Thus, and in marked contrast to existing contributions, the global public good is both a consumption and a production good.

A local public good (referred to as infrastructure) is also provided in each region to domestic producers. This allows us to consider a potential conflict, at the national level, between government resource allocation among alternative productive uses—spend domestically to provide a public input to firms, or finance a global fund, whose

[5] Philippopoulos and Economides (2003) also considered an endogenous growth framework, in which the externality associated with tax policy relates to its impact on environmental quality—representing, in effect, a global public good.

production indirectly benefits workers (and thus production) at home. Indeed, while our analysis focuses initially on separate budgets and tax rates for the financing of each type of public goods, the case of an integrated budget, with a single tax rate and total revenues allocated between the two categories of spending, is also considered. As a result, direct trade-offs in spending allocation between local and global public goods can be studied as well.

The model is used to study strategic interactions between national fiscal authorities. Distortionary tax rates are chosen to maximize welfare.[6] Both the noncooperative (Nash) equilibrium, in which each region determines independently its contribution to the global fund in order to maximize its own welfare, and the cooperative solution, in which regions jointly determine their contribution in order to maximize world welfare, are derived.[7]

Our main results can be summarized as follows. First, there is a trade-off between growth, welfare and the financing of the global public good—even when there is no simultaneous provision of a local public good. On the one hand, raising revenues to transfer to the global fund reduces savings and capital accumulation at home; on the other, greater access to the global public good improves health, which raises labor supply and productivity everywhere. In standard fashion, this trade-off is internalized by choosing optimally the health-specific tax rate, regardless of the policy regime.

Second, under financial autarky, the positive cross-border health externality is ignored under the noncooperative equilibrium; the optimal tax rate is inefficient and there is therefore under-provision of vaccines. Although cooperation does not necessarily entail a higher tax rate (it depends on the preference for health and the elasticity of production to effective labor), it enhances welfare. By contrast, when there is a direct trade-off in the allocation of public expenditure—between a transfer to the global health fund and spending on the local provision of infrastructure—when they act jointly policymakers internalize the fact that spending more on health creates benefits by increasing the production of vaccines, but also generates indirect costs for both regions—spending less on the local public good means less production and lower wages,

[6] Although efficient, lump-sum taxation is excluded due to feasibility constraints. We therefore do not consider—as in Barro and Sala-i-Martin (1992), for instance—whether these taxes may be dominated by suitable linear taxes to finance public goods in the presence of a congestion externality.

[7] As in common in the literature on macroeconomic policy games, throughout the paper the terms coordination and cooperation are used interchangeably.

which reduces the tax base in each region, and therefore the total amount of revenue that can be raised. Thus, cooperation leads to a smaller, rather than a larger, share of spending on health, that is, a relatively smaller contribution to the global fund.

Third, under financial openness, cooperation also improves welfare relative to noncooperation; this is because it preserves the tax base by internalizing the cross-border leakages associated with capital flows. This result is similar to the one obtained in Ghosh (1991),who also found that the noncooperative equilibrium is not efficient—except that here it applies to the health levy aimed at financing the global public good, rather than a tax aimed at financing a local public good. Finally, when the separate health levy takes the form of a tax on capital or wealth, cooperation is welfare-improving—just as it is under autarky—because once again it preserves the national tax base by mitigating incentives for tax evasion and capital flight. However, the existence of enforcement and collection costs may significantly narrow the scope of taxation under all policy regimes. These are important considerations in the context of the broader debate on wealth taxes and global inequality.

The remainder of the paper is organized as follows. Section 2 presents a core, two-region endogenous growth model of the world economy with local (infrastructure) and global (vaccines) public goods, under financial autarky. In each region, distribution of the global public good is subject to congestion. Separate, distortionary levies are used to finance infrastructure investment at home and to transfer resources to a global public fund for the production of vaccines, which improve health in both regions. The initial assumption of separate tax rates helps to clarify how cross-border spillovers arise. Section 3 derives the balanced growth equilibrium, for given tax policies. Welfare-maximizing tax rates and strategic interactions between national fiscal authorities are examined in section 4. Several important extensions, related to, namely, financial integration, a direct trade-off between productive components of public expenditure, and a capital- or wealth-based health levy, are considered in section 5. A Numerical evaluation of the gains from cooperation is provided in section 6. Policy implications, with respect, in particular, to wealth taxation as a means to finance a global health fund, are discussed in section 7. The last section considers some possible areas for future research.

2 The World Economy

The world economy consists of two regions, $j = 1, 2$. Both regions produce the same good, which is traded freely across borders.[8] Goods can be either consumed in the period they are produced, or stored (at no cost) to yield physical capital at the beginning of the following period. Individuals in each region live for two periods, adulthood and old age. Each individual is endowed with one unit of time in each period of life. At the beginning of adulthood, time is allocated between market work and improving one's health (exercise, preparing healthy meals, and so on), whereas in old age time is allocated entirely to leisure. Wage income, net of taxes, serves to finance consumption and saving for old age. Savings, at home or abroad, is held only in the form of physical capital, which is rented to firms. Endowments at time $t = 0$ in each region consist of an initial stock of private capital, which is held by an initial generation of retirees. There are no altruistically-motivated intergenerational bequests, implying that Ricardian equivalence does not hold.[9] Population is constant and of equal size in both regions.[10] In addition to individuals, the economy is populated by firms and an infinitely-lived policymaker, also referred to as a fiscal authority. Furthermore, there is a global health fund (or global fund, for short), whose production activity is financed by government contributions from both regions. Fiscal authorities in both jurisdictions can make binding policy commitments, that is, they can commit to following a path for the policy instruments that they select into the indefinite future.

Households and firms in each region have access to two public goods: a local good, infrastructure (or, equivalently, public capital), and a global good, which we refer to as vaccines, produced by the global health fund. Both goods generate external effects. Infrastructure benefits directly local producers only, whereas the global public good, which enhances individual health, benefits directly households in both regions. Specifically, workers in both regions operate in a confined environment and as a result face health risks in every period. Vaccination is thus needed in each period as well, to pre-

[8] Models of international fiscal policy coordination in which national goods are imperfect substitutes and relative-price or terms-of-trade effects are important include Turnovsky (1988), Chang (1990), Devereux (1991), Devereux and Mansoorian (1994), and Sorensen (1996). However, these effects are not central to our analysis.

[9] In fact, even with bequests, Ricardian equivalence would not hold here, due to the presence (as discussed later) of distortionary income taxation.

[10] The assumption of equal size is made for analytical convenience. It simplifies the analysis significantly, with little loss of generality.

vent sickness.[11] At the same time, because health status affects productivity, firms in both regions also benefit indirectly from the global public good. Both types of public goods are provided free of charge and are nonexcludable; but they are partially rival, due to congestion.

Firms produce goods using private capital, effective (or productivity-adjusted) labor, and infrastructure as inputs. Production technologies, as well as individual preferences, are identical worldwide. The fiscal authority spends on public goods and finances its expenditure by taxing wage income. In each region, only the home good can be purchased and stored by residents as capital to be used in domestic production in the following period. Labor cannot move across borders either.[12]

2.1 Producers

In each region there exists a continuum of identical firms, indexed by $i \in (0, 1)$. They produce a single tradable good, which is used either for consumption or investment. The production technologies are identical and require the use of private inputs, effective labor and private capital, which firms rent from the currently old agents, and public capital.

The production function of firm i in region j takes the form

$$Y_t^{j,i} = [\frac{K_t^{j,I}}{(N_t^j)^{\zeta_N}(K_t^{j,P})^{\zeta_K}}]^{\alpha}(L_t^{j,i})^{\beta}(K_t^{j,P,i})^{1-\beta}, \tag{1}$$

where $K_t^{j,P,i}$ denotes the firm-specific stock of capital, $K_t^{j,P} = \int_0^1 K_t^{j,P,i} di$ the aggregate private capital stock, $L_t^{j,i}$ labor in efficiency units, $K_t^{j,I}$ the stock of public capital, N_t^j total population of adults, $\alpha > 0$, $\zeta_K, \zeta_N > 0$, and $\beta \in (0, 1)$. Effective labor is defined as $L_t^{j,i} = A_t^j \ell_t^{j,W} N_t^{j,i}$, where $N_t^{j,i}$ is the number of workers employed by firm i, A_t^j average worker productivity, and $\ell_t^{j,W}$ the average amount of time spent working.

Equation (1) shows that production exhibits constant returns to scale in firm-specific inputs, $L_t^{j,i}$ and $K_t^{j,P,i}$. Public capital is exogenous to each firm's production process and affects all firms in the same way. It is also subject to congestion, measured in terms of the adult population (workers) and private capital. The magnitudes of these

[11] This assumption is consistent with the OLG structure of the model, in which one period (as noted later on) represents up to several decades.

[12] Because labor does not move across borders, household decisions in each region do not depend on wage taxes in the other region. The case of capital mobility is examined later on, whereas the role of labor mobility in the transmission of health risks is discussed in the conclusion.

congestion effects are measured by ζ_N and ζ_K, respectively.[13] In line with the empirical evidence (discussed later on), we impose $\alpha < 1$.

Each firm's objective is to maximize profits, $\Pi_t^{j,i}$, with respect to labor services and private capital, taking $K_t^{j,I}$ and $K_t^{j,P}$ as given:

$$\max_{N_t^{j,i}, K_t^{j,P,i}} \Pi_t^{j,i} = Y_t^{j,i} - (1 + r_t^j)K_t^{j,P,i} - w_t^j L_t^{j,i},$$

where $1 + r_t^j$ is the rental rate of private capital, which is assumed to depreciate fully in each period.

Assuming that input markets are competitive, in a symmetric equilibrium profit maximization yields

$$w_t^j = \beta Y_t^j / A_t^j \ell_t^{j,W} \bar{N}^j, \qquad 1 + r_t^j = (1 - \beta) Y_t^j / K_t^{j,P}. \tag{2}$$

where $\bar{N}^j = \int_0^1 N_t^{j,i} di$ is total population. The second expression equates the user cost of capital to its gross marginal physical product. The net return to capital, $r_t^j K_t^{j,P,i}$, is distributed to the owners of the capital stock.

Aggregate output is given by

$$Y_t^j = \int_0^1 Y_t^{j,i} di = (\bar{N}^j)^{\beta - \alpha\zeta_N} (k_t^{j,I})^\alpha (A_t^j \ell_t^{j,W})^\beta (K_t^{j,P})^{1-\beta+\alpha(1-\zeta_K)}, \tag{3}$$

where $k_t^{j,I} = K_t^{j,I} / K_t^{j,P}$ is the public-private capital ratio. To eliminate the scale effect associated with population and ensure permanent growth (linearity of output in the private capital stock) requires assuming that $\zeta_N = \beta/\alpha$ and $\beta - \alpha(1 - \zeta_K) = 0$.[14]

Under these assumptions, equation (3) yields aggregate output as

$$Y_t^j = (k_t^{j,I})^\alpha (A_t^j \ell_t^{j,W})^\beta K_t^{j,P}. \tag{4}$$

2.2 Individuals

In both regions individuals are identical, within as well as across generations. The utility of a representative individual born at t in region $j = 1, 2$ is given by

$$U_t^j = \ln c_t^{j,t} + \eta_C \frac{\ln c_{t+1}^{j,t}}{1+\rho} + \eta_H \ln h_t^j, \tag{5}$$

[13] See Agénor (2012) for a discussion of congestion effects in endogenous growth models with public infrastructure.

[14] Combining these two conditions yields $\zeta_K + \zeta_N = 1$. See Agénor (2012, chapter 1) for a more detailed discussion.

where $c_{t+s}^{j,t}$ denotes consumption of generation t individuals at date $t+s$, with $s=0,1$, h_t^j individual health status, η_C and η_H are preference parameters, and $\rho>0$ is the discount rate.[15] For simplicity, utility is assumed to be separable in the consumption of goods and health status, and leisure generates no direct benefit.[16]

In adulthood, individuals allocate a fraction $\ell_t^{j,W}$ of their time to market work, and the remaining fraction, $\ell_t^{j,H}$, to their own health. Thus, an individual's time constraint is

$$\ell_t^{j,H}+\ell_t^{j,W}=1. \tag{6}$$

The budget constraints that individuals face in adulthood and old age are given by

$$c_t^{j,t}+s_t^j=(1-\tau^j)\ell_t^{j,W}a_t^j w_t^j, \tag{7}$$

$$c_{t+1}^{j,t}=(1+r_{t+1}^j)s_t^j, \tag{8}$$

where a_t^j is individual productivity, $\tau^j\in(0,1)$ the overall tax rate on wages, and s_t^j saving.

Combining (7) and (8), the household's consolidated budget constraint is

$$c_t^{j,t}+\frac{c_{t+1}^{j,t}}{1+r_{t+1}^j}=(1-\tau^j)\ell_t^{j,W}a_t^j w_t^j. \tag{9}$$

Each individual maximizes (5) subject to constraints (6) and (9), as well as (17) and (18) below, which define individual health status and productivity, with respect to $c_t^{j,t}$, $c_{t+1}^{j,t}$, and $\ell_t^{j,H}$, taking w_t^j, r_{t+1}^j, and τ^j as given. Once the solution for $\ell_t^{j,H}$ is obtained, $\ell_t^{j,W}$, time allocated to market work, is solved for residually from constraint (6).

2.3 Fiscal Authorities

The policymaker in each region imposes a tax on wages, $\tau^{j,I}$, which serves to finance infrastructure investment and other (unproductive) spending, $G_t^{j,I}$ and $G_t^{j,O}$, respectively. It also imposes a separate tax, $\tau^{j,H}$, whose proceeds are transferred to the global fund to facilitate the production of vaccines. For convenience, the tax rate $\tau^{j,I}$ will be

[15] The utility function could be extended to account for preferences for the local public good, as in Ghosh (1991), in a related context, and Agénor (2016), for instance. However, we abstract from this complication.

