Democracy, inequality and the environment when citizens can mitigate health consequences of pollution privately or act collectively [1]

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Abstract

Democracy, inequality and the environment when citizens can mitigate health consequences of pollution privately or act collectively

We study the political economy of the environment in autocratic, weak and strong democracies when individuals can mitigate the health consequences of domestic pollution privately at a cost as well as control pollution collectively through public policies. The economic setting is that of a small open economy which comparative advantage in the production of dirty goods. When private mitigation is feasible, income inequality leads to an unequal distribution of the burdens of pollution (in accordance with the evidence), polarizing the interests of citizens over environmental regulation and trade openness. We show that the eco-friendliness ranking of political regime types varies with the cost of private mitigation and that increased inequality has non-monotonous effects on equilibrium pollution levels. We also find that in weak democracies, the political equilibrium may be characterized by low environmental regulation and highly restricted trade, thus leading to ambiguous outcomes regarding pollution levels.

Keywords: domestic pollution, environmental regulation, private mitigation, trade, income inequality, strong and weak democracy

JEL classification: C7, D7, F18, Q56

1 Introduction

It is well documented that that poorer individuals tend to suffer more from the adverse effects of domestic pollution.[1] This fact indicates that although private measures to mitigate the consequences for health of pollution do exist, including bottled water, filtration, air purifiers, medicines and house location among other methods, their cost prevents universal adoption.

While private mitigation of the consequences of pollution has been examined to some extent in an economic context,[2] its role has been largely neglected in the political economy literature.[3] In this paper, we explore the nature of environmental regulation in autocratic, weak and strong democracies when individuals may mitigate the health consequences of domestic pollution privately, as well as act collectively via public policy actions of different kinds. The economic setting is that of a small open economy in which domestic incomes depend importantly on the export of dirty goods. Many countries are small and open and in these cases we agree with others that the determination of environmental regulation is bound up with the choice of trade openness.[4]

The recognition that the health consequences of local pollution can be dealt with privately at a cost as a substitute for collective action adds an important dimension to the analysis of the political economy of the environment and yet, it has received little attention. To our knowledge, Hotte and Winer (2012) is the only existing paper that proposes a full-fledge model. It argues that when private mitigation of the consequences of pollution is feasible, income inequality leads to an unequal distribution of the burden of pollution in accordance with the evidence, thus polarizing the interests of citizens.[5] With the use of a Ricardian model of trade with full specialization, they show that free trade may further polarize interests concerning environmental regulation. Many issues, however, remain to be explored in this context.

Here we extend the analysis by introducing the following additional refinements and their interactions: we consider (i) a wider range of political regime types differentiated by the manner in which political influence is exerted by groups of different income levels; (ii) a trade tariff with partial specialization to be interacted with environmental regulation as an

[1] See Ash and Fetter (2004), Pearce et al. (2006), Brooks and Sethi (1997), Neidell (2004), Jayachandran (2008) and Evans and Smith (2005) and the reviews of Brunekreef and Holgate (2002) and O'neill et al. (2003).

[2] See, for instance, Coase (1960), Shibata and Winrich (1983), McKitrick and Collinge (2002), Neidell (2009), Hanna (2007), and Rosado (2006).

[3] Banzhaf and Walsh (2008) show that people move to improve environmental quality, which can be considered an earlier step in the context of the Tiebout class of political economy models. Also, although the work of Aidt et al. (2010) showing that British municipalities in the 1870s with a limited voting franchise invested more in sanitation control than did municipalities with a more extensive voting franchise, is not explained with reference to the cost of private mitigation, it could be interpreted in those terms.

[4] See, for example, Pethig (1976), Hillman and Ursprung (1992), Copeland and Taylor (1994), Chichilnisky (1994), Schleich (1999), Schulze and Ursprung (2001), Copeland and Taylor (2003), McAusland (2003) and Damania et al. (2004). None of these studies considers the role of private mitigation.

[5] Eriksson and Persson (2003) rely on the fact that higher income individuals may be less affected by pollution but the choice of defensive actions and trade openness are not part of their analysis.

additional policy instrument; (iii) changes in the distribution of incomes. The important role played by such factors in explaining the provision of various public goods has recently been highlighted by this journal. For instance, in their analysis of country-level decisions to limit emissions of greenhouse gases - a global public good - Buob and Stephan (2011) underscore the important role played by measures to attenuate the effects of global warming at the country level. Justesen (2012), in an analysis of the supply of public policies relating to the treatment of HIV/AIDS, argues that one should not only differentiate between autocratic and democratic governments, but also between types of democratic regimes. And finally, Markussen (2011) shows that income inequality has ambiguous effects on the provision of public goods. Here, those factors are considered simultaneously to yield new insights.

Three types of regimes are compared. The first is an autocratic one where only a rich elite determines what actions the government undertakes. In the second regime, referred to as strongly democratic, the selection of a policy combination responds to political voice exercised by all citizens but with varying influence. The third, which we refer to as weak democracy, is a regime where the elite fully controls one policy dimension, while elected governments have power only with respect to the other; we consider a case where the elite sets environmental regulation while the trade tariff is left to the government.

Comparative analysis highlights the roles of the cost of private mitigation and of income inequality in shaping the nature of political equilibria. When the cost of private mitigation is high, autocracies and strong democracies adopt the same set of policies, despite the fact that the rich elites bear a larger share of the resulting drop in national income. This stands in contrast to Congleton (1992) who pioneered the study of the relationship between regime type and environmental control, and who argues that rich elites in autocratic regimes prefer less regulation.[6] At intermediate cost levels - that is, when only the rich can afford private mitigation - an increase in the influence of lower income citizens in strong democracies leads to the adoption of stricter environmental controls. However, in this intermediate case we also show that the multi-dimensionality of the policy space in elections leads to indeterminacies regarding environmental outcomes when comparing weak and strong democracies. (More about this below). And when the cost of private mitigation is low, so that everyone can protect themselves privately to some extent, we show that a fully democratic regime may adopt laxer environmental policies than an autocratic one because once protected, the willingness to pay of poorer citizens for a cleaner environment is reduced.

In the course of the comparative analysis, we see that higher individual incomes (e.g., in rich democracies) are not always associated with greater demands for a cleaner environment in an equilibrium, the usual normal good prediction, a result that concurs with micro-based evidence provided by Kahn and Matsusaka (1997) and Kristrom and Riera (1996) showing that demands for environmental regulation can be lower among higher-income individuals

[6]Congleton's framework does not explicitly allow for private mitigation. Other political economy work that does not consider private mitigation, and which as a whole points to a complex relationship between political institutions and the environment includes Murdoch et al. (1997), Fredriksson et al. (2005), Farzin and Bond (2006), Dasgupta et al. (2006) and Fredriksson and Wollscheid (2007).

in some communities.[7] In this respect, it is important to keep in mind that demand for a cleaner environment is not the same as a demand for better health, and there tends to be a disconnect between the two when private mitigation technologies are available.

Concerning income inequality, we identify conditions under which greater inequality leads to a reordering of regime types in terms of their equilibrium pollution levels. When rich and poor choose to mitigate equally, as is more likely to occur when income inequality is low, the rich prefer relatively more pollution control: we then see that an autocracy can lead to lower pollution levels than in a strong democracy. But when private mitigation is a luxury that only the rich can afford, in societies with high income inequality, then the rich prefer higher pollution levels than do the poor. Autocracy in this case leads to more pollution than does full democratic choice.

The multi-dimensionality of the policy space creates interesting ambiguities in the comparative analysis we present. Multi-dimensionality introduces the possibility of ranking the eco-friendliness of regimes either by the stringency of direct environmental regulation, or by control of specialization in the production of dirty goods. The nice study by Damania et al. (2003), for instance, compares the ecological performance of various regimes by the stringency of their direct controls. But what if, as in the model explored here, a weak democracy combines weaker regulation with lower export of dirty goods?

