Environmental Regulation and Trade Openness in the Presence of Private Mitigation[1]

Louis Hotte[2] Stanley L. Winer[3]

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[2]Department of Economics, University of Ottawa (louis.hotte@uottawa.ca)

[3]School of Public Policy and Administration and Department of Economics, Carleton University (stan_winer@carleton.ca)

Abstract

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Acknowledging the differential ability of individuals to privately mitigate the consequences of pollution is essential for an understanding of demands for regulation of the environment and of trade in dirty goods, and for analysis of the implications of these demands for equilibrium policy choices. In a small open economy with exogenous policy, we first explain how private mitigation results in an unequal distribution of the health consequences of pollution in a manner consistent with epidemiologic studies, and consequently how the benefits and costs of trade in dirty goods interact with choices concerning private mitigation to polarize the interests of citizens concerning environmental stringency. The economy is then embedded in a broader political economy setting, and simulated to investigate the role of private mitigation in the determination of policy choices. We show that when citizens can effectively choose between costly collective and costly private alternatives for pollution control, the same polarization of interests underlies equilibrium policy choices concerning environmental regulation and trade openness in democratic and autocratic regimes.

Keywords: Environmental Regulation; Pollution; Private Mitigation; Trade, Dirty Goods; Individual Welfare; Health; Democracy; Representation Theorem.

JEL classification: D7, F18, Q56

1 Introduction

In this paper we analyze the demands by individuals of varying incomes for regulation of the environment and of trade, and the implications of these demands for equilibrium public policy choices. The economic setting is that of a small open economy producing two tradable goods, one of which is polluting, where more stringent environmental control reduces income. The differential ability of individuals to privately mitigate the adverse consequences of pollution at a cost is a key characteristic of the analysis throughout.

According to epidemiologic studies, the adverse health effects of pollution are not equally distributed across the population; those with lower socioeconomic status tend to suffer a heavier health burden.[1] For this reason, we might expect individual demands for environmental regulation to be more intense among lower income groups. Similarly, when a country's comparative advantage lies with the production of goods that are pollution-intensive, we might expect opposition to trade openness among lower income citizens to be stronger .

On the other hand, it is often argued that environmental quality is a *normal good* so that with diminishing marginal utility of consumption, richer individuals are willing to pay more for a cleaner environment. If that is the case, then poorer people will demand laxer environmental regulation and more trade with specialisation in dirty production. This is the basic reasoning behind Summers' provocative 1991 memo at the IMF, which put forward the idea that it may make sense for dirty industries to move South.[2]

In the absence of private mitigation, there is certainly every reason to believe that environmental quality *is* a normal good. But in the light of the epidemiologic studies,

[1]See, for instance, the empirical evidence in 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). Moreover, news stories about how it tends to be the poorest within the developing countries who are affected by pollution are legion: see, for example, Bernard (2006), Bradsher and Barboza (2006), French (2005) or The Economist (2005).

[2]In the theoretical literature, Copeland and Taylor (1994) show that based on the normal-good argument, a representative individual in a poor country optimally chooses lower environmental standards and thus specializes in dirtier industries. The assumption here is that all externalities are somehow internalized. If that is not the case, and at the other end of this normative literature, are the analyses of Pethig (1976) and Chichilnisky (1994) who take as given that environment standards are lower in developing countries, and argue that although these countries (also) attract dirtier industries, one cannot be sure that trade does not lower welfare; it depends on what drives the choice of standards. On trade and endogenous internalization, see Copeland (2005) and Hotte, Long and Tian (2000). Finally, we note that while this normative literature informs our work, our concern is with positive aspects of how individual interests are shaped and how these demands play a role in shaping equilibrium policy outcomes.

that this leads poorer individuals to always demand less stringent environmental regulation and more open trade in domestically produced polluting goods does not seem sensible.[3] Indeed, a similarly straightforward application of the normal good argument also leads one to infer that wealthier individuals in developed countries always demand more restricted trade in polluting goods than do the poor.

In our view, it is not environmental quality *per se* which is a normal good. Rather, it is the *health condition* associated with it. Once this consideration is combined with the fact that the impact of pollution on health can be privately mitigated, there are far-reaching implications for our understanding of the relationships between environment regulation, trade openness and individual welfare.

We consider a small open economy with Ricardian production technology in which individuals differ *a priori* by income levels, along with its autarkic counterpart. The model is simplified so that closed-form derivation and comparison of economic equilibria are possible. Here trade specialized in the polluting good versus autarky serves as a simplified policy option regarding the regulation of trade openness. The economic model (where policies are exogenously determined) allows for closed form interpersonal comparisons of the impact of environmental regulation even when pollution control interacts with the benefits of trade openness.[4]

The economy is then embedded in a broader political economy setting, and simulated to further investigate the role of private mitigation in the determination of public policy choices and their welfare consequences.

We show at the outset that in the economic framework we investigate, private mitigation results in an unequal distribution of the health consequences of pollution across income groups in a manner consistent with epidemiologic studies, in contrast to much of the literature which assumes equal health effects for all.[5] As a result, private mitigation polarizes the interests of rich and poor with respect to the stringency of regulation in a manner that we investigate in detail.

The interaction of private mitigation and trade openness exacerbates this diver-

[3]See Kahn and Matsusaka (1997) and Kristrom and Riera (1996) for some empirical evidence that *within* a community or country, demand for environmental regulation may decrease with individual income.

[4]The same qualitative effects would be present with the more general Heckscher-Ohlin framework but this would come at a cost in terms of insight and clarity. As Feenstra (2004) points out, "... the Ricardian model is as relevant today as it has always been." (p. 1)

[5] Analyses of the relationship between the environment and trade that assume equal health effects for all and which, one should note, are aimed at investigation of different issues than in this paper, include Fredriksson (1997), Aidt (1998), Schleich (1999), McAusland (2003) and Copeland and Taylor (2003). An exception includes Copeland and Taylor (2003; §7.3) where it is assumed that people's tastes about the environment differ *exogenously* and without relation to income. Eriksson and Persson (2003) is the only study we have found where the negative effects of pollution decrease with income. However, they assume that this happens exogenously and do not consider trade.

gence of interests. We show that when trade leads to a more polluted environment compared to autarky, the demand for publicly provided pollution control among high-income individuals may decrease. This is because the additional income that trade generates allows them to better insulated themselves from the heath consequences of pollution. Moreover, since the gains from trade may be weaker for lower income individuals, trade may lead to a strengthening of the poor's demand for environmental regulation. In such situations, a simple normal-good-based prediction will not serve as an accurate guide to the nature of individual interests in the open economy.[6]

It is reasonable to expect that the polarization of interests created by the interaction of private mitigation and trade will carry with it implications for the outcome of political competition. The basic reason is that introducing an ability to privately mitigate alters individual incentives to seek costly collective as opposed to costly private actions as a way of dealing with the health consequences of pollution. To study the role of private mitigation in a political context, we simulate the equilibrium relationship between environmental regulation, trade and welfare for two income groups in fully democratic and in autocratic regimes differentiated by the presence or absence of political voice for poorer citizens. The economic structure analyzed in the first parts of the paper is embedded in the model used, and the role of private mitigation is studied by varying its effective cost.

We show that the costliness of private mitigation or, equivalently, the nature of the underlying pollutant, is a key factor underlying the equilibrium choice of policy towards the environment and towards trade. When private mitigation is infeasible, fully democratic and autocratic regimes in which the poor have no voice adopt the same levels of regulation and of trade openness. But when mitigation is feasible at some cost, the interests of the mass of poorer voters in dealing publicly with environmental degradation diverge from the those of the rich, and the outcome in the fully democratic setting involves more regulation than in an autocracy. So the importance of the interaction of private mitigation and trade openness uncovered in the economic model with exogenous policy carries over to the equilibrium policy context. Other authors - see, for example, Congleton 1992 and Winslow 2005 - argue that democracy is good for the environment because elites have a greater share of any income generated by the production of dirty goods. Here we show why the cost of private mitigation must also be acknowledged in the study of the political economy of environmental policy.[7]

[6]Note that, as discussed in footnote 23, our analysis does not contradict the Environmental Kuznets Curve hypothesis. For additional micro-economic perspectives on the demand for environmental regulation in the presence of private mitigation, see Coase (1960), Courant and Porter (1981), Shibata and Winrich (1983), Bartik (1988) and McKitrick and Collinge (2002).

[7]In a broader political economy context, we also indicate how cases may even arise where the poor may oppose more trade openness in a democracy even though it has the potential to benefit

The paper is organized as follows. In section 2, we introduce the fundamental functions representing individual welfare as well as the production, regulation and private pollution-mitigating technologies. We solve for decentralized consumption and production decisions in section 3. Those decisions are combined with the market-clearing conditions in section 4, for both autarky and for trade, and the resulting effects on pollution are derived in 5. In section 6 we compare the marginal welfare consequences of environmental regulation for different income groups. We then describe, in section 7, how trade openness may create conflicting demands for environmental regulation. In section 8, we introduce the political economy setting for the determination of policy choices, which previously have been treated as exogenous, and we then analyze political equilibria in several scenarios differentiated by the costliness of private mitigation.