[16] For simplicity, utility is also assumed to depend on health in adulthood only. If there is persistence in health—a reasonable assumption, given the evidence reviewed in Agénor (2015, 2019)—so that $h_{t+1}^j=(h_t^j)^\phi$, with $\phi\in(0,1)$, replacing the last term in (5) by $\eta_H[\ln h_t^j+(1+\rho)^{-1}\ln h_{t+1}^j]$ would not affect the results.

referred to in what follows as the *infrastructure levy*, and the tax rate $\tau^{j,H}$ as the *health levy*.

We assume for the moment that the fiscal authority maintains separate, balanced budgets.[17] The first budget constraint is thus

$$G_t^{j,I} + G_t^{j,O} = \tau^{j,I} \bar{N}^j \ell_t^{j,W} a_t^j w_t^j. \tag{10}$$

Shares of spending are constant fractions of revenues:

$$G_t^{j,i} = \upsilon_i^j \tau^{j,I} \bar{N}^j \ell_t^{j,W} a_t^j w_t^j, \quad i = I, O \tag{11}$$

where $\upsilon_i^j \in (0,1)$. Combining (10) and (11) therefore yields

$$\upsilon_I^j + \upsilon_O^j = 1. \tag{12}$$

The second constraint equates revenue from the health levy to the transfer to the global fund, $G_t^{j,H}$:

$$G_t^{j,H} = \tau^{j,H} \bar{N}^j \ell_t^{j,W} a_t^j w_t^j. \tag{13}$$

Thus, the total tax rate on wages, τ^j, is defined as

$$\tau^j = \tau^{j,H} + \tau^{j,I}. \tag{14}$$

Assuming full depreciation, the law of motion of the public capital stock in infrastructure is given by[18]

$$K_{t+1}^{j,I} = G_t^{j,I}. \tag{15}$$

2.4 Global Health Fund

The global health fund produces vaccines, using resources provided by each region. The good is nonexcludable (all individuals in each region have unrestricted access to it) and is provided free of charge.

[17] Adding bond accumulation would significantly complicate the dynamics of the model and its solution – likely preventing the derivation of explicit analytical solutions. In addition, the issue of how to ensure debt sustainability would also have to be addressed. This creates significant challenges as discussed, for instance, in Miyazawa et al. (2019). A more formal argument for ignoring public debt is that, in overlapping generations models, it can be shown that government debt would, in fact, be equivalent to levying differential lump-sum taxes (see Atkinson and Sandmo (1980, p. 533)). Our focus, instead, is on the more realistic case of distortionary taxation.

[18] A more general specification would be to assume that the production of public capital requires combining both the spending flow on productive goods and the existing stock of public capital. Our results would remain qualitatively similar. Note also that we do not consider the issue of efficiency of public investment, which could be captured, as in Agénor (2010), for instance, by multiplying $G_t^{j,I}$ in (15) by a parameter that takes a value lower than unity.

The production function of the global public good, H_t, is given by

$$H_t = (G_t^{1,H})^{\varphi}(G_t^{2,H})^{1-\varphi}, \tag{16}$$

where $\varphi \in (0,1)$ measures the relative importance of region 1's contribution. The production function (16) implies that contributions from both regions are necessary to produce the global good.[19] It excludes, implicitly, the possibility of free-riding in the production process. Moreover, given that regions are taken to be symmetric in all respects, we set $\varphi = 0.5$.[20]

2.5 Health Status and Productivity

The health status of an individual in adulthood depends on the time that he or she allocates to health, $\ell_t^{j,H}$, and access to the global public good:

$$h_t^j = (\ell_t^{j,H})^{\nu}(\frac{H_t}{Y_t^j})^{1-\nu}, \tag{17}$$

where $\nu \in (0,1)$. Thus, while own health is a private benefit, individual time and the global public good are partial substitutes. Access to vaccines, for instance, makes it less necessary for individuals to engage in social distancing, which in turn frees up time to engage in market work. In addition, at the level of each region, supply of the global good is partially rival. Indeed, although *production* itself is nonrival (as implied by (16)), the *distribution* of vaccines is subject to (absolute) congestion, as measured by the level of output in each region.[21] For instance, vaccines may need to be kept at ultra low temperatures; yet, adequate refrigeration systems may be lacking in countries where population density is relatively low (Wouters et al. (2021)). Medical facilities in these countries may also be sparse, thereby hindering vaccination campaigns. Thus, the larger the size of the economy, the greater the difficulty of distributing the global

[19] The cost of producing vaccines could be accounted for by assuming that it represents a fraction of government spending. However, this would have no qualitative impact on the analysis. It could also be assumed that national spending levels are perfect substitutes, in which case H_t would depend on $G_t^{1,H} + G_t^{2,H}$.

[20] Asymmetry in funding can be studied by considering the case where $\varphi \neq 0.5$, but at the cost of making the analysis significantly less transparent. The broader case of an asymmetric world is discussed in the conluding section.

[21] Rivalry could also be captured by assuming that the production of vaccines is made available in equal proportions to each region. However, this would essentially mean adding the multiplicative constant $0.5^{1-\nu}$ in (17) and would not have any substantive effects on the results.

public good locally.[22] The sensitivity of the results to different values of ν is discussed later on, both analytically and numerically.

For simplicity, a worker's productivity is taken to be linearly related to his or her health status:

$$a_t^j = h_t^j. \tag{18}$$

2.6 Savings-Investment Equilibrium

Financial autarky prevails in the world economy.[23] Thus, only the domestically-produced good can be purchased and stored as capital to be used in home production in the next period. Given full depreciation of private capital, the savings-investment equilibrium in each region takes the form

$$K_{t+1}^{j,P} = \bar{N}^j s_t^j. \tag{19}$$

Figure 1 summarizes the structure of our core model of the world economy.

3 World Equilibrium

In this model, a world competitive equilibrium under autarky can be defined as follows.

Definition 1: *A world competitive equilibrium is, for $j = 1, 2$, a sequence of prices $\{w_t^j, r_t^j\}_{t=0}^{\infty}$, consumption-savings allocations $\{c_t^{j,t}, c_{t+1}^{j,t}, s_t^j\}_{t=0}^{\infty}$, time allocation $\{\ell_t^{j,H}, \ell_t^{j,W}\}_{t=0}^{\infty}$, public and private capital stocks $\{K_{t+1}^{j,I}, K_{t+1}^{j,P}\}_{t=0}^{\infty}$, tax rates, $\tau^{j,H}, \tau^{j,I}$, and spending shares $\upsilon_I^j, \upsilon_O^j$, such that, for all $t \geqq 1$, given the initial capital stocks $K_0^{j,I}$ and $K_0^{j,P} > 0$, in both regions individuals maximize utility, firms maximize profits, fiscal authorities run balanced budgets, and domestic savings equals domestic investment.*

In equilibrium, given (18), average productivity must also be equal to individual health status, so that $A_t^j = a_t^j = h_t^j$.

The following definition characterizes the global balanced growth path.

Definition 2: *A global balanced growth equilibrium is, for $j = 1, 2$, a world competitive equilibrium in which $c_t^{j,t}$, $c_{t+1}^{j,t}$, w_t^j, Y_t^j, $K_t^{j,P}$, $K_t^{j,I}$, and H_t, all grow at the constant*

[22] Proportional congestion, as assumed in (17), ensures that health status (as discussed later on) is stationary. Note that another potential congestion factor could be local population. However, in the present model population is constant; thus, accounting for it, in addition to output, would make no difference to the results.

[23] This assumption is a natural one to make if regions 1 and 2 are viewed as consisting of advanced economies and developing economies, respectively, given the evidence on capital mobility between them. Nevertheless, the polar case of full financial integration will also be considered later on.

rate $1+g$*, and individual health status,* h_t^j*, as well as rates of return to private capital,* r_t^j*, are constant over time.*

By implication, each region's public-private capital ratio, $k_t^{j,I} = K_t^{j,I}/K_t^{j,P}$, the relative public-private capital ratio across regions, $k_t^{1,I}/k_t^{2,I}$, and the home-foreign private capital ratio, $x_t = K_t^{1,P}/K_t^{2,P}$, are all constant in equilibrium.

For simplicity, suppose that both regions have population of equal size ($\bar{N}^1 = \bar{N}^2$), which is normalized to unity. As shown in the Appendix, the solution to the individual's optimization problem gives

$$\frac{c_{t+1}^{j,t}}{c_t^{j,t}} = \eta_C(\frac{1+r_{t+1}^j}{1+\rho}), \tag{20}$$

$$\ell_t^{j,H} = \ell^H = \max[\frac{\eta_H\nu(1-\sigma)}{1+\eta_H\nu(1-\sigma)}, \ell_m^H] < 1, \tag{21}$$

$$\ell_t^{j,W} = \ell^W = 1-\ell^H, \tag{22}$$

where σ is the marginal propensity to save, defined as

$$\sigma = \frac{\eta_C}{1+\rho+\eta_C}, \tag{23}$$

and $0 < \ell_m^H < 1$ is the minimum amount of time that must be allocated by individuals to their health.[24]

As also established in the Appendix, because the public-private capital ratio in each region is constant at all times, the model's dynamics are driven by a first-order linear difference equation in terms of (the log of) the home-foreign private capital ratio, $\ln x_{t+1}$. The solution is unique and stable, and the steady-state growth rate is given by

$$1+g^j = (k^{j,I})^\alpha (h^j \ell^W)^\beta \sigma\beta(1-\tau^j), \tag{24}$$

where $k^{j,I}$, region j's public-private capital ratio, is defined as

$$k^{j,I} = \frac{\upsilon_I \tau^{j,I}}{\sigma(1-\tau^j)}, \tag{25}$$

and h^j is health status in region j, given by

$$h^1 = h_0(\tau^{1,H})^{\theta_1}(\tau^{2,H})^{\theta_2}(\tau^{1,I})^{-\theta_3^1}(\tau^{2,I})^{\theta_4^1}(\frac{1-\tau^1}{1-\tau^2})^{-\theta_5^1}, \tag{26}$$

as well as

$$h^2 = h_0(\tau^{1,H})^{\theta_1}(\tau^{2,H})^{\theta_2}(\tau^{1,I})^{\theta_3^2}(\tau^{2,I})^{-\theta_4^2}(\frac{1-\tau^1}{1-\tau^2})^{\theta_5^2}, \tag{27}$$

[24] The restriction $\ell_m^H > 0$ eliminates corner solutions with zero output. Note also that the tax on wages has no distortionary effect on time allocation.

where $h_0 = (\ell^H)^{\nu}\beta^{1-\nu}$, and[25]

$$\theta_1 = \varphi(1-\nu) > 0, \quad \theta_2 = (1-\varphi)(1-\nu) > 0,$$

$$\theta_3^1 = \theta_2\phi_1 > 0, \quad \theta_3^2 = \theta_1\phi_1 > 0,$$
$$\phi_1 = \frac{\alpha}{\beta(1-\nu)} > 0, \quad \phi_2 = \frac{1-\alpha+\beta(1-\nu)}{\beta(1-\nu)} > 1,$$
$$\theta_4^1 = \theta_3^1, \quad \theta_4^2 = \theta_3^2,$$
$$\theta_5^1 = \frac{\theta_2(1-\alpha)}{\beta(1-\nu)} > 0, \quad \theta_5^2 = \frac{\theta_1(1-\alpha)}{\beta(1-\nu)} > 0.$$

Equations (26) and (27) show that, in equilibrium, health status in both regions depends not only on the health levies, $\tau^{1,H}$ and $\tau^{2,H}$, but also on the infrastructure levies. Consider, for instance, health status in region 1. An increase in the health levy at home, $\tau^{1,H}$, improves health status both directly (by increasing the supply of vaccines) and indirectly, by reducing savings and the private capital stock—thereby mitigating the congestion effect associated with domestic output captured in (17). The magnitude of these effects is measured by θ_1 and $-\theta_5^1$, respectively. By contrast, an increase in region 2's health levy, $\tau^{2,H}$, has both a direct positive effect (measured by θ_2) and a negative effect (measured by $-\theta_5^1$). On the one hand, holding the tax base constant, it raises region 2's transfer to the global fund; on the other, it lowers savings and output abroad, thereby reducing the tax base and region 2's contribution to the fund. An increase in the home infrastructure levy, $\tau^{1,I}$, raises the public-private capital ratio both directly and indirectly, but it has a conflicting effect on health status: on the one hand, the increase in that ratio raises home output and magnifies the congestion effect, thereby adversely affecting the distribution of vaccines and health outcomes, whereas the reduction in saving, and thus the private capital stock, lowers output and operates in the opposite direction. The magnitude of these effects are measured by $\left|\theta_3^1\right|$ and $-\theta_5^1$, respectively. Finally, an increase in the foreign infrastructure levy, $\tau^{2,I}$, also has conflicting effects on health status at home: on the one hand, it raises region 2's contribution to the global fund (as measured by θ_4^1) but, on the other, it reduces savings and output (as measured $-\theta_5^1$), and therefore the foreign tax base. Similar reasoning helps to explain the impact of tax rates on health status in region 2, as described in equation (27).

[25] Note also that $\theta_1 + \theta_2 = 1 - \nu$ and that $\theta_5^2 = \theta_5^1(\theta_1/\theta_2)$, which implies that $\theta_5^2 = \theta_5^1$ in a symmetric equilibrium, when $\varphi = 0.5$ and $\theta_1 = \theta_2$.

Equation (24) shows that in each region the steady-state growth rate is a function of the region's own public-private capital ratio, $k^{j,I}$, each region's tax policies, $\tau^{j,H}$ and $\tau^{j,I}$, and of the other region's tax policies. The reason is that in each region, health status (as discussed earlier) depends on all tax rates, whereas the propensity to save depends on own tax rates, which affect capital accumulation—both public and private. Indeed, equation (25) shows that the public-private capital ratio depends on both the health and investment levies: in addition to the health levy raising the public capital stock, both tax rates increase the public-private capital ratio by reducing the private capital stock. In particular, while the home health levy creates a negative externality on growth by reducing savings, it also helps to promote growth by raising the public-private capital ratio and by enhancing productivity. In standard fashion, as long as $\alpha < 1$, the negative savings effect dominates the effect on the public-private capital ratio. However, the positive effect on productivity may be quite significant. Put differently, as long as $\nu \in (0, 1[$, a domestic health levy whose goal is to finance a global public good generates a trade-off in terms of growth—just like investment in infrastructure generates standard crowding-in and crowding-out effects (see, for instance, Barro (1990))). The difference, in the latter case, is that the home infrastructure levy, $\tau^{1,I}$, also has a conflicting effect on health status (and thus labor productivity), due to congestion.

