International Environmental Agreements, Fiscal Federalism, and Constitutional Design[1]

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Abstract

In this paper, we analyse how the prospect of international negotiations over transboundary pollution shapes intra-country transfer schemes when the governments of the countries' polluting regions are in charge of environmental policy and negotiations. Federal governments can implement compensation payments between domestic regions and matching grants prior to the international negotiations between the polluting regions. The subgame-perfect transfer schemes fail to fully internalise the environmental externality, leading to an inefficient international environmental agreement. As the international spillover increases, the intra-country compensation rates increase, while the matching rates decline, distorting the incentives for the regional governments in opposing directions. We also show that decentralisation of environmental decision making can arise endogenously.

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1 Motivation

Most environmental problems are to some extent inter-regional in nature. Economic activities, which are often concentrated in some areas, not only pollute the environment where they take place but also in other regions. If a common jurisdiction comprised the polluting and the polluted regions, this inter-regional pollution would, in principle, cause no problem for environmental policy. Applying standard policy instruments, the central government could internalise the arising externalities between the regions and thus ensure an efficient outcome. Typically, however, the involved regions belong to different autonomous jurisdictions. Then, the environmental problems can only be resolved through voluntary international environmental agreements (IEAs).

This task is further complicated by the fact that within a jurisdiction the power to decide on environmental policy often lies with lower levels of government and not with the central government. In a federal system, the regional (or state) governments may also be entitled to negotiate IEAs.[1] Even if the federal government does not actively participate in these negotiations, it can nevertheless steer the bargaining behaviour of the regional governments by implementing an intra-country fiscal transfer scheme. In this paper, we explore how such transfer schemes affect IEAs, and how the prospect of IEAs shape the incentives for the federal governments to strategically design these schemes. We also analyse whether the decentralisation of environmental decision making can endogenously arise.

The analysis is carried out in a two-stage model with two countries, each consisting of a polluting and a non-polluting region. In the first stage, the federal governments decide on a matching grant to subsidise domestic abatement costs and on compensation payments from its country's polluting region to the non-polluting region. In the second stage, the polluting regions enter Nash bargaining over abatement levels. In an extension, the two countries choose in an initial constitutional stage whether the power to decide on environmental policy and to negotiate environmental agreements should be centralised or decentralised.

The main conclusions are as follows. Firstly, the equilibrium transfer schemes only partly internalise the externalities between the regions. As a result, the polluting regions agree on inefficiently low abatement levels. Secondly, the equilibrium policy mix crucially hinges on the degree of the international spillover. If the international spillover becomes stronger, the matching grant will decline, while the compensation rate will increase. This result shows a remarkable 'asymmetry' be-

[1] The term federal system refers to both federal states like the US and Germany and political unions like the EU.

tween the two instruments of fiscal federalism. Thirdly, the IEA becomes more inefficient if the federal governments have only one fiscal instrument at their disposal. Finally, decentralisation emerges endogenously as the constitutional choice in a symmetric subgame-perfect equilibrium.

Our analysis connects themes in fiscal federalism and international environmental agreements. The standard literature on fiscal federalism analyses how fiscal instruments are used to internalise externalities between different regions of a single jurisdiction (see, for instance, Oates, 1972, Guttman, 1978, Danziger and Schnytzer, 1991, Kaul et al., 2003, and Boadway et al., 2007 for some seminal and more recent papers). In contrast, we focus on fiscal instruments as a means to manipulate the negotiations between regions of different jurisdictions over reducing an international externality. Also in contrast to the 'traditional' theory on fiscal federalism, the resulting transfer schemes do not completely internalise intra-country externalities, and decentralisation results although there are intra-country externalities.[2]

Our paper is also related to the literature on strategic delegation or other strategically chosen actions prior to environmental negotiations (see, for instance, Copeland, 1990, Hoel, 1991, Buchholz and Konrad, 1994, Buchholz and Haslbeck 1997, Segendorff 1998, Buchholz et al., 2005, Beccherle and Tirole, 2011, and Harstad, 2012). In this context, Eckert (2003) analyses how the decentralisation of power within a country might be strategically used to alter the outcome of an IEA. In her framework, putting the federal governments in charge of negotiations can be an equilibrium outcome. In contrast, such a centralisation will never emerge if, as assumed in our paper, the federal governments have further fiscal instruments at their disposal. These additional instruments turn out to be a double-edged sword. As such instruments foster decentralisation, they render IEAs to be less efficient. However, given that countries decentralise environmental decision making, intra-country transfer schemes reduce the efficiency loss compared to the case of 'pure' decentralisation without accompanying schemes.

Covering decentralisation and its implications, our paper contributes to an ongoing political debate. This issue is not only of high importance for a fairly young political union such as the EU, which is still subject to rather drastic institutional change, but also for mature federal systems such as the US, where calls for less (federal) government frequently emerge, and even for traditionally centralised countries such as the UK, where devolution poses new institutional challenges.