Section 9 concludes our analysis of the role of private mitigation in the relationship between environmental policy, trade openness and economic well-being.

2 The economic model

2.1 Individual welfare

An individual i's welfare level, denoted $U(i)$, depends positively on his or her health condition, $h(i)$, and the quantity of goods and services consumed, $x(i)$. We further assume that the two are separable and exhibit decreasing marginal utility of consumption; that is,[8]

$$U(i) = u(x(i)) + h(i),\ u_x > 0,\ u_{xx} < 0.$$

In turn, the health condition depends negatively on the economy-wide pollution level, denoted $Q \geq 0$.[9] This effect can, however, be *privately* mitigated with effort level $d(i)$.[10] Hence, $h(i) = h(d(i), Q)$, $h_Q \leq 0$ and $h_d \geq 0$.

For tractability, we shall use the following functional forms in the ensuing analysis: $u(x(i)) = \ln(x(i))$ and $h(i) = -[\delta_0 - \delta_1 d(i)]Q$, where parameter δ_0 denotes

everyone, because of a concern that laxer environmental regulation with trade will then be imposed in the interests of richer citizens. Such a result is consistent with the shift of emphasis from anti- to alter-*mondialisation* among some (French and other) globalization protest movements. They do not oppose trade *per se*, but rather the type of trade that they observe.

[8]Unless otherwise noted, subscripts of functions denote partial derivatives.

[9]Note that the analysis does not consider transboundary pollution issues such as greenhouse gases.

[10]Examples of pollution mitigation measures include choice of house location, installation of household water filtration system, drinking bottled water, fetching water at a distance, chlorine pills, air cleaning system, weekends at the mountain, asthma medicines, etc. See, for instance, Neidell (2004), Hanna (2007) and Rosado (2006).

the marginal effect of pollution on health in the absence of private mitigation and parameter δ_1 summarizes the available private-mitigation technology. We thus have

$$U(i) = \ln(x(i)) - [\delta_0 - \delta_1 d(i)]Q, \quad d(i) \in (0, \delta_0/\delta_1). \tag{1}$$

In the absence of pollution ($Q = 0$), or with maximum private mitigation ($d(i) = \delta_0/\delta_1$), i's health condition attains its best state ($h(i) = 0$). Otherwise, if Q increases while $d(i)$ is fixed, the health condition worsens and the same holds if $d(i)$ decreases while Q is fixed. Because consumption exhibits decreasing marginal utility, the health condition is a *normal good*: a rise in income induces one to spend more on improving his health condition.[11] A crucial feature of the model here is that there are *two* channels through which an individual's $h(i)$ can increase: privately with higher $d(i)$ or collectively with lower Q.

Note finally that as $\delta_1 \to 0$, private mitigation becomes technologically impossible (or, equivalently, infinitely costly). In that case, with $h(i) = \delta_0 Q$, the fact that health is a normal good also makes environmental quality a normal good. This case will later on serve as a benchmark that will be used to underscore and study the role played by private mitigation.

2.2 The production technology

We assume an economy with two types of goods, denoted 1 and 2. Good 2 is a dirty good in the sense that its production creates pollution while good 1 is clean and does not pollute at all. Production uses a *Ricardian* technology as represented by the following (no-regulation) national production possibility frontier (PPF):

$$Z_2 = \hat{Z}_2 - bZ_1, \tag{2}$$

where Z_2 and Z_1 respectively denote the aggregate outputs of goods 2 and 1, parameter b is the constant opportunity cost of producing an extra unit of good 1 in terms of good 2, and $\hat{Z}_2$ measures the height of the PPF (an index of the country's total production capacity or wealth). With good 2 as the numéraire good and good 1 selling at price p, the national income is

$$Y = pZ_1 + Z_2. \tag{3}$$

2.3 Individual income

The economy is composed of a continuum of individual types indexed by $i \in [0, 1]$ and distributed according to density function $f(i)$. The total population size is normalized

[11] This can be readily verified by solving the following problem: $\max_{x,h} u(x) + h$ s.t. $y = x + ph$, where y is income and p is the price of the health condition in units of the consumption goods.

to one. *A priori*, individuals differ solely by their *claim* on the national income, which is expressed as the exogenous share $\alpha(i) > 0$. Individual income is thus

$$y(i) = \alpha(i)Y. \tag{4}$$

Individuals are ranked so that $\alpha(i)$ is non-decreasing in i. Note that this representation of heterogeneity allows us to concentrate on the divergent interests of citizens based solely on income differences. Since relative factor endowments play no role, we depart here from the manner in which the political-economic analysis of trade is often investigated. This is justified by the fact that individual interests in our framework depend importantly on the ability to privately mitigate the effects of pollution, and this ability is a function of income whatever its source.

2.4 Individual expenditures

Goods 1 and 2 are combined as imperfect substitutes for the creation of a final good $C(i)$. We represent this by using the following Cobb-Douglas form: $C(i) = C_1(i)^a C_2(i)^{1-a}$, where $C_1(i)$ and $C_2(i)$ respectively denote the quantities of goods 1 and 2 being combined. The unit cost of a final good is thus $c(p) = a^{-a}(1-a)^{a-1}p^a$ and we are left with the following budget constraint: $y(i) = c(p)C(i)$. Final goods are used either for consumption level $x(i)$ or private pollution mitigation effort $d(i)$ so that $x(i) + d(i) = C(i)$.[12]

Let consumption expenditures be expressed as $e(i) = c(p)x(i)$. The individual budget constraint is then

$$e(i) = \alpha(i)Y - c(p)d(i). \tag{5}$$

2.5 Pollution and its regulation

In the absence of environmental regulation, the economy-wide pollution level Q is simply given by $Q = Z_2$; that is, each unit of good 2 produces one unit of pollution. Environmental regulation requires the suppliers of good 2 to produce in a cleaner way. Some productive resources must be devoted to either cleaning up along the production process or using more sophisticated, cleaner production techniques. Either way, in comparison to the no-intervention case, environmental regulation has two direct effects:

i) A benefit in the form of less pollution for any production level Z_2;

[12] It should be noted that we are implicitly assuming that the consumption bundle and the pollution mitigation effort bundle are equally *pollution intensive*. There is no *a priori* reason to believe that pollution defensive measures are any more or any less pollution intensive than the mix of consumption goods on average.

ii) A cost in the form of more inputs necessary to achieve any production level Z_2.

Let us define the stringency of environmental regulation as a continuous variable $\theta \in [0, 1]$. $\theta = 0$ imposes no restriction on emissions, while $\theta = 1$ is an obligation to abate all emissions. Here there is no uncertainty surrounding the effectiveness of environmental policy, and all pollution affects only the domestic environment.

The benefits and costs of regulation are represented as follows:

$$\text{Benefit: } Q = h(\theta)Z_2, \text{ with } h'(\theta) < 0,\ h(0) = 1 \text{ and } h(1) = 0; \tag{6}$$

$$\text{Cost: } Z_2 = (1 - \theta)(\hat{Z}_2 - bZ_1). \tag{7}$$

It follows from from (7) that regulation results in a downward shift of the PPF: for any given amount of Z_i, less of Z_j is produced. Moreover, a pollution-free output of good 2 is prohibitively costly. From a producer's point of view, environmental regulation simply increases the opportunity cost of producing the dirty good from $1/b$ to $1/(1 - \theta)b$ in terms of the clean goods. The maximum amount of the clean good that can be produced is not affected by environmental regulation. We shall refer to equation (7) as the *regulated* production possibility frontier ($RPPF$) which is illustrated in figure 1.

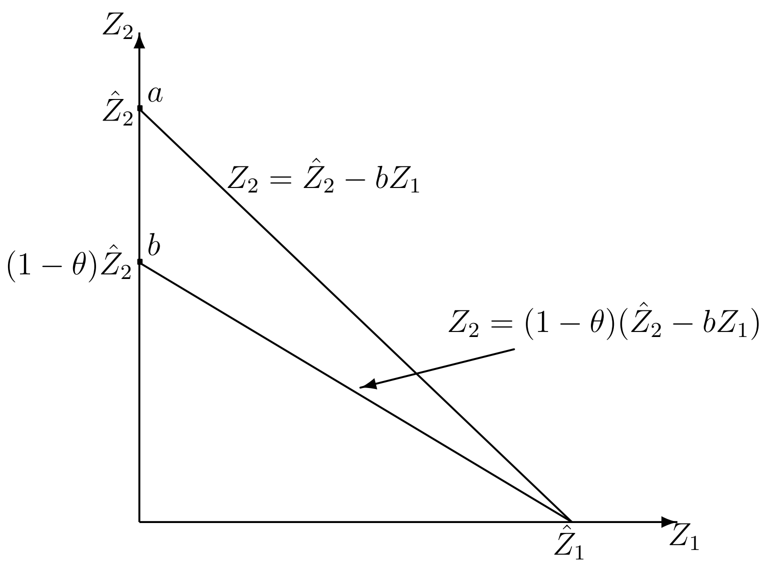

Figure 1: The regulated production possibility frontier (RPPF)

3 Output and consumption decisions

We assume price-taking behavior throughout.

