UNIVERSITY OF ABERDEEN

BUSINESS SCHOOL

Discussion Papers in
Economics and Finance

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Discussion Paper No 24-4

July 2024

ISSN 0143-4543

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June 28, 2024

Abstract

In this paper, we contribute to the topical debate on the welfare effects of a centralised policy setting within the federal union in the presence of transboundary externalities that affect production possibilities. It is shown that when the production of federal jurisdictions generates spillover effects, which in turn result in spillback effects, then harmonisation of their public policies towards the uniform optimal cooperative level does not ensure welfare improvement for the federation. We analyse and identify federal policies harmonising reforms that deliver Pareto improvement in the presence of spillback in addition to spillover effects. These reforms are designed to neutralise all the spillback effects by maintaining the aggregate level of spillover effects constant, while increase the welfare of the federation. This result holds irrespective of the nature and sign of the spillover and spillback effects as well as for both small and large open economies, where cross-border externalities coexist with terms of trade externalities that arise through market power in international commodity markets.

JEL classification:H20, H23, F18

Keywords: Fiscal Federalism, Spillovers and Spillbacks, Pareto Improving Reforms, Transboundary Externalities

Declarations of interest: none.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgments: We graciously acknowledge the constructive comments and suggestions by C. Kotsogiannis, C. Montagna, Frans de Vries, P. Hatzipanayotou, T. Kiso, F. Antoniou. The authors are responsible for remaining errors and omissions.

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1 Introduction

A central and topical issue in fiscal federalism revolves around determining whether, in the presence of spillovers among jurisdictions, decentralised or centralised policymaking leads to an efficient outcome, e.g., Oates (1972), Wellisch (1993, 1994, 1995), Ogawa and Wildasin (2009), Chari et al. (2023) and Agrawal (2023). The results of the literature are mixed, with the main body arguing that the existence of spillover effects calls for centralisation in the form of harmonisation or coordination of public policy, e.g., Keen and Kotsogiannis (2002), Eichner and Runkel (2012), Harstad (2007), Davies and Naughton (2014). On the other hand, Oates (1972), Wellisch (1993, 1994, 1995) and Ogawa and Wildasin (2009) identify plausible conditions under which decentralisation can lead to an efficient outcome.[1]

Specifically, Harstad (2007) analyses a two-country model with transboundary pollution, focusing on a bargaining game under private information. The study explores how the availability of side payments affects the effectiveness of complete policy harmonisation across countries. Cremer and Gahvari (2004, 2005), considered harmonisation reforms of public policies, focusing on a two small open economies framework in the presence of spillover effects arising from transboundary pollution. They argue that partial emission tax harmonisation, above its unrestricted Nash equilibrium value, delivers welfare improvements as firms adopt cleaner technology which reduces the aggregate emission levels. Keen and Wildasin (2004) demonstrate that, in the absence of international lump-sum transfers, a well structured system of trade policy interventions—involving compensatory taxes and subsidies on trade flows between different countries—has the potential to achieve Pareto efficiency. In a related context, Chari et al. (2023), utilising a dynamic international trade model, show that without international lump-sum transfers, every point on the Pareto frontier is production efficient and can be implemented using trade taxes, along with appropriate adjustments to consumption and labour income taxes. Consequently, the study suggests that tax coordination or harmonisation may not always be optimal.

Additionally, Kotsogiannis and Lopez-Garcia (2007) emphasise that when tax revenues are utilised for local public goods provision, considering the underlying preferences for public goods is crucial for tax harmonisation to result in welfare improvement. Extending their analysis, Kotsogiannis and Lopez-Garcia (2021a) delve into cases where governments provide global public goods, highlighting that tax coordinating reforms are always desirable in such scenarios and can coexist with tax diversity. Lopez-Garcia (2024) contributes to this debate by examining the welfare effects of tax harmonisation in the presence of international transfers that equalise the social marginal cost of public funds across countries. Despite these insights, the existing literature has not yet addressed efficient policy formation in the presence of spillbacks in addition to spillovers.

This paper contributes to the relevant literature by showing that when the production of federal

[1] For a detailed and comprehensive review of the literature on tax competition and tax coordination, see Agrawal et al. (2022).

jurisdictions generates spillover effects, which in turn result in spillback effects, the harmonisation of their public policies towards the uniform optimal cooperative level cannot ensure welfare improvement for the federation. To illustrate the complexity of this issue, consider the case of climate change, a prime example of spillover-spillback effects. Greenhouse gas emissions produced in one jurisdiction contribute to the accumulation of these gases in the atmosphere, leading to climate change. This affects the productivity and availability of factors of production for both federal and non-federal jurisdictions. For instance, economic activity in equatorial latitudes will likely shrink due to climate change. The increased temperatures, along with rising sea levels, floods, and droughts, can lead to the loss of effective factors of production in equatorial latitudes, such as the reduction and degradation of arable land. In contrast, countries in Northern latitudes may experience an increase in economic activity due to climate change, representing a positive spillover effect. For example, higher temperatures could expand arable land (see Desmet and Rossi-Hansberg, 2024).

In response to this spillover effect, some regions may adopt more (less) polluting technologies or practices to maintain or expand their economic activities, exacerbating (mitigating) the global environmental problem, which generates a spillback effect. Another potential spillback effect could be an increase in the labor force in certain regions and a reduction in others due to climate migration. In the presence of spillback effects, the traditional approach of public policies harmonisation towards the uniform optimal cooperative level, may not be sufficient to address the complex interplay of spillover and spillback effects arising from global challenges such as climate change. While climate change provides a great illustrative example, our analysis and results are not restricted to environmental issues or negative externalities. Our findings extend to various cases of spillover and spillback effects, which can emerge from both negative and positive externalities. Positive spillovers, in particular, can stem from technological advancements, research, knowledge dissemination, and public health improvements.