The paper is organized as follows. In section 2, we present a small open economy with domestic pollution, environmental regulation and a trade tariff. Individual welfare functions are introduced in section 3, where we characterize the optimal choice of effort to attenuate the adverse health effects of pollution as a function of given individual incomes. In section 4, the general equilibrium effects of environmental regulation and a trade tariff are introduced into individual welfare functions, allowing for the determination of private mitigation efforts as functions of individual national income shares and the cost of private mitigation. In section 5, we introduce political regimes differentiated by a role for voice for citizens in each policy dimension, derive full political and economic equilibria for autocratic, weak and strong democracies, and study the effects of varying private mitigation costs and degree of income inequality. Section 6 concludes.

2 The economy

We suppose at the outset that goods fall into one of two categories: *clean* or *dirty*. The difference between them occurs at the production stage only. The clean good (good 1) does not generate any pollution when produced, while the dirty one (good 2) does.

2.1 Aggregate demand

Clean and dirty goods are undistinguishable when it comes to their consumption. Consumers just prefer more to less, and assign more value to a balanced basket. Hence, if we let $z \in \Re^+$

[7] Other recent empirical work indicates that the effect of average income on environmental regulation may actually turn negative once one controls for the level of democracy. See Torras and Boyce (1998), as well as Fredriksson et al., Farzin and Bond, and Dasgupta et al. cited above.

denote the *real* national income level, then this level is achieved by combining the two types of goods in quantities x_1 and x_2 as per function $F(\mathbf{x}) \geq z$, $\mathbf{x} \equiv (x_1, x_2)$, which is strictly increasing, strictly quasi-concave and continuous. If $\mathbf{p} \equiv (p_1, p_2)$ is the domestic price vector of 1 and 2, then the total cost of z can be represented by the following cost minimization function:

$$e(\mathbf{p}, z) \equiv \min_{\mathbf{x}} \{\mathbf{px} \mid z \leq F(\mathbf{x})\}. \tag{1}$$

$e(\mathbf{p}, z)$ has the usual properties of a cost function. By Shephard's lemma, the *conditional* demand for good i is given by $x^i(\mathbf{p}, z) = e_i(\mathbf{p}, z)$, where subscript i denotes the partial derivative with respect to the price of good i.[8] $e(\mathbf{p}, z)$ also represents the national nominal *expenditure function* at income level z.

2.2 Aggregate supply and pollution

Goods 1 and 2 can be produced either domestically or imported. Let $\mathbf{y} \equiv (y_1, y_2)$ denote their domestic production vector. Good 2 generates $q(\theta)$ units of pollution per unit produced, where θ refers to the cleanliness of the production technology being used. θ will be treated as an environmental policy instrument.[9] The ambient pollution level is thus given by

$$Q = q(\theta) y_2, \text{ with } q(\theta) > 0 \text{ and } q'(\theta) < 0. \tag{2}$$

Cleaner production is however costly in terms of reduced product in sector 2 as represented by the following output function:

$$y_2 = (1 - \theta) f^2(\mathbf{v}_2), \tag{3}$$

where $\mathbf{v}_2$ denotes an input vector and f^2 is the output function for good 2 *in the absence of* efforts to control emissions.

The technology and production resources available in the economy are summarized by the strictly convex *production possibility set* $G(\mathbf{y}, \theta) \leq 0$. The *gross domestic product* (GDP) function at domestic prices is thus defined as

$$g(\mathbf{p}, \theta) \equiv \max_{\mathbf{y}} \{\mathbf{py} \mid G(\mathbf{y}, \theta) \leq 0\}. \tag{4}$$

$g(\mathbf{p}, \theta)$ has the usual properties of a profit function. By Hotelling's lemma, we have $y^i(\mathbf{p}, \theta) = g_i(\mathbf{p}, \theta)$.

[8] When there is no possibility of confusion, the subscript of a function denotes a partial derivatives.

[9] Note that we consider quantitative standards as the environmental policy instrument. Those are quite widely used in practice (Heyes and Kapur (2011)).

2.3 The general economic equilibrium

For a small open economy, let $\mathbf{p} = (p_1^* + \tau, p_2^*)$, where p_i^* is the world price of good i and τ is a tariff per unit of good 1 imported.[10] Imports of good 1 are given by $x^1(\mathbf{p}, z) - y^1(\mathbf{p}, \theta)$.

The economy's total earnings – or, equivalently, national nominal income I – are equal to GDP plus tariff revenues; that is, $I = GDP + \tau(x_1 - y_1)$. With balanced trade and government budget, the economy's general equilibrium is fully determined by the following expression:

$$e(\mathbf{p}, z) = g(\mathbf{p}, \theta) + \tau(x^1(\mathbf{p}, z) - y^1(\mathbf{p}, \theta)). \tag{5}$$

For fixed θ and τ, z is the sole endogenous variable in expression (5); we can thus write $z = z(\theta, \tau)$ and $Q = Q(\theta, \tau)$.

2.4 The general equilibrium effects of public policies

The production of good 2 generates pollution, and so trade exacerbates the pollution problem when, as we shall assume, the country's comparative advantage lies with the production of good 2. In this context, the government can intervene with two policy instruments: it can directly regulate the cleanliness of the production technology – summarized by parameter θ – or it can alter the degree of trade openness – summarized by parameter τ – in order to attenuate the trade-induced specialisation into dirty good 2.

In Appendix A, we derive the precise expressions corresponding to the general equilibrium effects of each policy instruments (see expressions (27) to (30)). As expected, we find that each policy instrument is costly in terms of real national income while providing welfare benefits in terms of lower pollution levels, i.e.,

$$z_\theta(\theta, \tau) < 0 \text{ and } z_\tau(\theta, \tau) < 0, \tag{6}$$

$$Q_\theta(\theta, \tau) < 0 \text{ and } Q_\tau(\theta, \tau) < 0. \tag{7}$$

3 Individual welfare and private mitigation efforts

Individual welfare functions are now introduced, and the optimal choice of effort to attenuate the adverse health effects of pollution is determined as a function of given individual incomes. *A priori*, individuals differ solely by the share of the national income that they receive, denoted s.[11] We shall refer to each individual type by his or her income share s.

[10] Since most trade policy models begin by providing a detailed analysis of the effects of an import tariff, it is conceptually more convenient to summarize the trade policy by an import tariff on the clean good. One should simply keep in mind that according to the "Lerner symmetry proposition", an import tariff on the clean good has the same effect as an export tax on the dirty good (Corden, 1984).

[11] Parameter s subsumes the various determinants of income such as innate skills, education, or even ability to appropriate existing resources. We do not allow for side payments.

Following Mayer (1984), we simplify by assuming that tariff revenues are redistributed neutrally with respect to pre-tax income parameter s. Since z is the only real wealth being created, this implies that individual s gets to spend sz.[12]

The well-being of individual s depends directly on (pure) consumption c_s and on a health condition h_s. The health condition depends negatively on the ambient pollution level Q, but this effect can be individually attenuated with pollution-mitigation effort d_s.[13] The following function summarizes individual welfare levels:

$$U_s = u(c_s) + h(d_s, Q). \tag{8}$$

Function u is strictly increasing, strictly concave and continuous. Function h has the following binary properties:

$$h(d, Q) = \begin{cases} h_0 - \bar{\ell}(Q) & \text{if } d < \underline{d}, \\ h_0 - \underline{\ell}(Q) & \text{otherwise.} \end{cases} \tag{9}$$

Parameter h_0 represents the health condition in the absence of pollution (the best possible health). Functions $\underline{\ell}$ and $\bar{\ell}$ correspond to a health deterioration due to pollution, respectively with and without private mitigation, with $\bar{\ell}(Q) > \underline{\ell}(Q)$, $\bar{\ell}'(Q) > 0$, $\underline{\ell}'(Q) > 0$ and $\bar{\ell}''(Q) > 0$, $\underline{\ell}''(Q) > 0$. The health gain from mitigation effort $\underline{d}$ is thus expressed as follows:

$$\Delta(Q) \equiv \bar{\ell}(Q) - \underline{\ell}(Q) > 0. \tag{10}$$

It is assumed that this health gain increases with the pollution level; that is, $\Delta'(Q) > 0$. This implies that the health benefit from a reduction in pollution is lower for those who invest in private mitigation so that $\bar{\ell}'(Q) > \underline{\ell}'(Q)$.