3.1 Production decisions

3.1.1 Autarky

Under the assumption of Ricardian technology, the opportunity cost of good 1 is constant in terms of good 2 and equal to $(1-\theta)b$. Therefore, if both goods are produced, we have $p_A = (1-\theta)b$, where subscripts A denotes *autarky.* The autarky national income is $Y_A = (1-\theta)bZ_1 + Z_2$. Substituting the $RPPF$ in (7), we obtain

$$Y_A = (1-\theta)\hat{Z}_2. \tag{8}$$

3.1.2 Trade

We consider the case of a small open economy. The world price of good 1 is fixed at p_T, where subscript T denotes trade. There are two polar cases to consider:

(i) Specialization in the clean good

If $p_T \geq (1-\theta)b$, only good 1 is produced and there is no pollution in equilibrium. Then national income is given by

$$Y_T = p_T \frac{\hat{Z}_2}{b}. \tag{9}$$

(ii) Specialization in the dirty good

If $p_T < (1-\theta)b$, only the dirty good is produced and there is pollution in equilibrium. National income in this case is

$$Y_T = (1-\theta)\hat{Z}_2. \tag{10}$$

It is important to note that whether p_T is larger or smaller than $(1-\theta)b$ depends on the stringency of environmental regulation.

3.2 Consumption decisions

With the assumed Cobb-Douglas forms for $C(i)$, the quantities demanded for goods 1 and 2 are, respectively, $a\alpha(i)Y/p$ and $(1-a)\alpha(i)Y$.

We now have to solve for the allocation of expenditures between consumption goods $(e(i))$ and pollution mitigation $(c(p)d(i))$. To simplify, define $v(p) \equiv 1/c(p)$

and substitute $x(i) = v(p)e(i)$ into the utility function so that the individual problem can be expressed as follows:

$$\max_{\{e(i),d(i)\}} V(i) = \ln(v(p)e(i)) - (\delta_0 - \delta_1 d(i))Q \tag{11}$$

$$\text{s.t. } e(i) = \alpha(i)Y - c(p)d(i). \tag{12}$$

The individual takes prices, pollution, environmental regulation and national income as given. Substituting $e(i)$ in (11) for the budget constraint, the problem of an individual reduces to choosing $d(i)$. The first-order condition for an interior solution is[13]

$$\frac{\partial V(i)}{\partial d(i)} = -\frac{c(p)}{e^*(i)} + \delta_1 Q = 0, \tag{13}$$

where superscript * denotes an individually optimal choice. This condition simply equates the marginal welfare loss from a lower consumption level to the health gain from an increase in the pollution mitigation effort. Given that $0 \leq d(i) \leq \delta_0/\delta_1$, we obtain the following interior and corner solutions:

$$d^*(i) = 0; \qquad e^*(i) = \alpha(i)Y \qquad \text{iff } \alpha(i) \leq \underline{\alpha}, \tag{14}$$

$$d^*(i) = \frac{\delta_0}{\delta_1}; \quad e^*(i) = \alpha(i)Y - c(p)\tfrac{\delta_0}{\delta_1} \quad \text{iff } \alpha(i) \geq \bar{\alpha}, \tag{15}$$

$$d^*(i) = \frac{\alpha(i)Y}{c(p)} - \frac{1}{\delta_1 Q}; \qquad e^*(i) = \tfrac{c(p)}{\delta_1 Q} \qquad \text{otherwise}, \tag{16}$$

where

$$\underline{\alpha} = \frac{c(p)}{Y}\frac{1}{\delta_1 Q}, \tag{17}$$

$$\bar{\alpha} = \frac{c(p)}{Y}\left[\frac{1}{\delta_1 Q} + \frac{\delta_0}{\delta_1}\right]. \tag{18}$$

According to corner solution (14), relatively poor individuals whose income share lies below $\underline{\alpha}$ choose not to spend anything on pollution mitigation because of their high marginal utility of consumption. Conversely, solution (15) denotes relatively wealthy individuals with income shares above $\bar{\alpha}$ who choose to be completely insulated from the effects of pollution. Interior solution (16) represents intermediate-income individuals who opt for a partial protection against pollution. Note how the pollution-mitigation effort tends to increase with the pollution level.

The welfare maximization solution allows us to assert the following:

Proposition 1 *The individual pollution-mitigation effort (weakly) increases with pollution and with individual income. Consumption expenditure (weakly) decreases with pollution and (weakly) increases with individual income.*

[13]It is straightforward to verify that the second-order conditions for a maximum are satisfied.

4 The general economic equilibrium

4.1 Equilibrium in autarky

In autarky, the supply of each good must be equal to its aggregate demand. We thus have

$$Z_{2A} = \int_0^1 (1-a) Y_A \alpha(i) f(i) di, \tag{19}$$
$$= (1-a)(1-\theta)\hat{Z}_2, \tag{20}$$

where (20) is obtained using expression (8) for the national income. In autarky, given θ, the economic general equilibrium is fully described by the following set of equations:

$$p_A = (1-\theta)b, \tag{21}$$
$$Z_{2A} = (1-a)Y_A, \tag{22}$$
$$Z_{1A} = \frac{aY_A}{p}, \tag{23}$$
$$Q_A = h(\theta)Z_{2A}, \tag{24}$$
$$Y_A = (1-\theta)\hat{Z}_2 \tag{25}$$

and $e^*(i)$ and $d^*(i)$ are defined according to either of conditions (14), (15) or (16). The system has 7 endogenous variables $\{p_A, Y_A, Z_{1A}, Z_{2A}, Q_A, e^*(i), d^*(i)\}$ and contains 7 equations.

4.2 Equilibrium with trade

4.2.1 Specialization in the clean good

As shown in section 3.1.2, we have $p_T \geq (1-\theta)b$. In the absence of pollution, we have $d^*(i) = 0$ and individual consumption spending is $e(i) = \alpha(i)Y_T = p_T(\alpha(i)\hat{Z}_2/b)$ (see (9)). In this case, consumers do not have any decision to make; they just spend all their income on consumption goods. Note that this is consistent with corner solution (14) when $Q \to 0$.

As we have pointed out earlier, whether p_T is larger or smaller than $(1-\theta)b$ depends on the stringency of environmental regulation. As a consequence, whether this outcome obtains or not hinges on the choice of θ, which ultimately depends on a political process (to be introduced later).

The general economic equilibrium with trade and specialization in the clean good is summarized by the following system:

$$Z_{2T} = 0, \tag{26}$$

$$Z_{1T} = \frac{\hat{Z}_2}{b}, \tag{27}$$

$$e^*(i) = \alpha(i) Y_T, \tag{28}$$

$$d^*(i) = 0, \tag{29}$$

$$Q_T = 0, \tag{30}$$

$$Y_T = \frac{p_T}{b} \hat{Z}_2 \tag{31}$$

4.2.2 Specialization in the dirty good

We now have $p_T < (1-\theta)b$ and the country produces only good 2. There is pollution in this trade equilibrium, which is summarized by the following system:

$$Z_{1T} = 0, \tag{32}$$

$$Z_{2T} = (1-\theta)\hat{Z}_2, \tag{33}$$

$$Q_T = h(\theta) Z_{2T}, \tag{34}$$

$$Y_T = (1-\theta)\hat{Z}_2 \tag{35}$$

with $e^*(i)$ and $d^*(i)$ being determined according to either of conditions (14), (15) or (16). Since the price is now exogenous, the economic system now has 6 endogenous variables $\{Y_T, Z_{1T}, Z_{2T}, Q_T, e^*(i), d^*(i)\}$ and 6 equations as well.

