Democracy Deficits, Inequality and Pollution. A Politico-Economic Analysis *

Thomas Drosdowski †

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Abstract

The article examines conditions, under which the degree of democratization influences environmental policy outcomes, with a given resource endowments' heterogeneity as a crucial feature of a politico-economic process. We develop an OLG model with pollution as an aggregate externality. The decisive voter chooses redistribution contributing to abatement financing. By comparing the optimal taxation under alternative political regimes we analyze their implications for environment, efficiency and growth. We find that left regimes, choosing more progressive redistribution, maintain better environmental quality, which supports empirical research. Inequality does not appear to be harmful for the environment, and it dampens the effect of democracy imperfections on redistribution.

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† Universität Hannover, Wirtschaftswissenschaftliche Fakultät, Institut für Makroökonomik, Königsworther Platz 1, 30 167 Hannover, e–mail: drosdowski@vwl.uni-hannover.de

1 Introduction

Recently, inequality and distributional issues seem to have returned to prominence as central topics of economic research and policy.[1] Moreover, an increasing amount of interest is being devoted to political economy as an alternative view on economic problems, going beyond the neoclassical paradigm. Within environmental and resource economics, however, a politico-economic approach linking inequality and pollution is rarely found. It is mostly a marginal theme contributing to the debate about the environmental Kuznets curve (EKC)[2] or an aspect of the rather unheralded environmental-justice literature.[3]

In our article, we try to fill the theoretical gap by examining conditions under which the degree of democratization influences environmental policy outcomes. An important feature of our research is heterogeneity of resource endowments whose distribution plays a crucial role in a politico-economic process. To our current knowledge, there do not yet exist many comparable investigations, although the literature has been recently extended by three related contributions. Magnani (2000) presents a simple static model, in which the median voter maximizes aggregate welfare by his choice of a pollution tax. She relates to the EKC-literature by trying to explain the falling part of the curve in richer countries. Politically preferred pollution tax is then an increasing function of the ratio of the median income to the average income. Relatively poorer individuals value consumption higher than environmental care. Inequality is showed to be detrimental to environmental expenditure if income growth reduces inequality, elasticity of preferences towards cleaner environment with respect to equality is larger than one and both environmental quality and consumed goods are normal goods. The author tests the impact of inequality on ecological R&D-expenditure in 11 OECD countries for the time period 1981-90, also controlling for per capita GDP and its squared measure. The results for Gini-index coefficients as inequality proxies are insignificant, whereas the ratio of the income shares of the first to the fourth quintile of the income distribution taken from Deininger and Squire (1996) performs better. However, the sign of the estimated regressor coefficient and its significance are mixed. Marsiliani and Renström (2000) also display conditions under which more equal income distribution may lead to cleaner environment using similar condition to obtain a negative relationship between inequality and environmental quality. Again, the main criterion is that both consumption and environmental quality are required to be normal goods. In their model, a decisive individual with skills close to the average maximizes her utility choosing both a capital and a pollution tax. Tax rev-

[1] The new World Bank Development Report (2005) supports this claim.

[2] See Torras and Boyce (1998). The EKC an empirical regularity linking economic development and pollution. It has a humped shape, similar to the original Kuznets curve.

[3] An example provides Martinez-Alier (2002).

enues are redistributed in a lump-sum manner. If the pivotal voter is poorer than the average, he will opt for higher capital taxation and a lower pollution tax, because of his lower marginal rate of substitution between environment and consumption. Finally, Eriksson and Persson (2003) expand the static version of Stokey's (1998) model, including heterogeneity of incomes and perceived environmental pollution. Environmental distribution is symmetric to the distribution of income, i.e. the richest individual is exposed to minimal pollution and vice versa. In a politico-economic process, the median voter decides about a pollution standard, equivalent to the cleanliness of the production process. There is a trade-off between a cleaner technology and the produced output. A democratization, which is understood as an expansion of the voting franchise towards the poor, changes the identity of the decisive individual. Therefore, the new median voter is poorer and more affected by pollution than the old one. Because it is also assumed that environmental quality and consumption are normal goods, he tightens the standard only if he suffers more from pollution than from smaller consumption opportunities. However, if there is no inequality with respect to pollution, a lower median income translates into higher marginal utility of consumption relative to environmental quality and therefore more natural degradation. Exogenous changes in income inequality have differential effects on aggregate pollution depending on the degree of democratization. When voting of the poor is restricted, more equality of distribution incurs an income loss of the decisive voter who chooses a dirtier technology, thereby exacerbating environmental quality. Conversely, under complete democratization a more equal distribution makes the median voter richer, leading to implementation of stricter pollution standards.

The enlisted models are fairly general. We offer some new features such as explicit modelling of democracy and income distribution, beyond the common usage of general functions. Furthermore, there is a more elaborate redistribution scheme and consideration of democratic restrictions towards richer individuals or social groups.

Basing upon Bénabou's "Inequality and Growth" (1996) we develop an overlapping generations model, augmented by environmental considerations. Therein, the production sector of the economy periodically generates an aggregate environmental externality causing disutility in the agents' utility functions. This externality can be reduced by an abatement technology, financed by the tax payers. Taxation of the young individuals' endowments, progressive or regressive in nature, provides the government with revenues, divided into purely redistributional transfers, as well as into a fixed share of the funds used as the foundation of the governmental abatement activity. Pollution reduction is considered as a public good (equivalent to provision of environmental quality), and it has distributional consequences. The devotion of funds to abatement is thus closely tied to redistribution in the model, describing a real process and being not merely a technical simplification. We do not model optimal environmental policy that usually aims at internalizing of the externality by equalizing marginal damage and benefits of pollution, which may add to the descriptive realism of our work. As Kirchgässner and Schneider (2003) recently stated, command and control measures still prevail in today's world, despite some observed slow changes in orientation towards market-based instruments.[4]

A politico-economic process can be formally pictured in many ways (competing lobbies, maximizing of political support functions or campaign contributions etc.) The easiest method, employed in the literature discussed above as well as here, is the median-voter approach that requires determination of redistribution in accordance with the voter's position in the distribution, single-peaked preferences and a large share of the voting population. Milanovic (2000) notes that this kind of collective-choice mechanism may not be an appropriate one, since in reality there are mostly representative democracies and direct voting usually does not take place, famous exception being Switzerland. His testing of the hypothesis, however, does not completely rule out the possibility that the middle class may be the deciding force in the political game.[5]

Following Bénabou (1996) and applying the median-voter theorem, we compare optimal tax rates chosen by the median voter and a social planner, at first. They are explicitly determined and could potentially be used for an empirical evaluation of the model's predictions. Later, we expand our analysis by allowing for exceptions from the median voter as the decisive individual in the politico-economic setting. In so doing, it is possible to observe how policy changes if the wealth of the decisive individual or group is higher or lower than the median one, given the lognormal distribution of endowments. Hence, we have an instrument to differentiate between "left" and "right" regimes and a possibility to constitute exceptions from the ideal of a perfect democracy with a complete enfranchisement of the citizens. Bénabou proposes dictatorship of the proletariat or unions' power as the rationale for the former, whereas the latter may take place through wealth-restrictions, lobbying, vote-buying and educational deficits of the poor. Milanovic and Gradstein (2004) also mention military suppression and information control by concentrated and censored media. Finally, Blankart and Mueller (2004) propound the argument that observed departures from full voting participation can be understood as a consequence of institutional weaknesses such as

[4]Bureaucratic instruments prevail, mainly because environmental bureaucracy, hand in hand with sectoral interest groups, favors them. The former focuses on the number of employees and budget size, which would probably decrease by introduction of simple, cost-efficient policies. The latter typically prefer more lax standards and oppose taxation or the obligation to buy permits, that reduce rents benefiting employers as well as workers.

