State Capacity, Constituency Size, and the Environmental Investment Gap in Authoritarian States

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Abstract: In this paper, we construct a two-period, constrained optimization model where the authoritarian ruler maximizes expected rents subject to the budget constraint of the surplus he has available in the short-term. We show that it is typically the case that the larger state capacity is at the first period, the worse environmental quality will be at the end of the second period: while both infrastructural investment and environmental protection increase with state capacity, the former increases at a faster rate which enlarges the gap between the two (what we call the environmental investment gap) based on the assumption that infrastructural public goods typically damage the environment. Furthermore, we show that the larger the size of the selectorate the bigger the environmental investment gap will be. Both these follow from rulers’ optimizing logic of equating marginal returns once we assume the declining marginal productivity of factors of production of surplus. The empirical test models three types of major air (SO2 and CO2) and water (biological oxygen demand, or BOD) pollutants in authoritarian states as a function of regime types (which we use to proxy the size of key constituencies), state capacity, and a battery of relevant variables. We find that state capacity is associated with higher levels of all three types of pollutants. Single-party regimes, which tend to have the largest key constituencies among four types authoritarian regimes, are positively associated with SO2 emissions.

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Introduction

In 1980, 55.9 per cent of the world population lived under some form of authoritarian rule. By 2000, after waves of democratization, this number was still as high as 42.1 per cent. How does authoritarian politics affect countries’ environmental performances? This is an important and yet unanswered question for students of political science. Previous research on political institutions’ environmental impacts often focuses on the democracy-non-democracy divide (Congleton 1992, Li and Reuveny 2006). Some have argued that democracies could be detrimental to environmental protection (Dryzek 1987, Midlarsky 1998). More recent research seems to suggest that democracies are often associated with more stringent environmental regulations and sometimes better environmental outcomes (Barret and Graddy 2000; Esty and Porter 2005; Bernauer and Koubi 2008). However, given the fact that different kinds of authoritarianism differ from each other as much as they differ from democracy (Geddes 1999), we need to further investigate the dynamics of environmental politics in the authoritarian world.

Our understanding of politics in authoritarian systems is much more limited than that of democratic systems. Recent literature on authoritarianism has been focusing on classification of authoritarian regimes (Geddes 1999, Lai and Slater 2006, Cheibub and Gandhi 2004, Cheibub, Gandhi and Vreeland 2009) and the links between these regime types and various phenomena such as regime survival (Geddes 2003), democratic transition and consolidation (Svolic 2008), economic development (Gandhi 2008, Wright 2008), and initiation of conflicts (Pickering and Kisangani 2010, Weeks 2011). Though there is an abundant case study literature on environmental regulations and outcomes in authoritarian systems (for example see Pryde 1991 and Economy 2004), unfortunately little systematic theoretical work has been carried out, and we lack systematic studies of how outcomes are related to variance among authoritarian systems.

In this paper, we present a model of environmental politics in the authoritarian world starting with the basic assumption of a rent-maximizing authoritarian ruler. We construct a two-period, constrained optimization model where the authoritarian ruler maximizes expected rents subject to the budget constraint of the surplus that he has available in the short-term. We show that it is typically the case that the larger state capacity is in the first period, the worse environmental quality at the end of the second period: strong state capacity increases both infrastructural investment and environmental protection, but as long as the productivity of infrastructural investment relative to its price is greater than that of environmental protection, the former would increase at a faster rate, which enlarges the gap between the two. We call this the environmental investment gap, based on the assumption that infrastructural public goods are typically provided in a way that damages the environment. Furthermore, we show that the larger the size of the selectorate the bigger the environmental investment gap will be. Both these results follow from rulers’ optimizing logic of equating marginal returns once we assume the declining marginal productivity of factors of production of surplus.

We test our theory by modeling three types of major air and water pollutants, sulphur dioxide (SO$_2$), carbon dioxide (CO), and biological oxygen demand (BOD) in authoritarian states as a

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2 These mainly include single-party, military, personalistic, monarchy, and their hybrid regimes. Percentages are calculated by the authors’ using Wright 2008’s extension of Geddes’ data of authoritarian regime types (Geddes 1999). Note these are likely to underestimate the number of people living under authoritarian rules, because there are non-democratic regimes that are not yet classified by the data.
function of regime types (which we use to proxy the size of key constituencies), capacity of the state, and a battery of relevant variables, for 1980-2003. The results strongly support our theory. State capacity is associated with higher levels of all three types of pollutants. Single-party regimes, which we believe to have the largest key constituencies among four types authoritarian regime (single-party, military, personalistic, and monarchy), are positively associated with SO$_2$ emissions. The rest of the paper describes our theoretical model, presents data and variable operationalizations, and finally discuss the empirical findings and direction of future research.