5 Trade regimes and the effect of environmental regulation on pollution

Since specialization in the clean good eliminates pollution completely, we concentrate on the more interesting case where trade induces a specialization in the dirty good. For a given regulation level θ, equations (22) and (33) imply that

$$Q_A(\theta) = (1-a)\Gamma(\theta)\hat{Z}_2, \tag{36}$$

$$Q_T(\theta) = \Gamma(\theta)\hat{Z}_2, \tag{37}$$

where $\Gamma(\theta) \equiv h(\theta)(1-\theta)$. As should be expected, regulation affects pollution through two channels: the cleaner technology effect $h(\theta)$ and the higher production cost effect $(1-\theta)$. Since both tend to reduce pollution, we have $\Gamma'(\theta) < 0$. Pollution in autarky is a fraction $1-a$ of the trade level. This difference is due to the fact that in autarky, the supply for each good must match its demand, thus determining the relative output proportions between the clean and dirty goods. With trade, however, demand and supply are disjoint. In the case of a Ricardian production technology, full specialization in the production of the dirty good 2 results in a jump in pollution. This leads us to assert the following:[14]

Proposition 2 *Compared to autarky, an increase in pollution regulation stringency has a larger pollution-reducing impact when the country is open to trade and specialized in the dirty good. More precisely, the impact of a change in the degree of pollution control in autarky is equal to a fraction* $1-a$ *of that with trade.*

and

Proposition 3 *Compared to autarky and for a fixed regulation level, trade with specialization in the dirty good induces individuals to (weakly) increase their pollution-mitigation effort.*

6 The welfare effects of environmental regulation

We now wish to analyze how an exogenous increase in the stringency of environmental regulation affects individual welfare in the general-equilibrium setting. (In the case of trade, we do so while assuming specialization in the dirty good only.) To this end, we make use of the following indirect utility function which can be obtained by direct substitution of the results in (14), (15) and (16):

$$\begin{aligned} &= \ln(v(p)\alpha(i)Y) - \delta_0 Q \text{ iff } \alpha(i) \leq \underline{\alpha}, \\ V^*(p, y(i), Q) &= \ln\left(v(p)\alpha(i)Y - \frac{\delta_0}{\delta_1}\right) \text{ iff } \alpha(i) \geq \bar{\alpha}, \\ &= \ln\left(\frac{1}{\delta_1 Q}\right) - \left[\delta_0 - \delta_1\left(\frac{\alpha(i)Y}{c(p)} - \frac{1}{\delta_1 Q}\right)\right] Q \text{ otherwise.} \end{aligned} \tag{38}$$

In general, we have that:

$$\frac{d}{d\theta}V^*(p, y(i), Q) = \underbrace{\left[\frac{\partial V^*(i)}{\partial p}p'(\theta) + \frac{\partial V^*(i)}{\partial y}\alpha(i)Y'(\theta)\right]}_{\text{price-income effect}} + \underbrace{\left[\frac{\partial V^*(i)}{\partial Q}Q'(\theta)\right]}_{\text{pollution effect}} \tag{39}$$

The impact of regulation on individual welfare reveals itself through prices, income and pollution. To gain insight, we analyze the *price-income* effect, represented by the

[14]Proofs of propositions are found in the Appendix.

first term between square brackets, separately from the *pollution effect*, given by the second term between square brackets.[15] In the economic equilibrium, we have

$$p'_A(\theta) = -b \text{ in autarky and } p'_T(\theta) = 0 \text{ with trade,} \tag{40}$$

$$Y'_A(\theta) = Y'_T(\theta) = -\hat{Z}_2, \tag{41}$$

$$Q'_A(\theta) = (1-a)\Gamma'(\theta)\hat{Z}_2 \text{ and } Q'_T(\theta) = \Gamma'(\theta)\hat{Z}_2. \tag{42}$$

In autarky and for trade with specialization in the dirty good, these conditions yield

$$\begin{aligned} &= -\nu_k \left\{ \left[\frac{1}{1-\theta} \right] + \left[\delta_0 \Gamma'(\theta)\hat{Z}_2 \right] \right\} \text{ iff } \alpha(i) \leq \underline{\alpha}_k, \\ \frac{d}{d\theta} V_k^*(i) &= -\nu_k \left[\frac{\alpha(i)\hat{Z}_2}{e_k^*(i)} \right] \text{ iff } \alpha(i) \geq \bar{\alpha}_k, \\ &= -\nu_k \left\{ \left[\frac{\alpha(i)\hat{Z}_2}{e_k^*(i)} \right] + \left[(\delta_0 - \delta_1 d_k^*(i))\Gamma'(\theta)\hat{Z}_2 \right] \right\} \text{ otherwise,} \end{aligned} \tag{43}$$

where $k \in \{A, T\}$, $\nu_A = 1 - a$ and $\nu_T = 1$. In each case, the first term between square brackets denotes the price-income effect while the second one – when present – is the pollution effect. For $\alpha(i) \geq \bar{\alpha}_k$, the pollution effect is absent since those highest income individuals are completely insulated from pollution. We begin by analyzing the pollution effects.

6.1 The pollution welfare effects of regulation

We have the following:

Proposition 4 *In both trade and autarky, the marginal pollution welfare gains from a more stringent pollution regulation (weakly) decrease with individual income share $\alpha(i)$.*

The intuition behind this result is that richer individuals tend to be better insulated from the effects of pollution because of their mitigation efforts.

We now want to compare the importance of the pollution welfare effects of regulation when moving from autarky to trade. In this respect, two opposite effects arise. One the one hand, there is a higher pollution reduction effect with trade than autarky (proposition 2). On the other hand, individuals tend to (weakly) increase their private-mitigation effort with trade (proposition 3). We thus obtain the following result:

[15] We expect that this approach will also be useful for the conduct of empirical work.

Proposition 5 *The pollution welfare effect of regulation is strictly more important with trade than autarky for individuals whose income share is below some unique value* $\dot{\alpha}$*, while it is (weakly) less important for all the other, richer individuals.*

This is a key result because it informs us about how the economic equilibrium structures a divergence of interests among citizens. Whether the economy is opened to trade or not, the poorest segment of the population remains highly exposed to pollution. These people choose not to privately mitigate because of the high marginal utility of their consumption. Then given that trade causes more pollution, regulating pollution must have a stronger beneficial effect on their health with trade than autarky. For richer individuals, recall that by increasing real income and pollution, trade induces them to mitigate further. For those who receive a large enough share of aggregate income, the increased mitigation effort is so large that they become less sensitive to a reduction in pollution. Figure 2 summarizes proposition 5.

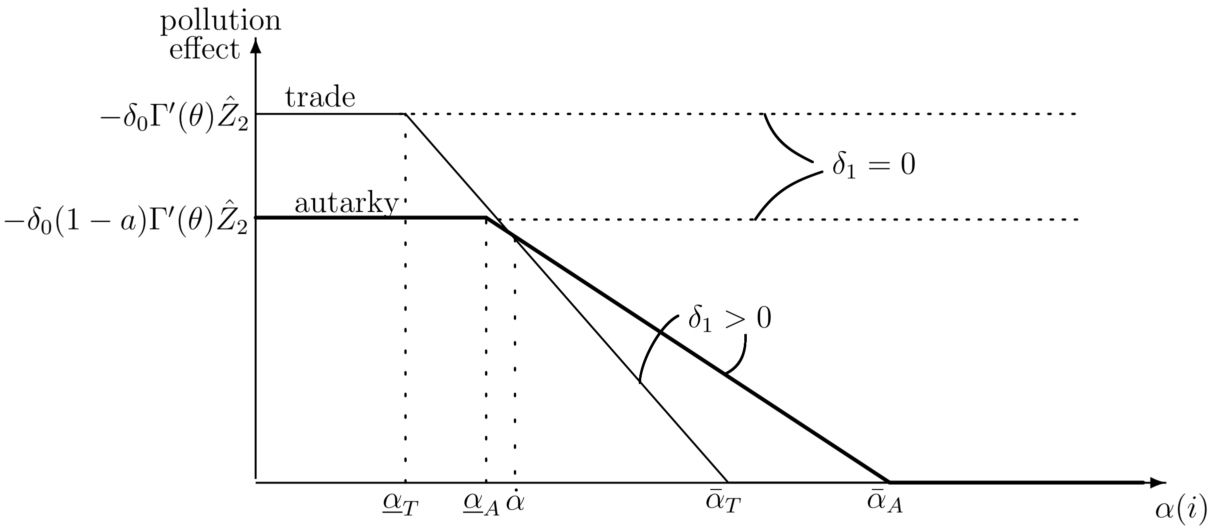

Figure 2: The marginal pollution welfare effect of regulation by income share for autarky and trade

6.2 The price-income welfare effects of regulation

In order to have a complete picture of the welfare effects of regulation, we must also consider the price-income effect. To do so, we can begin with the following proposition:

Proposition 6 *The marginal price-income effect of regulation varies non-monotonically with income shares. In absolute terms, it is (weakly) increasing at low income shares (below $\bar{\alpha}$) and decreasing at high income shares (above $\bar{\alpha}$).*

The best way to understand this result is by first observing that in the absence of private mitigation possibilities, the marginal price-income effect is the same regardless of income share. Indeed, even though those with higher income shares lose more from regulation in absolute terms, they also have a lower marginal utility of income, and the logarithmic form of utility that we use causes both effects to cancel out exactly. But once we introduce private mitigation possibilities, the diversion of expenditures away from consumption increases the marginal utility of income, so that there is now a net loss. The non-monotonicity stems from the fact that the poorest segment of the population does not privately mitigate while for the very rich, private mitigation has little effect on their consumption. Hence, for these two extreme income share levels, the marginal price-income effect converges to the same value, as if private mitigation possibilities were absent.

We also can assert the following:

Proposition 7 *In absolute terms, the marginal price-income effect of regulation is more important with trade than autarky for all income shares below or equal to $\bar{\alpha}_T$, as well as for arbitrarily large income shares.*

The basic intuition here is that with specialisation in the production of the dirty good, regulating pollution is more costly with trade than autarky. There is one possible exception for the income shares around $\bar{\alpha}_A$. The ambiguity is caused by the fact that $\bar{\alpha}_T < \bar{\alpha}_A$ and that the marginal price-income effect is decreasing under trade for $\alpha(i) > \bar{\alpha}_T$ while in autarky, it increases up to $\bar{\alpha}_A$.