In addition, both the health and infrastructure levies in the other region affect the growth rate at home, through its impact on the production and distribution of the global public good, and the impact of health on labor productivity. The cross-border externality of the global public good—or, equivalently, the tax rates used to finance them—exists as long as the use of vaccines is necessary to enhance individual health status, so that $\nu \in (0, 1[$, and each region contributes to the production of vaccines (equally in this case, so that $\varphi = 0.5$, as noted earlier). When $\nu = 1$ (health does not depend on access to vaccines), there are no cross-border spillovers; indeed, if $\nu = 1$, $h^1 = h^2 = h_0$.[26] In addition, as noted earlier, given that $-\theta_5^1 < 0$ in (26) and $\theta_5^2 > 0$ in (27), both the foreign health and infrastructure levies can generate a trade-off in terms of their impact on health status at home: on the one hand, they raise foreign output and increase the availability of vaccines to all; but on the other, they reduce foreign

[26] When $\varphi = 1$, so that only the home region contributes to the global health fund, the cross-border effect is asymmetric—only region 2 benefits. The opposite holds when $\varphi = 0$.

output, and thus the tax base, by lowering after-tax wages.

These results can be summarized in the following proposition.

Proposition 1. *With external effects associated with both local and global public goods ($\nu \in (0,1[$, $\alpha > 0$), domestic tax rates, $\tau^{j,I}$ and $\tau^{j,H}$, in each region j may generate a growth trade-off through three channels: private saving, the public-private capital ratio, and labor productivity. The cross-border externality associated with health and infrastructure levies in each region can be either positive or negative.*

Thus, while the production of the global public good financed by domestic contributions generate (as expected) direct cross-border spillovers, local public goods (in the presence of congestion) also exert cross-border effects. Both of these effects disappear when vaccines do not matter for individual health and productivity (that is, $\nu = 1$). This has important implications for studying strategic interactions between policymakers and for assessing the gains from cooperation, as discussed next.

4 Welfare Gain from Cooperation

To calculate the welfare gain from cooperation, we begin by defining the social welfare function that policymakers must maximize. We next solve for the optimal tax rates under independent decision-making and cooperation (which, for simplicity, entails no costs) and compare outcomes under these two regimes. Under the Nash equilibrium, each region ignores the benefit of the global public good for the other region, whereas under cooperation this effect is internalized. In addition, when they act independently, policymakers in each region internalize the benefit of the local public good for domestic production. Under both policy regimes, taxes are chosen subject to a world competitive equilibrium.

4.1 Welfare Criterion

Suppose that policymakers (acting either independently or jointly) are far-sighted and benevolent, in the sense that they take into account the welfare of all future generations of households. As discussed by De la Croix and Michel (2002, p. 91), the welfare criterion is thus the discounted sum of household utility across an infinite sequence of generations.

Formally, as established in the Appendix, the welfare criterion is given by

$$W_t^j = \sum_{s=0}^{\infty} \Lambda^s \Big\{ V_0 + (1 + \frac{\eta_C}{1+\rho}) \ln(1-\tau^j) w_{t+s}^j + (1 + \frac{\eta_C}{1+\rho} + \eta_H) \ln h_{t+s}^j \,, \tag{28}$$

$$+ \frac{\eta_C}{1+\rho} \ln(1 + r_{t+s+1}^j) \Big\},$$

where $\Lambda \in (0,1)$ is the policymaker's discount factor and V_0 is a constant term given by

$$V_0 = \ln(1-\sigma)\ell^W + \frac{\eta_C}{1+\rho} \ln \sigma \ell^W.$$

Along the balanced growth path, the real rate of return is constant, and so is health status. From (2), the wage rate is given by $w_t^j = \beta Y_t^j / h^j \ell^W$ and therefore grows at the same rate as output. Thus, as also shown in the Appendix, ignoring constant terms, the welfare function (28) can be approximated by

$$\mathcal{W}^j \simeq (1 + \frac{\eta_C}{1+\rho}) \frac{\ln(1-\tau^j)}{1-\Lambda} + \frac{\eta_H}{1-\Lambda} \ln h^j + \frac{\eta_C}{1+\rho} \frac{\ln(1+r^j)}{1-\Lambda} \tag{29}$$

$$+ (1 + \frac{\eta_C}{1+\rho}) \frac{\Lambda}{(1-\Lambda)^2} \ln(1+g^j),$$

where $1+g^j$ is defined by (24) and h^j in (26) or (27). The welfare objective consists therefore of four terms: a tax-related term (which captures the impact of taxation on net income, and consumption in both periods), a health-related term (which depends on how much health is valued), an interest rate term (which, holding the level of saving constant, captures the benefit of postponing consumption today for consumption in old age), and a growth-related term (which captures the effect of increasing wages on saving, and thus investment). The first term has a negative effect on household welfare, whereas the last three have a positive effect.

As established in the Appendix, substituting (2), (24), (26) or (27), and (25), for $1+r_t^j$, $1+g^j$, h^j, and $k^{j,I}$, in (29), and again ignoring constant terms, gives

$$\mathcal{W}^1 \simeq \Theta_1^A \ln(1-\tau^1) \tag{30}$$

$$+ \Theta_2 \ln[(\tau^{1,H})^{\theta_1} (\tau^{2,H})^{\theta_2} (\tau^{1,I})^{-\theta_3^1} (\tau^{2,I})^{\theta_4^1} (\frac{1-\tau^1}{1-\tau^2})^{-\theta_5^1}]$$

$$+ \Theta_3 [\ln \tau^{1,I} - \ln(1-\tau^1)],$$

and

$$\mathcal{W}^2 \simeq \Theta_1^A \ln(1-\tau^2) \tag{31}$$

$$+\Theta_2 \ln[(\tau^{1,H})^{\theta_1}(\tau^{2,H})^{\theta_2}(\tau^{1,I})^{\theta_3^2}(\tau^{2,I})^{-\theta_4^2}(\frac{1-\tau^1}{1-\tau^2})^{\theta_5^2}]$$
$$+\Theta_3[\ln \tau^{2,I} - \ln(1-\tau^2)],$$

where

$$\Theta_1^A = (1+\frac{\eta_C}{1+\rho})[\frac{1}{1-\Lambda} + \frac{\Lambda}{(1-\Lambda)^2}] > 0,$$
$$\Theta_2 = \frac{1}{1-\Lambda}(\eta_H + \frac{\eta_C \beta}{1+\rho}) + (1+\frac{\eta_C}{1+\rho})\frac{\Lambda\beta}{(1-\Lambda)^2} > 0,$$
$$\Theta_3 = \alpha\left\{\frac{1}{1-\Lambda}\frac{\eta_C}{1+\rho} + (1+\frac{\eta_C}{1+\rho})\frac{\Lambda}{(1-\Lambda)^2}\right\} > 0,$$

which shows that Θ_2 is increasing in the health preference parameter, η_H. In addition, as also established in the Appendix, $\Theta_1^A > \Theta_3$ and $sg(\beta^{-1}\Theta_2 - \Theta_1^A) = sg(\eta_H - \beta)$. These conditions are important to establish some of the properties of the optimal policy.

Based on the discussion of the previous section, it is clear from (30) and (31) that the objective function of each policymaker depends (through health status) on the health levy set by the other. There is also an indirect effect of each region's infrastructure levy on the other, related to the congestion effect alluded to earlier.

4.2 Optimal Policy

We now solve for the optimal tax rates under independent policymaking and cooperation.[27] For clarity, we consider separately two cases: first, the case where there is no external effect associated with public capital, and therefore no infrastructure levy; and second, the case where each region sets optimally both types of levies.

4.2.1 Health Taxes

We first solve for the optimal policy under the assumption that there is no externality associated with infrastructure ($\alpha = 0$). This implies that in (26), (27), (30), and (31) $\phi_1 = \Theta_3 = 0$ and $\theta_3^j = \theta_4^j = 0$.[28] A Nash equilibrium is thus the pair of strategies $(\tau_N^{1,H}, \tau_N^{2,H})$ which solves

$$\max_{\tau^{1,H}} \mathcal{W}^1(\tau^{1,H}, \tau^{2,H}), \quad \tau^{2,H} \text{ given}; \qquad \max_{\tau^{2,H}} \mathcal{W}^2(\tau^{1,H}, \tau^{2,H}), \quad \tau^{1,H} \text{ given},$$

[27] To determine the magnitude of the welfare gain from cooperation, relative to independent policymaking, a numerical analysis is conducted later on.

[28] An alternative would be to consider the case where α is positive and the infrastructure levy is set, for instance, at its optimal growth-maximizing value in the absence of health externalities. As discussed in the Appendix, under autarky this does not affect the results, even though local public goods have an indirect impact on health status. This is due to the log-linearity of preferences.

subject to $0 \leqq \tau^{j,H} \leqq 1$. Thus, $\partial\tau^{2,H}/\partial\tau^{1,H} = \partial\tau^{1,H}/\partial\tau^{2,H} = 0$. In a (symmetric) Nash equilibrium, $\tau_N^{1,H} = \tau_N^{2,H} = \tau_N^H$.

A (symmetric) cooperative equilibrium is the common health levy τ_C^H which solves the equally weighted global objective function

$$\max_{\tau^H} \sum_{j=1}^{2} 0.5\mathcal{W}^j(\tau^H),$$

subject to $0 \leqq \tau^H \leqq 1$ and $\mathcal{W}^j(\tau^H)$ is obtained by setting $\tau^{1,H} = \tau^{2,H}$ in (30) and (31).

As shown in the Appendix, in a symmetric equilibrium, where $\varphi = 0.5$, and $\theta_1 = \theta_2 = \theta = 0.5(1-\nu)$, so that $\theta_3^1 = \theta_4^1 = \theta_3^2 = \theta_4^2$ and $\theta_5^2 = \theta_5^1$, the following result can be demonstrated.

Proposition 2. *In a symmetric world and financial autarky, and with no external effects associated with the local public good ($\alpha = 0$), the welfare-maximizing health levy under a Nash equilibrium and under cooperation are given by, respectively,*

$$\tau_N^H = \frac{\Theta_2\theta}{\Theta_2\theta + \Theta_1^A - \Theta_2\Omega}, \qquad \tau_C^H = \frac{\Theta_2(1-\nu)}{\Theta_1^A + \Theta_2(1-\nu)}, \tag{32}$$

where $\Omega = \theta/\beta(1-\nu) > 0$.

The reason why an interior solution exists under both policy regimes is because there are conflicting effects on welfare. On the one hand, a higher health levy increases provision of the global good, which raises welfare directly, as well as indirectly, through labor productivity and growth. On the other, it also lowers savings and investment at home, which reduces private capital accumulation and growth, and therefore welfare. In addition, as discussed earlier, a higher health levy in one region affects the other, and this is internalized by each national fiscal authority under cooperation.

From these results, it is clear that $\tau_N^H = \tau_C^H = 0$ if $\nu = 1$ (in which case $\theta = 0$), that is, if vaccines do not affect individual health. Indeed, when $\nu = 1$, there can be no gains from cooperation. The reason is that there is no production of the global public good, and countries cannot benefit from each other's spending; thus, $h_t^j = \ell^H$. Moreover, $d\tau_N^H/d\nu$, $d\tau_C^H/d\nu < 0$; the weaker the importance of vaccines for individual health (the higher ν is), the smaller the optimal tax rate under both regimes. The same result obtains if β, which measures the impact of effective labor on the growth rate, increases.

The symmetric Nash equilibrium is illustrated in Figure 2. The reaction curves are vertical (region 1) and horizontal (region 2).[29] Nonetheless, as discussed next, there are gains from cooperation because the payoff for each policymaker is not independent of the other policymaker's strategy. The initial equilibrium is at point E if $\nu \simeq 1$ and at point N when $0 < \nu < 1$. An increase in ν, that is, a reduction in the individual health benefit provided by vaccines, lowers the optimal health levy, shifting the equilibrium from point N to point N'.

From the results above, and as shown in the Appendix, the following corollary can also be established.

Corollary to Prop. 2. *Under the conditions specified in Proposition 2, the optimal health levy is greater (respectively, lower) under cooperation than under Nash, $\tau_C^H > \tau_N^H$ (respectively, $\tau_C^H < \tau_N^H$), if $\eta_H < \beta$ (respectively, $\eta_H > \beta$). The optimal levy is the same under both regimes ($\tau_C^H = \tau_N^H$) if $\eta_H = \beta$, and there are no gains to cooperation.*

Thus, cooperation does not necessarily entail higher taxation. If the preference parameter for health, η_H, is low compared to the labor elasticity of output, β, there is under-provision of the global public good when health levies are chosen noncooperatively. Under Nash, each region fails to account for the benefits of its health levy (through the supply of vaccines) on the other. As a result, when tax rates are set unilaterally, they are generally too low to finance the optimal provision of global public goods. However, there is a also cost because, under noncooperation, each region fails to take into account the fact that the reduction in domestic consumption needed to finance its contribution to the production of the global public good leads to lower saving and thus a lower growth rate at home. The higher β is, relative to η_H, the larger this effect. As a consequence, the under-provision problem associated with national contributions to the global public good is more severe when policymakers act unilaterally. The reverse is true when η_H is high relative to β. In that case, the benefit of higher taxation on health and welfare is relatively large, even though the negative effect on growth is ignored under noncooperation. As a result, it is optimal to tax wages at a higher rate than under cooperation to finance the provision of vaccines. When $\eta_H = \beta$, the health and welfare benefits of taxing more under cooperation are offset by the adverse effect on production and wages, and cooperation generates no gain.[30]

[29] This is a standard result if the Nash equilibrium is dominant and if the assumption of a zero conjectured response is correct; see Turnovsky (1988), for instance.