[5]He discovered that it could be the case when not only transfers and pensions count but also transfers-in-kind. Nevertheless, he follows Bassett et al. (1999) in arguing that the decisive individual may be richer than the median voter.

certain voting procedures that keep voters from casting their ballots. From the existing literature on our specific topic, only Eriksson and Persson (2003), in a graphic way, show how the restriction of voting possibilities of the poor can influence environmental policies.

The endogenous policy determination allows us to examine efficiency, growth and environmental considerations under several political regimes. Additionally, we are able to discuss important trade-offs between these objectives, depending on the interaction of the model's parameters that underlie some restrictions. These parameters include the variance of the postulated lognormal distribution, as well as the exogenous fraction of tax revenues used for abatement, and the strength of the abatement technology versus the magnitude of technological contribution to environmental degradation. Given different parametric combinations, local pollution can strictly decrease with redistribution within its feasible boundaries, or, more likely, there can emerge an inverted U-shaped pattern with a maximum pollution rate. The growth rate of the economy has a similar relationship with redistribution, since pollution is a function of aggregate production. This result could be different in the presence of a savings-rate distortion whose absence may not be entirely unrealistic, since savings do not always follow changing taxation. Redistribution is often shown to be positively correlated with growth in general (Easterly and Rebelo (1993), Perotti (1996)) which could apply to this model for certain levels of redistribution.

In accordance with Bénabou's main findings, we show that "right" or wealth-oriented regimes wish less progressive redistribution than the median voter, which means more pollution, in case that pollution declines with more progressive redistribution. For a very low degree of progressivity, however, pollution may also be very low, since the credit-market restriction decreases income growth and thereby polluting activity. In turn, leftist regimes redistribute more to the poor, boosting abatement technology and environmental improvement.

In particular, the last insight finds increasing empirical support. In the most recent and conscious study using panel data from 21 OECD countries for the period 1980-99, Neumayer (2003) presents empirical evidence for a significantly negative impact of the parliament membership of parties identified as Green and left-libertarian on the levels of five air pollutants.[6] The same can be in general said about traditional left parties, i.e. Social Democratic parties in parliaments. However, once in power Social Democrats appear to conduct pollution-enhancing policies. Their cabinet membership is often associated with higher emissions. Jahn (1998) concludes in a previous study that a strong Social Democratic opposition (in 18 OECD countries between 1980 and 1990) is an important factor in improving environmental qual-

[6] Tanguay et al. (2004) obtain positive and significant coefficients in their regressions of environmental regulation on the votes of green parties in OECD countries.

ity measured by an aggregate index. He also shows that corporatism may be an important driving force for ecological advances, which is rejected by Neumayer's (2003) regressions. Another question he addresses is the explanation of "political regimes", characterized as "expansionist" ("consumption and growth oriented with short term problem solving and technological solutions"[7] and "limited" (putting emphasis on the limits to growth, resource preservation etc.), for which he utilizes energy use as a proxy. Out of the explanatory variables, two policy ones perform particularly well: strength of Social Democratic parties and, more pervasively, mobilization of new politics, an index capturing nuclear power protest, strength of environmental movement and election shares of pro-environmental parties. The effect of Social Democratic party strength is clearly stronger in the case environmental quality, indicating that traditional left parties are rather not inclined to change the policy regime. Further results indicate that they tend to focus primarily on the working class interests involving job security in polluting industries, arguably using environmental policies to attract Green votes. Accordingly, Kirchgässner and Schneider (2003) argue that left-wing parties are primarily interested in increasing revenues, helping the environment "for the wrong reason". It can be argued, however, that both Green and Social Democratic political forces are rooted in the same social movement, which emphasizes equity and solidarity among other issues. These objectives are linked to environmental problems, especially those of environmental justice.[8] Neumayer (2004) finds that left parties, traditionally displaying more pro-government and less pro-market stance combined with higher willingness to distribute, and their supporters are for stricter environmental measures. Especially left-libertarian and green parties are more willing to follow environmentally friendlier policies.[9] Developing countries do not differ in this respect from the industrial ones.
Policies labelled as (neo-)liberal and conservative do not seem to be well suited to protect the environment (Jahn 1998).

Growth considerations across regimes in this paper are constrained by parametric issues. With a humped shape of the growth function, the highest growth is realized in the range of taxes determined by wealth-oriented regimes. The maximal pollution is realized below the growth-maximizing redistribution rate, leading to a trade-off between environment and growth for rates below the pollution and above the growth maximum. Hence, the trade-offs occur in populist and highly wealth-oriented regimes. Between both maxima, i.e. for a moderately "right" regime, increasing progressivity of redistribution generates more growth and less pollution. Our theoretical results are in general highly dependent on the actual share of the tax

[7]See Jahn (1998, p. 144)

[8]A brief discussion is included in Neumayer (2003).

[9]They often differ from traditional left parties on such issues as protectionism and are more of advocates of individual freedoms, sharing postmaterialist values (ibid. p. 170).

rate, responsible for the level of abatement, which is realistically assumed to be very small. In addition, the value of the pollution parameter must not exceed the abatement parameter's value. Inequality, in the form of a mean-preserving spread, creates a need for higher taxation as an endogenous policy response. Furthermore, inequality dampens the effects of a given democracy imperfection on redistribution, e.g. moderate "left" regimes take marginally less from the rich in case of rising inequality. A higher fraction of tax revenues put into abatement, which corresponds to a smaller transfer volume, has ambiguous effects on the environment. If taxation is progressive, such direct strengthening of the abatement sector improves environmental quality, whereas regressive taxes render the opposite. The overall effect of inequality on pollution crucially depends on the magnitudes of the model's parameters. While the direct effect is always negative (pollution decreases), the indirect effect through taxes may be the opposite. It is more likely, though, that the overall effect is negative, which is inconsistent with the general result from the initially cited literature. Nevertheless, for some parameters, we may find an obviously non-linear relationship. The same can be said about the impact of inequality on growth. Whereas the direct effect is always negative due to the absence of capital markets, the indirect one is ambiguous. A comparison between socially optimal redistribution and various regime forms reveals that the left ones wish inefficiently high levels of taxation, whereas the "right" ones tend to implement taxes that serve the purpose of efficiency. We may thus expect a trade-off between efficiency and environmental goals in the case of a populist regime. For wealth-oriented regimes there may be a certain range of simultaneous efficiency and environmental improvements through progressive taxation. Otherwise, highly regressive taxation is associated with less efficiency and better environmental quality.

The paper is structured as follows. In section 2 we describe the economy's structure and the agents' optimizing behaviour. Section 3 introduces the environmental problem and shows how pollution changes with redistribution. In sections 4 and 5 we discuss socially and privately optimal taxation, as well as policies under various regime forms that have consequences for efficiency, growth and the environment. We conclude in section 6.

2 Economy

2.1 Economy's structure

We analyze an overlapping generations economy under perfect foresight. Each of its members i lives two periods and at each point in time there exist two generations, young and old. The population in a generation t is a continuum of agents normalized to one and it is not growing. A young individual is endowed with resources w_{it} which are independently and identically distributed with mean $w_t \equiv E[w_{it}]$ and normalized in a way that mean equals the aggregate. The government redistributes endowments, using a share of its revenues, B_t, to finance an abatement technology. The agent's remaining endowment is allocated between individual consumption c_{it} and investment k_{it} which is required to produce a second-period good y_{it}, consumed when old. The production sector causes an aggregate environmental externality X_t to the old generation. A credit market, allowing for borrowing or lending of resources, is absent.[10]

2.2 Households

Agent i in generation t derives life-cycle utility U_{it} from her consumption and disutility from the pollution flow, described by the following equation:

$$U_{it} = \ln c_{it} + \rho \ln d_{it} - \rho \ln X_t, \tag{1}$$

where d_{it} denotes second-period consumption and ρ is the time-preference factor with values between 0 and 1.[11] Thus, the individual budget restriction of a single member of the economy assumes the shape

$$\frac{\hat{w}_{it}}{B_t} = c_{it} + k_{it}, \tag{2}$$

with $\hat{w}_{it}$ meaning individual post-tax wealth resulting from redistribution (see subsection 2.5). The multiplicative redistribution scheme explains the form of the equation's left-hand side. In the second period, individual budget constraint is given by

$$d_{it} = y_{it}. \tag{3}$$

2.3 Production

The homogenous consumption good is individually produced, in accordance with individual flow of investment. Economy-wide resources, diminished by a fraction directed to abatement, yield an aggregate spillover, which generates endogenous growth as can be seen later. The individual production function is

$$y_{it} = A k_{it}^{\beta} \left(\frac{w_t}{B_t} \right)^{1-\beta}, \tag{4}$$

where A denotes a positive and constant technology parameter and $0 < \beta \leq 1$.

