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ABSTRACT: The literature on trade liberalization and environment has not considered federal structures. This paper shows how the design of environmental policy in a federal system has implications for the effects of trade reform. Trade liberalization leads to a decline in pollution taxes regardless of whether pollution taxes are set at the federal (centralized) or local (decentralized) level, and it increases social welfare. The effect under a decentralized system is smaller than if these taxes are set by the federal government, and pollution emissions therefore decline in this case. Moreover, majority bias interacts with trade liberalization if federal taxes are used.

KEYWORDS: trade and environment; environmental policy; trade liberalization; environmental federalism; political economy; majority bias; social welfare

JEL CLASSIFICATION: F1, H2, H7, Q2

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1. Introduction

The relationship between trade liberalization and the environment is a highly contentious public policy issue. For example, the environmental provisions of the current negotiations over the Trans-Pacific Partnership, which would be one of the world's largest trade agreements, have exposed deep rifts over environmental policy between the United States and eleven other Pacific Rim nations. The environmental parts of the trade deal have as of early 2014 been among the most highly disputed elements of the treaty negotiations (see Davenport (2014) in the New York Times). Moreover, Sierra Club (2013) raises significant concerns about the Transatlantic Trade and Investment Partnership (TTIP) being negotiated in 2014 by the European Union and the United States. In particular, the Sierra Club argues that any harmonization within TTIP must be towards stricter policies, and provide governments with the flexibility to maintain or strengthen environmental and climate policies without constraints. Meanwhile, the literature analyzing the effects of trade liberalization on environmental policy and quality continues to present contradicting results (see Copeland and Taylor (2004) for a survey). One deficiency of this literature is that it has not sufficiently taken political institutions into account, in particular the presence of a federal system (see Gulati and Kellenberg (2013)). Federations may assign authority over environmental policy to either local or federal levels of government (Oates (2002) provides a survey), and thus different levels of government may respond differently to trade liberalization depending on the institutional design. We investigate the effects of exogenous trade liberalization on pollution taxes in a federation with majoritarian electoral rule under decentralized and centralized environmental policy designs. We are not aware of any previous studies that analyze this particular issue.

Many countries currently take part in trade-liberalizing efforts, be it at the multilateral, bilateral, or even unilateral level. Trade liberalization may in turn affect domestic policies as well. Ederington and Minier (2003) suggest that unilateral incentives may emerge for governments to distort domestic environmental policies as a secondary tool of protection. The influence on environmental taxation is an important issue given the double dividend debate pertaining to environmental taxation (see, e.g., Parry and Bento (2001) and Jaeger (2011)). Moreover, trade liberalization and environmental taxation occur in a variety of countries ranging from federal states such as the United States and Canada to more centralized states such as France, and from states with majoritarian electoral systems to states with proportional presentation. It seems an important question to ask whether the impact of trade liberalization on environmental taxation hinges on political institutions, e.g., the governmental level at which environmental policy is decided and on the electoral system. The question whether free trade agreements should also include addenda on environmental policies to counteract negative environmental consequences may actually depend to some degree on the political institutions under which environmental policy decisions are taken. Moreover, taking the political institutions into account may be of importance in related empirical work as well.

In this paper, the electoral regime is a majoritarian system. This is of particular interest as such systems may exhibit a "majority bias" where the majority party favors its home districts (Grossman and Helpman (2005); Fredriksson, Matschke, and Minier (2010, 2011)). Taxes may be set at the federal or district level. In the case of federal government policy-making, pollution taxes can either be uniform across districts, or district-specific.

Our analysis shows that trade liberalization unambiguously leads to a decline in a sector's pollution tax regardless of whether pollution taxes are set centrally or decentrally. However, the effect of trade liberalization on pollution taxes under a decentralized system is smaller in absolute value than if these taxes are set by the federal government. If taxes are set at the federal level, pollution remains constant as the induced tax change completely offsets the tariff change. In the decentralized system, the tax response is smaller, and the effect of the tariff cut dominates. As a result, emissions and pollution tax revenue decrease when trade is liberalized. In either case, however, social welfare increases as a result of the tariff cut. If the federal government sets a pollution tax, majority bias influences the response. In particular, the response is relatively stronger in sectors which are disproportionally located in majority districts or which cause relatively more damage in minority districts. In addition, with district-specific federal pollution taxes, majority bias is relatively larger in majority districts. Our results suggest that future empirical work in this area should consider the governmental level at which regulations are decided. For example, studies of the pollution haven hypothesis, which treat environmental regulations as endogenous, now have an additional determinant to consider. When a measure of trade policy is included in such estimations, our findings imply that it should be interacted with a measure of environmental policy decentralization.