A Model of Environmental Politics in Authoritarian States

Rulers can obtain surplus either by extracting part of the national income stream or by selling or running down parts of the national stock of capital that they control. In attempting to maximise the rents they enjoy through monopoly of state power rulers face a short-term long-term tradeoff. The surplus the ruler has extracted at $t = 1$ might be enjoyed as rent at that time. On the other hand the ruler could invest it so as to enjoy higher rents in the long term at $t = 2$. First the ruler can invest in capital which increases the size of national income at $t = 2$. Second the ruler can invest in additional state capacity, which will allow him to extract more surplus at time $t = 2$. Third he may make investments in legitimacy, which increase the probability that he will survive in office until $t = 2$. We discuss each of these forms of investment in turn.

Part of surplus is extracted from national income. National income is produced by labour, capital, infrastructural public goods and environmental public goods. We assume a fixed supply of labour and capital in the hands of private owners. Positive investment by the ruler in infrastructural public goods such as roads and energy systems should increase future national income. On the other hand a ruler might run down the stock of infrastructural capital to increase the surplus he has at $t = 1$, with negative consequences for national income at $t = 2$. Infrastructural capital depreciates. One way of running it down is simply not to maintain it, for example, not to make road repairs. Environmental public goods are also important to production, and rulers can invest in future income by protecting them, through implementing environmental regulation. Again a ruler can disinvest, pushing up the surplus he enjoys in the short term at the cost of lower income at $t = 2$. For example a ruler may exploit national forests unsustainably, selling off the timber or allowing his cronies to do so, which we treat as an erosion of environmental protection.

We assume that the environmental quality at $t = 2$ is a function of the difference between the levels of infrastructural public goods and environmental protection in that period – the environmental investment gap. This is based on the assumption that infrastructural public goods are typically provided in a way that damages the environment. Of course this is not always true, for instance a more efficient electricity distribution system enhances the environment. We simply bypass this issue by definition by categorizing this as a positive environmental investment to the extent that this is the case.

Rulers control state capacity. If they invest in extra state capacity at $t = 1$, other things equal they should be able to enjoy higher rents at $t = 2$ (Besley and Persson 2010). However they may also disinvest. For instance they could run down the size of the military and sell the assets freed up. Again this would allow them to enjoy higher rents in the short term. State capacity is not just used to extract surplus, with associated forms of repression. It is also used
to maintain the rulers’ political machine. Following Bueno de Mesquita et al (2003),
important to the ruler are members of the selectorate from whom the ruler builds a winning
coalition. Ruler also need state capacity to define and to organize the selectorate. Rulers gain
legitimacy by channelling private goods to some members of the selectorate. They also use
state capital to make sure that such goods only go to those who give support and to identify
and repress others. While maintaining a political machine is most obviously burdensome in
the case of totalitarian and communist systems with their bloated party apparatuses, it is a
non-trivial task for all authoritarian rulers. We assume that the larger the size of the
selectorate the greater the fraction of any unit of state capital that must be used in this task.
To put it another way, the larger the size of the selectorate the less surplus a given unit of
state capital generates, other things equal. Besides the increasing costs of the political
machine, the larger the selectorate the smaller the remainder of the population from whom
surplus can be extracted in the form of income.

In Bueno de Mesquita et al (2003) attention is given to whether benefits will be focused on
the selectorate or a proper subset of it, the winning coalition. While we think rulers are likely
to have good reasons in practice to spread benefits somewhat more widely than the winning
coalition given uncertainty about loyalties, and because of the need to attract support from
those whose decision is based retrospectively on delivery, for our purposes it is only
necessary that the probability of continued tenure increases with private good transfers,
which is relatively uncontroversial. Rather than explicitly modelling competition for power,
we simply assume that the probability a ruler survives to \( t = 2 \) increases with the amount he
provides in private transfers to the selectorate. Of course such private good transfers cannot
take negative values, because income is extracted from the generality of citizens, not the
selectorate. We assume public good provision, whether infrastructural or environmental, does
not increase the chances of survival. Public goods are available both to the selectorate and to
other members of society, so they provide no particular motive to support rulers.\(^3\)

For clarity we state the model in text relegating derivations to Appendix A.