Figure 3 illustrates propositions 6 and 7 for both trade and autarky.

7 Trade regimes and the demand for environmental regulation

We now analyze how trade openness affects the aggregate demand for environmental regulation. In this section, we continue to take the regulation level as given and consider the marginal effect of regulation on welfare when moving from autarky to trade. In the following section, we shall compare welfare levels when the degree of regulation emerges from a political process.

Note that in the analysis of individual demands for regulation, we shall consider both the *number* of individuals who demand stricter or laxer regulation and also variations in the *intensity* or depth of individual demands. Both numbers and intensity of demands play a role in the political process. We first have the following result:

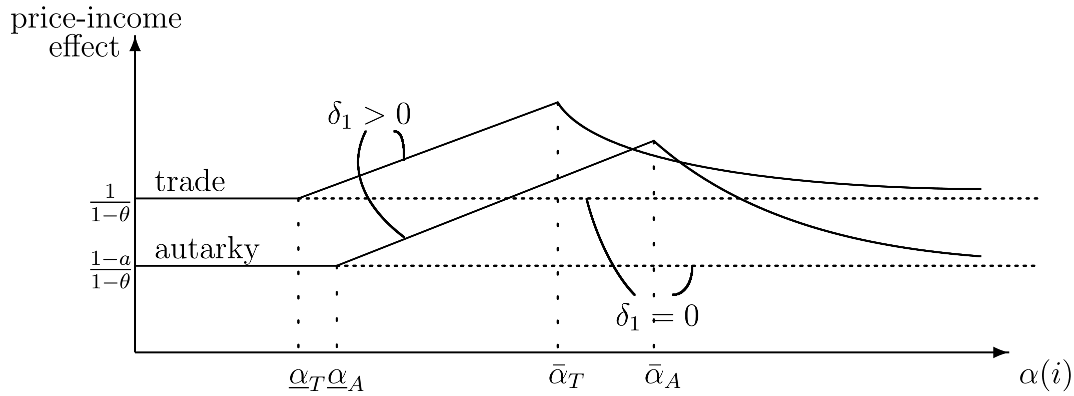

Figure 3: The marginal price-income welfare effect of regulation by income share for autarky and trade

Proposition 8 *The proportion of individuals who demand more environmental regulation is lower with trade than autarky.*

This proposition may appear counter-intuitive. Even though trade results in a more polluted environment, some individuals who in autarky preferred more stringent regulation now prefer less. But recall that the generation of more pollution constitutes only one channel through which trade affects the demand for regulation. One must also consider the price-income effect and the change in the pollution-mitigation effort that occur.

Under the assumptions of our model, the shift of expenditures from consumption to private mitigation induced by the higher pollution associated with open trade along with income gains makes individuals in the interior solution for $d^*_A(i)$ more sensitive to the price-income losses from regulation in comparison to the gains from lower pollution. This is illustrated in figure 4, where it is assumed that the following inequality holds: $1/(1-\theta) < -\delta_0 Q'_T(\theta)$.[16] The figure combines both the pollution and price-income marginal effects of figures 2 and 3. In autarky, the indifferent individual who receives income share $\tilde{\alpha}_A$ of the national income is (locally) indifferent between more or less regulation as his price-income loss is exactly compensated by his pollution gain. Under trade, his pollution gain falls while the price-income loss increases, and he now prefers strictly lower regulation. Under trade, the indifferent individual is one who receives a strictly lower income share $\tilde{\alpha}_T$.

[16]This inequality insures that in autarky, the lowest income individuals would prefer to have more stringent regulation. Given the previous results, this preference will become even more intense with trade.

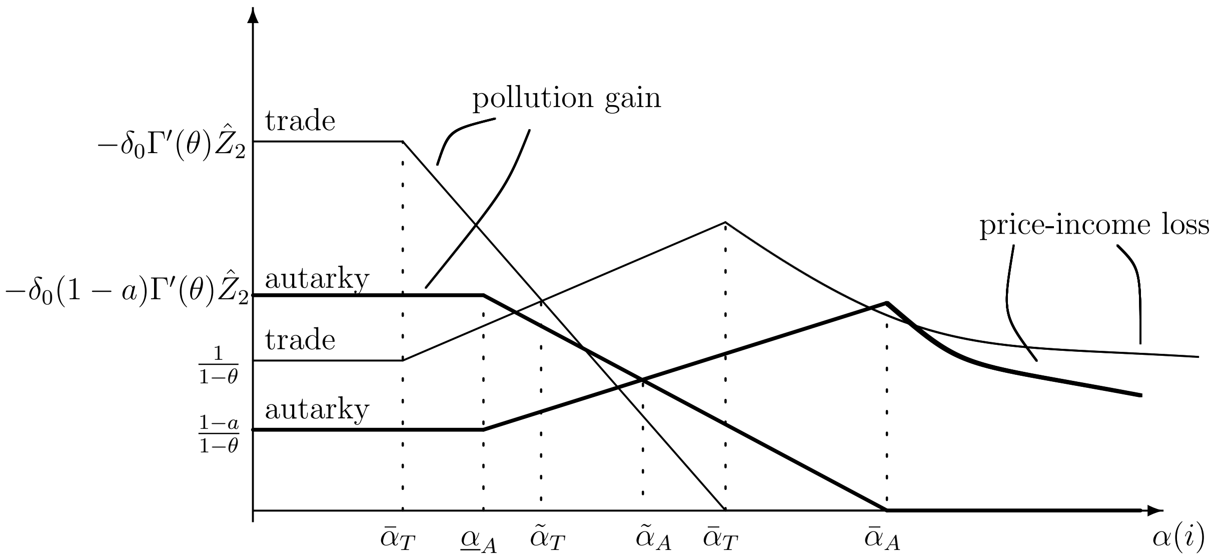

Figure 4: Pollution and price-income effects by income shares, for autarky and trade

One may be tempted to infer from the above that open trade leads to less stringent regulation. But this assumes that government policy is driven by numbers of voters only. A more complete view will account for changes in the *intensity* of preferences. In this respect, we have the following two propositions:

Proposition 9 *For lower income individuals, the intensity of the demand for more stringent pollution regulation increases with trade.*

This is illustrated in figure 4 by the fact that the gap between the pollution gain from more regulation and the price-income loss grows larger the lower the income share of an individual.

Proposition 10 *For high-income individuals and for a range of intermediate income levels, the intensity of the demand for less stringent pollution regulation increases with trade.*

For instance, in figure 4, one sees that those with high enough income will lose more from additional regulation under trade than under autarky.

We therefore have that on the one hand, trade reduces the number of people demanding more regulation (proposition 8). On the other hand, trade increases the intensity of the demand for *more* stringent regulation by the poorest individuals (propositions 9), while simultaneously increasing the intensity of the demand for *less* stringent regulation by the richest individuals, as well as for some intermediate income levels (proposition 10). These effects are not revealed by a simple normal good argument about environmental quality. Moreover, if regulation is a result of a political process that responds to the demands of citizens, then merely looking at changes at the number of individuals who demand more regulation may not suffice. One must also account for individual sensitivities to regulation.

In this respect, we are left with an indeterminacy concerning the impact of trade on the stringency of environmental regulation that is adopted. The policy outcome will depend on how the political process effectively weighs the heterogeneous and conflicting demands of various voters.[17] What we can say at this point is the following, which derives directly from propositions 9 and 10:

Proposition 11 *Trade exacerbates the divergence of interests over environmental regulation between low and high income individuals.*

In this section, we analyzed the effects of *marginal* variations in environmental regulation on individual welfare. We decomposed the marginal welfare effects of regulation into its various sub-components. This procedure yields insight into how the possibility of private mitigation, interacting with trade openness, leads to divergence of interests in environmental regulation when policy choices are exogenous. In the next section we depart from the marginal analysis of the effects of given policy choices and broaden the framework of analysis to include the determination of policy and the level of welfare in a political equilibrium.

8 The political-economy of environmental regulation in the presence of private mitigation

We proceed by simulating equilibria in political settings in which the economic structure analyzed above is embedded. To bring out the role of private mitigation, we first consider equilibria in which the possibility of mitigation is absent or prohibitively expensive for everyone, and then compare these outcomes to those that emerge when mitigation is feasible at some cost.