Earlier related theoretical work on the effect of trade policy on environmental regulation includes Bommer and Schulze (1999), Fredriksson (1999), Schleich (1999), Schleich and Orden (2000), Damania and Fredriksson (2003), Lai (2005, 2006, 2007), and Kawahara (2014) who study the effects of trade liberalization in lobby group models.[1] This literature finds that trade liberalization may raise environmental policy stringency under some conditions, but lower stringency in other situations. Gulati (2008), McAusland (2003, 2008), and McAusland and Millimet (2013) study how freer trade impacts the burden sharing of environmental policies between consumers and producers and the implications for environmental policy stringency. Ferrara, Missios, and Yildiz (2009) examine the role of trade discrimination for environmental standards. They argue that trade discrimination yields stricter standards than free trade.

On the empirical side, the results are mixed, but frequently provide support for our model predictions. Antweiler, Copeland, and Taylor (2001), Cole and Elliott (2003),

[1] For models without a political economy perspective, see. e.g., Copeland (1990), Burguet and Sempere (2003), Eerola (2006), and Lai and Hu (2008).

Cole (2004), and Frankel and Rose (2005) report that the effect of more open trade regimes varies by pollutant, but tends to reduce SO_2 emissions in most countries, in particular developing countries. In a similar vein, McAusland and Millimet (2013) provide evidence for the U.S. and Canada that international trade has a beneficial impact on environmental quality, while intranational trade harms the environment. In contrast, Kellenberg (2008) finds that trade liberalization increases pollution in the poorest and the richest countries, and Cole (2006) reports that it increases energy use. Findings by Busse and Silberberger (2013) indicate that an increase in the net exports of pollution-intensive goods leads to less stringent environmental regulations.

Our results also shed further light on whether environmental policy is a secondary trade barrier, as discussed by Ederington and Minier (2003). Taking endogeneity issues into account, Ederington and Minier (2003) find empirical evidence that environmental policies act as a secondary trade barrier in the U.S. In particular, import competing industries are underregulated in the area of the environment. However, they also find that a lower tariff rate is associated with a higher stringency of environmental regulations. Damania, Fredriksson, and List (2003) report that tariff liberalization decreases environmental policy stringency when the level of corruption is low, but the reverse effect occurs when corruption is endemic.[2] None of the literature, however, considers how the interplay of trade liberalization, federalism, and a majoritarian electoral system influences environmental taxation, pollution emissions, and social welfare.[3]

The remainder of this paper is organized as follows. Section 2.1 sets up the theoretical model. Sections 2.2, 2.3, and 2.4 derive the pollution tax rate and the comparative

[2]Stricter environmental regulations in one country may also induce the so-called pollution haven effect in another country. Levinson and Taylor (2008) show that U.S. industries whose pollution abatement costs increased the most also experienced the highest increases in net imports from Canada and Mexico.

[3]Our focus is on the interactions between trade liberalization, federalism, and majoritarian electoral systems. In order to keep the model tractable, we abstract from tax competition issues in decentralized systems which have been extensively studied (see, e.g., Oates and Schwab (1988), Oates (2002), Greaker (2003), and Ogawa and Wildasin (2009)).

statics for district-specific federal taxation, uniform federal taxation, and district-specific decentralized taxation. Section 3 concludes. The appendix contains a longer proof.

2. Model

2.1. **Setup.** A small open economy has individuals living in an odd (ruling out tied elections) number K of geographically and politically separate districts. The population is normalized to unity. Each individual i living in district $k \in \{1, ..., K\}$ consumes $G+1$ goods and has quasi-linear preferences linear in i's consumption of the clean numeraire good 0 and nonlinear and additively separable in the consumption of the other goods $g \in \{1, ..., G\}$ whose production causes pollution. The setup with a quasilinear utility function, popularized by Grossman and Helpman (1994), makes the demand of a non-numeraire good g independent of cross-price and income effects, provided income is sufficiently high. We abstract from lobbying and focus on the political institution of majoritarian electoral systems as in Grossman and Helpman (2005).