Note that according to expression (9), the private mitigation technology is summarized by parameter $\underline{d}$ – a measure of the cost of private mitigation – and function $\Delta(Q)$ – a measure of its effectiveness. Naturally, one encounters mention of many different specific forms of private mitigation measures within the empirical literature.[14] Although a full account would be too lengthy, let us simply mention for the purpose of this paper that specific measures depend largely on the pollutant type (e.g. sulfur dioxide, ground-level ozone, carbon monoxide, particulate matter, lead, microorganisms, noise, etc) and its medium (e.g. air, water, soil, dump site, etc). Universal private measures include moving away from the polluting source, more frequent visits to the doctor or the use of medicines. In the case of air pollution, specific measures include the installation of air purifiers or time spent indoors. For water

[12]See Cremer et al. (2004) and Aidt (2010) on the use of environmental taxes in order to redistribute income.

[13]In the literature, private pollution-mitigation efforts are also referred to as *defensive expenditures* and *averting efforts*. For more detailed analyzes of its implications for consumer behavior, see Courant and Porter (1981), Shibata and Winrich (1983), Bartik (1988) and McKitrick and Collinge (2002).

[14]Examples in this paragraph are drawn from empirical work on the value of environmental quality improvements which highlights the important role played by private mitigation measures such as Alberini et al. (1996), Alberini et al. (1997), Bresnahan et al. (1997), McConnell and Rosado (1997), Neidell (2009), Graff Zivin et al. (2011), Moretti and Neidell (2011), Dechênes et al. (2012).

pollution, measures include filters, boiling water, bottled water or a new well. The effects of noise pollution are mitigated with the installation of better windows or thicker walls.

Given that the form of private mitigation measures vary by type of pollutant, so will their cost and effectiveness; the analysis in section 5 will therefore explore the consequences of a menu of possibilities, from low cost to high cost technologies in terms of parameter value $\underline{d}$, and demonstrate its importance for the political-economy of environmental policy. We shall also compare with the case of prohibitively costly technologies for which there is no practical means to privately mitigate the health effects of pollution; our conjecture is that lead in gasoline and paint, depletion of the ozone layer and a nuclear fallout fall into that category.

Note that the choice of private mitigation is really binary: one either chooses effort level $\underline{d}$ or none at all. This dichotomous property of the health-mitigation function (9) simplifies the analysis while being consistent with many situations.[15]

Real income can be used for either pure consumption or pollution mitigation. The following budget constraint must therefore be respected: $c_s + d_s = sz$. The individual welfare maximizing problem is expressed as:

$$\max_{c_s,d_s} U_s = u(c_s) + h(d_s, Q), \tag{11}$$

$$\text{s.t. } c_s + d_s = sz. \tag{12}$$

For given z and Q, individual s therefore chooses $d_s^* = \underline{d}$ if, and only if, $u(sz - \underline{d}) - \underline{\ell}(Q) \geq u(sz) - \bar{\ell}(Q)$ or, equivalently,

$$\Delta(Q) \geq u(sz) - u(sz - \underline{d}). \tag{13}$$

This inequality states that an individual will spend on private mitigation as long as the drop in consumption utility does not exceed the gain in health condition. Defining $\tilde{s}$ as the individual who is indifferent between spending on private mitigation or not, we have

$$\Delta(Q) = u(\tilde{s}z) - u(\tilde{s}z - \underline{d}). \tag{14}$$

Equations (13) and (14) lead to several important properties of the demand for mitigation effort.

First, with $u_{cc} < 0$, the right-hand side of (13) is decreasing in s. Consequently, we have that $d_s^* = 0$ if $s < \tilde{s}$ and $d_s^* = \underline{d}$ otherwise. Second, with decreasing marginal utility of consumption, the welfare loss from spending a fixed amount $\underline{d}$ decreases with income. Given that the health gain is the same regardless of income, we then have the following lemma:

Lemma 1 *Private-mitigation effort is (weakly) increasing in individual income shares.*

[15] Various authors point out that mitigation measures are either binary or discrete, e.g. McConnell and Rosado (2000), Bartik (1988) and Alberini et al. (1997). Chapter 3 of Bernard (2010) considers a continuous version.

Now in the *absence of private mitigation*, a decreasing marginal utility of consumption makes environmental quality a normal good, as is typically assumed in the literature on trade and the environment. This is true, in fact, for any *fixed* private-mitigation effort. Let us define the *marginal willingness to pay* for environmental improvements (MWTP) as the reduction in individual income sz that leaves one indifferent to a unit marginal reduction in the pollution level Q. We have a second lemma:[16]

Lemma 2 *For given d_s, the MWTP increases with income share s.*

It is also important to point out that the presence of private mitigation blurs the monotonic relationship between income and the demand for environmental quality:

Proposition 3 *For a range of income shares directly above $\tilde{s}$, the MWTP is lower than from a range of income shares directly below $\tilde{s}$.*

4 Public policy and individual welfare in an economic equilibrium

In this section, we first derive an expression for the effects of public policies on individual welfare. We then illustrate how the demand for environmental regulation - for fixed trade tariff - is affected by the possibility of private mitigation and compare the cases of individuals with differing income shares. We then introduce the possibility of combining both environmental and trade policies and derive the individual demand for both policies when private mitigation is possible. Analysis of political equilibria comes in section 5.

4.1 Public policy and individual welfare

Let Ω generically represent a single policy instrument. Then the individual welfare effect of a marginal change in a policy instrument - either environmental regulation or trade openness - is given by

$$\frac{\partial U_s^*}{\partial \Omega} = [u_c(c_s^*)s]z_\Omega - [\ell'(Q)]Q_\Omega, \text{ where } \Omega \in \{\theta, \tau\}. \tag{15}$$

recall that z_Ω and Q_Ω are the economy-wide costs and benefits of each policy mentioned in (6) and (7). The terms between square brackets correspond to the respective weights that each individual assigns to these economy-wide effects.

Expression (15) has a convenient economic interpretation in terms of marginal willingness to pay for environmental improvements expressed in *units of real national income z*, denoted ω_s.[17] It is given by

$$\omega_s \equiv \frac{\ell'(Q)}{u_c(c_s^*)s}, \tag{16}$$

[16] Proofs of propositions and lemmas appear in Appendix B.

[17] This contrasts with the MWTP introduced in proposition 2 which is expressed in units of individual income.

while the national income cost of that unit reduction in pollution, using instrument Ω, is given by z_Ω/Q_Ω. Consequently, individual s gains from a marginal increase in Ω if

$$\omega_s > \frac{z_\Omega}{Q_\Omega}, \tag{17}$$

which does hold if the derivative in (15) is positive.

Since z_Ω/Q_Ω is independent of an individual's type, differences in interest stem from differences in the marginal willingness to pay ω_s. Through straightforward algebra, it can be verified that for $d = 0$, ω_s decreases with s if, and only if, $\sigma \equiv -u_{cc}c/u_c < 1$. This is because an individual with higher s faces the following tradeoff: on the one hand, he or she incurs a higher cost of regulation in absolute value; on the other hand, their marginal utility of income is lower.[18] If $\sigma < 1$, the cost effect prevails and the marginal willingness to pay decreases with income share. The opposite holds if $\sigma > 1$.

Since this trade-off has been noted and studied elsewhere in the literature (McAusland 2003), while our purpose is to point out the role of private mitigation when incomes are not equal, we shall remove the ambiguity by assuming that $\sigma = 1$. The cost effect is then exactly offset by the marginal utility effect, so that in the absence of any private mitigation effort, ω_s is independent of income share. Any remaining divergence of the interests of citizens of varying incomes is then driven only by the possibility of private mitigation.

4.2 Environmental regulation and private mitigation

In order to better understand the role played by the introduction of private mitigation, we now fix the trade tariff and consider the case of two types of individuals only, i.e., with low and high income shares denoted $\underline{s}$ and $\bar{s}$ respectively. $U^0_{\bar{s}}$ and $U^0_{\underline{s}}$ represent their respective welfare levels in the absence of private mitigation spending, and given that $\sigma = 1$, both types then prefer the same regulation level, denoted θ^0.