Our paper is organised as follows: in Section 2, we describe our model. Section 3

[2]More recently, the issue of decentralisation has also been analysed in politico-economic models (e.g., Besley and Coate, 2003, and Dur and Roelfsema, 2005). Like the classical papers, these articles focus on externalities within a federal country and ignore the externalities between countries.

characterises the Nash bargaining solution. We examine the basic properties of the transfer schemes and the efficiency of the subgame-perfect equilibrium in Section 4. Section 5 analyses how the optimal policy mix depends on the extent of the international spillover, and how the set of instruments affects the efficiency of the IEA. In Section 6, we explore how decentralisation emerges as endogenous constitutional choice in a symmetric equilibrium. Section 7 concludes the paper.

2 The Model

We consider two completely symmetric countries $i = 1, 2$, each of them consists of two regions. To take into account the fact that polluting industries are unevenly distributed within each country, emissions e_i of country i are generated in only one of its two regions. Emissions e_i cause environmental damage not only in the source region, but also in the other region of country i and, albeit to a possibly lower degree, in both regions of country j. The spillover between the two countries is captured by the parameter $s \in (0, 1]$, with $s = 1$ covering the case where pollution is a pure international public 'bad'.

Given the spillover parameter s, environmental damage in country i is assumed to be a linear function of the countries' emission levels e_i and e_j: $D(e_i, e_j) = e_i + se_j$. If no abatement measures are taken, the two countries have the same basic emission level $\overline{e}$, leading to environmental damage $\overline{D} = (1 + s)\,\overline{e}$ in each country. Let a_i and a_j denote the (non-negative) abatement levels in the polluting regions of countries i and j. Then, environmental damage in country i is reduced to $D_i = \overline{D} - (a_i + sa_j)$. The costs of abating a_i emission units are captured by the function $E(a_i)$, which exhibits the standard properties $E'(a_i) > 0$ and $E''(a_i) > 0$ for $a_i > 0$.

Jointly, environmental damage and abatement costs make up the total costs of country i:

$$TC_i^F = \left[\overline{D} - (a_i + sa_j)\right] + E(a_i), \tag{1}$$

where the superscript F stands for the federal government, which represents country i as a whole.

Assume that the share of each country's population living in the polluting region, and the share of each country's environmental damage borne by the polluting region, is $\alpha \in (0, 1)$. Thus, environmental damage is αD_i in the polluting region of country i and $(1 - \alpha)\,D_i$ in its non-polluting region. In contrast to environmental damage, the abatement costs $E(a_i)$ arise without further provisions only in the polluting region because abatement measures have to be carried out there.[3] However, the costs

[3]For instance, think of a fishing industry which is located in the countries' coastal areas. While

which fall on country i's polluting region can be affected by two fiscal instruments the federal government of country i can apply.

Firstly, each federal government can subsidise the abatement costs of its polluting region through a matching grant $m_i E(a_i)$, where $m_i \in [0, 1]$ denotes the matching rate in country i. This matching grant is funded by tax revenues which are generated in the non-polluting region, for instance, by means of a lump-sum tax levied on the residents there. In this way, the non-polluting region takes a share of the abatement costs, thereby reducing the effective abatement costs of the polluting region to $(1 - m_i) E(a_i)$.

Secondly, in the spirit of the polluters-pay-principle, each federal government can force its polluting region to (partially or fully) compensate the non-polluting region for the environmental damages occurring there through a compensation payment $\beta_i D_i$, where $\beta_i \in [0, 1 - \alpha]$ denotes the compensation rate. By imposing an upper bound $1 - \alpha$ on the compensation rate, over-compensation is prevented. The compensation payments flow to the non-polluting region where, for instance, they are distributed among the population in a lump-sum fashion.[4]

Both fiscal instruments provide some burden sharing between the polluting and the non-polluting regions within each country. Taking the matching grant and the compensation payments into account, the total costs of country i's polluting region are given by

$$TC_i^R = (\alpha + \beta_i) \left[\overline{D} - (a_i + s a_j) \right] + (1 - m_i) E(a_i), \tag{2}$$

where the superscript R stands for the government of the polluting region, which represents only this region.

While the federal governments have the authority to implement a transfer scheme with matching grants and compensation payments and do not take part in international negotiations, the government of each polluting region is entitled to choose abatement levels and to sign a binding international environmental agreement (IEA)

these regions bear the costs of tougher regulations, the whole population in the two countries benefits from the protection of species and the resulting maintenance of biodiversity. Further examples are the carbon mining industry and the nuclear power stations along the upper course of a river. Acid waste water and the waste heat can be only avoided in the upstream areas where the mines and cold-storage plants are located. The benefits of abatement, however, also arise in the regions downstream.

[4]The important features of the transfer schemes are that the compensation payments and the matching grant constitute 'real' transfers between the domestic regions, and that the way of distributing the compensation payments and financing the matching grant does not distort the initial incentives created by these schemes. Various detailed arrangements are compatible with these properties.

with the polluting region of the other country. Later on, we will analyse whether such a constitutional design is in the interest of a country as a whole, or whether there are incentives to completely centralise the power to determine the abatement level and to negotiate an IEA. For the time being, we take the decentralised structure as given, and consider the following two-stage game.