X_{kg} is sector g output produced in district k. θ_g is the pollution intensity coefficient of sector g production, and γ_{kgj} is the pollution exposure intensity coefficient reflecting pollution suffered by district j residents due to sector g pollution emitted in district k; when $k \neq j$, it represents cross-district transboundary pollution, following Fredriksson, Matschke, and Minier (2010). The numeraire good has world, domestic consumer, and producer prices equal to unity. Good $g \in \{1, ..., G\}$ has a world market price p_g^*.

The home country levies an exogenously given specific tariff $\tau_g > 0$ on imports of non-numeraire goods, yielding consumer price $p_g^* + \tau_g$. If $\tau_g < 0$ and good g is imported, we interpret τ_g as an import subsidy. In case the production of the good exceeds demand, the rate $\tau_g > 0$ represents an export subsidy. For expositional purposes, we concentrate on the case where non-numeraire goods are imported and an import tariff $\tau_g > 0$ is levied. Trade liberalization under GATT-WTO consists mainly of a gradual reduction of most-favored-nation (MFN) tariff rates.

An important assumption in our model is that trade liberalization and thus the faced tariff rates are exogenous for the small country. Indeed, it appears reasonable that a country unable to influence the world market price of a good g likewise has little power to impact WTO negotiations on the reduction of the import tariff rate τ_g. Instead, the country's legislature can unilaterally set a domestic pollution tax t_{kg} in district k for sector g; thus district k producers receive a sector g net price $p_{kg} = p_g^* + \tau_g - t_{kg}\theta_g$.

The numeraire good is produced from labor only with constant returns to scale and an input-output coefficient equal to unity. Assuming positive production of this good yields a wage rate equal to one. Good $g \in \{1, ..., G\}$ production requires labor and a sector-specific input. With a fixed wage rate, the aggregate factor reward for district k producers in sector g, $\pi_{kg}(p_{kg})$, depends on the producer price p_{kg}. All individuals receive a share of wage income, tariff revenue, and pollution tax revenue. Capital owners of an industry also receive a share of profit income. By Hotelling's Lemma, the derivative of π_{kg} with respect to the producer price equals output X_{kg}. Supply is upward-sloping ($X'_{kg} > 0$) and either linear or strictly convex in the producer price ($X''_{kg} \geq 0$).

Majority legislators care only about the welfare of their own constituents rather than the welfare of the entire country. As a group, they maximize the joint welfare of their districts. The objective function of the majority party in the legislature is:

$$W_M = \overbrace{\sum_{k=1}^{K}\sum_{g=1}^{G}\delta_k^M \pi_{kg}(p_{kg})}^{A} + \overbrace{\Lambda_M \sum_{k=1}^{K}\sum_{g=1}^{G} t_{kg}\theta_g X_{kg}(p_{kg})}^{B} + \overbrace{\Lambda_M \sum_{g=1}^{G}\tau_g \sum_{k=1}^{K}\{D_{kg}(\tau_g) - X_{kg}(p_{kg})\}}^{C}$$
$$- \underbrace{\sum_{k=1}^{K}\sum_{g=1}^{G} X_{kg}(p_{kg})\theta_g \sum_{j=1}^{K}\delta_j^M \gamma_{kgj}}_{D} + \underbrace{\sum_{k=1}^{K}\sum_{g=1}^{G}\delta_k^M C_{kg}(\tau_g)}_{E}. \quad (2.1)$$

D_g denotes demand of good g where $D'_g < 0$, and δ_k^M takes the value 1 if k is a majority district, 0 otherwise. Majority welfare consists of the sum of industry profits of firms located in majority districts (term A) and the tax (term B) and tariff revenue share (term

C) going to majority district residents ($\Lambda_M \in [.5, 1]$ denotes their population share). Pollution damage affecting majority districts (term D) is subtracted from welfare. The sum of consumer surplus C_{kg} for the population living in majority districts enters welfare (term E), but does not depend on the environmental tax in a small country. Only the producer price, not the consumer price, reflects the environmental taxation of production. Summing up, a pollution tax will lower industry profits, increase tax revenue via the tax rate effect, but lower it via the negative tax base effect. The reduction in domestic production increases imports and thus the tariff income base for the import tariff. Finally, a pollution tax reduces domestic output and pollution damage.

We consider three different environmental policy designs for sector g:

(1) A district-specific pollution tax t^F_{kg}, set at the federal (national) level.
(2) A uniform pollution tax t^F_g across districts, set at the federal (national) level.
(3) A district-specific pollution tax t^D_{kg}, set at the district level.