[10] The exclusion of the credit market from the analysis is the simplest way to analyze capital market imperfections. Moreover, it provides a justification for empirically observed redistribution.

[11] Note that the time preference is assumed to be equal for both d and X.

2.4 Individual optimisation

Prior to concentrating on the utility maximization of households it is necessary to describe the timing of decisions made in the model. In a first stage in each period, the young generation votes on policy, i.e. the redistribution measure τ, determining the political equilibrium. Given the chosen redistribution, every agent maximizes utility taking into account his budget constraints in a second stage. The solution of the model in the form of politico-economic equilibrium requires a backward calculation.
Therefore, each member of the generation t maximizes her lifetime utility subject to her intertemporal budget restriction, derived by combining of (2) - (4):[12]

$$\max_{c_i, d_i} \; \ln c_i + \rho \ln d_i - \rho \ln X$$

$$\text{s.t. } A \left[\frac{\hat{w}_i}{B} - c_i \right]^{\beta} \left(\frac{w}{B} \right)^{1-\beta} = d_i.$$

We obtain the standard Euler equation, calling for consumption smoothing between life periods in the economic equilibrium:

$$d_i = \rho \beta A k_i^{\beta - 1} \left(\frac{w}{B} \right)^{1-\beta} c_i \tag{5}$$

with the marginal rate of substitution of the individual being equal to her marginal productivity of investment. Substituting for d_i and rearranging the terms leads to an expression for the agent's optimal investment k_i, depending in linear fashion on his own post-tax wealth, since a credit market is missing:

$$k_i = \frac{\rho\beta}{1+\rho\beta} \frac{\hat{w}_i}{B} \equiv s \frac{\hat{w}_i}{B}. \tag{6}$$

Note that the savings rate s is constant and equal for all agents.[13] It is independent from taxation, due to redistribution of endowments instead of individual investment, as in the Bénabou paper.[14] Therefore, intertemporal resource allocation is not distorted by the government's fiscal policy.[15]
A household whose wealth has been redistributed before his consumption-saving decision cannot react, facing such a government intervention. Every agent invests a constant fraction of his post-tax wealth, produces and consumes according to his endowment. The Euler equation (5) shows that

[12] From now on we drop the time indices, where allowed.

[13] In fact, as Schmidt-Hebbel and Serrén (2000) report, there is no effect of income inequality on aggregate saving.

[14] He briefly discusses the possibility of such a way of redistribution but abstains from it due to time-inconsistency issues, which we ignore.

[15] In the seminal articles by Alesina and Rodrik (1994) and Persson and Tabellini (1994) a higher tax rate on investment reduces the propensity to save and thus aggregate saving.

marginal returns to investment decrease with invested wealth. Now, it is possible to rewrite the individual production function. Thus,

$$y_i = \frac{As^{\beta}}{B}\hat{w}_i^{\beta} w^{1-\beta}. \tag{7}$$

2.5 Government

The redistributing government has the following budget restriction:

$$w = \int_0^1 w_i di = E[(w_i)^{1-\tau}]\tilde{w}^{\tau} = E[(w_i)^{1-\tau}]\tilde{w}^{(1-\alpha)\tau}B. \tag{8}$$

τ is the redistribution rate, α an exogenous fraction of this rate devoted to abatement and $\tilde{w}$ the break-even wealth level resulting from the above balanced budget condition of the government. A household holding exactly this amount of wealth does neither gain nor lose in the process. Those poorer than it receive net transfers, whereas the richer ones make net payments. The economy-wide resources are taxed and spent on transfers and abatement. Redistribution occurs in a way that the expected value of pre-tax wealth equals the expected post-tax wealth. We use the log-linear Bénabou redistribution scheme resembling the concept of residual progressivity.[16] In this fashion, we are able to model progressive taxation for $0 < \tau < 1$ and regressive taxation for $-1 < \tau < 0$. The fraction of the budget devoted to abatement is expressed by

$$B = \tilde{w}^{\alpha\tau}. \tag{9}$$

Aggregation of the agents' individual production functions, using (7)-(9), results in the following expression:[17]

$$y = As^{\beta}E[(w_i)^{\beta(1-\tau)}]E[(w_i)^{(1-\tau)}]^{1-\beta}\tilde{w}^{(1-\alpha)\tau}. \tag{10}$$

2.6 Resource distribution and growth

In order to determine the long-run growth rate of the economy in scope, one must first specify the intergenerational linkage between the young and old. The second-period income of the generation t provides the endowment of the generation $t+1$ through an aggregate i.i.d. shock with mean value of one. Hence,

$$y_{t-1} = w_t \quad \text{and} \quad y_t = w_{t+1}.$$

[16] Musgrave and Tun Thin (1948) introduced the concept of residual income progression. τ is therefore the "ratio of the percentage change in income after tax to the percentage change in income before tax" (ibid. p. 507) or, simply put, post-tax income elasticity. This variable can be considered as a broad measure of redistribution including all sorts of transfers.

[17] $\hat{w}_i$ is equal to $w_i^{1-\tau}\tilde{w}^{\tau}$. Without stochastic endowments, y would collapse into an AK-type production function, with A, s and β being constants.

Division of both expressions provides the intergenerational change rate, which is equal to the intragenerational rate:

$$\frac{y_t}{y_{t-1}} = \frac{w_{t+1}}{w_t} = \frac{y_t}{w_t}.$$

While this kind of extremely simplified intergenerational link is obviously plausible for transmission of human capital, it may be considered as being problematic when physical capital is involved. However, as Bénabou (1996, p. 7) demonstrates, the linkage can be maintained by incorporating altruistic behavior of the parents into the analysis, and the resulting growth rate remains the same.[18] The growth rate $g(\tau)$ is defined as follows:

$$g(\tau) \equiv \ln(y/w), \tag{11}$$

which after substitution of expressions from (8)-(10) can be displayed as

$$g(\tau) = lnAs^{\beta} - ln\left(E[(w_i)^{(1-\tau)}]^{\beta}/E[(w_i)^{\beta(1-\tau)}]\right) - \ln B. \tag{12}$$

Whereas the intergenerational linkage and the definition of the growth rate stem directly from Bénabou (1996), the growth rate itself differs from his in two respects. First, the savings rate is tax-invariant. Second, and far more important, growth is directly diminished by abatement for $\tau > 0$.
The resource distribution is lognormal, i.e. the logarithms of w_i's are normally distributed with mean m and variance Δ^2 as its parameters,[19]

$$\ln w_i \sim \mathcal{N}(m, \Delta^2). \tag{13}$$

For every random $\ln w^*$ there exists unique probability p, which can be found by using the cumulative probability function of the standard normal distribution:

$$p = \Phi\left(\frac{\ln w^* - m}{\Delta}\right).$$

Inverting the function one obtains every possible quantile of the standard normal distribution, defined as λ:

$$\lambda \equiv \Phi^{-1}(p) = \frac{\ln w^* - m}{\Delta}, \tag{14}$$

thus $\ln w^* = m + \lambda\Delta$.

Note that for $\ln w^* = m$, λ is zero, i.e. the wealth position is the one of the median voter who is in the focus of the politico-economic process (e^m

[18] Basically, only the second-period consumption of the agents would be diminished due to their bequests. To keep matters as simple as possible, we have a reason to believe that it is justified to neglect such implications.