In stage 1, each federal government non-cooperatively sets its compensation rate β_i and its matching rate m_i, pursuing the interest of the country as a whole. Facing these fiscal incentives, the two polluting regions then bargain over the abatement levels and the side-payments in stage 2. The outcome of these negotiations is given by the Nash bargaining solution.

We solve for the subgame-perfect equilibrium of this two-stage game and analyse the properties of the equilibrium transfer schemes and abatement levels. The equilibrium outcome is compared with the globally efficient abatement policy which would minimise the aggregate costs of the two countries $\sum_{i=1}^{2} TC_i^F$. The optimal abatement level a^{opt} is the same for the two countries and determined by the first-order condition

$$E'\left(a^{opt}\right) = 1 + s, \tag{3}$$

i.e., the marginal abatement costs in each country must be equal to the marginal decline in aggregate environmental damage in the two countries together.

3 Bargaining between the Polluting Regions

Applying backward induction, we start by exploring the bargaining solution in stage 2. We first analyse the non-cooperative abatement levels which would be implemented if negotiations failed, since they determine the threat point of the Nash bargaining solution. When the governments of the polluting regions act non-cooperatively, each of them chooses the abatement level that minimises its total costs TC_i^R, taking the strategy of the other polluting region and the transfer schemes as given. The resulting abatement level a_{in} is given by first-order condition[5]

$$(1 - m_i)\, E'\left(a_{in}\right) = \alpha + \beta_i, \tag{4}$$

where the subscript n indicates the non-cooperative outcome. In the non-cooperative solution, marginal abatement costs net of the matching grant $(1 - m_i)\, E'\left(a_{in}\right)$ ex-

[5] As will become evident in Section 4, a matching rate of $m_i = 1$ can never be an optimum because the regional government would then abate as much as possible. Thus, we can exclude $m_i = 1$ (see proof of Lemma 1 in the Appendix for details). To guarantee an interior solution to the abatement problem, we assume $E'(0) = 0$ and $E'(\bar{e}) = +\infty$. Then, $a_{in} > 0$ and $a_{in} < \bar{e}$. The second-order condition is fulfilled: $\partial^2 TC_i^R / \partial a_{in}^2 = (1 - m_i)\, E''_{in} > 0$.

actly offset the marginal decline in environmental damage augmented by the associated compensation payment $\alpha + \beta_i$.

The first-order condition (4) directly implies that both a higher compensation rate and a higher matching rate foster abatement activities at home, i.e.,

$$\frac{da_{in}}{d\beta_i} > 0 \quad \text{and} \quad \frac{da_{in}}{dm_i} > 0, \tag{5}$$

while the abatement levels abroad remain unaffected.

Having analysed the abatement levels in the threat point, we can now explore the Nash bargaining solution. Thereby, we take into account the fact that agreements on environmental issues are frequently accompanied by side payments between governments. With such side payments, the calculation of the Nash bargaining solution is straightforward: the governments of the polluting regions determine the abatement levels that minimise their aggregate costs and, assuming that the two regions have the same bargaining power, then choose side payments which give both regions an equal share in the gains from cooperation.

The abatement levels (a_{1c}, a_{2c}) that minimise aggregate costs

$$AC = \sum_{i=1}^{2} TC_i^R \tag{6}$$

are implicitly given by first-order condition[6]

$$(1 - m_i)\, E'(a_{ic}) = \alpha + \beta_i + s\left(\alpha + \beta_j\right), \tag{7}$$

where the subscript c indicates the cooperative solution, which is optimal from the polluting regions' viewpoint. In contrast to the non-cooperative equilibrium, the abatement externality between the polluting regions is now internalised to some degree, which is reflected by the term $s\left(\alpha + \beta_j\right)$ on the right hand side of (7). Consequently, abatement levels are higher and environmental damage is lower than in the non-cooperative equilibrium.[7] Furthermore, condition (7) directly implies that, in contrast to the non-cooperative equilibrium, the abatement level in country i now also increases with the compensation rate in country j, and not only, as before, with the compensation and matching rates in country i. Thus, we have

$$\frac{da_{ic}}{d\beta_i} > 0, \quad \frac{da_{ic}}{dm_i} > 0, \quad \text{and} \quad \frac{da_{ic}}{d\beta_j} > 0. \tag{8}$$

[6] The objective function (6) is strictly convex in the abatement levels for $m < 1$. We can exclude a matching rate of 1, as already discussed in footnote 5. Again, assuming $E'(0) = 0$ and $E'(\bar{e}) = +\infty$ guarantees an interior solution to the abatement problem.

[7] Comparing the first-order conditions (7) and (4) gives $E'(a_{ic}) > E'(a_{in})$, and thus $a_{ic} > a_{in}$, $E(a_{ic}) > E(a_{in})$, and $D_i(a_{in}, a_{jn}) > D_i(a_{ic}, a_{jc})$.