In the first two scenarios, majority welfare given by (2.1) is maximized; in the third, district welfare is maximized.

2.2. **District-Specific Federal Pollution Tax.** The FOC for maximizing (2.1) w.r.t. a district-specific federal pollution tax t^F_{kg} is given by

$$-\theta_g X_{kg}\delta^M_k + \Lambda_M\theta_g X_{kg} - \Lambda_M\theta_g^2 t^F_{kg}X'_{kg} + \Lambda_M\theta_g\tau_g X'_{kg} + \theta_g^2 X'_{kg}\sum_{j=1}^{K}\delta^M_j\gamma_{kgj} = 0. \tag{2.2}$$

Proposition 1. *The federal district-specific pollution tax is*

$$t^F_{kg} = \overbrace{-\frac{\delta^M_k X_{kg}}{\Lambda_M\theta_g X'_{kg}}}^{A} + \overbrace{\frac{X_{kg}}{\theta_g X'_{kg}}}^{B} + \overbrace{\frac{\tau_g}{\theta_g}}^{C} + \overbrace{\frac{\sum_{j=1}^{K}\delta^M_j\gamma_{kgj}}{\Lambda_M}}^{D}, \tag{2.3}$$

where terms A, B, C, and D correspond to the profit, tax revenue, tariff revenue, and pollution damage effects. If district k is a minority district ($\delta^M_k = 0$), the government *sets a positive pollution tax for district k production of g. In a majority district k, however, the pollution tax may be positive, but also zero or even negative.*

Proof. Solve (2.2) for t_{kg}^F. To sign the tax, notice that $\delta_k^M \in \{0,1\}$ and $\Lambda_M \in [.5,1]$. □

The tax t_{kg}^F shows a clear majority bias: part A of the pollution tax is negative for a majority district and zero for a minority district: An environmental tax reduces the profits of the polluting firms, and if these reside in a majority district, the tax will be lower. At the same time, if k is a majority district, part A is increasing in the majority district population share Λ_M. Part B arises because for a given production quantity, a higher environmental tax rate increases the tax revenue which can then be distributed among the population. Parts A and B taken together add up to a negative tax for majority districts and a positive tax for minority districts. Only if all population is located in majority districts (i.e., if the majority party has won all districts), do parts A and B exactly cancel. Moreover, the majority disregards any cross-boundary pollution appearing in minority districts, as apparent from part D. Consequently, a higher concentration of production in majority districts and a lower level of negative production externalities affecting majority districts tend to reduce the equilibrium pollution tax. Part C shows that ceteris paribus a higher import tariff rate τ_g also increases the pollution tax. This must be true because an import tariff stimulates domestic production and thus increases the tax base for the environmental tax. If parts C and D are strictly positive and k is a majority district, a non-positive pollution tax is more likely if production of g in k is substantial (X_{kg} high) and/or its price sensitivity is low (X'_{kg} low).

The effect of a tariff decrease on t_{kg}^F can be unambiguously signed, however.

Proposition 2. *The derivative of t_{kg}^F w.r.t. τ_g equals*

$$\frac{dt_{kg}^F}{d\tau_g} = \frac{1}{\theta_g} > 0. \tag{2.4}$$

If trade is liberalized, the government recompensates producers for resulting losses via a lower pollution tax rate. Formulating the impact of a tariff change as an elasticity, we find $\epsilon^F_{t_{kg},\tau_g} = \frac{dt^F_{kg}}{d\tau_g}\frac{\tau_g}{t^F_{kg}} = \frac{\tau_g}{\theta_g t^F_{kg}}$, *where* t^F_{kg} *is given by* (2.3).

Proof. See appendix. □

Both the environmental tax and the import tariff affect the producer price: An increase in the import tariff increases the producer price one-to-one, whereas an increase in the pollution tax decreases it. The effect of the pollution tax increase on the producer price depends on the pollution intensity, however: The higher the pollution intensity, the lower the producer price for a given environmental tax rate. The optimal producer price remains the same from the government's perspective when the tariff rate decreases exogenously. For this reason, the environmental tax rate moves in the same direction, but the necessary change is lower the higher the pollution intensity coefficient. The pollution level remains constant, since the producer price and thus output do not change. Consumer surplus, however, increases since the the consumer price falls.