[19] Wealth distributions are lognormal, at least at low and middle levels (Atkinson 1971).

is the median wealth of the lognormal distribution). The beauty of such a specification lies in the possibility of modelling regimes or decisive voters lying left or right in the distribution, hence corresponding to negative or positive values of λ. In this way, political power inequality reflects economic inequality. Subsequently, we are able to transform the log expected value of a taxed endowment into
$\ln E[(w_i)^{\beta(1-\tau)}] = \beta(1-\tau)m + \beta^2(1-\tau)^2\Delta^2/2$
and
$\ln E[(w_i)^{(1-\tau)}]^{\beta} = \beta(1-\tau)m + \beta(1-\tau)^2\Delta^2/2$.[20]
Furthermore, $\ln w = m + \Delta^2/2$ and $\ln \tilde{w} = m + (2-\tau)\Delta^2/2$.[21]

Now, we turn again to the growth rate given by equation (12). It can be expressed as

$$g(\tau) = \ln As^{\beta} - \beta(1-\beta)(1-\tau)^2\Delta^2/2 - \underbrace{\alpha\tau[m + (2-\tau)\Delta^2/2]}_{\ln B}. \tag{15}$$

The growth function is concave with respect to τ if $\alpha < \beta(1-\beta)$. It possesses a maximum at τ^g if the condition $0 < \alpha < \left[\frac{2\Delta^2}{m+2\Delta^2}\right]\beta(1-\beta)$ is fulfilled. Then,

$$\tau^g = 1 - \frac{\alpha m}{[\beta(1-\beta)-\alpha]\Delta^2}.$$

If the growth function is hump-shaped with respect to redistribution[22], the intuition is straightforward. At first, rising progressivity of redistribution loosens the credit restriction of the poor and stimulates higher growth due to their higher profitability of investment. In this way, growth monotonously increases with progressive redistribution, given the fact that redistribution does not distort savings, therefore providing only benefits without cost. Yet further progressivity activates abatement and undermines efficiency, slowing down growth, after passing τ^g.[23] Inequality directly depresses growth due to missing credit markets and lower marginal returns from investment by the rich who gain, as compared to the standard case of a complete credit market, that is beyond the scope of this paper.[24]

3 Environment

The measure of flow pollution X is defined as follows:

$$X \equiv \frac{y^{\gamma}}{B^{\mu}} = \frac{y^{\gamma}}{\tilde{w}^{\alpha\tau\mu}}, \tag{16}$$

[20]For relevant information about lognormal distribution see Crow and Shimizu (1988).
[21]The proof is found in the appendix.
[22]This result has been empirically confirmed by Figini (1999).
[23]Incorporating a measure of deadweight loss in the model, as in Bénabou (2000), would illustrate the point even clearer.
[24]The indirect effect through taxes and the overall effect of inequality on growth are discussed in section 5.

where γ is the polluting contribution of the aggregate production, and μ denotes effectiveness of the abatement technology B^{μ}.[25] Both values are positive; μ is assumed to be bigger than γ, and the pollution parameter does not exceed unity. Taking logs for analytical convenience and using the properties of lognormal distribution from subsection 2.6, it is possible to express the components of the logarithmic pollution measure as follows:

$$\gamma \ln y = \gamma \ln As^{\beta} + \gamma(1-\alpha\tau)m + \gamma[(1+\beta^2-\beta)(1-\tau)^2 + (1-\alpha)\tau(2-\tau)]\Delta^2/2,$$

$$\mu \ln B = \mu\alpha\tau[m + (2-\tau)\Delta^2/2].$$

Log-pollution is then

$$\begin{gathered} \ln X = \gamma \ln As^{\beta} + [\gamma - \tau\alpha(\gamma+\mu)]m \\ +[(1-\tau)^2\gamma(1+\beta^2-\beta) + \tau(2-\tau)[\gamma - \alpha(\gamma+\mu)]]\Delta^2/2. \end{gathered} \tag{17}$$

To observe how pollution changes c.p. with policy, the expression (17) is differentiated twice with respect to τ:

$$\frac{\partial \ln X}{\partial \tau} = -\alpha(\gamma+\mu)m + (1-\tau)[\gamma\beta(1-\beta) - \alpha(\gamma+\mu)]\Delta^2,$$

$$\frac{\partial^2 \ln X}{\partial \tau^2} = -[\gamma\beta(1-\beta) - \alpha(\gamma+\mu)]\Delta^2.$$

In order to discuss the path of pollution in τ, we have to distinguish between two cases:

I. If $\alpha > \frac{\gamma}{\gamma+\mu}\beta(1-\beta)$, $\ln X$ is strictly decreasing in τ within the feasible interval $[-1, 1[$.

II. If $\alpha < \frac{\gamma}{\gamma+\mu}\beta(1-\beta)$, however, $\ln X$ is concave and reaches its maximum at τ^X if $0 < \alpha < \left[\frac{2\Delta^2}{m+2\Delta^2}\right] \frac{\gamma}{\gamma+\mu}\beta(1-\beta)$:

$$\tau^X = 1 - \frac{\alpha(\gamma+\mu)m}{[\gamma\beta(1-\beta) - \alpha(\gamma+\mu)]\Delta^2}.$$

Considering both cases, it is not immediately clear which one is more likely to occur. It depends on the political process and restrictions stemming from the median-voter theorem. Since the second one is more interesting, it will be discussed in more detail. The parameter α is chosen for comparisons.[26] Concentrating on it, we are able to determine its threshold values for

[25] Such a simplifying approach ignores, of course, the discrepancy between emissions and immissions.

[26] Numerical evaluations have shown that properties of the model are very sensitive to this variable's magnitude.

different situations applying to the second case. For $\tau^X < 0$ pollution peaks in the range of regressive taxes, thus decreasing with rising progressivity for

$$\alpha < \left[\frac{\Delta^2}{m+\Delta^2}\right]\frac{\gamma}{\gamma+\mu}\beta(1-\beta).$$

A ceteris paribus increase of α shifts τ^X to the left on the scale of taxes - the same impact having a change of μ. On the contrary, the tax rate increases with both Δ and γ. Thus, when inequality becomes c.p. larger in value, the turning point of log-pollution is reached for higher degree of progressivity. For high Δ, it is possible that this tax rate is also very high, which means that pollution may reach high rates over a wide range of possible redistribution values.

To analyze how inequality affects the environment, it is necessary to consider the effect of a mean-preserving spread on the median wealth first. Using the expression for mean wealth, $\ln w = m + \Delta^2/2$, it is clear that an increase in variance must be offset by a decrease in m by a standard deviation, or $\partial m/\partial\Delta = -\Delta$. The median individual of the distribution becomes poorer relative to the one with average wealth. Higher inequality has the following impact on the aggregate income:

$$\frac{\partial y}{\partial\Delta} = (1-\tau)[(1-\tau)(1+\beta^2+\beta)+(1-\alpha)\tau-1]\Delta.$$

Inequality reduces aggregate production for every feasible tax rate. The result is a direct consequence of the credit-market incompleteness, which restraints the income generation of poorer families with higher marginal returns to investment. The impact of inequality on abatement is given by

$$\frac{\partial B}{\partial\Delta} = \alpha\tau(1-\tau)\Delta.$$

It is positive for progressive and negative for regressive taxation. Only progressive redistribution activates the abatement technology. The whole direct effect on pollution, including the parameters γ and μ, reads:

$$\frac{\partial \ln X}{\partial\Delta} = (1-\tau)[-\gamma\beta(1-\beta)(1-\tau)-\alpha(\gamma+\mu)\tau]\Delta.$$

This effect is always negative, i.e. inequality reduces pollution by diminishing the aggregate production level (and thus growth), although regressive taxation redirects funds from abatement into polluting activities. A consideration of the indirect effect through taxes may change this basic result, which will be a matter of discussion in section 5. To complete our preliminary study of the pollution path, we differentiate $\ln X$ with respect to α:

$$\frac{\partial \ln X}{\partial\alpha} = -\tau(\gamma+\mu)-\tau(2-\tau)(\gamma+\mu)\Delta^2/2.$$

The second derivative equals zero, thus for $\tau < 0$, $\ln X$ increases with α in a linear fashion (proportionally more funds are taken from the abatement sector), while for $\tau > 0$ its decrease is proportional to rising α. What are the implications of this parameter in the model? As seen above, it is closely tied to redistribution and depends on the sign of the tax-variable.[27] For progressive taxes, its increase lowers transfers to the households and thus their savings, which leads to lower production and pollution levels. In addition, abatement financing becomes stronger, reducing pollution even further. Regressive taxation yields opposite effects.