In this paper, we analyse the welfare effects of a centralised policy setting within a federal union in the presence of spillbacks in addition to spillovers. We show that the standard result of the literature on policies coordination within a federation, towards their uniform optimal cooperative level, does not deliver welfare improvement. Intrigued by this result, we analyse and identify harmonising reforms that deliver Pareto improvement in the presence of spillover and spillback effects. Intuitively, these reforms are designed to neutralise all the spillback effects by maintaining the aggregate level of spillover effects constant. This result holds for both small and large open economies, where cross-border externalities coexist with terms of trade externalities that arise through market power in international commodity markets.

2 The Model

We consider a theoretic framework of a federal union that comprises of two small open economies, labeled with superscripts 1 and 2, and the Rest of the World, which is regarded as passive and labeled with superscript 3.[2] Each country produces and consumes n privately tradable goods, all of which generate cross-border pollution as a by-product of production. This pollution affects the countries' factor endowments and thus their production possibilities frontier. The production factors are fixed in supply and immobile internationally in each country. All commodity and factor markets are perfectly competitive. For convenience and simplicity our analysis is based on duality theory incorporating international externalities (see among others Copeland, 1994, 2011; Hatzipanayotou et al., 2005; Neary, 2006; Kotsogiannis and Woodland, 2013; Keen and Kotsogiannis, 2014) appropriately modified to consider the case of federal unions when externalities affects the effective factors of production.

The demand side of each country's representative consumer is described by the minimum expenditure function,

$$E^j(q, u^j) \equiv \min_{\{c\}} \left\{ (q'c^j) \mid U^j(c) \geqslant u^j \right\}, \tag{1}$$

where $c^j \equiv (c_0^j, c_1^j, ..., c_n^j)$ denotes the vector of goods consumption, $q \equiv (1, q_1, ..., q_n)$, is a $(1 \times n)$ vector of world commodity prices. Good zero is assumed to be the numeraire with $q_0 = 1$ and clean in production. $E^j(q, u^j)$ is the representative consumer's minimum expenditure in each country required to achieve a level of utility u^j at consumer prices q. The derivatives of the $E^j(q, u^j)$ function with respect to u^j denote the inverse of the marginal utility of income and is positive i.e., $E_{u^j}^j > 0$.[3]

The production side of each region is represented by the *GDP* (Gross Domestic Product) or revenue function:

$$R^j(q, \theta^j, \upsilon^j(k)) \equiv \max_{\{x^j\}} \left\{ q'x^j - \theta^{j\prime} z^j : F^j(x^j, z^j, \upsilon^j(k)) \leq 0 \right\}, \tag{2}$$

where F^j is the implicit production possibility frontier and x^j and υ^j are the country's vectors of output and factors of production, respectively. θ^j denotes the emission tax imposed on production by each country. Country's j vector of emission z^j can be derived by the partial derivative of the GDP function with respect to its emission tax, i.e., $\frac{\partial R^j}{\partial \theta^j} = R_{\theta^j}^j = -z^j$, and $R_{\theta^j \theta^j}^j$ is positive definite, e.g., Copeland (1994, 2011), Kotsogiannis and Woodland (2013).

Overall pollution is defined as the sum of production pollution generated at the two federal countries and the Rest of the World, and is given by:

$$k = i' \sum_{j=1}^{3} \left(-R_{\theta^j}^j \right) = i' \sum_{j=1}^{3} z^j, \tag{3}$$

where i is unit vector (n-vector of 1s) and prime indicates transposition.[4] The marginal impact of

[2] "Country 3" and the "Rest of the World" will be used interchangeably throughout.

[3] For the properties of the expenditure function see among others Copeland (1994, 2011) and Neary (2006).

[4] By relaxing the assumption of full transboundary externality, we can formulate each country's level of externality

an extra unit of emissions on each country's GDP function is given by $R^j_{\upsilon^j}\upsilon^j_k$, with υ^j_k indicating the effect of emissions on country's j effective factors of production.[5] The externality can have a negative ($\upsilon^j_k < 0$) effect on the effective factors of production, i.e., climate change can reduce arable land due to the rising sea levels, floods and droughts in equatorial latitudes, or a positive ($\upsilon^j_k > 0$) one, i.e., in Northern countries where temperatures are currently too low arable land can increase (see Desmet and Rossi-Hansberg, 2024). The term $R^j_{\upsilon^j}$ is positive, representing the effect on GDP resulting from a change in factor endowments.[6]

The budget constraint of the representative consumer in each country is given as follows:

$$E^j(q,u^j) = R^j(q,\theta^j,\upsilon^j(k)) + \theta^{j\prime} z^j. \tag{4}$$

Equations (4) states that the representative consumers' expenditure in the two regions must equal the income generated from production plus income from lump-sum distributed emission tax revenue.

Totally differentiating equation (3) we obtain,

$$dk = -\phi^{-1} i' \left(R^1_{\theta^1\theta^1} d\theta^1 + R^2_{\theta^2\theta^2} d\theta^2 \right), \tag{5}$$

where $\phi = 1 + i' \sum_{j=1}^{3} R^j_{\theta^j\upsilon^j}\upsilon^j_k$. The term $R^j_{\theta^j\upsilon^j}\upsilon^j_k$ denotes the spillback effect which arises from the impact of an extra unit of emissions on countries' endowments and, consequently, their production-generated emissions. The sign of the spillback effect depends not only on how emissions affect countries' endowments ($\upsilon^j_k \gtrless 0$), but also on the reaction of the private sector ($R^j_{\theta^j\upsilon^j} \gtrless 0$).