Corollary 1. *Assume federal district-specific pollution taxes. The level of pollution emissions is independent of the tariff rate. Trade liberalization reduces pollution tax revenue, while social welfare increases. A sufficient condition for trade liberalization to induce an increase in majority district welfare is a weakly greater than proportional share of sector* g *demand coming from the population in majority districts.*

Proof. To see that pollution emissions are constant, notice that the producer price and thus production does not change: $\frac{dp_{kg}}{d\tau_g} = 1 - \theta_g \frac{dt^F_{kg}}{d\tau_g} = 0$. Together with (2.4), this implies that tax revenue declines if $d\tau_g < 0$.

The change in majority welfare W_M, given in (2.1), due to an increase in the tariff rate τ_g and taking into consideration the response of the optimal environmental tax rate, equals

$$\frac{dW_M}{d\tau_g} = -\sum_{k=1}^{K} \delta_k^M D_{kg} + \Lambda_M \sum_{k=1}^{K} D_{kg} + \Lambda_M \tau_g \sum_{k=1}^{K} D'_{kg}.$$

A sufficient condition for its negativity is $-\sum_{k=1}^{K} \delta_k^M D_{kg} + \Lambda_M \sum_{k=1}^{K} D_{kg} \leq 0$.

To see that social welfare W increases, notice that social welfare equals W_M in (2.1) if $\delta_k^M = 1$ for all k and $\Lambda_M = 1$. Calculating the derivative of W with respect to τ_g yields $\frac{dW}{d\tau_g} = \tau_g \sum_{k=1}^{K} D'_{kg} < 0$. Hence trade liberalization ($d\tau_g < 0$) increases social welfare. □

Summarizing, all industries experience environmental tax decreases when trade is liberalized, but the change is smaller for more pollution-intensive industries, provided the tariff levels fall by the same absolute amount in all industries. In the elasticity formulation, we further see that the percentage change in the tax rate caused by a one-percent decrease in the tariff rate depends on whether a district is a majority district.

Corollary 2. *Majority bias causes the relative size of the trade liberalization effect on district-specific pollution taxes to be greater in majority than in minority districts.*

Proof. Proposition 1 shows that majority districts have, ceteris paribus, smaller pollution tax rates. Hence the percentage change of a positive pollution tax rate due to a one-percent tariff rate reduction is larger in majority districts. □

2.3. **District-Uniform Federal Pollution Tax.** The FOC of maximizing (2.1) w.r.t. a federal district-uniform pollution tax t_g^F is

$$-\theta_g \sum_{k=1}^{K} X_{kg} \delta_k^M + \Lambda_M \theta_g \sum_{k=1}^{K} X_{kg} - \Lambda_M \theta_g^2 t_g^F \sum_{k=1}^{K} X'_{kg} + \Lambda_M \theta_g \tau_g \sum_{k=1}^{K} X'_{kg}$$
$$+ \theta_g^2 \sum_{k=1}^{K} X'_{kg} \sum_{j=1}^{K} \delta_j^M \gamma_{kgj} = 0. \quad (2.5)$$

In contrast to (2.2), the federal district-uniform pollution tax affects the production in all districts, as is apparent from the summation over k in (2.5). Next, let us simplify notation by defining $X_g \equiv \sum_{k=1}^{K} X_{kg}$, $X_g^M \equiv \sum_{k=1}^{K} X_{kg}\delta_k^M$, and $X'_g \equiv \sum_{k=1}^{K} X'_{kg}$.

Proposition 3. *The federal district-uniform pollution tax equals*

$$t_g^F = -\overbrace{\frac{X_g^M}{\Lambda_M \theta_g X'_g}}^{A} + \overbrace{\frac{X_g}{\theta_g X'_g}}^{B} + \overbrace{\frac{\tau_g}{\theta_g}}^{C} + \overbrace{\frac{\sum_{j=1}^{K} \delta_j^M \gamma_{kgj}}{\Lambda_M}}^{D}. \tag{2.6}$$

Proof. Solve (2.5) for t_g^F. □

Apart from the fact that the total g production quantity and its derivative appear in (2.6) rather than the corresponding district k quantities, the formula for t_g^F is identical to the formula for t_{kg}^F given in (2.3).

Proposition 4. *The derivative of t_g^F w.r.t. τ_g equals*

$$\frac{dt_g^F}{d\tau_g} = \frac{1}{\theta_g} > 0. \tag{2.7}$$

Calculating the impact of a tariff change as an elasticity yields $\epsilon_{t_g,\tau_g}^F = \frac{dt_g^F}{d\tau_g}\frac{\tau_g}{t_g^F} = \frac{\tau_g}{\theta_g t_g^F}$, where t_g^F is given by (2.6).