So far, our analysis in this section was restricted to the environment as an isolated phenomenon. Given other general equilibrium effects, it is unlikely that the government chooses exactly this redistribution, thus not necessarily allowing for the realization of the highest possible pollution. To see which extent of taxation will actually be preferred, we have to closely analyze the politico-economic process.

4 Social and individual optima

In this section we examine the politico-economic process and compare its different redistributive outcomes.[28] Initially, we turn to the utilitarian social planner, concerned about aggregate intertemporal efficiency, whose decision is not affected by distributional pressures.[29] He maximizes the aggregate social welfare by his choice of policy, expressed by τ. Moreover, he now takes care of pollution, which has not been a subject of individual utility maximization. After substitution of aggregate values of c, d and X, his indirect utility function $W(\tau)$ takes the shape[30]

$$\begin{aligned} W(\tau) &= \ln c + \rho \ln d - \rho \ln X \\ &= \ln(1-s) + \rho(1-\gamma)\ln As^{\beta} + [1+\rho(1-\gamma) - \alpha\tau[1+\rho(1-\gamma-\mu)]]m \\ &\quad +[1+\rho(1-\gamma)[1+\beta^2-\beta]](1-\tau)^2\Delta^2/2 \\ &\quad +[[1+\rho(1-\gamma)](1-\alpha)+\rho\alpha\mu]\tau(2-\tau)\Delta^2/2. \end{aligned} \tag{18}$$

Taking derivatives yields
$W'(\tau) = -\alpha[1+\rho(1-\gamma-\mu)]m + (1-\tau)[\rho(1-\gamma)(\beta-\beta^2-\alpha) - (1-\rho\mu)\alpha]\Delta^2$ and

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[27] The same applies to c.p. increasing abatement parameter μ.

[28] Only the young generation votes throughout the paper as indicated earlier.

[29] In a setting with a complete credit market the planner would be the individual with average wealth, i.e. the representative agent, whose maximization of the net social benefit would be independent of the underlying wealth heterogeneity.

[30] $c = \int_0^1 c_i di = (1-s)w$, and $d = y$.

$$W''(\tau) = -[\rho(1-\gamma)(\beta-\beta^2-\alpha)-(1-\rho\mu)\alpha]\Delta^2.$$

For the function to be concave the expression in square brackets of the second derivative has to be positive. This means that the following condition for α must hold:

$$\alpha < \frac{\rho(1-\gamma)\beta(1-\beta)}{1+\rho(1-\gamma-\mu)}$$

with $1 > \rho(1-\gamma-\mu)$. A feasible, socially optimal tax rate, can be determined for $0 < \alpha < \left[\frac{2\Delta^2}{m+2\Delta^2}\right]\frac{\rho(1-\gamma)\beta(1-\beta)}{1+\rho(1-\gamma-\mu)}$. It reads

$$\tau^W = 1 - \frac{\alpha[1+\rho(1-\gamma-\mu)]m}{[\rho(1-\gamma)\beta(1-\beta)-(1+\rho(1-\gamma-\mu))\alpha]\Delta^2}. \tag{19}$$

Progressive taxation is chosen when $\alpha < \left[\frac{\Delta^2}{m+\Delta^2}\right]\frac{\rho(1-\gamma)\beta(1-\beta)}{1+\rho(1-\gamma-\mu)}$. It is not possible to conclude that the planner always chooses progressive taxation, as in Bénabou (1996), without several restrictions. The same caveat applies to every other tax rate determined below. Before we begin to compare the tax rates, that are optimal for different decision-makers, and their consequences, we have to go one step further and examine, which redistribution results from individual plans of other potentially decisive groups or agents. The indirect utility function of individual i is, after the usual transformation,

$$\begin{aligned} U_i(\tau) &= \ln c_i + \rho \ln d_i - \rho \ln X \\ &= \ln(1-s) + \rho(1-\gamma)\ln As^\beta + (1+\rho\beta)(1-\tau)[\ln w_i - m] \\ &\quad +[1+\rho(1-\gamma)-\alpha\tau[1+\rho(1-\gamma-\mu)]]m \\ &\quad +[\rho[1-\beta-\gamma\beta](1-\tau)^2[[1+\rho(1-\gamma)](1-\alpha)+\rho\alpha\mu](2-\tau)\tau]\Delta^2/2. \end{aligned} \tag{20}$$

As above, we concentrate on the individually optimal tax rate by maximizing the utility function with respect to τ. To ensure the function's concavity we have to examine the derivatives first:

$$\begin{aligned} U_i'(\tau) &= -(1+\rho\beta)(\ln w_i - m) - \alpha[1+\rho(1-\gamma-\mu)]m \\ &\quad +(1-\tau)[[-\rho[1-\beta-\gamma\beta]+[1+\rho(1-\gamma)](1-\alpha)+\rho\alpha\mu]]\Delta^2 \end{aligned}$$

and

$$U_i''(\tau) = -[1+\rho[\beta-\alpha-\gamma(1-\alpha-\beta)]-(1-\rho\mu)\alpha]\Delta^2.$$

Concavity is given for a positive term in the square brackets or

$$\alpha < \frac{1+\rho(\beta-\gamma(1-\beta))}{1+\rho(1-\gamma-\mu)}. \tag{21}$$

The individually optimal redistribution is then given by

$$\tau^i = 1 - \frac{(1+\rho\beta)(\ln w_i - m)+\alpha[1+\rho(1-\gamma-\mu)]m}{[1+\rho[\beta-\alpha-\gamma(1-\alpha-\beta)]-(1-\rho\mu)\alpha]\Delta^2}. \tag{22}$$

(22) shows that individuals richer than the median voter opt for a lower tax burden, whereas poorer ones want more progressivity of taxation. We will discuss these issues in more detail in the next section. In case of the median voter as the decisive individual, or $\ln w_i = m$, the expression reduces to

$$\tau^m = 1 - \frac{\alpha[1 + \rho(1 - \gamma - \mu)]m}{[1 + \rho[\beta - \alpha - \gamma(1 - \alpha - \beta)] - (1 - \rho\mu)\alpha]\Delta^2}. \tag{23}$$

It is feasible and satisfies the conditions of the median-voter theorem for

$$0 < \alpha < \left[\frac{2\Delta^2}{m + 2\Delta^2}\right] \frac{1 + \rho(\beta - \gamma(1 - \beta))}{1 + \rho(1 - \gamma - \mu)}.$$

Progressive taxation is implemented if

$$\alpha < \left[\frac{\Delta^2}{m + \Delta^2}\right] \frac{1 + \rho(\beta - \gamma(1 - \beta))}{1 + \rho(1 - \gamma - \mu)}.$$

A comparison between the socially efficient tax rate τ^W and the redistribution chosen by the median voter shows that the latter wishes more progressive redistribution if he is poorer than the planner, for $1 > \rho\gamma(1 - \beta)^2$, which is a standard insight of the literature (see e.g. Meltzer and Richards 1981).[31] How do politically determined taxes compare to those maximizing pollution and growth? Focusing at first on pollution, we are able to conclude that the pollution-maximizing rate is below the planner's solution, and thus the median voter's, if the following inequality is satisfied:

$$\mu > \frac{\gamma}{\rho}.$$

This condition is obtained by solving the inequality $\tau^X < \tau^W$ for μ. Having established the order between politically wished redistribution and the peak-pollution rate, we now perform this task with respect to the growth-maximizing rate. Once again, its position depends on the value of the abatement parameter μ. The striking result we obtain is that growth cannot be maximized by the median voter or a poorer decisive individual who votes for even higher redistribution. However, it is possible for the social planner or a slightly poorer decision-maker to attain maximal growth for $\mu \leq 1/\rho$. It is proved in the appendix. Thus, the following simple condition

$$\frac{\gamma}{\rho} < \mu \leq \frac{1}{\rho}$$

assures that taxes can be ordered in the following manner:

$$\tau^X < \tau^W < \tau^g < \tau^m,$$

which is helpful for conclusions drawn in the next section.