As the gains from cooperation are split evenly between the two negotiation parties, the side payments are such that, compared to the threat point, both polluting regions will enjoy the same reduction in total costs once side payments are included. Thus, with S_i denoting the side payments from the polluting region of country i to that of country j, we have

$$TC_i^R(a_{in}, a_{jn}) - TC_i^R(a_{ic}, a_{jc}) - S_i = TC_j^R(a_{in}, a_{jn}) - TC_j^R(a_{ic}, a_{jc}) + S_i \tag{9}$$

which gives

$$\begin{aligned} S_i = \tfrac{1}{2} \Bigg\{ & \underbrace{(\alpha + \beta_i)(a_{ic} + s a_{jc} - a_{in} - s a_{jn}) + (1 - m_i)[E(a_{in}) - E(a_{ic})]}_{\text{net gains of country } i\text{'s polluting region from cooperation}} \\ & - \underbrace{\left[(\alpha + \beta_j)(a_{jc} + s a_{ic} - a_{jn} - s a_{in}) + (1 - m_j)[E(a_{jn}) - E(a_{jc})]\right]}_{\text{net gains of country } j\text{'s polluting region from cooperation}} \Bigg\}. \end{aligned} \tag{10}$$

4 The Strategic Choice of the Transfer Schemes

The overall welfare of each country depends on the environmental damage in the whole country, its abatement costs, and the side payments. Let $P_i^F := TC_i^F + S_i$ denote the total costs of country i including side payments, which are given by

$$P_i^F = \left[\overline{D} - a_{ic}(\tau) - s a_{jc}(\tau)\right] + E(a_{ic}(\tau)) + S_i(\tau), \tag{11}$$

where $\tau = (\beta_i, \beta_j, m_i, m_j)$.

Taking the transfer scheme abroad as given, the federal government of country i chooses the compensation and matching rates which minimise objective function (11). In the case of an 'interior' solution, the optimal compensation and matching rates are defined by the first-order conditions

$$\frac{\partial P_i^F}{\partial \beta_i} = -\left(\frac{\partial a_{ic}}{\partial \beta_i} + s\frac{\partial a_{jc}}{\partial \beta_i}\right) + E'\frac{\partial a_{ic}}{\partial \beta_i} + \frac{\partial S_i}{\partial \beta_i} = 0 \tag{12}$$

$$\frac{\partial P_i^F}{\partial m_i} = -\frac{\partial a_{ic}}{\partial m_i} + E'\frac{\partial a_{ic}}{\partial m_i} + \frac{\partial S_i}{\partial m_i} = 0. \tag{13}$$

A higher matching or compensation rate increases the abatement level at home and, in the case of a higher compensation rate, also abroad (see (5) and (8)). Thus, domestic environmental damage falls, while abatement costs increase. Moreover, the transfer scheme affects the side payments.

Denote the solution to the first-order conditions (12) and (13) by $\widetilde{\beta}_i$ and $\widetilde{m}_i$. Taking into account that boundary solutions are possible, we can state the following Lemma (see the Appendix for all proofs).

Lemma 1 Country i's best responses $\beta_i^B = \beta_i^B\left(\beta_j, m_j\right)$ and $m_i^B = m_i^B\left(\beta_j, m_j\right)$ to country j's policy choices $\left(\beta_j, m_j\right)$ fulfil the following properties:

$$\alpha + \beta_i^B = \max\left\{\alpha, \alpha + \widetilde{\beta}_i\right\} < \min\left\{1 - \widetilde{m}_i, 1\right\} = 1 - m_i^B. \tag{14}$$

The resulting four best responses are consistent with each other in the subgame-perfect equilibrium, whose properties follow from Lemma 1 and are described in Proposition 1.

Proposition 1 *In the symmetric subgame-perfect equilibrium* (m^*, β^*, a_c^*),
(i) the compensation rate of each country internalises the domestic abatement externality only partially, i.e., $\alpha + \beta^* < 1$.
(ii) the polluting region's share of the abatement costs exceeds its share of the environmental damage including compensation payments, i.e., $1 - m^* > \alpha + \beta^*$.
(iii) the abatement levels are inefficiently low, i.e., $a_c^* < a^{opt}$, *and, consequently, environmental damage is inefficiently high.*

By implementing a transfer scheme as described in part (i) and (ii) of Proposition 1, each federal government ensures that the government of its polluting region benefits less from abatement than the entire country. Loosely speaking, such a scheme reduces the willingness of a country's regional government to carry out abatement activities and to make concessions in negotiations. Distorting the incentives for the regional governments in this way, the federal governments try to shift the benefits from cooperation to their own-country, at the expense of the neighbouring country.

Without any transfers, however, the government of the polluting region would usually care too little for the environment from the perspective of the country as a whole. Then, the regional governments would agree on too low abatement levels. The resulting negative environmental effect would overcompensate the positive benefit-shifting effect of abandoning all transfers. To avoid such an outcome, both federal governments introduce partial compensation payments and a limited matching grant in equilibrium. Only if, in the absence of intra-country transfers, the objectives of the polluting region were already very similar to those of the entire country, the federal governments could completely abstain from implementing a transfer scheme. This situation would arise if the population and environmental damage share of the polluting region were very large.[8]

Part (iii) of Proposition 1 directly follows from the properties of the transfer schemes. The IEA on abatement levels is efficient from the perspective of the governments of the two polluting regions. But since the transfer schemes are such that the polluting regions benefit less from abatement than their countries as a whole, the abatement levels are too low and the overall outcome is inefficient.