Proof. Differentiate (2.5) w.r.t τ_g and t_g^F and calculate $\frac{dt_g^F}{d\tau_g}$ as the negative ratio of the two partial derivatives. □

Corollary 3. *Assume a federally set uniform pollution tax. The level of pollution emissions is independent of the tariff rate. Trade liberalization decreases pollution tax revenue, while social welfare increases. A sufficient condition for trade liberalization to induce an increase in majority district welfare is a weakly greater than proportional share of sector g demand coming from the population in majority districts.*

Proof. Similar to the proof of Corollary 1. □

The absolute effect of a change in τ_g is thus the same for both kinds of federal pollution tax. The elasticity representation shows that since the uniform tax rate cannot differ by district, the percentage change in the tax rate caused by a one-percent decrease in the tariff rate must be uniform across districts as well, contrary to the case with district-specific taxes where majority districts experienced greater percentage changes in the pollution tax rate. Two forms of majority bias remain under federal district-uniform taxation. Pollution taxes will differ depending on the location of polluting industries (a higher concentration of production in majority districts leading to lower pollution tax rates in these sectors) and the distribution of pollution damage incidence between majority and minority districts (a higher concentration of pollution damage in majority districts leading to higher pollution tax rates in sectors causing this damage).

2.4. **District-Specific Decentralized Pollution Tax.** District k's welfare equals

$$\begin{aligned} W_k = \overbrace{\sum_{g=1}^{G} \pi_{kg}(p_{kg})}^{A} + \overbrace{\sum_{g=1}^{G} t_{kg}\theta_g X_{kg}(p_{kg})}^{B} + \overbrace{\lambda_k \sum_{g=1}^{G} \tau_g \sum_{j=1}^{K} \{D_{jg}(\tau_g) - X_{jg}(p_{jg})\}}^{C} \\ \underbrace{- \sum_{j=1}^{K}\sum_{g=1}^{G} X_{jg}(p_{jg})\theta_g \gamma_{jgk}}_{D} + \underbrace{\sum_{g=1}^{G} C_{kg}(\tau_g)}_{E}, \quad (2.8) \end{aligned}$$

where λ_k denotes district k's population share. We assume that the total tariff revenue is distributed across districts according to their respective population share. Compared to majority welfare in (2.1), two differences are noteworthy. First, we assume that the authority over tax revenue lies with the tax-setting entity, i.e., district k receives all pollution tax revenue accruing in it (term B). In contrast, when calculating majority welfare, the tax authority was assumed to lie with the federation, and the majority districts received only a share of total tax income. Second, the majority cared about all cross-border pollution affecting majority districts, whereas the district only cares about pollution affecting itself (term D). Consequently, the tax does not internalize any cross-border pollution externalities. The FOC for maximizing (2.8) is

$$\theta_g(\lambda_k\tau_g - t_{kg}^D\theta_g)X'_{kg} + \theta_g^2\gamma_{kgk}X'_{kg} = 0. \tag{2.9}$$

Proposition 5. *The district-set pollution tax is*

$$t_{kg}^D = \overbrace{\frac{\lambda_k\tau_g}{\theta_g}}^{C} + \overbrace{\gamma_{kgk}}^{D}. \tag{2.10}$$

Proof. Solve (2.9) for t_{kg}^D. □

The district-set pollution tax is simpler in structure than the federal district-specific tax t_{kg}^F in (2.3), and a comparison is instructive to understand why. If the district receives all tax revenue created within its boundaries, the negative profit effect A and the positive tax revenue effect B present in (2.3) cancel each other. The tariff revenue effect C is still present, but smaller in size in (2.10) because of the difference in revenue distribution: The pollution tax in the decentralized case goes entirely to the district, whereas only a fraction λ_k of tariff revenue goes to the district. In contrast, in the federal case the majority districts received a fraction Λ^M of both revenues. The pollution damage effect D differs in size because the federal government internalizes all majority districts' pollution externalities, whereas the district itself only worries about pollution damage within its own boundaries.

Proposition 6. *A decrease in the tariff rate τ_g lowers the decentralized pollution tax:*

$$\frac{dt_{kg}^D}{d\tau_g} = \frac{\lambda_k}{\theta_g} > 0. \tag{2.11}$$

Formulating the impact of a tariff change as an elasticity, we find $\epsilon^D_{t_{kg},\tau_g} = \frac{dt_{kg}^D}{d\tau_g}\frac{\tau_g}{t_{kg}^D} = \frac{\lambda_k\tau_g}{\lambda_k\tau_g+\gamma_{kgk}\theta_g}$, where t_{kg}^D is given by (2.10).