In response to an increase in the effective factors of endowments, a country increases its economic activity, thereby generating more emissions (under constant production pollution intensity), i.e., $R^j_{\theta^j\upsilon^j} = -\frac{\partial z^j}{\partial \upsilon^j} < 0$, or decreases its production generated emissions production by adopting less pollution-intensive technologies or practices, i.e., $R^j_{\theta^j\upsilon^j} = -\frac{\partial z^j}{\partial \upsilon^j} > 0$. Analogously, in response to a decrease in the effective factors of endowments, a country reduces its economic activity and thus production generated emissions (under constant production pollution intensity), i.e., $R^j_{\theta^j\upsilon^j} = -\frac{\partial z^j}{\partial \upsilon^j} < 0$, or increases its emissions by adopting more pollution intensive technologies in order to maintain its economic activities i.e., $R^j_{\theta^j\upsilon^j} = -\frac{\partial z^j}{\partial \upsilon^j} > 0$.

To analyse the welfare effects of a centralised policy setting within the federal union, we focus on the aggregate welfare of the participating countries, 1 and 2. By focusing on the aggregate welfare level, we implicitly assume the existence of lump-sum transfers within the federation. Totally differentiating equation (4), after using equation (5), we obtain the welfare effects of the federal

as follows $k_j = i'z^j + i' \sum_{\pi=1}^{3} \beta^{j,\pi} z^\pi$, where $\pi \neq j$ and $\beta^{j,\pi}$ captures the rate of externality arising from country π that affects country j. The parameter β can take values from 0 to 1. When $\beta^{j,\pi} = 0$, it denotes the case of local externality, while when $\beta^{j,\pi} = 1$, it denotes the case of perfect transboundary externality.

[5] Copeland and Taylor (1999) and Kotsogiannis and Woodland (2013) consider similar type of pollution externality effects, while the main body of the literature assumes that pollution externality affects consumers' welfare, see among others Copeland (1994, 2011), Hatzipanayotou et al. (2005), Neary (2006), Kreickemeier and Richter (2014).

[6] For the properties of the GDP function see Kotsogiannis and Woodland (2013).

union, resulted by small changes in member countries' emission taxes:

$$\phi\left(E^1_{u^1}du^1 + E^2_{u^2}du^2\right) = -\left[\theta^{1\prime} + R^1_{\upsilon^1}\upsilon^1_k i' + R^2_{\upsilon^2}\upsilon^2_k i' + \left(\theta^{1\prime} - \theta^{2\prime}\right)R^2_{\theta^2\upsilon^2}\upsilon^2_k + \theta^{1\prime}R^3_{\theta^3\upsilon^3}\upsilon^3_k\right]R^1_{\theta^1\theta^1}d\theta^1 - \left[\theta^{2\prime} + R^1_{\upsilon^1}\upsilon^1_k i' + R^2_{\upsilon^2}\upsilon^2_k i' + \left(\theta^{2\prime} - \theta^{1\prime}\right)R^1_{\theta^1\upsilon^1}\upsilon^1_k + \theta^{2\prime}R^3_{\theta^3\upsilon^3}\upsilon^3_k\right]R^2_{\theta^2\theta^2}d\theta^2. \tag{6}$$

It follows that the federal union's cooperative tax rates are obtained by setting $\frac{\phi\left(E^1_{u^1}du^1+E^2_{u^2}du^2\right)}{d\theta^1} = 0$ and $\frac{\phi\left(E^1_{u^1}du^1+E^2_{u^2}du^2\right)}{d\theta^2} = 0$ and solving simultaneously, denoted by:

$$\theta^1_c = \theta^2_c = \theta_c = -\frac{\left(R^1_{\upsilon^1}\upsilon^1_k + R^2_{\upsilon^2}\upsilon^2_k\right)}{1 + R^3_{\theta^3\upsilon^3}\upsilon^3_k}i. \tag{7}$$

Subscript c denotes the optimal cooperative tax rates. The availability of lump-sum transfers within the federation ensures that the optimal cooperative tax rates improve the federal union's welfare as well as the welfare of each member country.

Proposition 1 *Within a federal union and in the presence of perfect transboundary externality, all member countries should adopt a uniform emission tax rate, fully internalising the spillover effects to all member countries weighted by the spillback effects from the Rest of the World.*

The spillover effects, captured by the term $(R^1_{\upsilon^1}\upsilon^1_k + R^2_{\upsilon^2}\upsilon^2_k)$, indicate that each member country should fully internalise the impact of an extra unit of emissions arising from its production to all members' GDP. In addition, each country should account for the spillback effects that originate from the Rest of the World, captured by the term $(R^3_{\theta^3\upsilon^3}\upsilon^3_k)$. This results from the impact of an extra unit of emissions on the Rest of the World's endowments and, consequently, its production-generated emissions. In comparison with the results of global coordination, as presented in Kotsogiannis and Woodland (2013), equation (7) indicates that in the case of a federal union, the members' optimal emission tax rate is still uniform but at a different level, considering the spillback effects from the non-member country 3.[7] The level of the emission tax will be determined by the nature and magnitude of the spillover and spillback effects. More specifically:

Case I: when the effect of pollution on countries' endowments is symmetric, reducing the effective factors of production in all countries, i.e., $\upsilon^j_k < 0$, $j = 1, 2, 3$ and this increases the production generated emissions of the non-member third country, i.e., $R^3_{\theta^3\upsilon^3} > 0$. In this case, the sign of both the spillover and spillback effect is negative, i.e., $R^1_{\upsilon^1}\upsilon^1_k + R^2_{\upsilon^2}\upsilon^2_k < 0$ and $R^3_{\theta^3\upsilon^3}\upsilon^3_k < 0$. Consequently, a higher magnitude of the spillback effect requires a correspondingly higher optimal cooperative emission tax rate to mitigate its impact from non-member country 3, relative to the global coordination case as in Kotsogiannis and Woodland, 2013.