$U^d_{\bar{s}}$ and $U^d_{\underline{s}}$ denote the respective welfare levels when both types spend $\underline{d}$ on private mitigation. We first note that with private mitigation, the preferred level of public environmental control, denoted θ^d_s, is lower than in its absence for both types. We have then:

Lemma 4 *The preferred environmental regulation level decreases with private mitigation efforts.*

It is important to point out also that for two individuals who invest in private mitigation, the preferred regulation level is not equal in the presence of mitigation efforts. In this respect, we can state the following two propositions:

Lemma 5 *For those who invest in private mitigation, the preferred regulation level increases with income share.*

[18]In a more general context, higher income individuals may also end up supporting a higher cost of regulation because they tend to own more capital goods while capital-intensive goods pollute more, as in Copeland and Taylor (2003, chapter 4) and McAusland (2003).

Lemma 6 ***A single crossing condition*** *For a given trade tariff (or degree of trade openness) τ, the regulation level at which individual s is indifferent between investing in private mitigation or not, denoted $\hat{\theta}_s$, if it exists, is unique.*

The essence of propositions 4, 5 and 6 is illustrated in figure 1 (a). We present a case where $\hat{\theta}_{\underline{s}} < \theta^d_{\underline{s}}$ and $\hat{\theta}_{\bar{s}} \in (\theta^d_{\bar{s}}, \theta^0)$. Hence, the low-income type prefers not to engage in private mitigation even if the regulation level were at $\theta^d_{\underline{s}}$ (his preferred regulation level with private mitigation). The high-income type would similarly choose not to privately mitigate at θ^0 (the preferred regulation level without private mitigation). However, in contrast to the low-income type, he would choose to privately mitigate at $\theta^d_{\bar{s}}$.

The upshot is that the possibility of private mitigation drives a wedge between the interests of the rich and the poor. Both types would prefer regulation level θ^0 if private mitigation were not an option. But with the possibility of mitigation, we have a case where the high-income type prefers overall lower regulation level $\theta^d_{\bar{s}}$ with the adoption of private mitigation, at which point the welfare of the low-income type drops compared to welfare at θ^0, a welfare reduction that occurs whether or not the low-income person decides to privately mitigate.

4.3 Environmental regulation and trade openness

We now allow for both environmental regulation and the trade tariff to vary. Figure 1(b) is an extension of 1(a) when the tariff dimension is graphed along with θ. Note that figure 1(a) is just a transversal cut of 1(b) for a fixed τ value.

In figure 1(b), functions $\theta^0(\tau)$ and $\theta^d_s(\tau)$ denote the loci of preferred regulation levels for some individual s with respect to the tariff rate τ, respectively without and with private mitigation. (Keep in mind that in the absence of private mitigation, the preferred regulation level is independent of income share. It is thus not necessary to include subscript s.) They are obtained by graphing the following equalities derived by setting the expression in (15) equal to zero:

$$u_c(sz(\theta^0,\tau))sz_\theta(\theta^0,\tau) - \bar{\ell}'(Q(\theta^0,\tau))Q_\theta(\theta^0,\tau) = 0, \text{ for } d_s = 0 \tag{18}$$

$$u_c(sz(\theta^d_s,\tau) - \underline{d})sz_\theta(\theta^d_s,\tau) - \underline{\ell}'(Q(\theta^d_s,\tau))Q_\theta(\theta^d_s,\tau) = 0, \text{ for } d_s = \underline{d}. \tag{19}$$

Through implicit differentiation, one can verify that $\theta^0(\tau)$ and $\theta^d_s(\tau)$ are downward slopping.[19] According to proposition 4, we have $\theta^d_s(\tau) < \theta^0(\tau)$. The loci of the preferred tariff rates are also illustrated as $\tau^0(\theta)$ and $\tau^d_s(\theta)$ and are similarly obtained.

In the absence of private mitigation, individual welfare reaches a (local) maximum at point A (the intersection of curves $\theta^0(\tau)$ and $\tau^0(\theta)$), provided that $U^0_s(\theta,\tau)$ is (locally) strictly concave, which we assume to be the case.[20] This implies that as θ increases, curve $\theta^0(\tau)$ crosses curve $\tau^0(\theta)$ from above and the iso-welfare contours illustrated in figure 1(b) have an ellipse-like shape as illustrated. For $d_s = 0$, welfare decreases as the regulation and

[19] We assume that the second-order condition is verified and that functions u and ℓ are sufficiently concave and convex, respectively.

[20] That is, the Hessian matrix of $U^0_s(\theta,\tau)$ is negative definite at (θ^A,τ^A).

Figure 1 (a)

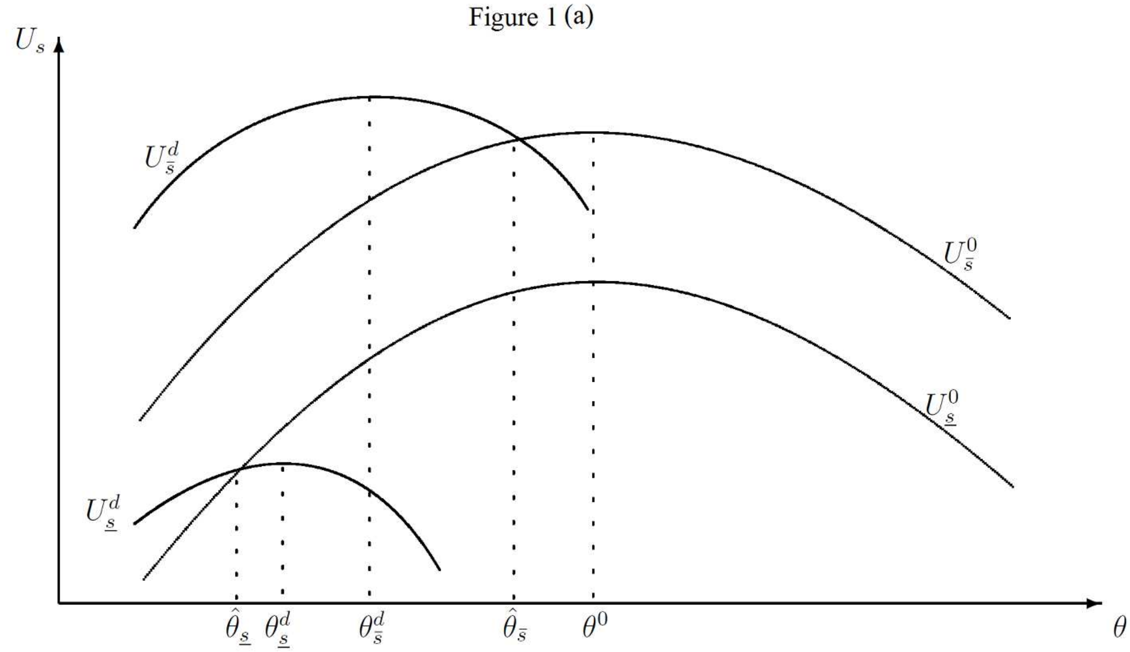

Figure 1 (b)