5 Policy Mix and International Spillover

We now cast more light on how the two policy instruments, the compensation rate and the matching rate, are exactly combined in the subgame-perfect equilibrium, and how this policy mix varies with the degree of the international spillover. To this end, we consider the case of quadratic abatement costs $E(a_i) = (1/2)\, a_i^2$. As shown in the Appendix, the equilibrium transfer schemes are then given by

$$\alpha + \beta^* = \frac{4(1+s)}{3(3+2s)} \quad \text{and} \quad 1 - m^* = \frac{4(1+s)^2}{3(3+2s+s^2)}. \tag{15}$$

Comparing the first-order conditions (3) and (7) reveals that the symmetric subgame-perfect equilibrium would be globally efficient if the transfer schemes fulfilled the condition $(\alpha + \beta^*) / (1 - m^*) = 1$. Using this condition as a benchmark to assess the efficiency of the transfer schemes, we define the efficiency ratio as

$$q^* := \frac{\alpha + \beta^*}{1 - m^*} = \frac{3 + 2s + s^2}{(3+2s)(1+s)}. \tag{16}$$

The more this ratio is below unity, the less efficient is the transfer scheme.

Figure 1 depicts how the transfer rates and the efficiency ratio will change with the international spillover parameter s. The effective regional share of environmental damage $\alpha + \beta^*$ and the regional share of the abatement costs $1 - m^*$ monotonically increase from 4/9 to 8/15 and 8/9, respectively. By contrast, the efficiency ratio monotonically falls from 1 to 3/5. As long as the population share α is below 4/9, there exists indeed an 'interior' equilibrium with positive compensation and matching rates for all $s \in (0, 1]$.[9] Otherwise, the restriction $\beta_i \geq 0$ would be binding

[8] As the optimal 'effective' environmental cost rate $\widetilde{\gamma}_i := \alpha + \widetilde{\beta}_i$ is independent of the share α (see proof of Lemma 1 for details), a country's optimal level of $\widetilde{\gamma}_i$ leads to a negative compensation rate $\widetilde{\beta}_i$ for a sufficiently large value of α. Then, the constraint $\beta_i \geq 0$ is binding and a subgame-perfect equilibrium with $\beta^* = 0$ can result. Similarly, $m^* = 0$ is possible.

[9] Note that without international externalities ($s = 0$), every transfer scheme that fulfils $(\alpha + \beta_i) / (1 - m_i) = 1$ would minimise the total costs of country i as a whole, and not only the scheme that satisfies $\alpha + \beta_i = 1 - m_i = 4/9$. For convenience, we exclude the case of $s = 0$. For all $s > 0$, the optimal transfer scheme is unique.

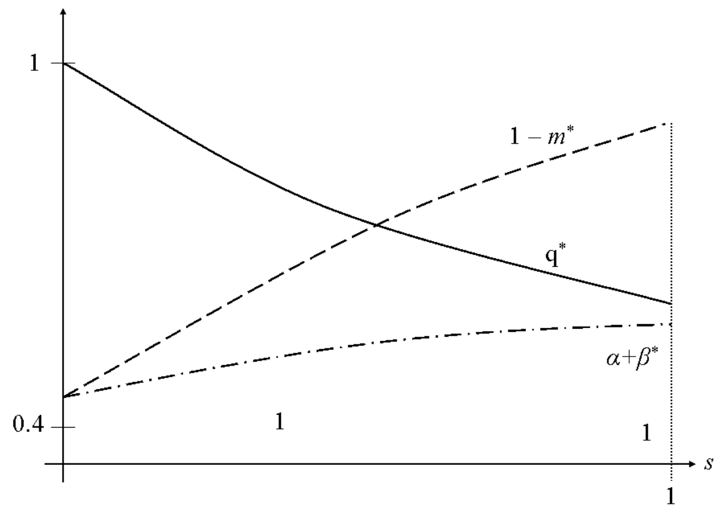

Figure 1: Efficiency Ratio, Compensation and Matching Rate

for sufficiently low spillover values.

These results are summarised in Proposition 2.

Proposition 2 *Let a quadratic abatement cost function be given. In the symmetric equilibrium, the compensation rate increases, while the matching rate decreases, with the international spillover parameter. The efficiency ratio declines, as the spillover parameter increases. That is,* $\partial\beta^*/\partial s > 0$*,* $\partial m^*/\partial s < 0$*, and* $\partial q^*/\partial s < 0$*.*

The explanation for the decline in the efficiency ratio is straightforward. The stronger the international spillover is, the higher are the potential benefits from an IEA, and the more each country can gain in absolute terms from shifting these benefits to its own country. To reap these higher gains from benefit shifting, the federal governments reduce even more the fiscal incentives for their regional governments to abate, which clearly results in a falling efficiency ratio.