[30] The relationship between the welfare-maximizing and growth-maximizing health levies is discussed in the Appendix.

4.2.2 Health and Infrastructure Taxes

Consider now the case where policymakers set both the infrastructure and health levies. A Nash equilibrium is now the set $(\tau_N^{1,H}, \tau_N^{1,I}, \tau_N^{2,H}, \tau_N^{2,I})$ which solves

$$\max_{\tau^{1,H},\tau^{1,I}} \mathcal{W}^1(\tau^{1,H}, \tau_N^{1,I}, \tau^{2,H}, \tau^{2,I}), \quad \tau^{2,H}, \tau^{2,I} \text{ given},$$

$$\max_{\tau^{2,H},\tau^{2,I}} \mathcal{W}^2(\tau_N^{1,H}, \tau^{1,I}, \tau^{2,H}, \tau^{2,I}), \quad \tau^{1,H}, \tau^{1,I} \text{ given},$$

subject to $0 \leqq \tau^{j,h} \leqq 1$, $h = H, I$, and $\tau^j = \tau^{j,H} + \tau^{j,I} \leqq 1$. In a Nash equilibrium, $\tau_N^{1,h} = \tau_N^{2,h} = \tau_N^h$.

A cooperative equilibrium is the set $(\tau_C^{1,H} = \tau_C^{2,H} = \tau_C^H,\ \tau_C^{1,I} = \tau_C^{2,I} = \tau_C^I)$ which solves the equally weighted global objective function

$$\max_{\tau^H,\tau^I} \sum_{j=1}^{2} 0.5\mathcal{W}^j(\tau^H, \tau^I),$$

where $\mathcal{W}^j(\tau^H, \tau^I)$ is obtained by setting $\tau^{1,H} = \tau^{2,H}$ and $\tau^{1,I} = \tau^{2,I}$ in (30) and (31).

As shown in the Appendix, in a symmetric equilibrium the following result can be established.[31]

Proposition 3. *In a symmetric world and financial autarky, and with external effects associated with the local public good ($\alpha > 0$), the welfare-maximizing health and infrastructure levies under a Nash equilibrium and under cooperation are given by, respectively,*

$$\tau_N^H = \frac{\Theta_2\theta}{\Theta_2\theta + \Theta_1^A - \Theta_2\Omega}, \quad \tau_N^I = \min[\max(0, \frac{\Theta_3 - \Theta_2\theta\phi_1}{\Theta_2\theta + \Theta_1^A - \Theta_2\Omega}), 1], \tag{33}$$

$$\tau_C^H = \frac{\Theta_2(1-\nu)}{\Theta_1^A + \Theta_2(1-\nu)}, \quad \tau_C^I = \frac{\Theta_3}{\Theta_1^A + \Theta_2(1-\nu)}, \tag{34}$$

where again $\Omega = \theta/\beta(1-\nu) > 0$.

These results show, in particular, that under both policy regimes the optimal health levies are the same as when there is no externality associated with the local public good (Proposition 2). In addition, as before $\tau_N^H = \tau_C^H = 0$ if $\nu = 1$, whereas $\tau_N^I = 0$ if $\alpha = 0$, given that in that case $\Theta_3 = \phi_1 = 0$.

As also shown in the Appendix, the following result can be established.

Corollary to Prop. 3. *Under the conditions specified in Proposition 3, whether the optimal health levy under cooperation exceeds the optimal value under a Nash equilibrium ($\tau_C^H \gtreqless \tau_N^H$) depends on $\eta_H \gtreqless \beta$, whereas the optimal infrastructure levy is always higher under cooperation than under a Nash equilibrium ($\tau_C^I > \tau_N^I$).*

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[31]The Appendix shows that for an interior solution for τ_N^I to exist, the elasticity of output with respect to infrastructure, α, must be sufficiently high.

Thus, as before, if distortionary health levies are chosen noncooperatively, there may be under-provision (if $\eta_H < \beta$) or over-provision (if $\eta_H > \beta$) of the global public good, depending on how much households value their health. In addition, there is also under-provision of the *local* public good under noncooperation. The reason is the same as before—under Nash, each region fails to internalize the benefit that a higher stock of public infrastructure—which raises output, the tax base, the contribution to the global fund, and thus the production of vaccines—provides to both of them. At the same time, the potentially adverse effects of taxation on consumption, savings and growth at home are fully accounted for as well, and this mitigates incentives for both regions to impose an infrastructure levy that is excessively high.

5 Extensions

In what follows, we consider three extensions of the analysis: the case when financial markets are fully integrated; the case of a direct expenditure trade-off, in a setting where there is a single distortionary tax rate, and government allocate revenues between its contribution to the global health fund and infrastructure investment at home; and the case where each region's contribution to the global fund is financed by a tax on capital or wealth.

5.1 Financial Integration

The foregoing analysis was based on the polar case where capital does not flow across regions. If the two regions of the world economy are viewed as consisting of advanced (core) economies and developing (periphery) economies, this assumption is consistent with the evidence which suggests that capital remains imperfectly mobile between these two regions. At the same time, however, there is evidence that, in the past decades—and abstracting from the temporary retrenchment associated with the global financial crisis—that the degree of capital mobility (as measured, for instance, by the magnitude of gross capital flows or changes in net international asset positions) has increased, in part due to the globalization of banking.[32] In the present setting, imperfect financial integration could be accounted for by introducing capital relocation costs across borders, as in Becker and Rauscher (2013), for instance. However, to

[32] See, for instance, Lane and Milesi-Ferretti (2018) and Avdjiev t al. (2022).

sharpen the contrast with autarky, we will focus instead on the polar case where full integration prevails.

Under full integration, and perfect capital mobility across borders, rates of return must be equalized across regions:[33]

$$1 + r_t^1 = 1 + r_t^2, \tag{35}$$

and the global equilibrium between savings and investment takes the form

$$K_{t+1}^{1,P} + K_{t+1}^{2,P} = \bar{N}^1 s_t^1 + \bar{N}^2 s_t^2, \tag{36}$$

which implies that, in each region, the stock of private capital can be greater or smaller than domestic saving. Thus, under financial integration, the definition of a world competitive equilibrium provided earlier must be amended to include the requirement that world savings must be equal to world investment, whereas the definition of the global balanced growth equilibrium must include equality between the rates of return on private capital across regions.

As established in the Appendix, the model's dynamics are now driven by a first-order, highly nonlinear dynamic system in $k_{t+1}^{1,I}$ and $k_{t+1}^{2,I}$. The steady-state growth rate is now given by

$$1 + g^j = (k^{j,I})^{\alpha}(h^j \ell^W)^{\beta}(\frac{x}{1+x})\sigma\beta[(1-\tau^1) + (\frac{1-\tau^2}{x})], \tag{37}$$

where h^1 and h^2 are defined by expressions similar to (26) and (27), this time with $\theta_5^1 = \theta_5^2 = 0$. The equilibrium public-private capital ratio is now given by

$$k^{j,I} = \upsilon_I \tau^{j,I}/\sigma \left\{ (\frac{x}{1+x})[(1-\tau^1) + (\frac{1-\tau^2}{x})] \right\}, \tag{38}$$

which implies that

$$\frac{k^{1,I}}{k^{2,I}} = \frac{\tau^{1,I}}{\tau^{2,I}}, \tag{39}$$

whereas x, the domestic-foreign private capital ratio, is given by

$$x = (\frac{\tau^{1,I}}{\tau^{2,I}})^{\phi_1}. \tag{40}$$

[33] Of course, if countries are symmetric in all respects, then rental rates would be the same—regardless of how mobile capital is, internationally. However, underlying (35) is the assumption that perfect capital mobility ensures equal rates of return—even if there are structural differences across countries.

Thus, from (37), under financial integration the growth rate in each region is now a function not only of the region's own public-private capital ratio, $k^{j,I}$, and of each region's tax policies, τ^1 and τ^2, both directly and indirectly (through health status, as discussed earlier), but also directly on the allocation of private capital across regions, x. From (38), and in contrast to the case of financial autarky (see(25)), the public-private capital ratio in each region depends also on tax rates in *both* regions—and so does the steady-state growth rate.

Intuitively, these results obtain because now changes in one region's tax rates influence private capital accumulation both at home and abroad, as well as its global distribution, as implied by (40). As long as $\alpha > 0$, this creates therefore a cross-border spillover associated with local public goods—or, equivalently, the tax rates used to finance them.[34] This is indeed the key difference with the benchmark case of financial autarky. In particular, health levies continue to generate the same type of conflicting effects on the domestic growth rate, in large part because of the trade-off associated with health status—a direct positive externality through contributions to the production of vaccines, and a negative externality through congestion.

As shown in the Appendix, under financial integration, and ignoring again constant terms, the welfare function approximations are now given by

$$\mathcal{W}^1 \simeq \Theta_1^O \ln(1-\tau^1) \tag{41}$$

$$+\Theta_2 \ln[(\tau^{1,H})^{\theta_1}(\tau^{2,H})^{\theta_2}(\tau^{1,I})^{-\theta_3^1}(\tau^{2,I})^{\theta_4^1}] + \Theta_3 \ln \tau^{1,I} + (\Theta_3 - \Theta_4)\ln[1 + (\frac{\tau^{1,I}}{\tau^{2,I}})^{\phi_1}]$$

$$-(\Theta_3 - \Theta_4)\ln[(\frac{\tau^{1,I}}{\tau^{2,I}})^{\alpha}(1-\tau^1) + (1-\tau^2)],$$

and

$$\mathcal{W}^2 \simeq \Theta_1^O \ln(1-\tau^2) \tag{42}$$

$$+\Theta_2 \ln[(\tau^{1,H})^{\theta_1}(\tau^{2,H})^{\theta_2}(\tau^{1,I})^{\theta_3^2}(\tau^{2,I})^{-\theta_4^2}] + \Theta_3 \ln \tau^{2,I} + (\Theta_3 - \Theta_4)\ln[1 + (\frac{\tau^{1,I}}{\tau^{2,I}})^{\phi_1}]$$

$$-(\Theta_3 - \Theta_4)\ln[(\frac{\tau^{1,I}}{\tau^{2,I}})^{\phi_1}(1-\tau^1) + (1-\tau^2)],$$

where parameters are as defined previously and, in addition,

$$\Theta_1^O = \frac{1}{1-\Lambda}(1 + \frac{\eta_C}{1+\rho}), \qquad \Theta_4 = (1 + \frac{\eta_C}{1+\rho})\frac{\Lambda}{(1-\Lambda)^2},$$

[34] When $\alpha = 0$ (no externality associated the local public good), $\phi_1 = 0$ and equation (40) implies that $x = 1$; the private capital stock is the same in both countries.

so that $\Theta_1^O + \Theta_4 = \Theta_1^A$.

As before, consider first the case where there is no externality associated with infrastructure ($\alpha = 0$).[35] In the Appendix it is shown that under noncooperation the optimal solutions are determined by

$$\frac{\Theta_1^O}{1-\tau^{1,H}} + \frac{\Theta_2\theta_1}{\tau^{1,H}} - \frac{\Theta_4}{(1-\tau^{1,H})+(1-\tau^{2,H})} = 0,$$

$$\frac{\Theta_1^O}{1-\tau^{2,H}} + \frac{\Theta_2\theta_2}{\tau^{2,H}} - \frac{\Theta_4}{(1-\tau^{1,H})+(1-\tau^{2,H})} = 0,$$

which define the reaction functions of the two policymakers. These functions are highly nonlinear and, in general, may exhibit multiple solutions. However, as established in the Appendix, in a symmetric equilibrium the following result can also be established.

Proposition 4. *In a symmetric world and financial integration, and with no external effects associated with the local public good (*$\alpha = 0$*), the welfare-maximizing health levy under a Nash equilibrium and under cooperation are given by, respectively,*

$$\tau_N^H = \frac{\Theta_2\theta}{\Theta_2\theta + \Theta_1^O + 0.5\Theta_4}, \quad \tau_C^H = \frac{\Theta_2(1-\nu)}{\Theta_1^A + \Theta_2(1-\nu)}. \tag{43}$$

Thus, under cooperation, the solution is the same as in (34); if countries act jointly, the degree of financial integration does not matter for the optimal policy when $\alpha = 0$. By contrast, comparing (33) with (43) shows that, even though $\Theta_1^A > \Theta_1^O + 0.5\Theta_4$, the relationship between the optimal health levy in a Nash equilibrium under financial integration and under autarky is ambiguous. The reason, as noted earlier, is that under perfect capital mobility there are two additional effects when policymakers act in noncooperative fashion: they do not internalize the fact that their choice of the health levy affects private capital accumulation abroad, and they do not account for the fact that higher taxes abroad, through their impact on foreign savings, also has an impact on the *distribution* of savings across regions—and thus capital accumulation at home, which in turn affects domestic growth and welfare.

In addition, a comparison of τ_N^H with τ_C^H in (43) yields the following result.

Corollary to Prop. 4. *Under the conditions specified in Proposition 4, the optimal health levy is greater under cooperation than under a Nash equilibrium,* $\tau_C^H > \tau_N^H$.

This result therefore differs from the corollary to Proposition 2: independent policymaking entails now under-provision of the public good, regardless of the value of η_H.

[35] The case where there is no health externality associated with the global public good ($\nu = 1$) is discussed in the Appendix. Not surprisingly, the results obtained under financial autarky remain the same.

In the general case where $\alpha > 0$ and fiscal authorities choose both types of levies, it is shown in the Appendix that under cooperation the optimal health and infrastructure levies are the same as those obtained under financial autarky (Proposition 3) and, for the health levy, the same also as what obtains under financial integration and $\alpha = 0$ (Proposition 4). Thus, once again, the degree of financial integration does not matter for the optimal policy when policymakers cooperate, and neither does the value of α. However, under noncooperation, the optimal levies are

$$\tau_N^H = \frac{\Theta_2\theta}{\Theta_2\theta(1-\phi_1)+\Theta_1^O+0.5\Theta}, \quad \tau_N^I = \min[\max(0, \frac{\Theta_3-\Theta_2\theta\phi_1}{\Theta_2\theta(1-\phi_1)+\Theta_1^O+0.5\Theta}), 1], \tag{44}$$

where $\Theta = \Theta_3 + \Theta_4$. These expressions are fairly complex, so whether they are higher or lower than under cooperation cannot be established unambiguously.