[7] Using equations (A.1) and (A.2) in the Appendix, it can be shown that from the first order conditions the Nash tax rates are given by $\theta^1_n = \frac{-R^1_{\upsilon^1}\upsilon^1_k}{1+R^3_{\theta^3\upsilon^3}\upsilon^3_k+R^2_{\theta^2\upsilon^2}\upsilon^2_k}i$ and $\theta^2_n = \frac{-R^2_{\upsilon^2}\upsilon^2_k}{1+R^3_{\theta^3\upsilon^3}\upsilon^3_k+R^1_{\theta^1\upsilon^1}\upsilon^1_k}i$. Clearly, the non-cooperative tax rates are inefficient as they do not not internalise the externalities generated by the spillover effects.

On the contrary, when the decrease in the effective factors of production, due to pollution, results in the decrease of the production generated emissions in the third country, i.e., $R^3_{\theta^3\upsilon^3} < 0$, the spillback effect is positive, i.e., $R^3_{\theta^3\upsilon^3}\upsilon^3_k > 0$. The higher the spillback effect, the lower the uniform optimal cooperative emission tax will be.

Case II: when the effect of pollution on countries' endowments is asymmetric, reducing the effective factors of production for the Federal union, i.e., $\upsilon^1_k < 0$, $\upsilon^2_k < 0$, while it increases the ones of the non-member country 3, i.e., $\upsilon^3_k > 0$, and this reduces the production generated emissions of the non-member third country, i.e., $R^3_{\theta^3\upsilon^3} > 0$. In this case, the federation will set a lower optimal cooperative emission tax rate, harvesting the benefits of the positive spillback effect ($R^3_{\theta^3\upsilon^3}\upsilon^3_k > 0$).

On the contrary, when the increase in the effective factors of production, due to pollution, results in the increase of the production generated emissions in the third country, i.e., $R^3_{\theta^3\upsilon^3} < 0$, the spillback effect is negative ($R^3_{\theta^3\upsilon^3}\upsilon^3_k < 0$). This will require a higher level of optimal cooperative emission tax rate.

Case *II* allows us to capture the diverse spatial impact of emissions as climate change will reduce economic activity on equatorial latitudes, while it will expand it on northern ones. Additional cases can be developed to consider a symmetric positive impact of pollution on the federation's factor endowments or even an asymmetric one.

The question that naturally arises is how, starting from an arbitrary level of emission taxes and in the presence of lump-sum transfers, coordination towards their uniform optimal cooperative level within the federation can ensure welfare improvement. To answer this, we adopt a well-known welfare improving reform of the relevant literature, which requires small coordinated movements of emission taxes from their initial arbitrary level towards their optimal cooperative one, see among others, Hatzipanayotou et al. (2005), Kotsogiannis and Woodland (2013), Kotsogiannis and Lopez-Garcia (2021a).[8]

To see this, suppose that emission taxes change according to $d\theta^1 = (\theta_c - \theta^1)d\lambda^1$ and $d\theta^2 = (\theta_c - \theta^2)d\lambda^2$, where λ^1, λ^2 are positive scalars and $d\lambda^1, d\lambda^2 > 0$. In this case equation (6) becomes:

$$\begin{aligned}\phi\left(E^1_{u^1}du^1 + E^2_{u^2}du^2\right) = &\left(1 + R^3_{\theta^3\upsilon^3}\upsilon^3_k\right)\left(\theta'_c - \theta^{1\prime}\right)R^1_{\theta^1\theta^1}(\theta_c - \theta^1)d\lambda^1 \\ &- \left(\theta^{1\prime} - \theta^{2\prime}\right)R^2_{\theta^2\upsilon^2}\upsilon^2_k R^1_{\theta^1\theta^1}(\theta_c - \theta^1)d\lambda^1 \\ &+ \left(1 + R^3_{\theta^3\upsilon^3}\upsilon^3_k\right)\left(\theta'_c - \theta^{2\prime}\right)R^2_{\theta^2\theta^2}(\theta_c - \theta^2)d\lambda^2 \\ &- \left(\theta^{2\prime} - \theta^{1\prime}\right)R^1_{\theta^1\upsilon^1}\upsilon^1_k R^2_{\theta^2\theta^2}(\theta_c - \theta^2)d\lambda^2.\end{aligned} \tag{8}$$

Equation (8) indicates that, following Cases *I* and *II*, the aggregate welfare effect of the suggested reform is ambiguous irrespective of the direction of the spillback effect arising from the non-member

[8] The above literature has emphasised the significance of international lump-sum transfers. When coupled with a movement of current policies towards their uniformly optimal cooperative level, these transfers contribute to Pareto welfare improvements. International lump-sum transfers can serve as a mechanism to alleviate the adverse impact of such reforms across countries.

country 3. Specifically, the first and third terms of the right-hand-side of equation (8) are positive, increasing the aggregate welfare, while the sign of the second and the fourth terms is ambiguous. Notice that in the absence of spillback effects, i.e., when $R^{j}_{\theta^j \upsilon^j} \upsilon^{j}_{k} = 0$, the suggested reform is aggregate welfare improving.[9] The following proposition summarises the above result:

Proposition 2 *Within a federal union and in the presence of spillbacks in addition to spillovers, a policy reform that requires small coordinated movements of the federations' emission taxes from their initial arbitrary level towards their uniform federal union's optimal cooperative rates may not deliver welfare improvement, despite the existence of lump-sum transfers within the federation.*

Intuitively, the ambiguity stems from the fact that changes in a country's emission taxes affect its own production generated pollution and thus overall pollution, which in turn affects production possibilities abroad. This result expands the existing literature, see, among others, Kotsogiannis and Lopez-Garcia (2021a), which suggests that small coordinated movements of taxes from their initial arbitrary level towards their optimal cooperative one, unambiguously deliver welfare improvements. Clearly this is not the case in the presence of spillback in addition to spillover effects.