Proof. Directly differentiate t^D_{kg} in (2.10) w.r.t. τ_g. □

In the elasticity representation, we see that the percentage impact of a one-percent tariff change is increasing in the population share of the district and the tariff rate. The size of the effect is decreasing in the pollution exposure in the district itself and in the pollution intensity coefficient.

Corollary 4. *Trade liberalization has a smaller effect (in absolute value) on the level of decentralized than on the level of federally-set pollution taxes. Pollution emissions and the pollution tax revenue decline, whereas social welfare increases if trade is liberalized. A sufficient condition for district k welfare to increase as a result of trade liberalization is that sector g in district k is weakly importing (i.e. $D_{kg} - X_{kg} \geq 0$) and that the price elasticity of demand (in absolute value) weakly exceeds 1.*

Proof. Since $\lambda_k < 1$, (2.11) is smaller in absolute value than (2.4) and (2.7).

The derivative of national pollution damage with respect to τ_g can be calculated as $\sum_{k=1}^{K} X'_{kg}(1-\lambda_k)\theta_g \sum_{j=1}^{K} \gamma_{kgj} > 0$. This means trade liberalization causes pollution to decline because production X_{kg} shrinks in all districts if $d\tau_g < 0$, i.e., $\frac{dX_{kg}}{d\tau_g} = (1-\lambda_k)X'_{kg} > 0$. Together with the fact that the environmental tax rates decline as well, this means that the environmental tax revenue will shrink in all districts.

The derivative of social welfare W with respect to τ_g, after taking the effect on the optimal environmental tax rates t^D_{kg} into consideration, equals

$$\frac{dW}{d\tau_g} = \tau_g \sum_{k=1}^{K} D'_{kg} + \sum_{k=1}^{K} X'_{kg}(1-\lambda_k)[t^D_{kg}\theta_g - \tau_g - \theta_g \sum_{j=1}^{K} \gamma_{kgj}],$$

or, after substituting for t^D_{kg} from (2.10),

$$\frac{dW}{d\tau_g} = \tau_g \sum_{k=1}^{K} D'_{kg} + \sum_{k=1}^{K} X'_{kg}(1-\lambda_k)[(\lambda_k - 1)\tau_g - \theta_g \sum_{j=1, j\neq k}^{K} \gamma_{kgj}] < 0,$$

i.e., trade liberalization increases social welfare.

The derivative of district k welfare, assuming that the tariff rate change induces environmental tax changes in all districts, equals

$$\frac{dW_k}{d\tau_g} = X_{kg} - D_{kg} - \lambda_k \tau_g \sum_{j \neq k} (1-\lambda_j) X'_{jg} - \theta_g \sum_{j \neq k} \gamma_{jgk} (1-\lambda_j) X'_{jg} - \lambda_k \sum_j X_{jg} + \lambda_k (\sum_j D_{jg} + \tau_g \sum_j D'_{jg}). \quad (2.12)$$

It is strictly negative if (but not only if) $D_{kg} - X_{kg} \geq 0$ and $\sum_j D_{jg} + \tau_g \sum_j D'_{jg} \leq 0$. □

Regardless of whether environmental taxes are set at the federal or district level, trade liberalization triggers a decrease in the environmental tax rates. In both cases, the effect is smaller the higher the pollution intensity of an industry. However, when taxes are set decentrally, the change in the environmental tax is smaller the lower the population share of the district. The tariff decrease also reduces the producer price and pollution, a lower population share implying a higher reduction. In the extreme case, when the population share tends to zero, the decrease in the environmental tax rate triggered by a tariff reduction approaches zero as well, and the pollution-reduction effect of trade liberalization is maximal.

The difference in the pollution tax response to trade liberalization between decentralized and centralized taxation arises because in the case of decentralized pollution taxation, the tax revenue goes exclusively to the district, whereas the district only receives a small share of the tariff revenue. The revenue of both the centralized pollution tax and the import tariff, however, are collected at the federal level and then distributed across districts according to population. The allocation of revenue from the pollution tax and import tariff is symmetric for majority districts in this case, contrary to the case when pollution taxation is decentralized and the pollution tax revenue effect is stronger. In the centralized case, the change in the import tariff is thus completely offset by a counteracting pollution tax change in equilibrium, whereas in the decentralized case, the pollution tax changes less, resulting in a producer price and pollution reduction.