Our principal interest is in the role of mitigation in a fully democratic, competitive process. As is well-known, the outcome of such a political process can be represented by maximization, over the set of available policy instruments, of a synthetic function S that is a weighted sum of individual (indirect) utilities of the poor V_P^* and of the

[17] This is consistent with the recent empirical evidence in Farzin and Bond (2006) and Dasgupta et al. (2006).

rich V_R^* (see for example, Coughlin and Nitzan 1981, Coughlin 1992, and Hettich and Winer 1999):

$$S = s\eta_P V_P^* + (1-s)\eta_R V_R^* \tag{44}$$

Here the economic structure outlined earlier has been substituted into the indirect utility functions. Maximization of (44) is carried out with respect to the degree of environmental regulation θ, which is a continuous policy choice, and trade openness, which in our framework is a discrete choice. To simplify, but in a manner that allows the previous analysis to be used, all individuals have been aggregated into two groups, poor (P) and rich (R), with population weights s and $(1-s)$. The use of two income groups is sufficient to bring out the importance of the role of private mitigation.[18] The weights η_P and η_R reflect the effective political influence of the representative member of each group. These weights need not be identical in a democracy, but we shall assume that they are, further strengthening our focus on the role of private mitigation.[19]

It is important to note that the form of the support function in (44) and the weights on utilities are the result of the political process, and that the support function is not a social welfare function. The maximization problem in (44) is just a convenient way of calculating an equilibrium. The intuition behind the representation theorem is this: if a political party in a competitive, democratic system does not propose or implement platforms that move the society towards the Pareto frontier, it leaves open the possibility that the opposition can improve the welfare of voters and thereby increase its chances of electoral success. Competition insures that no such policy moves remain in equilibrium.[20]

To proceed further, we assume the following functional form for the effect of environmental regulation on pollution:

$$h(\theta) = 1 - \theta. \tag{45}$$

We also need to choose parameters for the economic structure, to be held constant throughout. The following values are ones that we have found to produce simulations that are especially illuminating:

$$b = 1,\ \hat{Z}_2 = 3,\ a = 0.5,\ \delta_0 = 2,\ p_T = 0.1.$$

[18] The use of two income groups is a simplification that has been used in many other political economy investigations, such as that by Acemoglu and Robinson (2006).

[19] On the difference between economic interests and political influence, see Hotte and Winer (2001).

[20] While policy choices are efficient in this formulation, the representation theorem can be generalized to allow for inefficient policy by breaking the link between utility and voting behavior (see, for example, Hettich and Winer 1999, ch. 6). We are not concerned with these inefficiencies here.

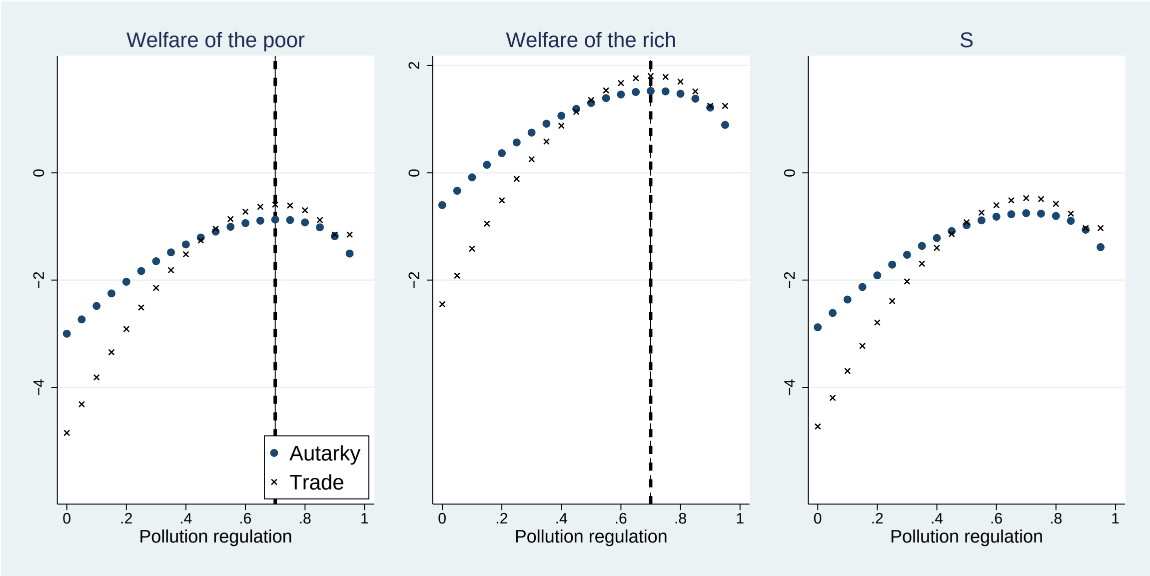

Figure 5: The welfare of the poor and the rich in autarky and trade, autocracy and democracy without private mitigation technology ($\delta_1 = 0$)

Finally, to set up the simulations, the poor and the rich respectively are assumed to make up 95% and 5% of the total population, the total size of which is normalized to one, with the income share of a rich individual set at eleven times that of a poor one, that is, $\alpha_R = 11\alpha_P$.

8.1 Equilibria without private mitigation

We begin the simulations with the case in which private mitigation is impossible for anyone, that is, when $\delta_1 = 0$. The resulting zero mitigation equilibria are illustrated in figure 5. The first panel shows the welfare of the poor in autarky and in the open economy, the second panel shows the welfare of the rich or equivalently, the welfare of the elite in the autocratic regime, again in autarky and under trade. Panel three shows political support S in (44), the maximization of which can be used to model the democratic outcome.

To help in understanding the shape of the curves in figure 5, we note first that in the absence of private mitigation, both groups prefer autarky over trade when the regulation level is low. This is because trade gains then cannot make up for the health losses that come with full specialisation in the production of the dirty good. We note also that when $\theta \geq 0.9$, political support in a democracy, illustrated in the third panel, is constant under trade. This is because at $\theta = 0.9$ there is a complete shift of specialisation in the economy from the dirty good to the clean good, and so any further increase in regulation has no consequence for the welfare of voters.

Globally speaking, the interests of the poor and the rich are perfectly aligned in the absence or infeasibility of private mitigation. Both groups globally prefer open trade with a substantial pollution regulation level set at $\theta = 0.7$.[21] Since both groups have the same interests with respect to public policy, autocracy and democracy lead to the same equilibrium policy choices.

Proposition 12 *In the absence of private mitigation, the political equilibria are identical under both democracy and autocracy, and both groups gain from trade.*

8.2 Equilibria when private mitigation is feasible

Things are quite different when private mitigation is feasible at a cost, as illustrated by the simulations with $\delta_1 = 0.2$ shown in figure 6. The interests of the rich and the poor are still perfectly aligned in autarky as in figure 5 (at point b in panel 1 and at e in panel 2). However, for the rich we see that the best option is for the economy to be opened to trade, and that trade openness be combined with the lowest regulation level in order to attain the highest welfare (at point a in panel 2). The higher pollution levels from specialisation that accompanies trade, combined with the higher income this produces, induce the rich to spend so much on private mitigation that they are insulated from the effects of pollution, and they would then prefer to reduce the regulation level to its minimum in order to benefit fully from trade gains.[22] Such an outcome turns out to be the worst for the poor who cannot afford to protect themselves (see point d in panel 1). Thus when private mitigation is feasible, it turns out that in the simulations of political equilibria, as in the marginal economic analysis earlier, trade openness interacts with choices about private mitigation to polarize the interests of citizens.

How are these interests represented in the political equilibrium of autocracy and of the democratic state? We see from figure 6 that trade openness is chosen under both political regimes, because both the welfare of the rich (in the case of autocracy) and political support (in the democratic case) are highest then. But environmental regulation levels are different in these two regimes.

In the open economy, an autocratic regime controlled by a rich elite would reduce the regulation level to zero, making the rest of the population worse-off than under

[21] This welfare maximizing value for θ is approximate since we simulated the economy with discrete increments of θ of 0.05.

[22] On the other hand, panel 2 indicates that with trade openness and increasingly strict regulation, the rich eventually will choose not to privately mitigate anymore, if given the choice, because of the consequent fall in their income and in the level of pollution, and they thus would return to public regulation as a preferred choice for dealing with pollution. This explains the presence of two local welfare maxima for the rich illustrated in the second panel of figure 6.

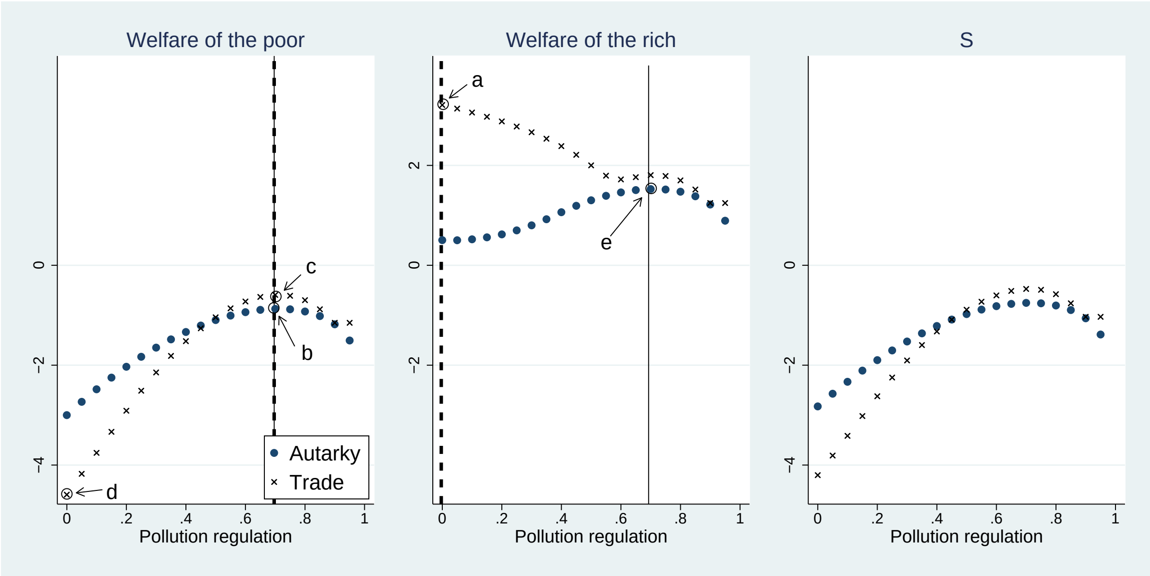

Figure 6: The welfare of the poor and the rich in autarky and trade, autocracy and democracy with private mitigation ($\delta_1 = 0.2$)

autarky (compare points b and d in panel 1 of figure 6). In this sense, trade and the feasibility of private mitigation together bring out the worst aspects of the non-democratic regime. In the democratic case, or speaking more generally, when lower income voters exercise political voice, the interests of the mass of voters swamp that of the rich. A stricter equilibrium regulation level of $\theta = 0.7$ (that maximizes S in the third panel of figure 6) emerges. In that case, collective choice leads to public action concerning environmental externalites because most voters cannot mitigate privately.