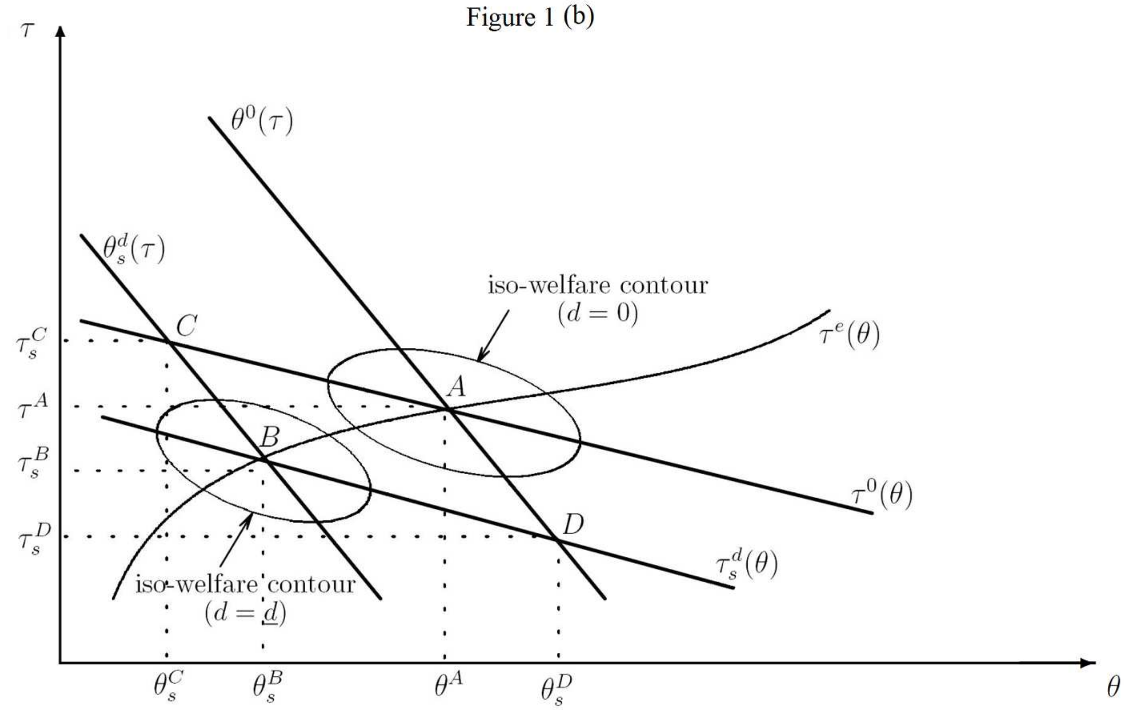

Figure 1: (a) Income shares, private mitigation and individual interests over environmental regulation for fixed τ (b) Income shares, private mitigation and individual interests for both policy instruments

tariff combination moves away from (θ^A, τ^A) in any direction. In the adoption of private mitigation, we find analogous properties around point B.[21]

Note that coordinate points A and B must fall on the efficiency curve $\tau^e(\theta)$, defined as the combinations of θ and τ values which yield a given pollution level at lowest cost in terms of real national income, i.e., curve $\tau^e(\theta)$ respects the following condition: $z_\theta/Q_\theta = z_\tau/Q_\tau$. At points A and B, the marginal willingness to pay ω_s is simultaneously equal to z_θ/Q_θ and z_τ/Q_τ. We therefore have the following proposition:

Proposition 7 *The preferred policy combination (θ_s^B, τ_s^B) is decreasing in the cost of private mitigation ($\underline{d}$) and increasing in income share (s).*

4.4 Considering environmental regulation, trade openness and private mitigation together

We are now in a position to derive an individual's overall preferred combination in economic equilibrium of all three variables that can be used to improve one's health condition: collective action using environmental regulation and trade openness, and private mitigation effort.

We shall restrict our analysis to the surface formed by $(\theta, \tau) \in ((\theta_s^C, \tau_s^D), (\theta_s^D, \tau_s^C))$, where it is assumed that $U^0(\theta, \tau)$ and $U^d(\theta, \tau)$ are both strictly concave. Coordinate points A and B therefore define two local maxima. Policy combination (θ_s^B, τ_s^B) is preferred to (θ^A, τ^A) if, and only if, the following holds:

$$u(sz(\theta^A, \tau^A)) - \bar{\ell}(Q(\theta^A, \tau^A)) < u(sz(\theta_s^B, \tau_s^B) - \underline{d}) - \underline{\ell}(Q(\theta_s^B, \tau_s^B)). \tag{20}$$

Whether condition (20) holds depends in part on the magnitude of the private mitigation cost $\underline{d}$. We have the following proposition:

Proposition 8 *Let $\underline{d}(s)$ denote the maximum value for which policy (θ_s^B, τ_s^B) is (weakly) preferred by an individual to (θ^A, τ^A). $\underline{d}(s)$ exists and is increasing in s.*

5 Endogenous policy: Political regimes compared

The preceding analysis provides the background for our comparative analysis of political regimes concerning the choices of environmental regulation and of trade openness that emerge in a political equilibrium. In conducting this analysis, we will see that the technology of private mitigation plays an important but different role in each type of regime.

To proceed further, we first need to specify more precisely what is meant by changes in mitigation technology, and then by the nature of political regimes. In what follows, points A to D referred to are illustrated in figure 1(b).

[21] To better understand figures 1(a) and 1(b), note that for any given τ, $\hat{\theta}_s$ in figure 1(a) is represented by an intersection between two equally-valued iso-welfare contours in figure 1(b).

5.1 A menu of mitigation technologies

To study the role of mitigation technology, we shall consider three types of private mitigation technologies ranked according to their cost as follows: $\underline{d}_1 < \underline{d}_2 < \underline{d}_3$, designed to take advantage of the simplification introduced earlier, that mitigation has a binary nature. For each cost $\underline{d}_i$, $i \in \{1, 2, 3\}$, there will correspond a different individually preferred policy pair which is decreasing in i and increasing in s (see proposition 7). In order to keep track of this, type s's preferred policy pair when the mitigation cost is $\underline{d}_i$ will be referred to as $(\theta_{is}^B, \tau_{is}^B)$.

We assume the different costs of private mitigation to be such that they yield one or the other of the following outcomes concerning the level of private mitigation adopted by richer and poorer individuals:[22]

Prohibitive cost $\underline{d}_3$: Private mitigation is not a practical option even at point B in figures 1(b) for both rich and for poorer citizens. That is, $U_{\bar{s}}^0(\theta^A, \tau^A) > U_{\bar{s}}^d(\theta_3^B, \tau_3^B)$.

Intermediate cost $\underline{d}_2$: In this case, the cost is such that type $\bar{s}$ chooses to spend on private mitigation at options A, C and D in figure 1(b), but type $\underline{s}$ never does. This implies that for type $\bar{s}$, $U_{\bar{s}}^d(\theta^A, \tau^A) > U_{\bar{s}}^0(\theta^A, \tau^A)$, that the preferred tariff curve is $\tau_{\bar{s}}^d(\theta)$ for $\theta \leq \theta_{\bar{s}}^D$, and the preferred regulation curve is $\theta_{\bar{s}}^d(\tau)$ for $\tau \leq \tau_{\bar{s}}^C$.

Low cost $\underline{d}_1$: Both types prefer to spend on private mitigation and have a more polluted environment; that is, $U_{\underline{s}}^0(\theta^A, \tau^A) < U_{\underline{s}}^d(\theta_{1\underline{s}}^B, \tau_{1\underline{s}}^B)$.

Note that except for the low cost case $\underline{d}_1$, we assume that for individual $\underline{s}$, private mitigation is never chosen. Besides a change in its cost $\underline{d}$, we assume no other change in the properties of the private mitigation function defined in (9).

5.2 Alternative political regimes

We now turn to detailed specification of the three types of political regimes and their associated equilibria. The analysis proceeds by specifying a set of related but distinct optimization problems that can be conveniently used to derive the associated policies and pollution level for each regime type. In this section, equilibrium policies are described for each regime considered by itself. A comparative analysis follows later. Again points A to D in figures 1(b) are used to illustrate our arguments. As in section 4, the analysis is simplified by restricting attention to two income groups, rich and poor; this proves adequate for our purposes.[23]

[22] Given that $U_s^d(\theta_s^d(\tau), \tau) - U_s^0(\theta^0(\tau), \tau)$ is monotonic decreasing in τ for $\tau \in (\tau_s^B, \tau^A)$, one may also envision an intermediate case in which the preferred regulation curve equals $\theta_s^d(\tau)$ below some threshold value of $\tilde{\tau} \in (\tau_s^B, \tau^A)$ and equals $\theta^0(\tau)$ above that value. In other words, though private mitigation, with its associated lower regulation level, may be preferred at low tariff rates, it may not be the case at higher rates, as the relative benefits from private mitigation are reduced because output of the dirty good is reduced. For brevity, this case has been omitted here (See Bernard et al. (2010)).

[23] A similar simplification is used in other political economy analyses, such as that of Acemoglu and Robinson (2006).

5.2.1 The autocratic regime

We define as autocratic (AU), a political regime in which a rich elite chooses both environmental regulation and trade openness unilaterally. Our view of autocratic regimes encompasses two characteristics highlighted by Besley and Kudamatsu (2006): autocracies are dictatorships of the rich and are accountable to a small number of people. Here the ordinary (poorer) citizen has no voice whatsoever, and government policies in the service of the elite can be described by maximizing the welfare of the high-income elite:

$$\max_{\theta,\tau} S^{AU} = U^*_{\bar{s}}(\theta,\tau). \tag{21}$$

For each private mitigation cost and the corresponding welfare rankings outlined in section 5.1, the resulting political equilibrium choice of policies is reported in table 1.