[31] We simply compare the denominators of both tax rates.

5 Democracy issues

5.1 Redistribution across regimes

As described in section 2, there is a possibility to examine policy outcomes of processes led by decisions of agents differing in their respective endowments from the median voter. For every λ a unique tax rate can be determined, given the fact that $\ln w^* = m + \lambda\Delta$. Substituting $\lambda\Delta$ for $\ln w_i - m$ in the expression for individually optimal tax rate (21) yields optimal redistribution seen from a pivotal group's perspective, the group being identified by its λ:

$$\tau^\lambda = 1 - \frac{(1+\rho\beta)(\lambda\Delta) + \alpha[1+\rho(1-\gamma-\mu)]m}{[1+\rho[\beta-\alpha-\gamma(1-\alpha-\beta)] - (1-\rho\mu)\alpha]\Delta^2}. \tag{24}$$

The main objective of this investigation is our coming to conclusion about the nature of redistribution and, subsequently, environmental consequences in situations of various democracy imperfections. Hence, it is crucial to confront optimal policies of the social planner and the median voter (perfect democracy) with those preferred by "left" or "right" regimes, relying on the order of the tax rates established in the previous section.

As far as perfect democracy is concerned to be the benchmark, it is easily seen that political domination of less wealthy groups leads to more progressive (less regressive) redistribution, compared with the median voter's solution, hence $\tau^\lambda > \tau^m$ for $\lambda < 0$, which results from the expression (24). Consequently, growth is lower, declining with redistribution for $\tau \geq \tau^m$. As already seen, the growth maximum is below τ^m. Thus, values above this rate are associated with the falling part of the hump-shaped growth curve. The environmental quality is better, since pollution is decreasing with tax progressivity. There is a clear trade-off between environmental goals and growth. In the opposite case, that is $\lambda > 0$ ($\tau^\lambda < \tau^m$), rich pivotal voters enforce less progressive (more regressive) redistribution, thus opting for more aggregate growth, which is maximal if the redistribution is not excessive.[32] Very regressive redistribution, however, is far from the growth maximum, which means that growth becomes low. On relatively moderate levels of regressive redistribution, pollution is expected to be rather high. Still further redistribution in this direction leads to the pollution maximum, after which pollution declines. For tax values below τ^X, the trade-off also takes place. Only in the range between τ^X and τ^g higher progressivity generates more growth and less pollution.

[32] The real link between workers or the poor and left parties on the one hand and between upper classes and right parties on the other hand appears to have weakened in recent years, which somewhat obscures the picture. See e.g. Grofman et al. (1999).

5.2 Democracy, environment and growth

This subsection contains a brief overview of the relevant theoretical and empirical literature linking aspects of democracy (voting participation, electoral competition, electoral systems) to environment and growth. Some of the results are compared to those obtained in the paper.

Democratic participation
While in reality populist regimes with decisive voters poorer than the median are usually not observed, there appears to be a historical tendency towards power sharing of the wealthy elites in the form of democratization and increasing redistribution.[33] One of the explanations is provided by Acemoglu and Robinson (2000) who argue that Western elites of the nineteenth century extended the voting franchise for strategic reasons in order to avoid violent upheavals of the lower classes. Gradstein (2005) demonstrates in his theoretical framework that democratization could have been a rational outcome of the elite's long-term benefit considerations. They may have introduced growth enhancing property rights and other institutions without the violent threat by the masses in situations where initial inequality was not excessive.[34] Otherwise, rent-seeking was their preferred option. To prove its point the paper compares the cases of Russia and Britain. Empirically, the connection between distribution of power and economic resources and endogenously determined institutions is strongly supported, using World Bank data from 121 countries. The income share of the middle class is also positively correlated with institutional indicators. Lizzeri and Persico (2004) concentrate directly on the link between democratisation and the provision of public goods without focusing on institutions such as property rights. In their work, enfranchisement is a product of internal power struggles within the elite and is associated with more public goods.

This kind of reasoning lies behind the already mentioned story told by Eriksson and Persson (2003), which can easily be incorporated into the framework presented here. A democratization means that the identity of the decisive voter shifts from a more or less wealthy group towards the median voter, corresponding to a diminishing λ. In this case, redistribution increases, environmental quality as well, while growth decreases. This result is partly confirmed by the findings of Mueller and Stratmann (2003), who assert that higher democratic participation is associated with more equal income distribution, larger government sectors and lower growth rates, testing various hypotheses empirically. While the participation in voting directly reduces inequality, it has also indirect effects on inequality through increased government spending or transfers (generally only in democracies with strong

[33]The theoretical possibility that poorer members of society obtain larger political weight due to appropriate interest organization is nevertheless still valid.

[34]Related work linking inequality and institutions is e.g. Glaeser et al. (2003).

institutions), reflecting the "class bias" caused by limited participation of the poor in elections due to educational deficits, which impose higher costs of being informed about them. However, in weakly democratic Latin and Central American countries the indirect effect leads to more inequality being an indicator for a common "government capture" by the rich in this part of the world.[35] For this capture does not occur in weak democracies outside this continent, the authors do not support the thesis of Li et al. (1998) that link this phenomenon to weak democratic institutions. Increased government size due to larger participation is negatively related to growth which could reflect inefficiencies brought about by redistribution and thus the equity-efficiency trade-off.

Milanovic and Gradstein (2004) provide an insightful survey on the relationship between inequality and democracy, concentrating on political freedoms such as freedom of speech or party formation and accountability of political elites. They suggest that political stability and quality of governance are not necessarily indicators of democratization, for they can be observed in autocratic regimes as well. Their summary of case studies referring to the role of voting franchise extensions as the sole factor responsible for inequality reductions indicates that while historically important, especially concerning voting rights of women, such expansions do not play a bigger role in explaining the current relationship between inequality and democracy in developed countries. A brief examination of the literature linking political liberties to inequality, which may be a better proxy for democracy, leads them to the conclusion that the relationship in contemporary empirical studies using steadily improving data tends to be negative. However, their own regression analysis shows that a change of political and civil freedoms in transitional, i.e. formerly communist, economies seems to be associated with a positive change in inequality, which decreases with the degree of democratization. The intriguing theoretical possibility of the finding is that inequality reducing democratization simply takes some time and the transition period may exacerbate equality at first.