3 Pareto improving tax reforms

Consider now a reform policy that implies a non-uniform proportional convergence of domestic emission tax structures towards a target vector H given by:

$$\begin{bmatrix} d\theta^1 \\ d\theta^2 \end{bmatrix} = \gamma \begin{bmatrix} H - \theta^1 \\ H - \theta^2 \end{bmatrix}, \tag{9}$$

where γ is a small positive scalar and H is an $n \times 1$ vector of the appropriately weighted average of the two initials emission tax structures, given by:

$$H = \left(R^{1}_{\theta^1\theta^1} + R^{2}_{\theta^2\theta^2}\right)^{-1} \left(R^{1}_{\theta^1\theta^1}\theta^1 + R^{2}_{\theta^2\theta^2}\theta^2\right). \tag{10}$$

Using equations (9) and (10) we obtain the following emission tax reforms:

$$d\theta^1 = \gamma \left(R^{1}_{\theta^1\theta^1} + R^{2}_{\theta^2\theta^2}\right)^{-1} R^{2}_{\theta^2\theta^2} \left(\theta^2 - \theta^1\right), \tag{11}$$

$$d\theta^2 = \gamma \left(R^{1}_{\theta^1\theta^1} + R^{2}_{\theta^2\theta^2}\right)^{-1} R^{1}_{\theta^1\theta^1} \left(\theta^1 - \theta^2\right). \tag{12}$$

It follows that:

$$R^{1}_{\theta^1\theta^1} d\theta^1 + R^{2}_{\theta^2\theta^2} d\theta^2 = 0 \Rightarrow R^{1}_{\theta^1\theta^1} d\theta^1 = -R^{2}_{\theta^2\theta^2} d\theta^2. \tag{13}$$

[9] In this case the aggregate welfare is given by
$\phi\left(E^{1}_{u^1} du^1 + E^{2}_{u^2} du^2\right) = \left(\theta'_c - \theta^{1\prime}\right) R^{1}_{\theta^1\theta^1} (\theta_c - \theta^1) d\lambda^1 + \left(\theta'_c - \theta^{2\prime}\right) R^{2}_{\theta^2\theta^2} (\theta_c - \theta^2) d\lambda^2 > 0.$

Following this reform property, the overall pollution level remains constant. Intuitively, the suggested harmonising reform neutralises all the spillback effects by maintaining the aggregate level of spillover effects constant and thus $dk = 0$. Due to this property, we refer to this reform as "aggregate spillovers constant reform".

Such type of fiscal policy piecemeal reforms have been central to the public policy literature. Keen (1987) introduced a harmonization fiscal policy reform that harmonises taxes, within a two large open economies framework, so as to leave world prices constant. In a two country world context, Lopez-Garcia (1996, 2024), Delipalla (1997), Kotsogiannis et al. (2005), developed variations of this type of reform addressing different settings but with the same property of maintaining constant world prices. Lahiri and Raimondos-Moller (1998), Kotsogiannis and Lopez-Garcia (2021b), in the absence of international externalities consider welfare improving harmonization reforms in a two small open economies context. We contribute to this discussion by introducing spillback effects, in addition to spillovers, which arise due to the presence of the Rest of the World, i.e., country 3. Such effects have been short-sighted by the existing literature due to its focus on two-country models. In addition, the suggested reform adds to the relevant literature by focusing on maintaining the aggregate spillover constant.[10]

Using (11), (12) and (13) in equation (6) we obtain:

$$E^1_{u^1} du^1 + E^2_{u^2} du^2 = \gamma \left(\theta^{1\prime} - \theta^{2\prime}\right) \Omega \left(\theta^1 - \theta^2\right) > 0. \tag{14}$$

The sign of the right-hand-side of equation (14) is positive since $\Omega = R^1_{\theta^1\theta^1} \left(R^1_{\theta^1\theta^1} + R^2_{\theta^2\theta^2}\right)^{-1} R^2_{\theta^2\theta^2} = \left[\left(R^1_{\theta^1\theta^1}\right)^{-1} + \left(R^2_{\theta^2\theta^2}\right)^{-1}\right]^{-1}$ is positive definite.

Proposition 3 *Within a federal union, in the presence of perfect transboundary externality, and with member countries' emission taxes set at an arbitrary level in which $\theta^1 \neq \theta^2$, harmonising the emission taxes across the federation, according to the reform (9), delivers a strict Pareto improvement for the federation irrespective of the nature and sign of the spillover and spillback effects.*

Adopting this "aggregate spillovers constant reform", the federal countries adjust their emission taxes to achieve a common target, denoted by H. Intuitively, the country with the highest emission tax will decrease its tax rate, while the country with the lower tax rate will increase it. This leads to a reallocation of production, production emissions, and consequently, emission tax revenues within the federation. Despite this reallocation effect, the aggregate pollution level remains constant. With a fixed pollution level all positive or negative internal and external spillback effects within the federation, arising from a decrease or an increase in the effective factors of production, are neutralised. This reform policy increases efficiency as it reduces the aggregate deadweight loss of the federation resulting from emission taxes. The reduction of the distortions generated by taxation

[10] Raimondos and Woodland (2018), Zissimos and Wooders (2008) provide an overview of the piecemeal trade policy reforms.

will lead to an increase in the aggregate welfare level of the federation. This holds irrespective of the nature and sign of the spillover and spillback effects, as described in *Cases I* and *II*.

Endogenous world prices

Relaxing the assumption of small open economies, we analyse the effect of the federation's emission tax reform with endogenous world prices. Focusing on large open economies a terms of trade externality is introduced in the model, since any change in emission taxes now affects also the world prices and thus the terms of trade in both countries. In this case, the market clearing condition for the tradable goods is given as follows:

$$E_q^1 - R_q^1 + E_q^2 - R_q^2 + E_q^3 - R_q^3 = 0. \tag{15}$$

Totally differentiating equation (3) we obtain:

$$\phi dk = -R^1_{\theta^1\theta^1} d\theta^1 - R^2_{\theta^2\theta^2} d\theta^2 - \left(R^1_{\theta^1 q} + R^2_{\theta^2 q} + R^3_{\theta^3 q} \right) dq. \tag{16}$$

Comparing equation (16) with (5) we can observe the indirect effect of emission taxes on countries' generated pollution through world prices, i.e., $R^j_{\theta^j q} = -\frac{\partial z^j}{\partial q} < 0$.