Mitigation cost	Policy equilibrium
$\underline{d}_1$	$(\theta^B_{1\bar{s}}, \tau^B_{1\bar{s}})$
$\underline{d}_2$	$(\theta^B_{2\bar{s}}, \tau^B_{2\bar{s}})$
$\underline{d}_3$	(θ^A, τ^A)

Table 1: Mitigation costs and environmental policy in an autocratic regime

In the autocratic regime, the government always chooses policy combinations at the intersection of the high-income group's preferred regulation and tariff curves. Hence, the policy choices fall on curve $\tau^e(\theta)$. In terms of pollution level, let Q^r_i denote the equilibrium pollution level under political regime r and mitigation cost $\underline{d}_i$. In light of proposition 7, we have $Q^{AU}_2 > Q^{AU}_1 > Q^{AU}_3$. The pollution level is highest in the case where the cost of private mitigation is low enough to be adopted by the rich, but still high enough that they become reticent to sacrifice additional consumption through more stringent pollution control. The pollution level is lowest when private mitigation is too costly to be adopted by anyone. There is, thus, a discontinuity in the relationship between the cost of private mitigation and the equilibrium pollution level:

Proposition 9 *In an autocratic regime, pollution initially increases with the cost of private mitigation $\underline{d}$ and then drops once this cost exceeds a threshold value.*

Proposition 10 *As far as ordinary (poorer) citizens are concerned, the autocratic regime leads to equilibria in which there is too much pollution in intermediate case $\underline{d}_2$, just the right amount at prohibitively high cost $\underline{d}_3$, and too little pollution at low cost $\underline{d}_1$.*

This last case of too little pollution may seem counterintuitive. It follows from proposition 7 and is explained by the fact that once they adopt private mitigation, poorer citizens become more reticent than the elite to sacrifice more of their consumption in order to reduce pollution.

5.2.2 *Strong Democracy*

We define a strong democratic regime (SD) to be one in which all citizens exert a voice. The equilibrium in such a regime can be represented by maximizing a weighted sum of utilities of all citizens in the country:

$$\max_{\theta,\tau} S^{SD} = \gamma U^*_{\bar{s}}(\theta,\tau) + (1-\gamma)U^*_{\underline{s}}(\theta,\tau), \tag{22}$$

where γ denotes the relative influence of the high-income-share group in the political arena.[24] Note that the objective in (22) is not a social welfare function; rather, it represents a political equilibrium which accounts for the influence and interests of two groups of voters.

In the present environmental context, equilibrium in a strong democracy always involves a policy pair located somewhere along the pollution efficiency curve $\tau^e(\theta)$. The political equilibrium of the fully democratic government is characterized by

$$\begin{aligned}&\gamma\left\{u_c(c^*_{\bar{s}})\bar{s}[z_\theta + z_\tau\tau^{e\prime}(\theta)] + h_Q(d^*_{\bar{s}},Q)[Q_\theta + Q_\tau\tau^{e\prime}(\theta)]\right\} = \\ &\qquad (1-\gamma)\left\{u_c(c^*_{\underline{s}})\underline{s}[z_\theta + z_\tau\tau^{e\prime}(\theta)] + h_Q(d^*_{\underline{s}},Q)[Q_\theta + Q_\tau\tau^{e\prime}(\theta)]\right\}.\end{aligned} \tag{23}$$

The terms between square brackets denote general equilibrium effects in terms of national income and pollution changes, and are multiplied by the respective individual sensitivities $u_c s$ and h_Q. This means, for instance, that even in a situation where the poor wield little direct political clout - that is their "weight" $(1-\gamma)$ is small - they may still have a significant impact on the equilibrium if their individual sensitivities to pollution are much higher than those of the higher income individuals, because this affects their voting behavior. Those sensitivities are thus a measure of their interest.

The resulting equilibrium menu of policies is reported in table 2. $\theta(\gamma)$ denotes the equilibrium stringency of environmental regulation as a function of the influence of the rich. We also account for the fact that policy pairs with private mitigation at point B depend on income share and are denoted $B_{\bar{s}}$ and $B_{\underline{s}}$ for the rich and the poor respectively; in accordance with proposition 7, $B_{\underline{s}}$ lies to the south-west of $B_{\bar{s}}$.

Mitigation cost	Policy equilibrium $\theta(\gamma)$
$\underline{d}_1$	on $\tau^e(\theta)$ with $\theta(\gamma) \in (\theta^B_{1\underline{s}}, \theta^B_{1\bar{s}})$ and $\theta'(\gamma) > 0$
$\underline{d}_2$	on $\tau^e(\theta)$ with $\theta(\gamma) \in (\theta^B_{2\bar{s}}, \theta^A)$ and $\theta'(\gamma) < 0$
$\underline{d}_3$	(θ^A, τ^A)

Table 2: Mitigation costs and environmental policy in a strong democratic regime

At prohibitive cost $\underline{d}_3$, the equilibrium policy coincides with both group's preferred policy combination and the pollution level is lowest. At intermediate cost level $\underline{d}_2$, the policy outcome is located between points $B_{\bar{s}}$ and A somewhere along the efficiency curve and moves *up* from $B_{\bar{s}}$ towards A as the influence of the rich decreases. At lost cost $\underline{d}_1$, equilibrium

[24] This model of a fully democratic state is inspired by the well-known Representation Theorem. See, for example, Coughlin (1992) and Hettich and Winer (1999).

policies now fall between points $B_{\underline{s}}$ and $B_{\bar{s}}$ and moves *down* from $B_{\bar{s}}$ towards $B_{\underline{s}}$ as the influence of the poor increases. We therefore have the following proposition:

Proposition 11 *In a full democracy, the pollution level is lowest when the cost of private mitigation is prohibitively high; it increases with the influence of the rich at intermediate mitigation cost levels; while it increases with the influence of the poor at low mitigation cost levels.*

Note how the presence of private mitigation introduces the possibility of a reversal regarding the effect of the poor's political influence on equilibrium pollution levels: At intermediate mitigation costs, only the rich mitigate and therefore the poor push for more stringent environmental policies; at low mitigation costs, the poor are also protected and therefore push for less stringent environmental policies in return for more consumption.

5.2.3 Weak democracy

The strong democratic regime discussed above assumes that all citizens vote in a manner that takes into account both policy dimensions, and political platforms are shaped accordingly. But this may not be so in all democratic contexts. Rodrik (1992), for instance, investigates situations of what he calls subordinate government in which a rich elite leads by setting some policies, with a democratically elected government acting as a follower in setting other policies. Besley and Burgess (2002), Downs (1957) and many others argue that influence is linked to the availability of information about policies, and that politicians may exploit the fact that the poor are often not well informed about some of their actions. Damania, Fredriksson and List (2004) propose a model in which there is an interaction between the choice of trade tariff and environmental taxation which is dependent on the corruption level. Because of corruption, producers gain influence over environmental policies.[25] List and Sturm (2006) classify policy issues as either "frontline" or "secondary" and develop models where the voter's effective influence varies across issues.

Although the justifications may vary, a fundamental consequence of these and many other analogous situations is that some citizens may control aspects of public policy in nominally democratic regimes to a greater extent than others. This situation has important implications in the environmental context. To see why, we consider the following case: the high-income group, or elite, sets the degree of environmental regulation stringency, while the government, responding to the mass of (lower income) voters, chooses the degree of trade openness. The outcome is modeled as a Nash equilibrium where the equilibrium policies fall at the intersection between the elite's preferred environmental regulation curve and the low income voters' preferred tariff curve.

[25] This story is reminiscent of arguments heard in Costa Rica by one author during the summer of 2007 leading up to an October referendum on a free trade agreement with Central America and the USA. Many believed that due to corrupt civil servants and politicians, Costa Rica would not be able to retain high environmental and labor standards once opened to trade, unlike Canada with NAFTA. Hence, though they could influence trade policy through a referendum, many felt that they would lose influence over social policies.