Electoral competition

Fredriksson et al. (2005) analyze the importance of democratic participation combined with electoral competition, which is also an intrinsic element of democratization, for environmental policy. Using data from 82 developing countries and 22 OECD countries while taking the lead content of gasoline as their proxy for environmental quality, they show in the empirical part of their paper that political competition positively affects environmental policies under the condition that democratic participation is broad. However, participation alone is not sufficient to ensure better policy outcomes - the reported positive effects vanish in dictatorships. Interestingly, the authors

[35] More on political economy in Latin America contains e.g. Chong and Zanforlin (2004).

derive a policy implication for developing countries suggesting that environmental groups in these countries should be supported with aid. Since environmental policy is still widely regarded as being a "secondary" policy issue, List and Sturm (2004) investigate whether it has some importance for re-election purposes of politicians. They find that environmental spending is very likely to be changed as a reaction on a stronger political competition. When the support for an incumbent politician (state governor in the US) is sufficiently strong he will not change his policy, whether it is environment-friendly or not. However, when the re-election is at stake, the incumbent will reduce environmental spending in a "green" (i.e. having ecologically friendlier policies) state and increase it in a "brown" (i.e. neglecting environmental issues) state. The general importance of political competition is highlighted in Besley et al. (2005), showing that the abolishment of the voting impediments in the form of poll taxes and literacy tests following the Civil Rights and the Voting Rights Act in the southern states of the US significantly improved not only their growth performance but also the quality of policies and politicians. Whereas before reforms the Democrats with de facto political monopoly power, obtained by racist politics, often served special interests, were not forced to be accountable and did not have to rely on qualified personnel, the situation changed with their implementation. Afterwards, with more competition more skilled politicians became incumbents, promoting growth-enhancing policies that included lower taxes. These insights too are compatible with our theory. Considering an initial situation with a strong wealth bias, low growth and highly regressive taxation, a higher degree of electoral competition and participation shifts political power to the "middle" of the distribution, generating growth and reducing redistribution in absolute terms (less is redistributed in a more progressive way).[36] Stratmann (2005) points out that participation in political competition is often restricted by party endorsement, filing fees and signature requirements. Using data on state elections in the US from 1998 and 2000 he shows that indeed incumbents prevent political competition (entry barriers), mainly by imposing filing fees.[37] Signature requirements are only significantly negative for the entry of major party candidates, while the impact of endorsements has not been tested. Similar analysis has not yet been made in the area of environmental policy. Yet despite current data scarcity, especially pertaining to developing countries, there are some indications that democratic countries are more likely to tackle various aspects of environmental devastation.[38]

[36]Complementary to Besley et al. (2005), Husted and Kenny (1997) report that the end of the voting restrictions in the South was associated with increasing transfers but lower overall spending.

[37]A 1000$ increase of those reduces the number of major party candidates by 5 percent and minor party candidates by 43 percent.

[38]Congleton (1992) shows that democratic countries from a sample of 118 ones are significantly more inclined to sign international treaties to reduce ozone depleting sub-

Electoral rules and political systems
Another important political determinant of stricter environmental policies is the set of given electoral rules within countries. The proportional voting rule forces political parties to consider the welfare of the entire electorate. Under a majoritarian system with single-member districts a party must only win the majority of votes in the majority of constituencies, having the leeway to ignore some of the preferences of the voting individuals. In fact, Fredriksson and Millimet (2004b) find supporting evidence that in majoritarian systems environmental policy is much weaker.[39] When more members are elected in a district a need for a proportional voting rule arises, which forces parties to target the votes of each district, resulting in more redistribution and less inequality.[40] Empirical evidence for this conjecture has recently been provided by Verardi (2005). Employing panel data for 28 democratic countries, he demonstrates that an increase in the mean voting district magnitude significantly lowers inequality measures. Another institutional feature may also be of some importance for environmental outcomes: the distinction between parliamentary and presidential-congressional regimes. Fredriksson and Millimet (2004a) find evidence that in the former gasoline taxes tend to be higher. They see this result as being supportive of the theoretical framework provided by Persson et al. (2000), within which legislative incentives are different across both regimes. Assuming that political delegates act in their own interest without being held accountable by the voters, presidential systems are associated with a stronger separation of powers, since a president and a legislative body are directly elected. In addition, such a system displays less disciplined behavior on the part of the parliament members, often building loose arrangements on single issues. The opposite is true for parliamentary systems, in which governments require stable majorities (less separation of powers and more legislative cohesion). Therefore, the former regimes are expected to redistribute rents in a more moderate way than the latter. Fredriksson and Millimet (2004a) argue that their data may support lobby theories as well.

5.3 Efficiency considerations

If the decisive voter in the model is poorer than the median voter, she automatically chooses more redistribution than the social planner, which results in even more economic inefficiency. The situation is much less clear for pos-

stances (Vienna Convention and the Montreal Protocol). The insight that democracies are faster to ratify international treaties is confirmed by Fredriksson and Gaston (2000) and Neumayer (2002).

[39] Using a sample of 86 "democratic" countries, they show that their majoritarian-system variable is negatively correlated with the Environmental Sustainability Index, at the 10 percent level.

[40] See for instance Person and Tabellini (1999), Milesi-Ferretti et al. (2000) or Lizzeri and Persico (2001).

itive λ-values, corresponding tax rates being above or below τ^W. However, it is still possible to obtain a threshold value λ^W, for which the chosen tax rate is socially optimal, i.e.:[41]

$$\lambda^W = \frac{\alpha[1 + \rho(1 - \gamma - \mu)]m(1 - \rho\gamma(1 - \beta)^2 + \rho\beta^2)}{(1 + \rho\beta)[\rho(1 - \gamma)(\beta - \beta^2 - \alpha) - (1 - \rho\mu)\alpha]\Delta}. \tag{25}$$

$>$From (21) it is known that the denominator must be positive. For $1 > \rho\gamma(1-\beta)^2 + \rho\beta^2$, the numerator of (24) is positive either, which guarantees a positive λ^W. Thus, for pure efficiency purposes some kind of wealth-oriented regime is required. Nevertheless, it is worth mentioning that too large a wealth-bias against the poor is also inefficient, considering the resulting insufficient redistribution.

5.4 Properties of tax rates

Politically determined tax rates have some common properties. In particular, ceteris paribus changes of exogenous variables lead to changes in optimal redistribution. This value increases with higher pollution parameter, inequality and, perhaps surprisingly, abatement technology parameter, while decreasing with higher tax-share for abatement.
Increasing γ depresses environmental quality. To mitigate negative welfare effects for the optimizing decisive individual, higher taxation is needed to make abatement work. Interestingly, the same effect is found for increasing μ, although it does not directly harm the environment. It can do so for regressive taxation, which is the reason why increased redistribution may be needed. For progressive taxes, the abatement technology counters natural degradation. However, it is optimal to raise them incrementally to fully realize welfare gains from improving abatement efficiency. The negative effect of higher tax-share for abatement on taxation is not easy to explain, since α influences all important endogenous variables of the model. Consumption and income growth are depressed, while pollution depends on the sign of τ. For progressive taxes, environmental quality improves while consumption decreases, growth (and income) being inversely U-shaped with respect to taxation, which leads to higher welfare losses than gains. Thus, redistribution must become less progressive. For regressive taxes, consumption increases while pollution rises and even more regressive taxation is required to be optimal.

5.5 Inequality's impact on growth and pollution

What can be said in detail about the differential effects of inequality on redistribution? Differentiation of the optimal tax rate τ^λ with respect to the

[41] We simply equalize (19) and (23) and then solve for λ.

measure of inequality Δ, taking into account the effect on the median wealth (mean-preserving spread, as in section 3), gives a unanimously positive relationship for all feasible values of λ. Hence, rising inequality creates the necessity to redistribute more, no matter who the deciding voter is:

$$\frac{\partial \tau^{\lambda}}{\partial \Delta} = \frac{(1+\rho\beta)\lambda\Delta + \alpha(2m+\Delta)[1+\rho(1-\gamma-\mu)]}{N\Delta} > 0, \tag{26}$$