5.2 Expenditure Trade-off

In the foregoing discussion, health and infrastructure levies were modeled separately, in order to characterize in the clearest fashion the intrinsic trade-offs involved in each case. Consider now a setting where there is a single tax rate on wages, τ^j, whose revenues are split between a contribution to the global fund, in proportion $\upsilon^{j,H}$, infrastructure investment, with share $\upsilon^{j,I}$, and other spending, in proportion $\upsilon^{j,I}$. The government budget constraint (10) therefore becomes

$$G_t^{j,H} + G_t^{j,I} + G_t^{j,O} = \tau^j \bar{N}^j \ell_t^{j,W} a_t^j w_t^j, \tag{45}$$

with each component being set as

$$G_t^{j,h} = \upsilon^{j,h}\tau^j \bar{N}^j \ell_t^{j,W} a_t^j w_t^j. \tag{46}$$

Thus, combining (45) and (46) yields

$$\upsilon^{j,H} + \upsilon^{j,I} + \upsilon^{j,O} = 1, \tag{47}$$

which implies that, holding $\upsilon^{j,O}$ constant, health and infrastructure spending allocations are not independent. Thus, the direct trade-off between health and infrastructure spending can be captured by imposing $d\upsilon^{j,H} + d\upsilon^{j,I} = 0$. In that case, the instruments that policymakers in each region choose are τ^j, and $\upsilon^{j,H}$.

As shown in the Appendix, the steady-state growth rate is now given by an expression similar to (24), with τ^j the single tax rate, whereas the welfare function approximations take the form, ignoring again constant terms,

$$\mathcal{W}^1 \simeq \Theta_1^A \ln(1-\tau^1)$$
$$+\Theta_2 \ln\left\{(\upsilon^{1,H})^{\theta_1}(\upsilon^{2,H})^{\theta_2}(\upsilon^{1,I})^{-\theta_3^1}(\upsilon^{2,I})^{\theta_4^1}(\frac{1-\tau^1}{1-\tau^2})^{-\theta_5^1}(\tau^1)^{\theta_6^1}(\tau^2)^{\theta_7^1}\right\}$$
$$+\Theta_3[\ln \upsilon^{1,I} + \ln \tau^1 - \ln(1-\tau^1)],$$

and

$$\mathcal{W}^2 \simeq \Theta_1^A \ln(1-\tau^2)$$
$$+\Theta_2 \ln\left\{(\upsilon^{1,H})^{\theta_1}(\upsilon^{2,H})^{\theta_2}(\upsilon^{1,I})^{\theta_3^2}(\upsilon^{2,I})^{-\theta_4^2}(\frac{1-\tau^1}{1-\tau^2})^{\theta_5^2}(\tau^1)^{\theta_6^2}(\tau^2)^{\theta_7^2}\right\}$$
$$+\Theta_3[\ln \upsilon^{2,I} + \ln \tau^2 - \ln(1-\tau^2)],$$

where all coefficients are as defined before and, in addition,

$$\theta_6^1 = \theta_1 - \theta_2\phi_1, \quad \theta_7^1 = \theta_2(1+\phi_1),$$

$$\theta_6^2 = \theta_1(1+\phi_1), \quad \theta_7^2 = \theta_2 - \theta_1\phi_1.$$

As also established in the Appendix, in a symmetric equilibrium, $\theta_3^1 = \theta_4^2$, $\theta_5^1 = \theta_5^2$, $\theta_7^1 = \theta_6^2$, and $\theta_6^1 = \theta_7^2$. Assuming that $\upsilon^{j,O} = 0$ for simplicity, so that from equation (47) $\upsilon^{j,I} = 1-\upsilon^{j,H}$, the Appendix shows that the optimal tax rate and investment spending share can be solved for separately. Given the focus here on spending allocation, the solutions for the tax rate are relegated to the Appendix; for the spending share, the results can be summarized in the following proposition.

Proposition 5. *In a symmetric world and financial autarky, and with a direct trade-off between health and infrastructure spending (and thus $\alpha > 0$), the welfare-maximizing health and infrastructure levies under a Nash equilibrium and under cooperation are given by*

$$\upsilon_N^H = \min[\max(0, \frac{\Theta_2\theta}{\Theta_2\theta(1-\phi_1)+\Theta_3}), 1], \quad \upsilon_C^H = \frac{\Theta_2(1-\nu)}{\Theta_3+\Theta_2(1-\nu)}. \tag{48}$$

Because policymakers internalize the direct trade-off between productive components of spending, these solutions are not directly comparable with those obtained earlier. Nevertheless, an examination of their properties yields several results. First, under both policy regimes, the optimal share of spending on health is positively (negatively) related to β (α). Whether they act jointly or not, policymakers internalize the fact that there is a domestic trade-off between productive components of expenditure. Thus, as $\alpha \rightarrow 0$ (weak externality associated with the local public good), this trade-off vanishes, and under either regime the optimal share of spending on health tends to unity.

Second, a comparison of υ_C^H and υ_N^H yields the following result.

Corollary to Prop. 5. *Under the conditions specified in Proposition 5, the optimal share of spending on health is lower under cooperation than under a Nash equilibrium,* $\upsilon_C^H < \tau_N^H$.

Intuitively, when there is a direct trade-off between components of public expenditure, policymakers acting jointly internalize the fact that spending more on health creates benefits but also indirect costs for both regions—spending less on infrastructure means less production and lower wages, which reduces the tax base in each region, and therefore the total amount of revenue that can be raised and transferred to the global fund. Thus, cooperation leads to a smaller, rather than a larger, share of spending on health.

5.3 Wealth-based Health Levy

Suppose now that, to finance the production of the global public good, each fiscal authority imposes a levy on gross income from capital. Thus, in contrast to much of the existing literature on capital taxation, the capital tax is earmarked and directly productive. It potentially exerts not only a static cross-border allocation effect but also a dynamic, permanent growth effect, as in Krueger and Ludwig (2021) and Guvenen et al. (2023), for instance. With implementability concerns in mind, we only consider a linear tax.

Equations (7) and (8) become

$$c_t^{j,t} + s_t^j = (1 - \tau^{j,I})\ell_t^{j,W} a_t^j w_t^j, \tag{49}$$

$$c_{t+1}^{j,t} = (1 - \tau^{j,H})(1 + r_{t+1}^j)s_t^j, \tag{50}$$

whereas revenue from the health tax, as defined in (13), is now

$$G_t^{j,H} = \tau^{j,H}(1 + r_t^j)K_t^{j,P}, \tag{51}$$

with all other equations remaining the same.[36] If only capital *income* is taxed—as is common in the literature on capital taxation—equations (50) and (51) would take the form $c^{j,t}_{t+1} = [1+(1-\tau^{j,H})r^j_{t+1}]s^j_t$ and $G^{j,H}_t = \tau^{j,H} r^j_t K^{j,P}_t$, respectively. Our specification assumes instead that both the capital stock, and the income that it generates, are taxed at the rate $\tau^{j,H}$. Thus, because capital is the only asset that households can hold, the capital-based health levy in our setting is also a wealth tax.[37]

In the Appendix, it is shown that the welfare function approximations take now the form

$$\mathcal{W}^1 \simeq \Theta_1^A \ln(1-\tau^{1,I}) + \frac{\eta_C}{1+\rho}\frac{\ln(1-\tau^{1,H})}{1-\Lambda} \tag{52}$$
$$+\Theta_2 \ln\left\{(\tau^{1,H})^{\theta_1}(\tau^{2,H})^{\theta_2}(\tau^{1,I})^{-\theta_3^1}(\tau^{2,I})^{\theta_4^1}\left(\frac{1-\tau^{1,I}}{1-\tau^{2,I}}\right)^{-\theta_5^1}\right\}$$
$$+\Theta_3[\ln\tau^{1,I} - \ln(1-\tau^{1,I})],$$

and

$$\mathcal{W}^2 \simeq \Theta_1^A \ln(1-\tau^{2}) + \frac{\eta_C}{1+\rho}\frac{\ln(1-\tau^{2,H})}{1-\Lambda} \tag{53}$$
$$+\Theta_2 \ln\left\{(\tau^{1,H})^{\theta_1}(\tau^{2,H})^{\theta_2}(\tau^{1,I})^{\theta_3^2}(\tau^{2,I})^{-\theta_4^2}\left(\frac{1-\tau^{1,I}}{1-\tau^{2,I}}\right)^{\theta_5^2}\right\}$$
$$+\Theta_3[\ln\tau^{2,I} - \ln(1-\tau^{2,I})].$$

Under financial autarky, and in a symmetric equilibrium, the following results are established in the Appendix.

Proposition 6. *In a symmetric world and financial autarky, with a wealth tax on private capital, and no external effects associated with the local public good ($\alpha = 0$), the welfare-maximizing health levy under a symmetric Nash equilibrium and under cooperation are given by, respectively,*

$$\tau_N^H = \frac{\Theta_2\theta}{\Theta_2\theta+\Theta_5}, \qquad \tau_C^H = \frac{\Theta_2(1-\nu)}{\Theta_2(1-\nu)+\Theta_5}, \tag{54}$$

where $\Theta_5 = \eta_C/(1+\rho)(1-\Lambda) > 0$.

The properties of these solutions are similar to those obtained earlier under autarky. In particular, the optimal tax on capital is zero, under either regime, if access to vaccines generates no externality for individual health ($\nu = 1$). This is the same result

[36] Note that because of the log-linear form of preferences, the savings rate remains independent of the interest rate—and thus of the capital tax rate as well.

[37] Conditions under which a capital income tax can be interpreted as a wealth tax are discussed by Guvenen et al. (2023). Note also that if only capital itself is taxed, (50) and (51) would take the form $c^{j,t}_{t+1} = (1+r^j_{t+1})s^j_t$ and $G^{j,H}_t = \tau^{j,H}K^{j,P}_t$.

as was obtained earlier with a tax on wages (see Propositions 2 and 3). This is also in line with the literature on optimal capital taxation, when the productive use of the tax is ignored and only its adverse effects on savings and investment is accounted for (see, for instance, Bastani and Waldenström (2020)). Put differently, when $\nu < 1$, the model provides a rationale for capital income taxation that is not directly related to redistributive considerations, heterogeneity in preferences, borrowing constraints, and so on: through its impact on the supply of global public goods, it improves the *quality* of human capital, which benefits growth and welfare everywhere. There is therefore a sort of redistributive effect from capital owners to workers, but it operates indirectly.

In addition, the following result is derived in the Appendix.

Corollary to Prop. 6. *Under the conditions specified in Proposition 6, the optimal health levy is higher under cooperation than under a Nash equilibrium,* $\tau_C^H > \tau_N^H$.

This result is the same as under a wage-based health levy and financial integration (see corollary to Proposition 4). Intuitively, a higher tax on either wages or capital is efficient because, regardless of whether capital flows freely between regions or not, cooperation internalizes the cross-border externality associated with the provision of vaccines. Once again, this result no longer depends on the value of η_H.

With $\alpha > 0$, the following results are also established in the Appendix.

Proposition 7. *In a symmetric world and financial autarky, with a wealth tax on private capital, and external effects associated with the local public good* ($\alpha > 0$)*, the welfare-maximizing health and infrastructure levies under a Nash equilibrium and under cooperation are given by, respectively,*

$$\tau_N^H = \frac{\Theta_2\theta}{\Theta_2\theta + \Theta_5}, \quad \tau_N^I = \min[\max(0, \frac{\Theta_3 - \Theta_2\theta\phi_1}{\Theta_1^A - \Theta_2\Omega}), 1], \tag{55}$$

$$\tau_C^H = \frac{\Theta_2(1-\nu)}{\Theta_2(1-\nu) + \Theta_5}, \quad \tau_C^I = \frac{\Theta_3}{\Theta_1^A}, \tag{56}$$

where $\Theta_5 = \eta_C/(1+\rho)(1-\Lambda) > 0$.

Comparing Propositions 6 and 7 shows, importantly, that whether an externality associated with the local public good is present or not does not affect the optimal solution for the health levy.[38] In addition, the following corollary holds.

Corollary to Prop. 7. *Under the conditions specified in Proposition 7, the optimal health and infrastructure levies are both higher under cooperation than under a Nash equilibrium,* $\tau_C^H > \tau_N^H$ *and* $\tau_C^I > \tau_N^I$.

[38] As shown in the Appendix, the solution for τ_C^I (which satisfies $\tau_C^I < \alpha$) is the same that would be obtained if there was no externality associated with the global public good.

The result $\tau_C^H > \tau_N^H$ is the same as when $\alpha = 0$ (see corollary to Proposition 6).

However, do these results hold in the polar case of perfect capital mobility? Under financial integration and a wealth tax, the arbitrage condition (35) becomes

$$(1 - \tau^{1,H})(1 + r_{t+1}^1) = (1 - \tau^{2,H})(1 + r_{t+1}^2), \tag{57}$$

which shows that it is now the *after-tax* rates of return that are equalized across region.

The approximations to the welfare functions are now a bit more cumbersome and are relegated to the Appendix, where it is also shown that now the home-foreign private capital ratio is given by, instead of (40),

$$x = (\frac{\tau^{1,I}}{\tau^{2,I}})^{\phi_1}(\frac{1 - \tau^{1,H}}{1 - \tau^{2,H}})^{\phi_3}, \tag{58}$$

where

$$\phi_3 = \frac{1 + \beta(1 - \nu)}{\beta(1 - \nu)} > 1.$$

Thus, the home-foreign private capital ratio depends also directly on the health levies, with the home (foreign) levy having a negative (positive) effect on that ratio. Intuitively, as can be inferred from (57), an increase in the home levy, $\tau^{1,H}$, holding foreign variables constant, must be offset by a fall in the rate of return on domestic private capital. From (2) and (4), holding productivity constant, the home public-private capital ratio must increase, and for that to occur the private capital stock must fall—and so does x.