Totally differentiate equation (15), after using equation (16), to obtain the effect of federal countries' emission taxes on world prices, given by:

$$\begin{aligned} \Delta dq = & \left[R^1_{q\theta^1} - \left(R^1_{q\upsilon^1}\upsilon^1_k + R^2_{q\upsilon^2}\upsilon^2_k + R^3_{q\upsilon^3}\upsilon^3_k \right) \phi^{-1} R^1_{\theta^1\theta^1} \right] d\theta^1 \\ & + \left[R^2_{q\theta^2} - \left(R^1_{q\upsilon^1}\upsilon^1_k + R^2_{q\upsilon^2}\upsilon^2_k + R^3_{q\upsilon^3}\upsilon^3_k \right) \phi^{-1} R^2_{\theta^2\theta^2} \right] d\theta^2, \end{aligned} \tag{17}$$

where $\Delta = E^1_{qq} + E^2_{qq} + E^3_{qq} - R^1_{qq} - R^2_{qq} - R^3_{qq} + \left(R^1_{q\upsilon^1}\upsilon^1_k + R^2_{q\upsilon^2}\upsilon^2_k + R^3_{q\upsilon^3}\upsilon^3_k \right) \phi^{-1} \left(R^1_{\theta^1 q} + R^2_{\theta^2 q} + R^3_{\theta^3 q} \right)$.

To analyse the effects of a centralised policy setting within the federal union on its welfare, we totally differentiate the equilibrium conditions given by equations (3), (4) and (15), using (16) and (17). The welfare effects of the federal union resulted from small changes in member countries' emission taxes are given by:

$$\begin{aligned} \phi \left(E^1_{u^1} du^1 + E^2_{u^2} du^2 \right) = & -\phi \left(E^1_q + E^2_q - R^1_q - R^2_q \right) dq - \left(R^1_{\upsilon^1}\upsilon^1_k + R^2_{\upsilon^2}\upsilon^2_k \right) \left(R^1_{\theta^1 q} + R^2_{\theta^2 q} + R^3_{\theta^3 q} \right) dq \\ & + \left(\theta^{1\prime} R^1_{\theta^1\upsilon^1}\upsilon^1_k + \theta^{2\prime} R^2_{\theta^2\upsilon^2}\upsilon^2_k \right) \left(R^1_{\theta^1 q} + R^2_{\theta^2 q} + R^3_{\theta^3 q} \right) dq - \phi \left(\theta^{1\prime} R^1_{\theta^1 q} - \theta^{2\prime} R^2_{\theta^2 q} \right) dq \\ & - \left[\left(\theta^{1\prime} + R^1_{\upsilon^1}\upsilon^1_k i' + R^2_{\upsilon^2}\upsilon^2_k i' \right) + \left(\theta^{1\prime} - \theta^{2\prime} \right) R^2_{\theta^2\upsilon^2}\upsilon^2_k + \theta^{1\prime} R^3_{\theta^3\upsilon^3}\upsilon^3_k \right] R^1_{\theta^1\theta^1} d\theta^1 \\ & - \left[\left(\theta^{2\prime} + R^1_{\upsilon^1}\upsilon^1_k i' + R^2_{\upsilon^2}\upsilon^2_k i' \right) + \left(\theta^{2\prime} - \theta^{1\prime} \right) R^1_{\theta^1\upsilon^1}\upsilon^1_k + \theta^{2\prime} R^3_{\theta^3\upsilon^3}\upsilon^3_k \right] R^2_{\theta^2\theta^2} d\theta^2. \end{aligned} \tag{18}$$

A comparison of equation (18) with (6) reveals that in the presence of endogenous world prices, an additional term arises due to the effect of federation emission taxes on world prices. Specifically, the first term of the right-hand-side of equation (18) captures the effect of world prices on federation's terms of trade effect i.e., $\left(E_q^1 + E_q^2 - R_q^1 - R_q^2\right)$. The second, third and fourth terms capture the spillover and spillback effects resulted from the effect of world prices on:

- global pollution and thus endowments which in turn affects firms' production capabilities i.e., $-\left(R_{\upsilon^1}^1 \upsilon_k^1 + R_{\upsilon^2}^2 \upsilon_k^2\right)\left(R_{\theta^1 q}^1 + R_{\theta^2 q}^2 + R_{\theta^3 q}^3\right)$,
- emission tax revenues indirectly through endowments i.e., $\left(\theta^{1\prime} R_{\theta^1 \upsilon^1}^1 \upsilon_k^1 + \theta^{2\prime} R_{\theta^2 \upsilon^2}^2 \upsilon_k^2\right)\left(R_{\theta^1 q}^1 + R_{\theta^2 q}^2 + R_{\theta^3 q}^3\right)$,
- emission tax revenues directly through production i.e., $-\phi\left(\theta^{1\prime} R_{\theta^1 q}^1 - \theta^{2\prime} R_{\theta^2 q}^2\right)$.

The rest of the terms of equation (18) are identical to the one described by equation (6) capturing the direct spillbacks and spillover effects arising from the distortions of the federation's emission taxes. It can be easily shown that, as in the case of small open economies, equation (8), a policy reform that requires small coordinated movements of emission taxes from their initial arbitrary level towards their uniform optimal cooperative rates may not deliver welfare improvement. Intuitively, the presence of endogenous world prices exaggerates the ambiguity resulted by this reform.