N being the denominator from (23).[42] Looking at the cross-partial second derivative with respect to inequality and wealth bias we find that it is unambiguously positive, i.e. rising λ amplifies the above discussed effect on taxes. Thus, a richer decisive individual reduces redistribution less, whereas a poorer one increases taxation more moderately. Considering the indirect effect of inequality on growth through taxes, which can be denoted as

$$\frac{\partial g(\tau)}{\partial \Delta} = \underbrace{\frac{\partial g(\tau)}{\partial \tau}}_{+/-} \underbrace{\frac{\partial \tau}{\partial \Delta}}_{+},$$

we can conclude that it is only negative for tax rates exceeding the growth-maximizing rate, which essentially includes redistribution chosen by leftist regimes, given the fact that the direct effect is always negative. For sufficiently regressive redistribution the indirect effect turns positive and may outweigh the direct effect. Then inequality would marginally increase progressivity, which would have very strong marginal impact on growth (the slope of the growth function being high), because of larger transfers to the poor with higher marginal returns to investment. This ambiguity seems to reflect a variety of problems found in the literature analyzing the relationship between inequality and growth. The theoretical models using credit-market imperfections and/or political economy as explanations for this link[43] are inconclusive about the actual shape of a curve illustrating it. Empirically, a similar picture arises. While some rather older studies suggest that it might be negative, newer ones using more advanced econometric methods and data sets (Li and Zou 1998, Barro 2000, Forbes 2000) claim that the opposite may be true. The most elaborate recent study by Banerjee and Duflo (2003) criticizes all of them, especially for employing linear specifications of the estimated relationship. Their analysis, using an array of robustness checks, shows that, if anything, there is a non-linear, U-shaped relationship between net changes in inequality and the growth rate. Changes in inequality seem to be always associated with growth losses. Abstaining from the problem

[42] Only a decisive voter on the far left, already implementing an excessive level of transfers, would choose to c.p. lessen the degree of taxation, confronted with rising inequality, for $\lambda < -\frac{\alpha(2m+\Delta)(1+\rho(1-\gamma-\mu))}{(1+\rho\beta)\Delta}$. However, it is not feasible, because the lower bound for λ, corresponding to full expropriation, is $-\alpha m(1+\rho(1-\gamma-\mu))/(1+\rho\beta)\Delta$.

[43] Others being social conflict, status or demand-side considerations.

of reversed causality, a simple politico-economic model provides a theoretical rationale for the result. Therein, higher inequality creates demands for redistribution which in turn initiate efficiency- and growth-reducing redistribution. Lower inequality is only possible if there is a class struggle and an enforced transfer (in whose absence the economy would not grow at all), which also reduces growth. In sum, it is still possible that the steady influx of new high-quality data and ever improving econometric tools will illuminate this hidden nexus. For now, however, the evidence on this central economic issue is far from being satisfactory.
The indirect effect of inequality on log-pollution is also ambiguous:

$$\frac{\partial \ln X}{\partial \Delta} = \underbrace{\frac{\partial \ln X}{\partial \tau}}_{+/-} \underbrace{\frac{\partial \tau}{\partial \Delta}}_{+}.$$

A mean-preserving spread in the underlying distribution causes more progressive taxation, while rising taxes have an ambiguous impact on environmental quality. Concentrating on the bell-shaped relationship between pollution and taxes, known from section 3 as the case II, it is clear that if the chosen tax rate is below the one associated with the highest pollution, τ^X, environmental damage rises with taxation, and the indirect effect is positive.

However, if it is above τ^X, pollution declines with higher taxation. Keeping in mind, that the direct effect of inequality on pollution is negative, the overall effect is always negative for $\tau > \tau^X$. It could theoretically become positive for highly regressive taxation, which would support the result from the related literature.[44] Then an inequality-induced marginal tax-increase would cause a production boost, due to high marginal productivity of the poor, which, combined with an inactive abatement sector, would increase aggregate pollution. Unfortunately, it is not possible to determine the crucial threshold value of τ, for which the change of direction of the overall effect could still occur, without employing a numerical evaluation.
Finally, we devote our attention once again to the c.p. effects of rising contribution of tax revenues to financing the abatement, or simply rising α, on the optimal taxation. Recall that there is a negative influence of rising environmental expenditures on redistribution. The cross-partial second derivative with respect to λ is negative, which means that the marginal effect of increasing environmental tax share becomes stronger with the political power shifting towards the richer individuals, if the λ-value is not too low. The cross-partial second derivative with respect to inequality is positive, i.e. in most cases rising tax share for environmental technology diminishes the marginally positive effect of inequality on tax progressivity.

[44] See the introduction for the discussion.

6 Conclusions

Within the proposed framework it is possible to analyze how political economy and inequality influence environmental outcomes. We obtain numerous results being in accordance with theoretical and empirical findings, especially those stemming from both the public-choice and the environmental-economics literature, despite its complexity. As always in such investigations parameter restrictions are crucial for the outcomes. In this respect our article provides no exception. Tax-determination and the state of the environment crucially depend on the characteristics of the analyzed economy. In this paper, the relevant exogenous variables are variance of distribution, tax share for abatement, a pollution and an abatement parameter.

The main general result is that left regimes tend to improve environmental quality and decrease growth through higher progressivity of taxation, while neglecting economic efficiency. On the other hand, wealth-oriented decision-makers usually opt for less environmental protection and higher growth, combined with more efficiency. These results rely heavily on the assumptions that the tax share used for abatement and the measure of abatement technology are bounded by parametric constraints, which allows an ordering of various redistribution values, and that the production sector is moderately polluting. In addition, the abatement parameter must always outweigh the pollution parameter. Under the median-voter hypothesis, perfect democracy would establish a compromise on these three issues between both extremes, i.e. moderate pollution, growth and inefficiency. This finding is contrasted with one of the conclusions of Eriksson and Persson (2003), namely that power shifting to the less wealthy individuals materializes in less abatement and more pollution if the externality is equally detrimental to every citizen.

Inequality has an ambiguous relationship with growth. While it directly depresses growth in the absence of a credit market, the indirect effect through taxes can be positive or negative, depending on politically determined redistribution. The overall effect of inequality on pollution is also ambiguous. It directly reduces pollution, because of a lower level of aggregate production, being again a consequence of an absent capital market, as well as the abatement technology. Its indirect effect on on pollution is ambiguous, and the overall effect may stimulate natural degradation, if taxation was highly regressive. In most cases, however, inequality does not appear to be harmful for the environment, which is a new result in this strand of theoretical literature. Additionally, inequality dampens the effect of democracy imperfections on redistribution. The higher it is, the lower is marginal tax increase (decrease) chosen by a left (right) regime.

There are several complex subjects omitted from our work that would be its interesting extensions, such as sustainability, trade or endogenous determination of abatement financing. An extensive empirical analysis of the described channels of environmental degradation would be an exciting, though admittedly adventurous task, worth pursuing. The fact, that testable expressions for optimal redistribution are obtained, could alleviate it.

Appendix

The expression for the logarithm of the break-even wealth is found in the following way. The equation (8) can be written as $w = E[(w_i)^{1-\tau}]\tilde{w}^{\tau}$. Taking logs and using standard properties of the lognormal distribution, i.e. $\ln w = m + \Delta^2/2$ and $\ln E[(w_i)^{(1-\tau)}] = (1-\tau)m + (1-\tau)^2\Delta^2/2$, one obtains

$$\ln w = m + \Delta^2/2 = (1-\tau)m + (1-\tau)^2\Delta^2/2 + \tau \ln \tilde{w},$$

which after simple calculations leads to $\ln \tilde{w} = m + (2-\tau)\Delta^2/2$.

To prove that the growth maximum cannot be found for $\tau \geq \tau^m$ the inequality $\tau^g \geq \tau^m$ has to be examined. Solving for μ, the condition gives

$$\mu \geq 1 + \frac{1}{\rho} + \frac{\gamma}{\beta} - \gamma - \frac{1+\rho\beta}{\rho\beta(1-\beta)}.$$

It is sufficient to show that this condition is violated for every positive μ. The right-hand side of the equation is bigger than zero for $\gamma(1-\beta)^2 - \beta^2 > (1-\beta)^2/\rho + \beta/\rho$ which is obviously untrue.
The finding that $\tau^g > \tau^W$ for $\mu < 1/\rho$ is obtained straightforward by solving the inequality for μ.

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