The following result is established in the Appendix.

Proposition 8. *In a symmetric world and financial integration, with a wealth tax on private capital, no external effects associated with the local public good ($\alpha = 0$), the welfare-maximizing wealth levy under a symmetric Nash equilibrium and under cooperation are given by, respectively,*

$$\tau_N^H = \min[\max(0, \frac{\Theta_2\theta}{\Theta_2(\theta - \Omega) + \Theta_5}), 1], \quad \tau_C^H = \frac{\Theta_2(1 - \nu)}{\Theta_2(1 - \nu) + \Theta_5}. \tag{59}$$

It can be verified (see the Appendix) that a necessary and sufficient condition for an interior solution for τ_N^H is $\Theta_2\Omega < \Theta_5$. In addition, comparing (56) and (59), it can readily be seen that under noncooperation, if the solution in (59) is interior, the wealth tax is higher under financial integration than under autarky.

These results show that, once again, under cooperation, the optimal health levy under financial integration is the same as under financial autarky. The reason is that any leakage under openness is fully internalized for when regions cooperate. However, this is not necessarily the case under a Nash equilibrium.

The following result is also derived in the Appendix.

Corollary to Prop. 8. *Under the conditions specified in Proposition 8, the optimal health levy is lower under cooperation than under Nash,* $\tau_C^H < \tau_N^H$.

Thus, the result for the health levy under financial integration is *opposite* to what obtains under financial autarky, as noted in the corollary to proposition 6. Intuitively, when capital can move freely across regions, the arbitrage condition (57) implies that taxation at home induces a cross-border leakage in the allocation of capital, or capital flight. Under independent policymaking, this leakage is ignored and it is optimal to tax domestic capital at a higher rate. By contrast, under cooperation, cross-border leakages are internalized by both policymakers acting jointly, and it is now optimal to tax capital *less* than under Nash.

In the general case where $\alpha > 0$, it is shown in the Appendix that, under cooperation, the optimal health and infrastructure levies under financial integration are again the same as those obtained when $\alpha = 0$ under autarky—leakages that occur when capital is perfectly mobile are fully internalized when regions choose to cooperate. In addition, under independent policymaking, the same result obtains for the optimal health levy, and the corollary to Proposition 8 continues to hold: the optimal health levy under cooperation is again *lower* than under Nash ($\tau_C^H < \tau_N^H$), in contrast to what obtains under autarky. However, an explicit analytical solution can no longer be obtained for the optimal infrastructure levy under independent policymaking. Consequently, the sign of the difference between τ_C^I and τ_N^I cannot be readily established.

Table 1 summarizes all the previous analytical results. To gain further insight and evaluate the welfare gain associated with policy coordination, we now turn to a simple numerical evaluation.

6 Numerical Evaluation

To calibrate the model, we begin by setting he elasticity of output with respect to labor, β, to 0.7, in line with the empirical evidence (see, for instance, Cette et al. (2019)). This yields a value of the elasticity of output with respect to private capital equal to 0.3, a common benchmark.[39] The first set of results assumes that the elasticity of output with respect to the public-private capital ratio, α, is 0, whereas the second set assumes

[39] An alternative value of $\beta = 0.65$, and thus an elasticity of output with respect to private capital equal to 0.35, yields results that are qualitatively similar to those reported in this section.

that $\alpha = 0.17$, consistent with the evidence provided by Calderón et al. (2015) and the meta-analysis of Bom and Ligthart (2014). This allows us, in line with the foregoing derivations, to contrast the cases with and without local public goods, and thus (in the latter case) a single tax rate to solve for. The parameter ν, which measures the elasticity of health status with respect to time devoted to health-related activities, is set initially at 0.8, to capture the case where vaccines do not have a significant impact on health outcomes.

The household savings rate, σ , is set at 15 percent, in line with the evidence.[40] The annual discount rate is set to a standard value of 0.02. Interpreting one period in the model as 30 years yields an intergenerational discount factor of $[1/(1+0.02)]^{30} = 0.552$. The policymaker's discount factor, Λ, is set at the same value. From the definition of the savings rate given in (23), the preference parameter for current consumption can be solved backward to give $\eta_C = 0.15 \cdot 0.552^{-1}/(1 - 0.15) = 0.319$. Parameter η_H is set at 0.95, a value slightly less than unity, to capture the view that although households value health, they don't do so nearly as much as current consumption. Thus, the benchmark case corresponds to a situation where $\eta_H > \beta$. Sensitivity analysis is reported later on with respect to both ν and η_H. As noted earlier, $\varphi = 0.5$, consistent with the assumption that the two regions are symmetric in all respects.

Welfare gains are measured in terms of the relative difference between the value of the welfare objective functions (30) and (31) under cooperation and independent policymaking.[41]

6.1 Core Model

The results for the core model are reported in Table 2, which has the same structure as Table 1. When $\alpha = 0$, consistent with Propositions 2 and 3, the optimal health levy is higher under Nash than under cooperation; 0.155, compared to 0.137. The welfare gain is also not large (about 0.3 percent). When $\alpha = 0.17$, the results for the health levy under both regimes are the same as under $\alpha = 0$, and the infrastructure levy is now higher under cooperation than under Nash (0.091, compared to 0.017).

[40] See https://data.oecd.org/hha/household-savings.htm.

[41] Alternatively, as in Devereux and Mansoorian (1994), welfare could be measured in terms of the proportional increase in permanent consumption that an individual in the Nash regime would require so as to be left as well off as one in a cooperative regime. In the present case, the two measures give similar results.

In addition, at 10.5 percent, the welfare gain from cooperation is now substantially higher than before. With $\nu = 0.9$, which implies that vaccines play a less significant role as determinants of health outcomes in both regions, the optimal health levies are lower under both regimes (for instance, with $\alpha = 0$, the optimal value is now 0.084 under Nash, compared to 0.155 before), whereas the optimal infrastructure levies (with $\alpha = 0.17$) are fairly similar. This therefore illustrates the trade-offs alluded to earlier when maximizing household welfare. The other results are qualitatively the same; in particular, the gain from cooperation is substantially higher when there are external effects associated with the local public good.

Table 2 also shows the results when $\eta_H = 0.55$, that is, when the condition $\eta_H < \beta$ holds. This time, and consistent with the corollaries to Propositions 2 and 3, the optimal health levy is higher under cooperation than under Nash; but the difference between the two regimes is now smaller. As a result, the gain from cooperation, independently of the value of α, is also significantly smaller than in the previous case when $\eta_H > \beta$. For instance, with $\nu = 0.8$ and $\alpha = 0.17$, the welfare gain from cooperation is now 3.2 percent, compared to 10.5 percent. Similar results obtain for $\nu = 0.9$ (gain of 4.1 percent, instead of 13.1 percent). The main difference is that, as can be inferred from equation (17), and the discussion of Proposition 2, optimal health levies are lower under both regimes when vaccines matter less for individual health.

In general, one would expect the value of ν to depend on the quality of access to public and private health care systems. Because such quality may vary significantly across jurisdictions in the real world, the role of ν is further examined by varying it systematically in the interval $(0, 0.9)$.[42] The results are shown in Figure 3, in the case where $\eta_H > \beta$.[43] They indicate that, as the importance of own time, relative to vaccines, increases in contributing to individual health status, the optimal health levy falls under both independent policymaking and cooperation. This is consistent with the results established earlier and the corollary to Proposition 2 ($\tau_N^H > \tau_N^C$, for $\eta_H > \beta$). In addition, the gap between the two tax rates falls as well as ν increases. By contrast, the optimal infrastructure levy increases under both policy regimes as ν increases, and so does the gap between them. As a result, while the welfare gain tends to fall, at an increasing rate, with higher ν with $\alpha = 0$, it grows larger, also at an

[42] The case $\nu = 1.0$ is excluded from the numerical experiments because in that case degenerate solutions are obtained.

[43] The results with $\eta_H < \beta$ are not reported to save space.

increasing rate, when $\alpha = 0.17$.

Another parameter whose role is worth exploring further is η_H—a parameter for which there is also limited consensus in the literature. Figure 4 illustrates outcomes for tax rates and the welfare gain from coordination, for η_H varying over the interval (0.4, 1). The upper panel shows the optimal health levies under independent policymaking and under cooperation. As discussed earlier, these values are the same, regardless of the value of α. Both levies are monotonically increasing in η_H; the greater the utility derived from being healthy, the higher the optimal tax rate.[44] Both rates are equal for $\eta_H = \beta = 0.7$, whereas (for the reasons discussed previously) the tax rate is higher (respectively, lower) under cooperation relative to Nash when $\eta_H < \beta$ (respectively, $\eta_H > \beta$). At the same time, the optimal infrastructure levy (when $\alpha = 0.17$), shown in the middle panel, is decreasing in η_H. Importantly, the lower panel also shows that, when $\alpha = 0$, the welfare gain from cooperation follows a U-shaped pattern. With $\eta_H < \beta$, the optimal health levy is higher under cooperation; while this is optimal, a relatively higher tax rate lowers utility relative to independent policymaking. This reflects the fact that in that case, the indirect growth effect, which operates through wages, is stronger. But when $\eta_H > \beta$, the opposite occurs: the optimal health levy is lower under cooperation; the direct utility effect on health dominates the indirect growth effect operating through wages and income. When $\eta_H = \beta = 0.7$ (the benchmark case for β), as noted earlier, there are no gains from cooperation, as these effects cancel out.

6.2 Model Extensions

Consider next the case of financial integration. When $\alpha = 0$, the optimal health levy is lower (and significantly so) under Nash than under cooperation; for instance, with $\nu = 0.8$, $\tau_N^H = 0.098$, compared to 0.155 under autarky. At the same time, the optimal value is the same as in autarky under both regimes. Consequently, the gain from cooperation is magnified. When $\alpha = 0.17$, the results for the optimal health levy under cooperation are also the same as under $\alpha = 0$, but under Nash it is slightly higher (0.105, compared to 0.098). The welfare gain from cooperation (at 14.7 percent, for instance, with $\alpha = 0.17$) is also more substantial than under autarky. These larger gains result from the fact that (as noted earlier) leakages across regions through capital flows

[44] From the definition of Θ_2 and equations (32), it can readily be established that $\partial\tau_N^H/\partial\eta_H = (\partial\tau_N^H/\partial\Theta_2)(\partial\Theta_2/\partial\eta_H) > 0$.

are internalized when policymakers choose to act together. Similar outcomes (with, as before, lower optimal health levies) are obtained with $\eta_H = 0.55$ or $\nu = 0.9$.[45]

The case of expenditure trade-offs is also illustrated in Table 2. The results show that the optimal share of spending on health is indeed significantly lower under cooperation, 60.2 percent with $\nu = 0.8$ and $\eta_H = 0.95$, than under Nash, 90.1 percent. At the same time, the relative gain from cooperation, at 5.3 percent, is fairly substantial. Qualitatively, the same results hold when instead $\eta_H = 0.55$ or $\nu = 0.9$, with lower optimal spending shares on health.[46]

Finally, consider the case where the health levy takes the form of a tax on capital or wealth. The results are shown in Table 2 for both values of α under financial autarky, and $\alpha = 0$ only under financial openness. Under autarky, the optimal health levy is substantially *higher* under cooperation than under Nash, regardless of the values of α, η_H, and ν. The relative gain from cooperation is also quite significant; for instance, with $\nu = 0.8$ and $\eta_H = 0.95$, the result is 8.2 percent with $\alpha = 0$ and 18.1 percent with $\alpha = 0.17$.

Under financial openness, it was established the wealth tax under cooperation (which is the same as under autarky) is *lower* than under nonncooperation (see Proposition 8 and its corollary). The reason is that under cooperation policymakers fully internalize the leakages associated with capital flows, when these flows can move freely across borders. At the same time, as noted earlier, comparing (56) and (59), under noncooperation the wealth tax (if the solution is interior) is *higher* under financial integration than under autarky. However, under financial openness, given our calibration, the necessary and sufficient condition for an interior solution, $\Theta_2\Omega < \Theta_5$, is not satisfied. Instead of changing the calibration for this particular experiment, in Table 1 τ_N^H under financial openness is set at a value that exceeds τ_C^H by 10 percent. This also ensures that, under noncooperation, the health levy is higher under financial openness than under autarky. Thus, for instance, with $\nu = 0.9$ and $\eta_H = 0.55$, $\tau_N^H = 0.537 > \tau_C^H = 0.489$, with a welfare gain of about 0.7 percent. Similar results obtain for alternative values of ν and η_H.

[45] Results obtained with varying ν and η_H do not add much qualitatively to those diplayed in Figures 3 and 4. To save space, this analysis is not reported for any of the model's extensions considered in this subsection.

[46] As shown in the Appendix, and as noted in Table 1, whether the optimal tax rate is higher under cooperation is in general ambiguous analytically. In Table 2, this is always the case, regardless of the values of ν and η_H.

Of course, given the relative simplicity of the model, these results should be taken with some degree of caution. For instance, given the log-linear structure of preferences, the propensity to save does not depend on the (after-tax) interest rate; thus, the distortionary effects of changes in the health levy on savings and investment, as well as growth and welfare, are not fully accounted for. In addition, as discussed next, it does not account for the disincentives (for fraud and tax evasion, in particular) that wealth taxation creates. Doing so could reduce drastically the optimal value of the health levy. The key point, however, is that in a financially integrated world economy, the optimal tax on capital or wealth may be lower under cooperation than under independent policymaking. This is important if compliance, as is often the case, depends on the magnitude of the tax rate.