These patterns lead us to offer a final proposition and corollary about the relationship between environmental regulation and democracy:

Proposition 13 *('Democracy is good for environmental protection') When the health consequences of pollution can be mitigated privately at a cost, the nature of the political regime matters for the nature of equilibrium policy. In small open economies, public regulation of pollution will be stricter in democracies than in autocracies or in regimes governed by elites.*

The corollary is that when private mitigation is feasible, poorer citizens lose from trade in non-democratic regimes, while they gain from trade in a fully competitive, democratic system. In contrast, the rich gain from trade regardless of the regime type.

In assessing these results, it is important to recall that when private mitigation is infeasible, environmental regulation in the equilibria of both democratic and non-democratic regimes is the same. So in the present framework, it is not simply the fact that the poor have voice in a democracy that distinguishes them. The interaction of the cost of private mitigation and the consequences of trade in determining the level and distribution of economic welfare is also crucial.

As we noted in the introduction, both Congleton (1992) and Winslow (2005) argue that pollution control is greater in democracies because elites in non-democratic regimes receive a larger share of the income produced by the expansion of dirty industries, as they do in our framework. They also provide some empirical evidence to this effect. Proposition 13 and its corollary point also to the critical role of private mitigation in the relationship between the type of regime and the nature of environmental control, the cost of which will vary for different types of pollution, and which is not acknowledged in these interesting studies.

8.3 Intensity of preferences and the democratic equilibrium

In a last simulation, we illustrate our assertion that when it comes to trade and pollution in the presence of private mitigation, the intensity of preferences for regulation along with the size of interest groups is likely to play a role in determining the outcome of the democratic process.

In our representation of democratic political equilibria, the government maximizes a particular weighted sum of utilities S in (44). The effect of a change in regulation on optimized political support is therefore given by

$$\frac{\Delta S}{\Delta \theta} = s\frac{\Delta V_P^*}{\Delta \theta} + (1-s)\frac{\Delta V_R^*}{\Delta \theta}. \tag{46}$$

Here, population numbers interact multiplicatively with the sensitivities of welfare to changes in environmental controls - in other words, with the intensity of preferences for regulation - to determine which way the policy equilibrium will change.[23]

According to Proposition 11, trade exacerbates the divergence of interests between the poor and the rich. In expression (46), this translates into situations in which, for example, trade increases $\Delta V_P^*/\Delta\theta$ and reduces $\Delta V_R^*/\Delta\theta$. Figure 7 illustrates such a case. The only change from the situation illustrated in figure 6 is that the private mitigation technology parameter is raised from 0.2 to 0.4. This change - which reduces

[23] Note that we do not deal here with how pollution control and pollution vary with *mean* income levels, which is the subject of the Environmental Kuznets Curve (EKC), and our results are not inconsistent with it. Recent empirical results suggest that the EKC is driven mostly by how governance correlates with mean income (see, for example, Torras and Boyce (1998), Fredriksson et al. (2005), Farzin and Bond (2006) and Dasgupta et al. (2006)).

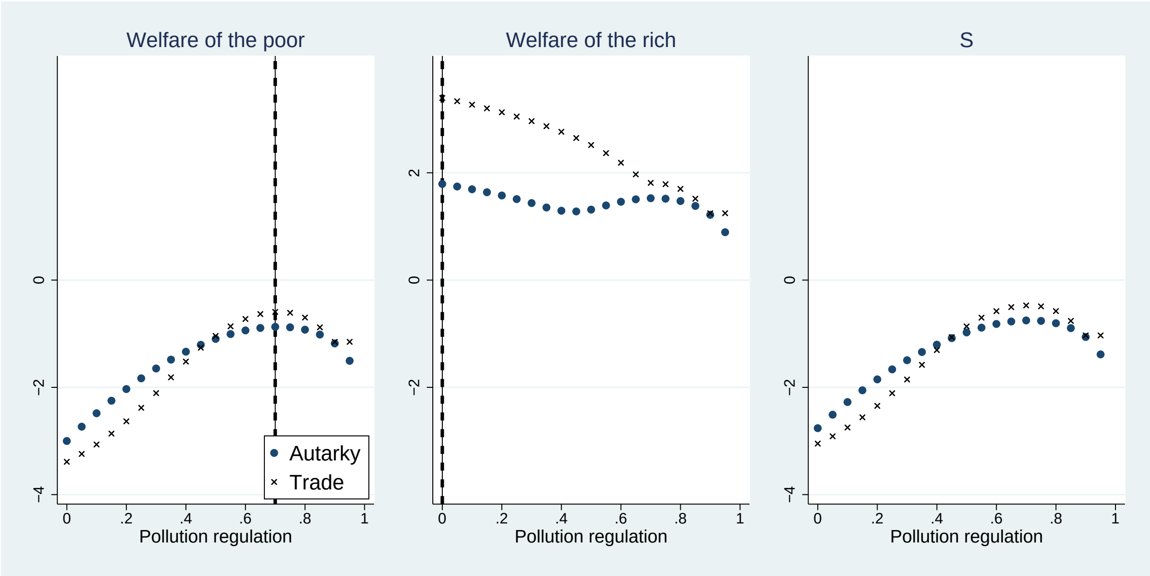

Figure 7: The role of the intensity of preferences ($\delta_1 = 0.4$)

the effective cost of private mitigation - has little impact on the decisions of the poor about mitigation. But it is enough of a change to induce the rich to be well protected privately against the health effects of pollution in autarky when the level of public regulation level is low.

As a consequence, the rich now prefer that there be no public regulation at all, either with or without trade, while the poor still want some positive level of public pollution control. And in line with proposition 11, this divergence of interests is exacerbated by a move to open trade. We see in figure 7 that as regulation increases, the welfare of the rich drops more sharply under trade than under autarky, while the welfare of the poor increases more sharply.

Due to their larger number, the democratic equilibrium under trade still favors the poor, at $s = 0.95$. But the fact remains that with trade, the absolute loss for the rich from stricter regulation is larger than in the closed economy. So while the rich may not mind so much about stricter environmental regulation under autarky, they may not be so pliable in an open economy. This observation suggests that (in a more complicated political setting than we have simulated) the rich may bargain harder before accepting stricter environmental regulation when their welfare is relatively more sensitive to policy changes. And if commitment to policy is a problem from the perspective of the poor, one can envisage situations in which the poor vote against more open trade even though it has the potential to improve the welfare of everyone, because they fear that more lax regulation will then be introduced in the interests of the rich.

It is interesting to point here to a comparison with Verdier's (2004) work on trade integration. He argues that since trade openness affects a government's ability to redistribute, it is not possible to discuss the politics of globalization without also considering those of internal redistribution. In this paper, the ability to redistribute is not explicitly part of the analysis. But in the analysis and simulations we have conducted, trade does raise the need for compensation of the poor due to the health effects of the pollution generated, depending on the costliness of private mitigation, and in a democratic equilibrium the rich essentially make sacrifices in their favor. In other words, when trade leads to environmental degradation, it is important to jointly analyze the distributive consequences of trade openness and of environmental regulation, and to do so in the presence of private mitigation, in order to understand public policy in either dimension.

9 Conclusion

We have analyzed in detail how the nature and heterogeneity of demands for public regulation of environmental externalities among citizens of differing incomes depend on the cost of private mitigation. And we have shown how the study of public policy towards regulation of the environment and of trade in dirty goods is altered when individual citizens can choose between costly collective and costly private alternatives for pollution control.