This overall conclusion conceals that the policy mix radically changes, as the spillover parameter increases. Despite the fact that the federal governments wish to reduce the incentive for their regional government to cut emissions, they actually increase the compensation rates, which works in the exact opposite direction. But this rise in compensation rates is overcompensated for by the drop in the matching rates.

The rationale for these opposing changes in the structure of the transfer scheme is as follows. In contrast to a higher matching grant, higher compensation payments lead to a greater cooperative abatement level not only at home, but also abroad (see (8)). The positive impact on abatement abroad in the Nash bargaining solution is the more important, the stronger is the international externality. Thus, as the spillover parameter rises, each federal government raises the compensation rate to induce an increase in the abatement level abroad. At the same time, each federal government has to reduce the matching rate to depress the abatement level at home, and to shift the benefits from cooperation to its own country.

The strategic use of the transfer scheme raises the question whether the resulting inefficiency of the IEA would be less severe if the federal governments had only one transfer instruments at their disposal. To shed some light on this issue, we consider next two cases: in the first one, the federal governments can only implement compensation payments; in the second one, they can only use matching grants.

In these two cases, the transfer schemes in an 'interior' symmetric equilibrium are described by

$$\alpha + \beta^{**} = \frac{2\,(1+s^2)}{2+2s+3s^2} \quad \text{and} \quad 1 - m^{**} = \frac{4\,(1+s)^2\,\alpha}{4\,(1+s)+3s^2\alpha}, \tag{17}$$

where $\beta^{**} = \beta^*|_{m=0}$ and $m^{**} = m^*|_{\beta=0}$. Then, the corresponding efficiency quotients are

$$q_\beta^{**} = \alpha + \beta^{**} \quad \text{and} \quad q_m^{**} = \frac{\alpha}{1-m^{**}} = \frac{4\,(1+s)+3s^2\alpha}{4\,(1+s)^2}. \tag{18}$$

Comparing these equilibrium values with our previous results enables us to state Proposition 3.

Proposition 3 *The equilibrium rates β^{**} and m^{**} and the corresponding efficiency quotients q_β^{**} and q_m^{**} decline with the international spillover parameter s. For all $s \in (0,1]$, the equilibrium rates β^{**} and m^{**} exceed their counterparts β^* and m^*, whereas the efficiency quotients q_β^{**} and q_m^{**} fall short of q^*.*

Reducing the set of fiscal instruments has three important implications. Firstly, the remaining compensation or matching rate is higher with only one instrument than with two instruments, simply in order to compensate for the lack of the second policy tool. Secondly, the compensation rate now also decreases with the spillover parameter s if it is the only instrument. The reason is that benefit shifting becomes more important as the international externality increases, and that this can only be achieved by cutting the compensation rate in the absence of a matching grant.

Thirdly, the inefficiency of the transfer scheme becomes even worse. As discussed above, the federal governments aim at shifting the benefits from cooperation towards their own country, but still would like to avoid substantial drops in abatement levels.

Once the federal governments have only one fiscal instrument at their disposal, they find it more difficult to reconcile these two opposing goals, and abatement levels further fall.

6 Constitutional Choice

We have so far assumed an exogenously given federal structure with decentralised environmental decision making. In this section, we explore whether such a constitutional design can emerge endogenously. To analyse this issue, we assume now that, in an initial constitutional stage 0, the federal governments non-cooperatively decide whether the power to set the abatement levels and to negotiate over an IEA should lie with them or with the governments of the polluting regions.

If a federal government decentralises environmental decision making in stage 0, it chooses its transfer scheme in stage 1 before its polluting region enters negotiations in stage 2, as in the basic model. However, if a federal government centralises environmental powers in stage 0, no decision is to be made in stage 1, and the federal government itself negotiates over abatement levels and side payments in stage 2. The Nash bargaining solution is then still given by (7) and (10), with $\beta_i = 1 - \alpha$ and $m_i = 0$ if country i opts for a centralised system. (For the specific transfer scheme $(\beta_i, m_i) = (1 - \alpha, 0)$, the total costs of the federal government (1) and those of the regional government (2) coincide, and the Nash bargaining solution in Section 3 is identical to the outcome under centralised decision making in country i.)

However, centralisation can never arise in a symmetric subgame-perfect equilibrium, since whenever one country chooses centralisation the other country's best response is opting for decentralisation. The reason is straightforward. Assume that country j chooses centralisation, implying $\beta_j = 1 - \alpha$ and $m_j = 0$. As Lemma 1 states, country i's best response in stage 1 is to implement a transfer scheme with $\alpha + \beta_i^B < 1 - m_i^B$ for given $\beta_j = 1 - \alpha$ and $m_j = 0$ (see (14)). This best response, however, requires the active use of fiscal instruments, which is only feasible if country i opts for decentralisation in stage 0.

We summarise the subgame-perfect constitutional choices in Proposition 4.

Proposition 4 *In a symmetric subgame-perfect equilibrium, both federal governments delegate the authority to decide on environmental policy and to negotiate IEAs to the government of their polluting region.*

Thus, the previously assumed constitutional structure endogenously arises in a symmetric equilibrium, leading to the transfer schemes which are characterised in Proposition 1. The overall picture is one of 'mixed' federalism: a country first decentralises environmental decision making, but then imposes a transfer scheme to steer the decision of its polluting region.