Following the emission tax harmonisation reform as described by equations (9), (10) and assuming that one unit of production generates a units of emissions, i.e., $x^j = az^j$ where $a > 0$,[11] the reform property (13) now becomes:

$$R_{q\theta^1}^1 d\theta^1 + R_{q\theta^2}^2 d\theta^2 = 0. \tag{19}$$

Using (19), it follows that the world prices remain unchanged i.e., $dq = 0$. Intuitively, this reform policy adjusts the Federation's countries' emission taxes in such a way that world prices are constant.[12]

Applying the suggested harmonising reform, as described by equations (9), (10), using (19), which leads to $dq = 0$, in federal welfare (18) we obtain:

$$E_{u^1}^1 du^1 + E_{u^2}^2 du^2 = \gamma\left(\theta^{1\prime} - \theta^{2\prime}\right)\Omega\left(\theta^1 - \theta^2\right) > 0. \tag{20}$$

It is easy to observe that equations (20) and (14), representing the large and small open economies respectively, are identical even though the fact that the harmonisation reform delivers welfare improvement through different channels and irrespective of the direction and sign of the spillover and spillback effects. As analysed in the previous section, in the case of small open economies, the emission tax harmonisation reform property, described by equation (13), induces

[11] Given that $R_{\theta^j}^j = -z^j$ and $R_q^j = x^j$ it follows that $R_{q\theta^j}^j = -aR_{\theta^j\theta^j}^j$.

[12] This is consistent with the harmonisation reforms followed by the relevant literature, i.e., Keen (1987), extended to capture the spillover and spillback effects, see the relevant discussion following equation (13).

aggregate pollution level to remain constant which neutralises all the spillbacks. While, in the case of large open ones the emission tax harmonisation reform property, described by (19), results in world prices to remain unchanged. This neutralises all internal and external spillback effects within the federation arising through the impact of emission taxes on world prices. The remaining effects resulting from the adoption of this reform policy are identical to the ones described in the small open economies case. Thus, this emission tax harmonisation reform ensures welfare improvement in the case of endogenous world prices. The following Corollary summarises this result.

Corollary 1 *Within a federal union, in the presence of perfect transboundary externality, endogenous world prices, and with member countries' emission taxes set at an arbitrary level in which $\theta^1 \neq \theta^2$, harmonising the emission taxes across the federation, so as to maintain world prices constant, results in a strict Pareto improvement for the federation irrespective of the nature and sign of the spillover and spillback effects.*

4 Concluding Remarks and Policy Implications

Both policymakers and the academic community advocate for the centralisation of policy setting to address externalities stemming from global challenges, such as climate change. The rationale behind this proposition is that any distortions and resulting inequalities in the marginal utilities of income across countries, arising from the coordination or harmonisation of policies, will be mitigated through international lump-sum transfers. While this idea finds support in the literature e.g., Keen and Kotsogiannis (2014), Keen and Wildasin (2004), Turunen-Red and Woodland (2004), we demonstrate that in the presence of spillback effects, in addition to spillovers, international lump-sum transfers may not be sufficient to deliver Pareto improvement.

In contrast to the findings of the related literature, we show that when spillover and spillback effects are present, small coordinated movements of emission taxes within a federation toward their uniformly optimal cooperative rates may not necessarily yield welfare improvement despite the existence of international lump-sum transfers. Instead, we illustrate that shifting federal countries' emission taxes towards an "aggregate spillovers constant harmonisation reform", as specified by our analysis, has the potential for Pareto improvement. This result is driven by the fact that the suggested harmonising reform neutralises all the spillback effects by maintaining the aggregate level of spillover effects constant, while increases welfare for the federation. This outcome applies to both small and large open economies.

This result holds significant policy implications as it is applicable irrespective of the nature and sign of the spillover and spillback effects. For example, in the case of global externalities such as climate change, the spillover effect can be negative in equatorial latitudes where endowments will be degraded and underutilised due to higher temperatures, rising sea levels, drought, and floods. In contrast, northern countries might experience a positive effect from climate change, increasing the utilisation of their available endowments. These spillover effects, in turn, can result in positive or negative spillback effects, either exacerbating or mitigating the impact of the externality.

On one hand, a change in the effective factors of production might prompt the affected countries to adopt cleaner production technologies, thereby mitigating their contribution to the negative externality. On the other hand, the loss of effective factors of production might lead to the adoption of more intensive and polluting production practices to maintain their production levels, exacerbating the effects of the externality. The proposed harmonisation reform will deliver a Pareto improvement in the presence of both symmetric and asymmetric spillover and spillback effects resulting from negative externalities.

The relevance of our results extends to any other type of symmetric and asymmetric spillover and spillback effects. For instance, in the presence of positive externalities such as technological advancements, research, and knowledge dissemination, the proposed harmonisation reform is welfare improving for the federation.

Appendix

$$\phi E^1_{u^1} du^1 = -\left[\theta^{1\prime}\left(1 + R^2_{\theta^2\upsilon^2}\upsilon^2_k + R^3_{\theta^3\upsilon^3}\upsilon^3_k\right) + R^1_{\upsilon^1}\upsilon^1_k\right] R^1_{\theta^1\theta^1} d\theta^1 - \left(R^1_{\upsilon^1}\upsilon^1_k - \theta^{1\prime} R^1_{\theta^1\upsilon^1}\upsilon^1_k\right) R^2_{\theta^2\theta^2} d\theta^2, \tag{A.1}$$

$$\phi E^2_{u^2} du^2 = -\left[\theta^{2\prime}\left(1 + R^1_{\theta^1\upsilon^1}\upsilon^1_k + R^3_{\theta^3\upsilon^3}\upsilon^3_k\right) + R^2_{\upsilon^2}\upsilon^2_k\right] R^2_{\theta^2\theta^2} d\theta^2 - \left(R^2_{\upsilon^2}\upsilon^2_k - \theta^{2\prime} R^2_{\theta^2\upsilon^2}\upsilon^2_k\right) R^1_{\theta^1\theta^1} d\theta^1. \tag{A.2}$$

References

[1] Agrawal, D.R., 2023, Limits to competition: strategies for promoting jurisdictional cooperation, *NBER* Working Paper no. 31660.