3. Conclusion

In this paper, we have considered a model in which a small country liberalizes its trade policy. The trade policy change is modeled as exogenous, likely the result of a WTO negotiation round which forces the country to lower its import tariff. In contrast, the pollution tax is endogenous and is set either at the federal level or decentralized at the district level. We ask how a tariff cut affects the politically optimal pollution tax, social welfare, and the local pollution level and pollution tax revenue in the country.

We show that the optimal pollution tax reacts differently to trade policy changes depending on the way pollution tax rates are determined. If the pollution tax is decided at the federal level, a tariff decrease reduces the pollution tax such that the producer price and pollution level remain constant, whereas the pollution tax revenue falls. Social welfare, driven mainly by a consumer price reduction, increases. On the other hand, if the pollution tax is decentralized and set by districts, a decrease in the tariff level reduces the pollution tax as well. However, the producer price, pollution emissions and the pollution tax revenue fall as a result of trade liberalization. Social welfare rises.

Majority bias (indirectly) affects trade liberalization under both types of federal pollution tax design: the tariff elasticity of the pollution tax is greater in majority districts when the majority party in (federal) government sets taxes that favor its home districts. Under either form of federal taxation, the tariff elasticity is also higher in sectors heavily concentrated in majority districts, and in sectors causing pollution damage mostly in minority districts. No majority bias arises under decentralized pollution taxation.

Our results also provide some answer to the question whether trade agreements should include environmental regulations (see, e.g., Ederington (2010)). While our model results do not predict an increase in pollution due to trade liberalization, it is notable that the environmental policy becomes less stringent as a result of trade liberalization. Hence, if one wants to rule out this effect, an addendum to trade liberalization agreements concerning the stringency of environmental policy could be considered, in particular if the country under consideration decides on environmental taxes at the federal level. Our findings suggest that future empirical work that seeks to endogenize environmental policy may want to take into account at which governmental level policy is set.

Appendix A. Proofs

Proof of Proposition 2:

Starting point is the FOC of welfare maximization eq. (2.2) from which we want to calculate

$$\frac{dt^F_{kg}}{d\tau_g} = -\frac{\frac{\partial FOC}{\partial \tau_g}}{\frac{\partial FOC}{\partial t^F_{kg}}}.$$

Here,

$$\frac{\partial FOC}{\partial \tau_g} = -\theta_g \delta^M_k X'_{kg} + \theta_g \Lambda_M X'_{kg} - \theta^2_g t^F_{kg} \Lambda_M X''_{kg} + \theta_g \Lambda_M X'_{kg} + \theta_g \Lambda_M \tau_g X''_{kg} + \theta^2_g X''_{kg} \sum_{j=1}^{K} \delta^M_j \gamma_{kgj}$$

or simplified $\theta_g[(2\Lambda_M - \delta^M_k)X'_{kg} + \theta_g[(\frac{\tau_g}{\theta_g} - t^F_{kg})\Lambda_M + \sum_{j=1}^{K} \delta^M_j \gamma_{kgj}]X''_{kg}]$.

Similarly,

$$\frac{\partial FOC}{\partial t^F_{kg}} = \theta^2_g \delta^M_k X'_{kg} - \theta^2_g \Lambda_M X'_{kg} + \theta^3_g t^F_{kg} \Lambda_M X''_{kg} - \theta^2_g \Lambda_M X'_{kg} - \theta^2_g \Lambda_M \tau_g X''_{kg} - \theta^3_g X''_{kg} \sum_{j=1}^{K} \delta^M_j \gamma_{kgj}$$

or simplified $-\theta^2_g[(2\Lambda_M - \delta^M_k)X'_{kg} + \theta_g[(\frac{\tau_g}{\theta_g} - t^F_{kg})\Lambda_M + \sum_{j=1}^{K} \delta^M_j \gamma_{kgj}]X''_{kg}]$.

We thus find eq. (2.4)

$$\frac{dt^F_{kg}}{d\tau_g} = -\frac{\frac{\partial FOC}{\partial \tau_g}}{\frac{\partial FOC}{\partial t^F_{kg}}} = \frac{1}{\theta_g},$$

having taken into account that X_{kg} depends on the pollution tax and the import tariff.

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