7 Policy Implications

From a policy perspective, the foregoing analysis establishes two main results: cooperation can be beneficial in terms of providing a global health-related public good, regardless of the degree of financial integration, and (abstracting from incentives for tax evasion) a wealth-based health tax may be fairly effective under financial integration. Although our focus has been on the global production of vaccines, our analysis could be easily adapted to a number of other public goods (the environment, security, and so on). If, for instance, pollution has an adverse effect on worker productivity, and climate change can be mitigated through global cooperation, most of our results would likely remain the same—with a suitable reinterpretation.

In practice, cooperation in the production of global public goods raises a number of issues—some of which have been discussed thoroughly in the literature (see Sandmo (2016) and Buchholz and Sandler (2021)). Building consensus and support from national governments for international tax cooperation, with the goal of financing a global public good—as opposed to avoiding a *race to the bottom*, a common theme in the literature (see Keen and Konrad (2013))—is difficult, as illustrated by the debate on setting a global minimum corporate tax rate, and may require strong multilateral institutions. Yet, setting up institutions that guarantee simultaneously both commitment and cooperation is challenging. As documented by Kyle et al. (2017), for instance, increased funding for the provision of global public goods by some countries may have an adverse effect on funding by others—a typical *free rider* problem: some parties want to benefit from the good, without having to contribute to its provision.

But rather than focus on these dimensions, it is perhaps of greater interest to explore further two aspects of our contribution—the benefit (or lack thereof) of cooperation when there is a direct trade-off between productive spending components, and the use of a wealth-based tax to finance the development and production of vaccines by a global fund. With respect to the first point, our key result—that cooperation in deciding how much to tax to finance the production of global public goods may be sub-optimal if the externality associated with the local public good is sufficiently high—is important in light of the fact that international institutions like the International Monetary Fund (2020) and the World Bank (2020) in the initial stages of the COVID-19 pandemic advocated large increases in infrastructure investment to sustain growth of the world economy. Our analysis suggests that, if governments face a trade-off in allocating resources, the benefit of infrastructure for growth may not be the only (or even the main) consideration when global public goods provide a direct benefit in terms of individual health and welfare.

With respect to the second point, one argument for advocating a wealth-based tax to finance efforts to prevent the spread of infectious diseases—through an institution such as the World Health Organization, or more generally global partnerships such as the Coalition for Epidemic Preparedness Innovation—is that income taxes are already quite high in many countries, and so are fiscal deficits and debt ratios (see International Monetary Fund (2024, chapter 1)). In many countries, this situation has been made worse as a result of the increase in emergency spending triggered by the COVID-19 pandemic. If financing through conventional taxes or debt are not viable options, a low wealth tax assigned to a productive use may prove attractive. Indeed, if compliance by taxpayers is influenced by the public's perception of the efficiency of resource utilization, as illustrated by the supply and quality of public services, the explicit earmarking of a wealth tax to the production of a global public good may be well received. In addition to side benefits—a reduction in inequality, which has increased significantly in many countries in recent years (see Piketty (2020) and World Inequality Lab (2021))—the tax can also be viewed as a measure of international solidarity.

Nevertheless, and regardless of its objective, the implementation of a wealth tax faces substantial challenges at both technical and political levels. As discussed by the OECD

(2018) and Viard (2019), for instance, the experience so far has not been conclusive, with a number of countries eventually backtracking in their efforts to impose such a tax.[47] Indeed, wealth taxes have proved difficult to administer and enforce. They may also have adverse effects on incentives and make it harder for new entrants to build wealth, which could contribute to persistence in inequality.[48] In addition, a recurrent argument is the fact that wealth taxes have been implemented at the individual country level, in a context where the opportunity to engage in offshore tax evasion is high and cooperation is not feasible or sustainable (see, for instance, Rotberg and Steinberg (2024)). As a result, to avoid a collapse of their tax base—or its shrinkage to only physical assets, such as land—countries have been forced to eliminate them.[49] At the same time, our analysis suggests that, in line with some policy-oriented contributions, coordination can "solve" the problem in that case, by mitigating incentives for capital to move across borders. Our analysis is therefore broadly consistent with the views of those who have advocated a European wealth tax, for instance, on the ground that migration of wealthy taxpayers within the European Union would then less of a concern (Landais et al. (2019) and Kleven et al. (2020)) and that enforcement would be facilitated by cross-border cooperation within the union (Saez and Zucman (2019)).

Our analysis it too stylized to provide any concrete guidance as to what a common wealth tax should be. But clearly, if accounting for tax avoidance, and enforcement and collection costs, are important considerations, they would militate in favor of a relatively low rate—well below the ballpark numbers reported earlier in our simple numerical experiments—together with a fairly high exemption threshold and/or a narrow focus on the type of assets that should be subjected to imposition. Indeed, if these costs are significant, the scope of taxation may be fairly narrow regardless of the policy regime.

[47] Sweden is a case in point. See Björklund et al. (2012), Waldenström 92018), and Bastani and Waldenström (2020), for instance.

[48] These adverse effects include individuals' incentives to accumulate human capital (Blandin and Peterman (2019)), entrepreneurs' incentives to innovate (Jones (2022)) or to accumulate wealth and build collateral, which affects their ability to secure investment loans. If so there may be a negative effect on long-run growth.

[49] Note that the same issue arises in the context of federal states, where capital mobility between regions is *de facto* high. This is worth bearing in mind, given the current push in the United States by some progressive member states to introduce legislation aimed at taxing assets of the wealthy—with one of the objectives being, incidentally, the need to pay for health care.

8 Concluding Remarks

This paper presented a two-region endogenous growth model of the world economy with local and global public goods, and used it to study strategic interactions between national fiscal authorities. The main results were summarized in the introduction; to conclude, it is worth highlighting possible extensions of our analysis.

First, it may be useful to provide a more thorough analysis of optimal policies when wealth taxation generates not only incentives to engage in evasion and capital flight, or hampers access to the credit market by reducing collateral values, as discussed earlier, but also positive effects. For instance, if wealth taxes reduce inequality through redistribution, they may foster borrowing and investment (in both human and physical capital), which in turn may have positive effects on growth and welfare. Second, accounting for the possibility of public borrowing may help to consider the trade-off that may arise between the benefits associated with increases in spending allocated to the provision of local and global public goods, and their impact on public debt sustainability and growth through adverse effects on world interest rates. Third, it would be useful to account for the production of vaccines through a *local* health fund, which possibly faces lower congestion costs associated with distribution—but with weaker economies of scale and a greater risk of cross-border transmission of infections, if the rest of the world's capacity to produce vaccines is subject to financial or human capital constraints. This could be modeled as a two-stage process—first, the determination of how much resources to levy (through an income or wealth tax, for instance) and, second, how these resources should be allocated between the local and global health funds. In some way, this is addressed indirectly in our analysis of a direct trade-off between health and infrastructure spending, if the good produced by the local health fund is viewed as benefiting production—in a manner similar to public capital. What is missing though in this analogy is the possibility that "going it alone" in the production of vaccines could magnify the risks of international transmission of infections (or new variants), if other countries cannot generate the resources needed to engage in that activity as well. Such an asymmetry could be an incentive for cooperation through a global institution, which in turn could result in potentially large welfare gains for all parties.

Taking this idea further, a more substantive departure from the existing framework would be to consider an asymmetric world where regions differ in several dimensions—for instance, a "rich" region, where vaccines are created, produced, and distributed relatively easily, and a "poor" region, where government resources are limited, health infrastructure is weak, vaccines cannot be produced, and vaccination campaigns are difficult to initiate due to high population size, low density, or a lack of qualified workers (see Miguel and Mobarak (2022)). Thus, the poor region could be fertile ground not only for the emergence of new viruses but also of more deadly mutations of existing ones, which can be transmitted to the rich region, thereby creating a negative externality for the better off. Such a model could be used to discuss the role of a global fund (this time financed by the rich region only), differentiated pricing, and cooperation in the context of a strategy focused this time on the distribution, rather than the production, of vaccines.

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Figure 1
Core Model of the World Economy
(Separate tax rates, financial autarky)

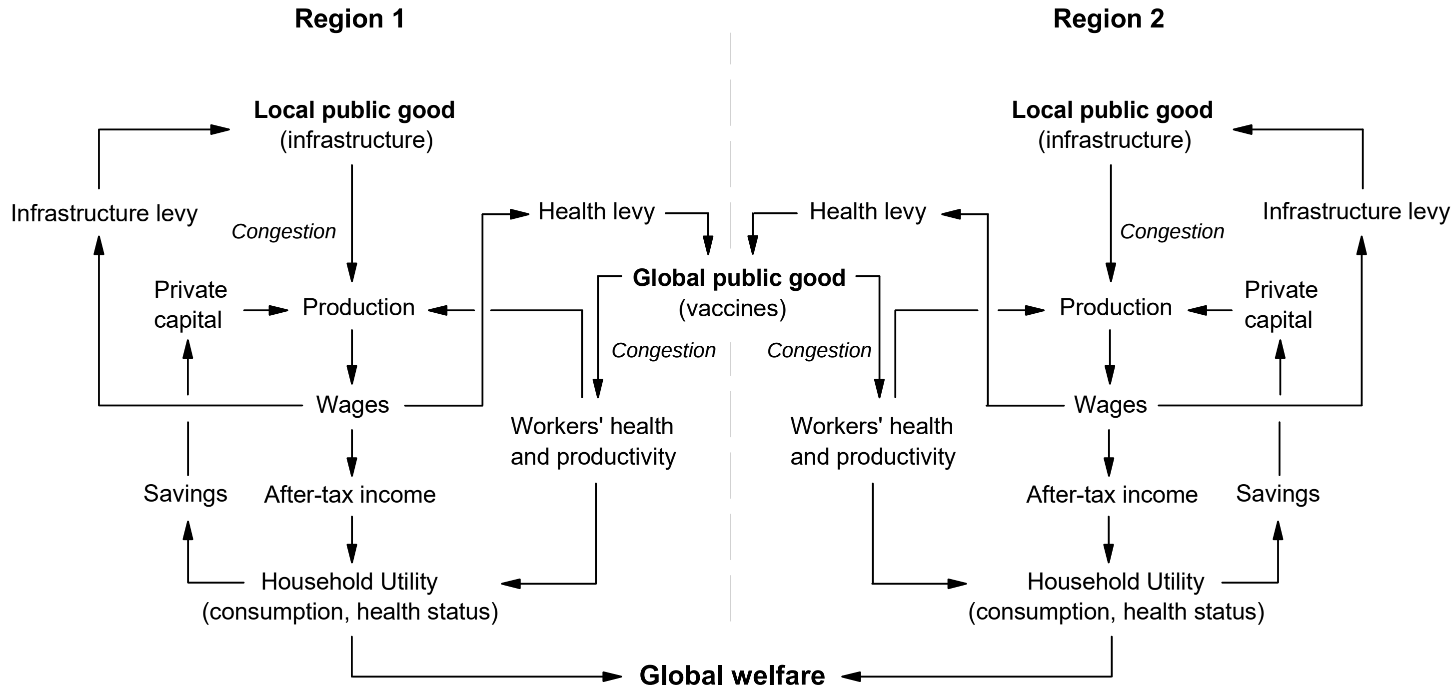

Figure 2
Health Levies: Symmetric Nash Equilibrium

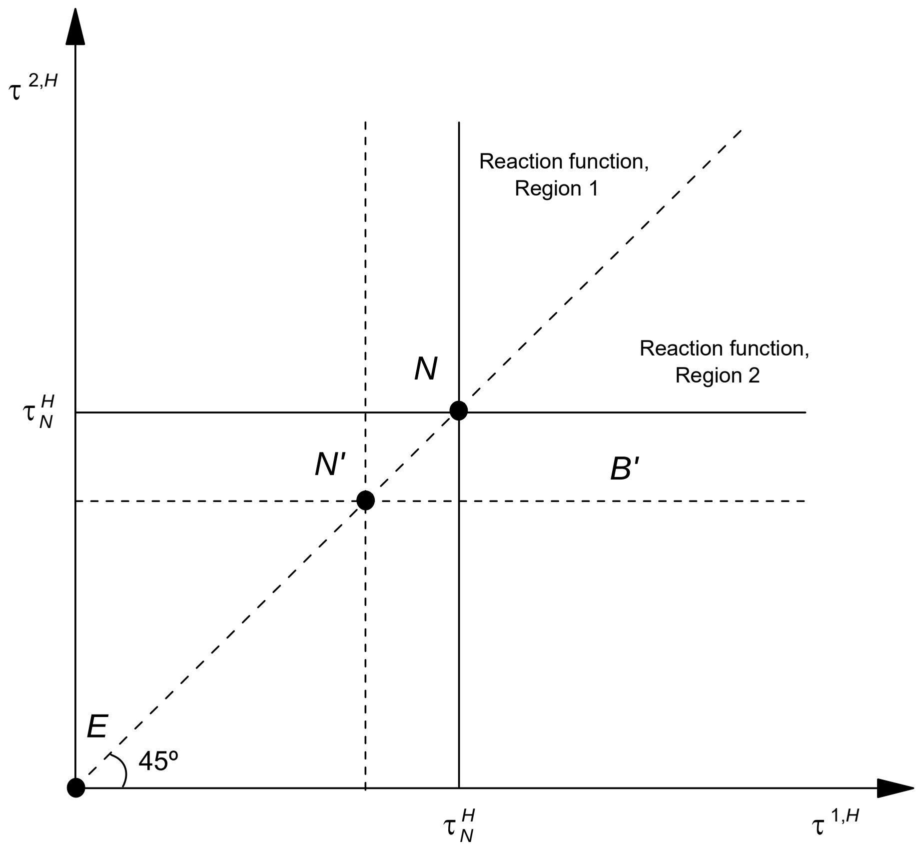

Figure 3
Optimal Health and Infrastructure Levies,
and Welfare Gain from Cooperation: Basic Model, Variable ν