Mitigation cost	Policy equilibrium
$\underline{d}_2$	(θ^C, τ^C)
$\underline{d}_3$	(θ^A, τ^A)

Table 3: Mitigation costs and environmental policy in a weak democracy

Table 3 reports the political equilibria corresponding to each mitigation cost level. (Cost level $\underline{d}_1$ is omitted for brevity.)

As in the autocracy and full democracy cases, with high mitigation cost $\underline{d}_3$, we still find political equilibria at the most stringent policies (θ^A, τ^A). Both groups' preferred policy combinations are perfectly aligned and pollution is lowest.

When the cost of mitigation drops to $\underline{d}_2$, however, the rich always choose to mitigate; their preferred environmental regulation level is given by curve $\theta_s^d(\tau)$ in figure 1(b). The (poorer) citizens, however, do not mitigate such that $\tau^0(\theta)$ is their preferred tariff rate curve. The Nash equilibrium, policy outcome is at point C where the rich opt for low environmental regulation because they believe the poor will choose a high trade tariff while the poor choose a high tariff because they believe the rich will chose a low level of environmental regulation.[26] One notes that in this equilibrium, the policy pair does not fall on curve $\tau^e(\theta)$; it is therefore inefficient in the sense that real income could be increased for all while keeping the pollution level unchanged. We furthermore cannot predict whether a change in the cost of private mitigation leads to more or less equilibrium pollution since θ and τ move in opposite directions when $\underline{d}$ increases.

Proposition 12 *In a weak democracy where a rich elite control environmental policies while the (poorer) citizens control the degree of trade openness, at intermediate private mitigation costs, the equilibrium is characterized with inefficiently high trade tariffs and low environmental regulation.*

Note that if the groups' control over each policy were reversed such that the rich elite controls the import tariff rate while poorer citizens control environmental regulation, then the political equilibrium under intermediate private mitigation costs would fall at point D. In this case, a high regulation level is paired with a low tariff rate, thus leading to the same ambiguity regarding the pollution outcome.

5.3 A comparative analysis

When comparing political regimes, we first observe that when private mitigation is prohibitively costly, equilibrium public policy choices are not affected by the nature of the regime. The interests of both income groups coincide in the absence of private mitigation.

[26]This result is consistent with the empirical work of Damania, Fredriksson and List (2003), who find that in more corrupt countries, trade openness is positively linked to stringency of regulation regarding lead in gasoline.

Everyone wants to rely entirely on public policy to reduce pollution. The resulting pollution burden is distributed equally across individuals because no one privately mitigates. This leads to the lowest pollution levels for both autocratic and strongly democratic governments.

At the other end of the private mitigation cost spectrum, when mitigation costs are low so that *both* rich and poor prefer to adopt private mitigation and reduce the level of public regulation, regime type matters. Just as in the standard normal good case, the rich want stricter public policies than the poor. An autocratic regime may thus adopt more stringent policies than will a democratic one in which the poor pressure the government for less regulation and hence more income. We thus find that an autocratic government is more eco-friendly than a democratic one and the pollution burden is equally distributed.

At the intermediate private mitigation cost level, the rich prefer to privately mitigate and advocate lax public policies while the poor prefer not to privately mitigate, and to push for more stringent public policies. Contrary to the low-cost case, environmental quality is not a normal good anymore. Autocracy therefore leads to a highly polluted environment, with the poor being entirely exposed. A strong democracy adopts generally more stringent public policies, with pollution levels declining as the influence of the poor increases. In this intermediate case, strong democracy is more eco-friendly than autocracy. The pollution burden is unequally distributed in both regimes, but the poor suffer more from pollution under an autocratic government.

At intermediate mitigation costs, we cannot compare directly the level of pollution between a weak democracy and either strong democracy or autocracy. If the rich control the regulation level in a weak democracy, for instance, they will set it low and buy private mitigation. Anticipating that they will be fully exposed to pollution, poorer citizens pressure the government to adopt a high tariff rate. Since the two public policy instruments move in opposite directions, we cannot say whether the resulting pollution level is lower or higher than in the other, purer regimes.

As a whole, these comparisons establish clearly that the cost of private mitigation is a critical determinate of differences in policy equilibria across regime types. Differences across regimes in environmental policies and pollution levels are most evident for types of pollution that can be addressed partially or fully via private mitigation.

5.4 The Effect of Increasing Income Inequality

The foregoing analysis allows us to make predictions about how political institutions affect environmental stringency when income inequality increases. For brevity, we compare the cases of autocracy and strong democracy only.

We define an increase in inequality as a strictly higher income share for the rich ($\Delta^+\bar{s}$) and a strictly lower income share for the poor ($\Delta^-\underline{s}$). Population sizes and relative political influence weights are assumed constant. We proceed by considering two scenarios depending on whether or not the rich and the poor privately mitigate initially.

Scenario 1: Suppose that initially, when income inequality is relatively low, both income groups prefer overall policy combination (θ^A, τ^A) in figure 1(b). This means that both groups have the same interests in public policy because they both prefer stringent environmental policies while saving on private mitigation costs. Autocratic and democratic regimes thus yield the same policy outcomes.

Given proposition 1, an increase in $\bar{s}$ will eventually lead the rich to switch to private mitigation. The rich then prefer less stringent public policies at $(\theta^B_{\bar{s}}, \tau^B_{\bar{s}})$. Whether the political regime is of the autocratic or strong democratic type, increased inequality therefore leads to laxer environmental policies. However, since the poor still exert some influence in a democratic regime, the extent of the reduction in government action (due to increased inequality) is less marked under democracy.

But the story does not end there. According to proposition 7, once the rich can afford private mitigation, further increases in $\bar{s}$ cause them to prefer more stringent environmental policies. Regardless of the political regime, we then have the opposite result that increased inequality beyond this point leads to a cleaner environment.

Scenario 2: Suppose that initially, and in contrast to the first scenario, when income inequality is relatively low, individuals in both groups prefer to privately mitigate. In accordance with proposition 7, the rich then prefer more stringent regulation than the poor.

Further increases in inequality lead the poor to demand less stringent environmental policies as long as they still choose to privately mitigate. The rich, on the other hand, want more stringent environmental policies. In an autocratic regime, this leads to more stringent policy. In a strong democracy, in contrast, the outcome is indeterminate as each group pulls different policies in opposite directions.

But according to proposition 7, further increases in inequality will eventually lead the poor to prefer stricter environmental policies while forgoing private mitigation. When that takes place, their preference jumps from being less stringent to being more stringent than that of the elite. This makes little difference under an autocratic regime as the rich still choose to privately mitigate. But in a fully democratic one, increased inequality then unambiguously leads to the adoption of more stringent environmental policies.

In general, we see that the sign of the effects of increased inequality on pollution levels depends on initial conditions, the political regime type and the costs of private mitigation. It may also be non-monotonous. This analysis indicates that empirical work on the relationship between inequality and environmental policy will be complex, and it is easy to see why imperfect controls in a regression equation may lead to a wide variety of results.

6 Conclusion

We have conducted a comparative analysis of the eco-friendliness of political regimes, showing how the degree of environmental policies interacts with the cost of privately mitigating the health consequences of domestic pollution and with income inequality. With costly private mitigation, higher income is not always associated with greater demands for a cleaner environment; this fact leads to divergence of demands for pollution control among citizens of varying incomes in a way that has received very little attention in the literature on the political-economy of the environment.

Equilibria in three types of regimes are compared: autocratic, weak and strong democracies. We found the result that at intermediate costs of private mitigation, equilibrium pollution will be higher in an autocracy than a strong democracy. The converse holds, however, at low costs of private mitigation. And when this cost is prohibitively high, the two regimes lead to the same outcome.

In the case of a weak democracy, however, predictions regarding equilibrium pollution levels at intermediate costs of private mitigation are ambiguous because of the presence of two policy instruments affecting pollution levels. Indeed, the political equilibrium is characterized with lax environmental regulation paired with a high trade tariff rate aimed at reducing specialization in the production of dirty good. We show that this outcome is inefficient.