To better isolate the role of private mitigation, we have broken the link between factor endowments and citizen interests employed in much of the existing literature on trade and pollution, because private mitigation depends solely on individual income regardless of its source. In the context of a small open economy, we then analyzed in detail how the benefits and costs of open trade in dirty goods interacts with choices concerning private mitigation to polarize the interests of citizens concerning the degree of environmental regulation. Even though trade openness leads to increased pollution, the possibility of using some of the extra income generated by trade for private mitigation may allow the wealthiest to actually shelter themselves so as to be less affected by pollution. Poorer individuals may not be in a position to afford such protection even after benefitting from the gains that open trade produces, and will tend to favor collective rather than private action. In addition, we have analyzed how the intensity, as well as the direction, of individual demands for environmental regulation is affected by the possibility of private mitigation.

It follows from this analysis that the demands for trade openness are heterogeneous with respect to direction and intensity, and are also importantly influenced by the possibility of private mitigation. For it matters what kind of trade, with what degree of pollution regulation, one considers when analyzing who is in favor and who is against more openness. It is not surprising, therefore, that introducing the ability to privately mitigate at a cost opens up a host of possibilities concerning the nature of environmental regulation and its relationship to trade openness in a political equilibrium.

We conclude that acknowledging the role of private mitigation is essential for a full understanding of the political economy of the environment - trade - welfare nexus.

APPENDIX

Proof of proposition 2: It derives directly from equations (36) and (37).

Proof of proposition 3: Note first that with specialization in the dirty good, we have $Y_T = Y_A$. Given θ, trade causes both an increase in pollution Q and a decrease in the unit cost $c(p)$ of the pollution-mitigating effort. From (16), this results in a higher interior $d^*(i)$. As for corner solutions (14) and (15), it can be readily verified from (17) and (18) that trade's higher Q and lower $c(p)$ reduces $\underline{\alpha}$ and increases $\bar{\alpha}$.

Proof of proposition 4: In the case of corner solutions, the marginal pollution effect is independent of $\alpha(i)$. In the interior solution, the marginal pollution effect is equal to $-(\delta_0 - \delta_1 d_k^*(i))Q_k'(\theta)$. The result follows from the fact that $d_k^*(i)$ is increasing in $\alpha(i), \forall k \in \{A, T\}$.

Proof of proposition 5: The proof proceeds from the fact that the marginal pollution effect curve is continuous and non-increasing in $\alpha(i)$, as per proposition 4. The idea is then to show that the trade curve is steeper than the autarky one, that it begins above it and ends below it.

(a) Since $\underline{\alpha}_T < \underline{\alpha}_A$, all individuals with $\alpha(i) \leq \underline{\alpha}_T$ choose $d^*(i) = 0$, whether with trade or autarky. For them, the marginal pollution effect is equal to $-\delta_0(1-a)\Gamma'(\theta)\hat{Z}_2$ in autarky and $-\delta_0\Gamma'(\theta)\hat{Z}_2$ with trade (see (43)). Hence, the marginal pollution effect curve under trade is strictly above that of autarky at low $\alpha(i)$.

(b) For those who choose to be completely insulated from the effects of pollution, the marginal pollution effect is at the minimum value of zero. Since $\bar{\alpha}_T < \bar{\alpha}_A$, the marginal pollution effect is zero under trade for all $\alpha(i) \geq \bar{\alpha}_T$, while it is strictly positive under autarky for all $\alpha(i) \in (\bar{\alpha}_T, \bar{\alpha}_A)$. This implies that at $\bar{\alpha}_T$, the marginal pollution effect under trade is strictly below that of autarky and that for all $\alpha(i) \geq \bar{\alpha}_T$, the curve under autarky is not below the trade curve.

(c) For $\alpha(i) \leq \underline{\alpha}_T$, the slope is zero for both trade and autarky. For $\alpha(i) \in (\underline{\alpha}_T, \bar{\alpha}_T)$, the slope under trade is strictly negative while it is either zero or strictly negative under autarky. Now the strictly negative slopes correspond to the interior

value for $d_k^*(i)$ and are given by the following (see (43)):

$$\frac{\partial}{\partial \alpha(i)} \left\{ -\nu_k \left[(\delta_0 - \delta_1 d_k^*(i)) \Gamma'(\theta) \hat{Z}_2 \right] \right\} = \nu_k \left[\delta_1 \Gamma'(\theta) \hat{Z}_2 \right] \frac{\partial}{\partial \alpha(i)} d_k^*(i), \ k \in \{A, T\}.$$

According to (16), we have

$$\frac{\partial}{\partial \alpha(i)} d_k^*(i) = \frac{Y_k}{c(p_k)}$$

Since $Y_A = Y_T = (1-\theta)\hat{Z}_2$, $c(p_A) > c(p_T)$ and $\nu_A < \nu_T$, we have that the (negative) slope is steeper with trade than autarky.

Proof of proposition 6: The marginal price-income effects of regulation are given by the first terms between square brackets in (43) for all income shares. Taking the derivatives with respect to $\alpha(i)$ yields the following:

$$\begin{aligned} \frac{\partial}{\partial \alpha(i)} \left[\nu_k \frac{1}{1-\theta} \right] &= 0 \quad \text{when } \alpha(i) \leq \underline{\alpha}_k, \\ \frac{\partial}{\partial \alpha(i)} \left[\nu_k \frac{\alpha(i)\hat{Z}_2}{\alpha(i)Y - c(p)\frac{\delta_0}{\delta_1}} \right] &< 0 \quad \text{when } \alpha(i) \geq \bar{\alpha}_k, \\ \frac{\partial}{\partial \alpha(i)} \left[\nu_k \frac{\alpha(i)\hat{Z}_2}{\frac{c(p)}{\delta_1 Q}} \right] &> 0 \quad \text{when } \underline{\alpha}_k < \alpha(i) < \bar{\alpha}_k. \end{aligned} \tag{47}$$

Hence, the marginal price-income effect is initially constants up to $\alpha(i) = \underline{\alpha}_k$, is increasing for $\underline{\alpha}_k < \alpha(i) < \bar{\alpha}_k$ and is decreasing for $\alpha(i) \geq \bar{\alpha}_k$. The proof is complete by noting that the marginal effect is continuous at both $\underline{\alpha}_k$ and $\bar{\alpha}_k$, which can be verified by substituting the values in (17) and (18).

Proof of proposition 7: The marginal price-income effects of regulation are given by the first terms between square brackets in (43) for all income shares. For $\alpha(i) \in [0, \bar{\alpha}_T]$, the result is obtained by substituting for $\nu_A = 1 - a$ and $\nu_T = 1$, and for $e_A^*(i)$ and $e_T^*(i)$ in (14) and (16). For $\alpha(i) > \bar{\alpha}_A$, one can verify that $\lim_{\alpha(i)\to\infty} dV_k^*(i)/d\theta = -\nu_k/(1-\theta)$, $\forall k \in \{A, T\}$. The result follows from the fact that $\nu_T > \nu_A$.

Proof of proposition 8: Let $\tilde{\alpha}_k$ denote the wealth level of an individual who is marginally indifferent between more or less regulation, given θ. From (43), it can be verified that $\tilde{\alpha}_k$, if it exists, is unique and must be in an interior solution with respect to the pollution-mitigation effort. Moreover, $\tilde{\alpha}_k$ necessarily exists if there are some individuals who would prefer strictly more environmental regulation. $\tilde{\alpha}_k$ must be such that the price-income and pollution effects are equal; that is,

$$\frac{\tilde{\alpha}\hat{Z}_2}{e_k^*(i)} = (\delta_0 - \delta_1 d_k^*(i))\Gamma'(\theta)\hat{Z}_2. \tag{48}$$

From (16), we have that $e_A^*(i) > e_T^*(i)$ and $d_A^*(i) < d_T^*(i)$. Hence, the LHS of (48) is higher with trade than autarky while the converse holds for the RHS. An indifferent individual in autarky will see his price-income effect of regulation strictly exceed the pollution effect with trade and specialization in the dirty good. The proof is made complete by the fact that the price-income effect increases with $\alpha(i)$ while the opposite holds for the pollution effect.

Proof of proposition 9: For all those whose pollution mitigating-effort is nil with trade, the gap between the marginal pollution effect and the marginal price-income effect is higher by a factor $1/(1-a)$ when opening up to trade; their demand for additional regulation is thus more intense with trade. Among those who protect themselves partially, we have determined that income share $\tilde{\alpha}_T$ denotes the marginally indifferent individuals with trade and that the same individuals demanded strictly more regulation in autarky; the intensity of their demand for additional regulation has decreased with trade. By continuity of both marginal effect curves, an income share must exist which is comprised strictly between $\underline{\alpha}_T$ and $\dot{\alpha}_T$ and for which the intensity of the demand for additional regulation is equal in both autarky and trade.

Proof of proposition 10: Concerning the wealthiest individuals, we have seen that for arbitrarily large income shares, the pollution effect is nil while the price-income effect increases with trade (proposition 7). Concerning intermediate income shares, it can be verified that although the price-income effect of regulation peaks at $\bar{\alpha}_k$ in both trade and autarky, its magnitudes is higher with trade than autarky. Hence, by continuity of the curves, individuals with income shares located next to $\bar{\alpha}_k$ on both sides are more severely and negatively affected by regulation with trade than autarky.

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