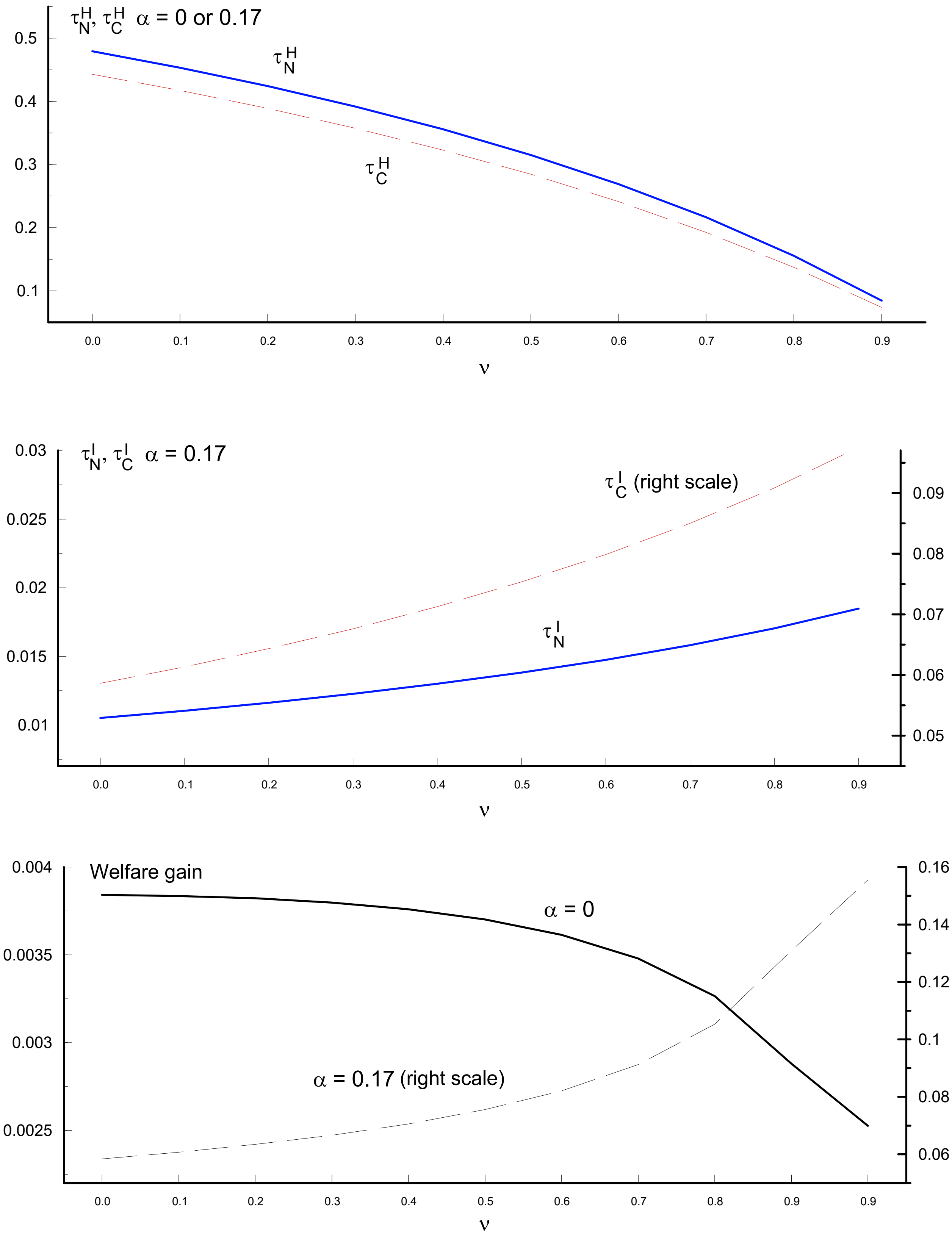

Figure 4

Optimal Health and Infrastructure Levies, and Welfare Gain from Cooperation: Basic Model, Variable η_H

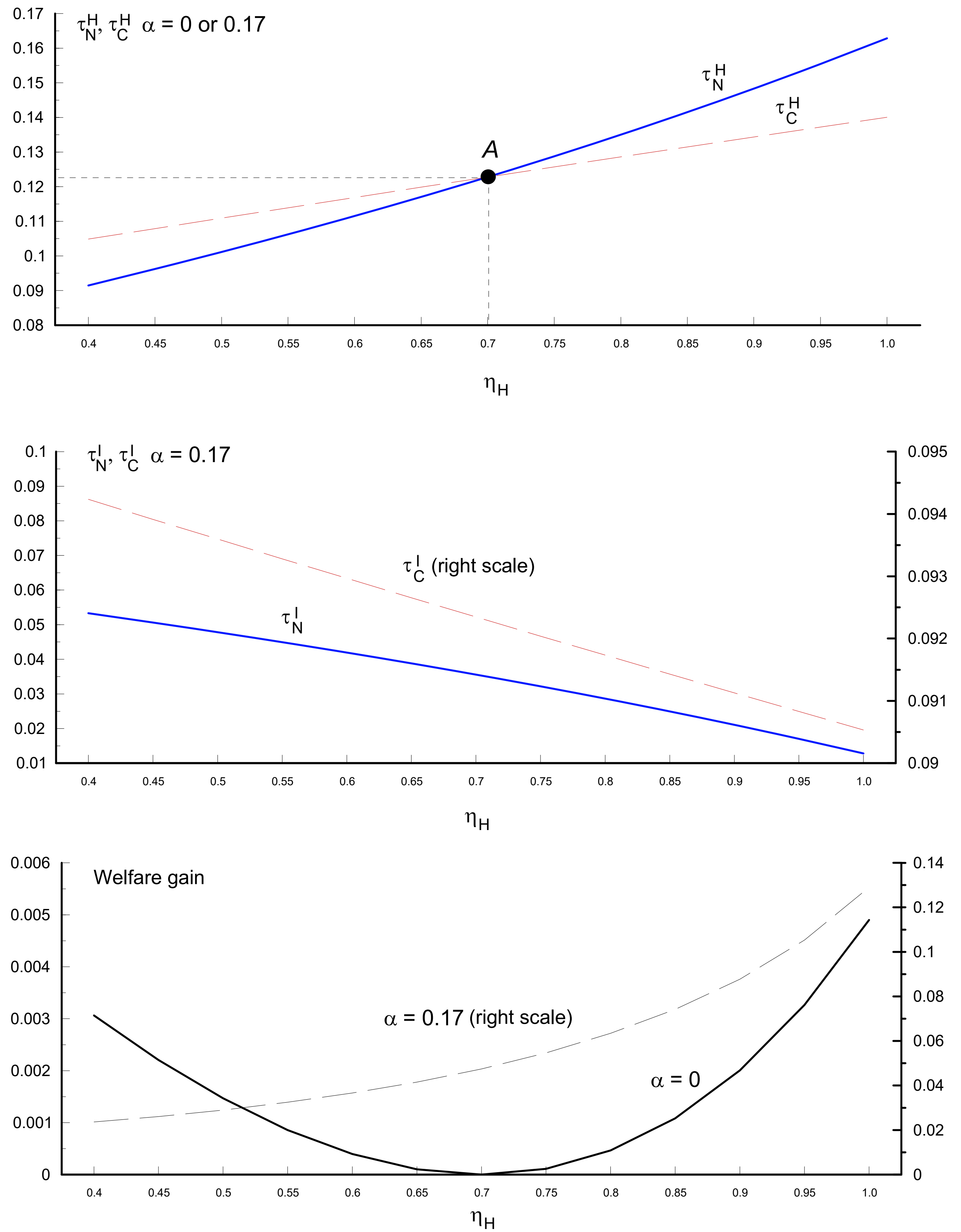

Table 1
Summary of Analytical Results

Model structure and fiscal policy regime	$\alpha = 0$	$\alpha > 0$	
	Optimal τ^H	Optimal τ^H or υ^H	Optimal τ^I or τ
Core model: Autarky[1]			
Nash	$\frac{\Theta_2\theta}{\Theta_2\theta+\Theta_1^A-\Theta_2\Omega}$	Same as $\alpha = 0$	$\min[\max(0,\frac{\Theta_3-\Theta_2\theta\phi_1}{\Theta_2\theta+\Theta_1^A-\Theta_2\Omega}),1]$
Cooperation	$\frac{\Theta_2(1-\nu)}{\Theta_1^A+\Theta_2(1-\nu)}$	Same as $\alpha = 0$	$\frac{\Theta_3}{\Theta_1^A+\Theta_2(1-\nu)}$
Difference $\tau_C^h - \tau_N^h$	?	?	+
Core model: Openness			
Nash	$\frac{\Theta_2\theta}{\Theta_2\theta+\Theta_1^O+0.5\Theta_4}$	$\frac{\Theta_2\theta}{\Theta_2\theta(1-\phi_1)+\Theta_1^O+0.5\Theta}$	$\min[\max(0,\frac{\Theta_3-\Theta_2\theta\phi_1}{\Theta_2\theta(1-\phi_1)+\Theta_1^O+0.5\Theta}),1]$
Cooperation	Same as autarky	Same as autarky	Same as autarky
Difference, $\tau_C^h - \tau_N^h$	+	?	?
Wealth tax: Autarky			
Nash	$\frac{\Theta_2\theta}{\Theta_2\theta+\Theta_5}$	Same as $\alpha = 0$	$\min[\max(0,\frac{\Theta_3-\Theta_2\theta\phi_1}{\Theta_1^A-\Theta_2\Omega}),1]$
Cooperation	$\frac{\Theta_2(1-\nu)}{\Theta_2(1-\nu)+\Theta_5}$	Same as $\alpha = 0$	$\frac{\Theta_3}{\Theta_1^A}$
Difference, $\tau_C^h - \tau_N^h$	+	+	+
Wealth tax: Openness			
Nash	$\min[\max(0,\frac{\Theta_2\theta}{\Theta_2(\theta-\Omega)+\Theta_5}),1]$	Same as autarky	See Appendix
Cooperation	Same as autarky	Same as autarky	Same as autarky
Difference, $\tau_C^h - \tau_N^h$	−	−	?
Spending trade-off[2]			
Nash	NA	$\min[\max(0,\frac{\Theta_2\theta}{\Theta_2\theta(1-\phi_1)+\Theta_3}),1]$	τ_N: See Appendix
Cooperation	NA	$\frac{\Theta_2(1-\nu)}{\Theta_3+\Theta_2(1-\nu)}$	τ_C: See Appendix
Difference, $\upsilon_C^H - \upsilon_N^H$	NA	−	?

[1]Under autarky, regardless of whether $\alpha = 0$ or $\alpha > 0$, $\tau_C^H \gtrless \tau_N^H$ depends on whether $\eta_H \lessgtr \beta$.
[2]Case of autarky only. By definition, $\upsilon^I = 1 - \upsilon^H$.

Table 2
Optimal Health and Infrastructure Levies or Shares, and Welfare Gain from Cooperation
under Alternative Policy Regimes

Model structure and fiscal policy regime	$\nu = 0.8$				
	$\alpha = 0$		$\alpha = 0.17$		
	Heatlh levy	Welfare gain	Heatlh levy	Infra. levy	Welfare gain
Core model: Autarky					
$\eta_H = 0.95$	0.155, 0.137	0.003	0.155, 0.137	0.017, 0.091	0.105
$\eta_H = 0.55$	0.106, 0.114	0.001	0.106, 0.114	0.045, 0.093	0.032
Core model: Openness					
$\eta_H = 0.95$	0.098, 0.137	0.018	0.105, 0.137	0.012, 0.091	0.147
$\eta_H = 0.55$	0.082, 0.114	0.017	0.084, 0.114	0.038, 0.093	0.054
Wealth tax: Autarky					
$\eta_H = 0.95$	0.542, 0.703	0.082	0.542, 0.703	0.020, 0.105	0.181
$\eta_H = 0.55$	0.489, 0.657	0.081	0.489, 0.657	0.050, 0.105	0.072
Wealth tax: Openness					
$\eta_H = 0.95$	0.773, 0.703	0.021	--	--	--
$\eta_H = 0.55$	0.722, 0.657	0.016	--	--	--
	Health share	Welfare gain	Health share	Tax rate	Welfare gain
Spending trade-off					
$\eta_H = 0.95$	--	--	0.901, 0.602	0.172, 0.228	0.105
$\eta_H = 0.55$	--	--	0.703, 0.549	0.151, 0.207	0.032
	$\nu = 0.9$				
	$\alpha = 0$		$\alpha = 0.17$		
	Heatlh levy	Welfare gain	Heatlh levy	Infra. levy	Welfare gain
Core model: Autarky					
$\eta_H = 0.95$	0.084, 0.074	0.003	0.084, 0.074	0.018, 0.097	0.131
$\eta_H = 0.55$	0.056, 0.060	0.001	0.056, 0.060	0.047, 0.098	0.041
Core model: Openness					
$\eta_H = 0.95$	0.052, 0.074	0.016	0.055, 0.074	0.012, 0.097	0.178
$\eta_H = 0.55$	0.043, 0.060	0.015	0.044, 0.060	0.040, 0.098	0.062
Wealth tax: Autarky					
$\eta_H = 0.95$	0.371, 0.542	0.079	0.371, 0.542	0.020, 0.105	0.188
$\eta_H = 0.55$	0.324, 0.489	0.077	0.324, 0.489	0.050, 0.105	0.069
Wealth tax: Openness					
$\eta_H = 0.95$	0.596, 0.542	0.009	--	--	--
$\eta_H = 0.55$	0.537, 0.489	0.007	--	--	--
	Health share	Welfare gain	Health share	Tax rate	Welfare gain
Spending trade-off					
$\eta_H = 0.95$	--	--	0.820, 0.430	0.103, 0.171	0.131
$\eta_H = 0.55$	--	--	0.542, 0.379	0.104, 0.159	0.041

0

Notes: Entries in Columns 2 and 3, and 4 and 5, are the optimal health and infrastructure levies, or optimal health spending and infrastructure spending shares, under Nash and under cooperation, respectively. Calculations are based on the formulas in the text. The welfare gain from cooperation is measured relative to Nash. Under wealth taxation, and for illustrative purposes, the health levy under nooncooperation and financial openness is set at a value that exceeds by 10 percent the value obtained under cooperation. This is because, given our calibration, the necessary and sufficient condition for an interior solution is not satisfied in that case.

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