[2] Agrawal, D.R., Hoyt, W.H., and Wilson, J.D., 2022, Local Policy Choice: Theory and Empirics, *Journal of Economic Literature* 60, 1378–1455.

[3] Chari, V. V., Nicolini, J. P. and Teles, P., 2023, Optimal cooperative taxation in the global economy, *Journal of Political Economy* 131, 95-130.

[4] Copeland, B.R., 1994, International trade and the environment: Policy reform in a polluted small open economy, *Journal of Environmental Economics and Management* 26, 44-65.

[5] Copeland, B.R., 2011, Trade and the Environment, *Palgrave Handbook of International Trade*, chapter 15, McMillan, London.

[6] Copeland, B.R., and Taylor, M.S., 1999, Trade, spatial separation, and the environment, *Journal of International Economics*, 47, 137-168.

[7] Cremer, H., and Gahvari, F., 2004, Environmental Taxation, Tax Competition, and Harmonization, *Journal of Urban Economics* 55, 21-45.

[8] Cremer, H., and Gahvari, F., 2005, Environmental Taxation in Open Economies: Unilateralism or Partial Harmonization, *Southern Economic Journal* 72, 352-371.

[9] Davies, R., and Naughton, H., 2014, Cooperation in environmental policy: a spatial approach, *International Tax and Public Finance* 21, 923-954.

[10] Delipalla, S., 1997, Commodity tax harmonisation and public goods, *Journal of Public Economics* 63, 447–466.

[11] Desmet, K., and Rossi-Hansberg, E., 2024, Climate change economics over time and space, CEPR Discussion Paper No. 18924.

[12] Eichner, T. and M. Runkel, 2012, Interjurisdictional spillovers, decentralized policymaking, and the elasticity of capital supply, *American Economic Review* 102, 2349-2357.

[13] Harstad, B., 2007, Harmonization and side payments in political cooperation, *American Economic Review* 97, 871-889.

[14] Hatzipanayotou, P., Lahiri, S. and Michael, M.S., 2005, Reforms of environmental policies in the presence of cross-border pollution and public-private clean-up, *Scandinavian Journal of Economics* 107, 315-333.

[15] Keen, M., 1987, Welfare effects of commodity tax harmonization, *Journal of Public Economics* 33, 107–114.

[16] Keen, M.J., and Kotsogiannis, C., 2002, Does federalism lead to excessively high taxes?, *American Economic Review* 92, 363-370.

[17] Keen, M.J., and Kotsogiannis, C., 2014, Coordinating climate and trade policies: Pareto efficiency and the role of border tax adjustments, *Journal of International Economics* 94, 119-128.

[18] Keen, M., and Wildasin, D., 2004, Pareto-efficient international taxation, *American Economic Review* 94, 259–275.

[19] Kotsogiannis, C., and Lopez-Garcia, M-A., 2007, Imperfect competition, indirect tax harmonization and public goods, *International Tax and Public Finance* 14, 135–149.

[20] Kotsogiannis, C., and Lopez-Garcia, M-A., 2021a, Pareto-improving indirect tax coordination and tax diversity, *Oxford Economic Papers* 73, 561-577.

[21] Kotsogiannis, C., and Lopez-Garcia, M-A., 2021b, On commodity tax harmonization and public goods provision, *Journal of Public Economic Theory* 23, 1220–1227.

[22] Kotsogiannis, C., Lopez-Garcia, M-A, and Myles G.D., 2005, The origin principle, tax harmonization and public goods, *Economics Letters* 87, 211-219.

[23] Kotsogiannis, C. and Woodland, A., 2013, Climate and international trade policies when emissions affect production possibilities, *Journal of Environmental Economics and Management* 66, 166-184.

[24] Kreickemeier, U., and Richter, P.M., 2014, Trade and the environment: The role of firm heterogeneity, *Review of International Economics* 22, 209-225.

[25] Lahiri, S., and Raimondos-Møller, P., 1998, Public good provision and the welfare effects of indirect tax harmonisation, *Journal of Public Economics* 67, 253–267.

[26] Lopez-Garcia, MA., 1996, The origin principle and the welfare gains from indirect tax harmonization, *International Tax and Public Finance* 3, 83–93.

[27] Lopez-Garcia, M.-A., 2024, Harmonizing fiscal policy: Indirect taxes and global public goods. *Review of International Economics*, DOI: 10.1111/ROIE.12769.

[28] Neary, P.J., 2006, International Trade and the Environment: Theoretical and Policy Linkages, *Environmental and Resource Economics* 33, 95-118.

[29] Oates, W.E., 1972, Fiscal Federalism. New York: Harcourt, Brace, Jovanovich.

[30] Ogawa, H. and D. Wildasin, 2009, Think locally, act locally: Spillovers, spillbacks and efficient decentralized policy making, *American Economic Review* 99, 1206-1217.

[31] Raimondos, P., and Woodland, A., 2018, Reciprocity in trade negotiations and welfare, *Journal of International Economics* 111, 134-142.

[32] Turunen-Red, A.H., and Woodland., A.D., 2004, Multilateral reforms of trade and environmental policy, *Review of International Economics* 12, 321-336.

[33] Wellisch, D., 1993, On the decentralized provision of public goods with spillovers in the presence of household mobility, *Regional Science and Urban Economics* 23, 667-679.

[34] Wellisch, D., 1994, Interregional spillovers in the presence of perfect and imperfect household mobility, *Journal of Public Economics* 55, 167-184.

[35] Wellisch, D., 1995, Can household mobility solve basic environmental problems?, *International Tax and Public Finance* 2, 245-260.

[36] Zissimos, B. and Wooders, M., 2008, Public good differentiation and the intensity of tax competition, *Journal of Public Economics* 92, 1105-1121.