This conclusion is in contrast to Eckert (2003) who analyses a similar constitutional choice in a two-country setting and argues that both countries might opt for centralisation in equilibrium. The reason is that, in her setting, there are no accompanying policy instruments, such as intra-country transfers, available. Under these circumstances, both countries might choose centralisation, since the negative effect of decentralisation on cooperative abatement levels can outweigh the positive benefit-shifting effect in the case of 'pure' decentralisation (i.e., without additional transfer schemes). Then, the ensuing IEA between the federal governments is globally efficient. By contrast, if the federal governments have additional transfer instruments at their disposal as in this paper, they can fine-tune the bargaining incentives for their regional governments and thus avoid the potentially negative implications of 'pure' decentralisation. Then, an equilibrium with both countries opting for centralisation never emerges, and the ensuing IEA is always inefficient.

However, given that decentralisation takes place in the subgame-perfect equilibrium, the use of accompanying transfer instruments actually reduces the inefficiency compared to the case of 'pure' decentralisation. The abatement levels are higher under decentralisation with accompanying compensation payments or matching grants than under 'pure' decentralisation. Overall, the impact of the availability of fiscal instruments on efficiency is ambiguous. On the one hand, it fosters decentralisation and thus inefficiency. On the other hand, it enhances the inefficiency of a decentralised system.

7 Concluding Remarks

In this paper, we have related key topics of fiscal federalism with issues of international environmental negotiations. Considering matching grants and compensation payments, we have characterised the mix of fiscal instruments which is strategically chosen by federal governments in a symmetric subgame perfect equilibrium to steer the governments of their polluting regions in international negotiations (see Proposition 1). We have also showed how the equilibrium policy mix varies with the degree of the international spillover (see Proposition 2). Importantly, the inefficiency of the IEA becomes worse if the federal governments can only apply one fiscal instrument (see Proposition 3). Finally, we have argued that decentralisation emerges endogenously in an extended model (see Proposition 4).

Throughout our analysis, we have assumed that the federal governments pursue the interests of their entire countries. However, the feasibility of a policy might depend on its support by each region of a country. An interesting extension of our model would be to consider transfer schemes that actually make all regions in a country better off and not only the country as a whole. This additional requirement would put restrictions on the feasible transfer schemes and thus might render decentralisation a less attractive choice. We leave this issue for further research.

Appendix

Proof of Lemma 1:

Let

$$\Omega\left(\beta_i, m_i, \beta_j\right) := \left[\frac{\alpha + \beta_i + s\left(\alpha + \beta_j\right)}{1 - m_i} - 1 - s\left(\alpha + \beta_j\right)\right]. \tag{19}$$

Then, using the first-order conditions (4) and (7) and side payments (10), we can reformulate the derivatives of the first-order conditions (12) and (13), yielding

$$\begin{aligned} \frac{\partial P_i^F}{\partial \beta_i} &= \Omega\left(\beta_i, m_i, \beta_j\right) \frac{\partial a_{ic}}{\partial \beta_i} - s\left[1 - \left(\alpha + \beta_i\right)\right] \frac{\partial a_{jc}}{\partial \beta_i} \\ &\quad + \frac{1}{2}\left[D_{in} - D_{ic} + s\left(\alpha + \beta_j\right) \frac{\partial a_{in}}{\partial \beta_i}\right] \end{aligned} \tag{20}$$

$$\frac{\partial P_i^F}{\partial m_i} = \Omega\left(\beta_i, m_i, \beta_j\right) \frac{\partial a_{ic}}{\partial m_i} + \frac{1}{2}\left[E\left(a_{ic}\right) - E\left(a_{in}\right) + s\left(\alpha + \beta_j\right) \frac{\partial a_{in}}{\partial m_i}\right], \tag{21}$$

where $D_{in} - D_{ic} = a_{ic} + s a_{jc} - a_{in} - s a_{jn}$.

Consider the derivative (21). Note that

$$\Omega\left(\beta_i, m_i, \beta_j\right) \gtreqless 0 \Leftrightarrow \frac{\alpha + \beta_i}{1 - m_i} \gtreqless 1 - \frac{m_i}{1 - m_i}\left[s\left(\alpha + \beta_j\right)\right] < 1. \tag{22}$$

Then, as $E\left(a_{ic}\right) > E\left(a_{in}\right)$ (see Section 3 and footnote 7), $\partial a_{in}/\partial m_i > 0$ (see (5)) and $\partial a_{ic}/\partial m_i > 0$ (see (8)), the inequalities (22) imply that for any given $\beta_i, \beta_j \in [0, 1 - \alpha]$, country-wide total costs P_i^F increase with m_i if $m_i \geq 1 - \alpha$. Therefore, a best response $m_i^B \in [0, 1 - \alpha)$, which minimises P_i^F, exists. In the case of $m_i^B > 0$, the best response $m_i^B = \widetilde{m}_i$ is characterised by the first-order condition $\partial P_i^F/\partial m_i = 0$. Then, as $E\left(a_{ic}\right) > E\left(a_{in}\right)$, $\partial a_{in}/\partial m_i > 0$ and $\partial a_{ic}/\partial m_i > 0$, the condition $\partial P_i^F/\partial m_i = 0$ can only be fulfilled if $\Omega\left(\beta_i, m_i, \beta_j\right) < 0$. This shows that $1 - m_i^B > \alpha + \beta_i^B$ if $m_i^B = \widetilde{m}_i > 0$.