Regarding the effects of increased inequalities on equilibrium pollution, we find that the effect is non-monotonous in a complex manner as it depends on the initial situation and the regime type. For instance, if at low levels of inequalities both the rich and the poor cannot afford private mitigation, then increasing inequalities initially leads to higher equilibrium pollution levels but the effect is eventually reversed; this holds true for both autocracies and democracies. But if at low levels of inequalities both the rich and the poor can afford private mitigation, then increasing inequalities leads to lower equilibrium pollution levels in an autocracy; for a democracy, the effect is initially indeterminate but will lead to lower pollution levels when inequality increases substantially.

A The general equilibrium effects of environmental and trade policies

Recall that equation (5) defines the implicit relation between z and the policy instruments. Total differentiation with respect to changes in θ and τ respectively yield:

$$e_z(\mathbf{p}, z)dz = g_\theta(\mathbf{p}, \theta)d\theta + \tau(x_z^1(\mathbf{p}, z)dz - y_\theta^1(\mathbf{p}, \theta)d\theta) \quad (24)$$

$$e_z(\mathbf{p}, z)dz = \tau\{(x_1^1(\mathbf{p}, z) - y_1^1(\mathbf{p}, \theta))d\tau + x_z^1(\mathbf{p}, z)dz\}. \quad (25)$$

Expression (24) indicates that an increase in θ reduces national income through a decrease in GDP (negative technological effect g_θ) and a decrease in tariff revenue as more of good 1 gets locally produced (positive price effect τy_θ^1). In the absence of an adjustment in output z, expenditures exceed income. A decrease in output re-establishes the equilibrium through a reduction in expenditures ($e_z dz$) which induces a further reduction in tariff revenues from a drop in demand for good 1 ($x_z^1 dz$).

In the case of an increase in tariff, note first that expression (25) makes use of the fact that $dp_1 = d\tau$ for a small open economy. Tariff revenues decrease because of a fall in imports. This is matched by a decrease in expenditures ($e_z dz$) which induces a further reduction in tariff revenues as the demand for good 1 drops by $x_z^1 dz$.

Now the real output level z can be conveniently expressed by the following problem:

$$z(\mathbf{p}, I) \equiv \max_{\mathbf{x}}\{F(\mathbf{x}) \mid p_1x_1 + p_2x_2 \leq I\}. \quad (26)$$

$z(\mathbf{p}, I)$ represents the national *real output function*; it has the usual properties of an indirect utility function. By Roy's identity, the (ordinary) demand for good i is given by $\tilde{x}^i(p, I) = -z_i(\mathbf{p}, I)/z_I(\mathbf{p}, I)$. The conditional demand for good 1 can thus be expressed as $x^1(\mathbf{p}, z) = \tilde{x}^1(\mathbf{p}, e(\mathbf{p}, z))$, so that $x^1_z(\mathbf{p}, z) = \tilde{x}^1_I(\mathbf{p}, e(\mathbf{p}, z))e_z(\mathbf{p}, z)$. Inserting this into total differential equations (24) and (25), we get

$$\frac{\partial}{\partial\theta} z(\theta, \tau) = \frac{g_\theta - \tau y^1_\theta}{(1 - \tau \tilde{x}^1_I)e_z} < 0, \tag{27}$$

$$\frac{\partial}{\partial\tau} z(\theta, \tau) = \frac{\tau(x^1_1 - y^1_1)}{(1 - \tau \tilde{x}^1_I)e_z} < 0. \tag{28}$$

Note that expression $1/(1 - \tau\tilde{x}^1_I)$ is the *tariff multiplier* (Jones, 1969) and is generally assumed to be positive (Anderson and Neary, 2005:33). As for the general pollution effects of regulation and control over trade openness, they are respectively given by

$$\frac{\partial}{\partial\theta} Q(\theta, \tau) = q'(\theta)y_2 - q(\theta)y^2_\theta < 0, \tag{29}$$

$$\frac{\partial}{\partial\tau} Q(\theta, \tau) = q(\theta)y^2_1 < 0. \tag{30}$$

Expressions (27) and (28) correspond to the real national income cost of each policy, while (29) and (30) are the benefits in terms of lower pollution.

B Proofs of lemmas and propositions

Proof of lemma 2: Generally, the utility of an individual s who spends amount d_s on private mitigation and suffers $\ell(Q)$ from pollution is given by $U_s = u(sz - d_s) + h_0 - \ell(Q)$. Taking the total differential and equating it to zero yields $d(sz)/dQ = \ell'(Q)/u_c(sz - d_s)$, which corresponds to the MWTP. Since $u_{cc} < 0$, the MWTP increases with s for fixed d_s.

Proof of proposition 3: From the assumed properties of the welfare functions for consumption and health, we have, for all s, $\bar{\ell}'(Q)/u_c(sz) > \underline{\ell}'(Q)/u_c(sz - \underline{d})$. By the definition of $\tilde{s}$, since the inequality is strict and the MWTP is continuous for given d_s, there must exist $\varepsilon > 0$ such that for any $\delta \in (0, \varepsilon)$ we have $\bar{\ell}'(Q)/u_c((\tilde{s} - \delta)z) > \underline{\ell}'(Q)/u_c((\tilde{s} + \delta)z - \underline{d})$.

Proof of lemma 4: In the absence of private mitigation, the preferred mitigation level θ^0 is defined by

$$\frac{\bar{\ell}'(Q(\theta^0, \tau))}{u_c(sz(\theta^0, \tau))s} = \frac{z_\theta(\theta^0, \tau)}{Q_\theta(\theta^0, \tau)}. \tag{31}$$

With $\sigma = 1$, this equality is respected for all s. With private mitigation, the willingness to pay for regulation drops since $\underline{\ell}'(Q) < \bar{\ell}'(Q)$ by assumption and $u_c(sz - \underline{d}) > u_c(sz)$ since $u_{cc} < 0$. As a result, with private mitigation, the left-hand side of (31) becomes strictly smaller than the right-hand side for all s at θ^0, which implies that a decrease in regulation raises welfare.

Proof of lemma 5: Without loss of generality, take two individuals with income shares $\bar{s}$ and $\underline{s}$, with $\bar{s} > \underline{s}$. It suffices to show that with private mitigation, the willingness to pay for regulation is higher for $\bar{s}$ than for $\underline{s}$. To this end, we must simply show that $u_c(\bar{s}z - \underline{d})\bar{s} < u_c(\underline{s}z - \underline{d})\underline{s}$.
Let $s_1 z = \bar{s}z - \underline{d}$ and $s_2 z = \underline{s}z - \underline{d}$. Since $\sigma = 1$, we have $u_c(s_1 z)s_1 = u_c(s_2 z)s_2$ or, by substitution, $u_c(s_1 z)(\bar{s} - \underline{d}/z) = u_c(s_2 z)(\underline{s} - \underline{d}/z)$. Rearranging, we get $u_c(s_1 z)\bar{s} - u_c(s_2 z)\underline{s} = (u_c(s_1 z) - u_c(s_2 z))\underline{d}/z < 0$. The latter inequality is due to the fact that $u_{cc} < 0$ and $s_1 > s_2$. Substituting $s_1 z = \bar{s}z - \underline{d}$ and $s_2 z = \underline{s}z - \underline{d}$, we get $u_c(\bar{s}z - \underline{d})\bar{s} < u_c(\underline{s}z - \underline{d})\underline{s}$.

Proof of lemma 6: By substitution, it is straightforward to verify that the following holds:

$$\frac{\partial U_s^d}{\partial \theta} < \frac{\partial U_s^0}{\partial \theta}.$$

Consequently, continuous utility functions U_s^d and U_s^0 can cross only once as θ varies.

Proof of proposition 7: The first part derives from the fact that after spending on private mitigation, a lower $\underline{d}$ allows for higher consumption, which results in a higher willingness to pay for reducing pollution. The second part is a restatement of proposition 5, generalized to the case of both pollution regulation and a trade tariff. The proof is a straightforward extension to this case.

Proof of proposition 8: Using the envelope condition, we have $\partial U_s^d / \partial \underline{d} = -u'(sz(\theta_s^B, \tau_s^B) - \underline{d}) < 0$. Existence derives from the continuity properties. The fact that $\underline{d}(s)$ is increasing can be shown by first assuming that (20) holds with equality for some s. It is then easy to show that the inequality is re-established with larger s. Hence, $\underline{d}$ can be further increased while respecting the inequality.

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