If, however, $m_i^B = 0$, we also have $1 - m_i^B = 1 > \alpha + \beta_i^B$, since $\alpha + \beta_i^B < 1$. To see the latter inequality, we evaluate the derivative (20) at $\beta_i = 1 - \alpha$ and $m_i = 0$:

$$\left.\frac{\partial P_i^F}{\partial \beta_i}\right|_{\substack{\beta_i = 1-\alpha \\ m_i = 0}} = \frac{1}{2}\left[D_{in} - D_{ic} + s\left(\alpha + \beta_j\right)\frac{\partial a_{in}}{\partial \beta_i}\right] > 0, \tag{23}$$

where the inequality follows from $D_{in} > D_{ic}$ (see Section 3 and footnote 7) and $\partial a_{in}/\partial \beta_i > 0$ (see (5)). Thus, irrespective of the transfer scheme in country j, the federal government of country i can always diminish its country-wide total costs P_i^F by implementing a rate β_i that is (marginally) lower than $1 - \alpha$. This implies $\alpha + \beta_i^B < 1$.

Proof of Proposition 1:

Inequality (14) of Lemma 1 implies $\alpha + \beta^* < 1 - m^* \leq 1$, and thus part (i) and (ii) of Proposition 1. Thus, we have $(\alpha + \beta^*)/(1 - m^*) < 1$. Using the first-order conditions (3) and (7), we then obtain that $E'(a_c^*) < E'(a^{opt})$. This gives us $a_c^* < a^{opt}$, since the cost function $E(a)$ is strictly convex. Consequently, $D_c^* = \overline{D} - (1+s)\,a_c^* > \overline{D} - (1+s)\,a^{opt} = D^{opt}$. This proves part (iii) of Proposition 1.

Proof of Proposition 2:

We first derive the optimal transfer scheme. Using $E'(a_i) = a_i$, the non-cooperative and cooperative abatement levels are given by $a_{in} = (\alpha + \beta_i)/(1 - m_i)$ and $a_{ic} = \left[\alpha + \beta_i + s\left(\alpha + \beta_j\right)\right]/(1 - m_i)$, respectively. Inserting these terms into (10) and differentiating the resulting expression with respect to the transfer instruments yields

$$\frac{\partial S_i}{\partial \beta_i} = \frac{3s^2}{2}\frac{\alpha + \beta_i}{1 - m_j} \quad \text{and} \quad \frac{\partial S_i}{\partial m_i} = -\frac{3s^2}{4}\left(\frac{\alpha + \beta_j}{1 - m_i}\right)^2. \tag{24}$$

Again making use of the optimal abatement levels and inserting (24) into (12) and (13) leads to

$$\left.\frac{\partial P_i^F}{\partial \beta_i}\right|_{\beta_i = \beta_j} = 0 \quad \Leftrightarrow \quad \frac{\alpha + \beta^*}{1 - m^*} = \frac{1 + s^2}{1 + s} - \frac{3s^2}{2(1+s)}\left(\alpha + \beta^*\right) \tag{25}$$

$$\left.\frac{\partial P_i^F}{\partial m_i}\right|_{m_i = m_j} = 0 \quad \Leftrightarrow \quad \frac{\alpha + \beta^*}{1 - m^*} = \frac{1}{1 + s} + \frac{3s^2}{4(1+s)^2}\left(\alpha + \beta^*\right) \tag{26}$$

in a symmetric equilibrium. The second-order conditions are fulfilled (the cumbersome details are provided upon request).

Combining (25) and (26) gives the equilibrium values (15) and the efficiency ratio (16). Differentiating these terms with respect to the spillover parameter s yields the results of Proposition 2.

Proof of Proposition 3:

Evaluating (25) at $m^* = 0$ and (26) at $\beta^* = 0$ gives the equilibrium values (17) and the efficiency ratios (18). Differentiating these terms with respect to s leads to $d\beta^{**}/ds < 0$, $dm^{**}/ds < 0$, $dq_\beta^{**}/ds < 0$, and $dq_m^{**}/ds < 0$. Moreover, $d\beta^*/ds > 0$, $d\beta^{**}/ds < 0$ and $\alpha + \beta^*|_{s=1} = 8/15 < 4/7 = \alpha + \beta^{**}|_{s=1}$ imply that $\beta^{**} > \beta^*$ for all $s \in (0, 1]$. Finally, comparing (15) and (17) as well as (16) and (18) gives $m^{**} > m^*$, $q_\beta^{**} < q^*$, and $q_m^{**} < q^*$.

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