Let the levels of infrastructural public goods, environmental protection, and state capacity at \( t = 1 \) be \( I, E \) and \( C \), respectively. Let investments at \( t = 1 \) in these things \( \Delta I, \Delta E \) and \( \Delta C \)
respectively. Recalling that the ruler can disinvest up to the point that all these factors are
used up, we have \( \Delta I \geq -I, \Delta E \geq -E, \) and \( \Delta C \geq -C \). Let \( p \) be the level of private good transfers
to the selectorate at \( t = 1 \). Notice that \( p \geq 0 \).

Let \( Y_1 \) be what the ruler has extracted from national income at \( t = 1 \). Then a further constraint
is that

\[
Y_1 \geq p + p_I \Delta I + p_E \Delta E + p_C \Delta C
\]

where the price of private goods is \( 1 \), so they are the numeraire, and \( p_I, p_E \) and \( p_C \) are the
prices of infrastructural public goods, environmental protection and state capacity,
respectively. Notice that if the ruler disinvests in infrastructure, say, this constraint becomes

\(^3\) If private goods only provide services that can be enjoyed if adequate levels of public goods
are also available this would not generally be the case. For instance a member of the
selectorate could only enjoy privileged access to private a car to the extent to which
uncrowded roads exist to drive on. We do not attempt to model this aspect here.
easier to satisfy. Implicitly it allows both for extraction from income and running down capital.

Let $S_2$ be surplus at $t = 2$. We assume $S_2$ depends on a Cobb-Douglas ‘surplus production function’:

$$S_2(I, \Delta I, E, \Delta E, C, \Delta C) = A (I + \Delta I)^\alpha (E + \Delta E)^\beta (C + \Delta C)^\gamma(s)$$

where $A > 0$ and $0 < \alpha, \beta, \gamma(s) < 1$. Notice that $\alpha$, $\beta$, and $\gamma(s)$ measure the productivity for the ruler’s surplus of, respectively, infrastructure, environmental protection and state capacity. Notice that the productivity of state capacity is a function of the size of the selectorate, $s$. Specifically, we assume $d\gamma/ds < 0$ because the larger $s$ is the less can be extracted using a unit of state capacity, as explained above.

The ruler may or may not survive in power until period 2, but in any case he anticipates this will certainly be his last in office. He expects to retain any surplus extracted in that period 2 as rent, because then there will be no personal future for him to invest in.\(^4\)

The ruler’s probability of surviving to $t = 2$ is

$$\Pi(p); \quad 0 < \Pi(\ . \ ) < 1;$$

such that $d\pi/dp > 0$.

The ruler seeks to maximize expected rents over the two periods, $R$, subject to constraints, where

$$R = Y_1 - p - p_I \Delta I - p_E \Delta E - p_C \Delta C + \Pi(p) S_2((I + \Delta I), (E + \Delta E), (C + \Delta C))$$

The constraints are those outlined above, namely

$$C1: \Delta I \geq -I$$
$$C2: \Delta E \geq -E,$$
$$C3: \Delta C \geq -C$$
$$C4: p \geq 0$$
$$C5: Y_1 \geq p + p_I \Delta I + p_E \Delta E + p_C \Delta C$$

Notice that if the ruler disinvests at $t = 1$, say in infrastructure so $\Delta I < 0$, $R$ increases, so we allow both for surplus derived from income extraction and disinvestment at $t = 1$.

We do not explicitly model rulers’ time discount rate, because we cannot measure it empirically. However, it is easily seen that only an extremely future-orientated ruler would take no rents at $t = 1$, investing his entire first-round surplus. To rule out this empirically unlikely occurrence we assume $C5$ is slack. We also assume $C1$-$C4$ are slack on the grounds that it is probably impractical for rulers to completely disinvest during their lifetimes. So we

\(^4\) Thus the model is an approximation to an infinite time-horizon planning model, assuming very high rates of time discount such as an authoritarian ruler might have.
avoid discussion of corner solutions to the programme, focusing on the properties of the internal solution.

Environmental quality at t = 2 is assumed to be a function of the environmental investment deficit \( D = ((I + \Delta I) - (E + \Delta E)) \), \( \varepsilon_2(D) \) such that \( \delta \varepsilon_2 / \delta D < 0 \). In the online appendix we show that

\[
D = ((\alpha p_E - \beta p_I) (k + p_I I + p_E E + p_C C))/(p_I p_E (\alpha + \beta + \gamma(s)))
\]

Where \( k \) is the amount invested, excluding what is spent on private goods going to the selectorate. It is plausible empirically that

\( (k + p_I I + p_E E + p_C C) > 0 \)

Because even if levels of disinvestment are such as to give a negative \( k \), the values of stocks of \( I, E, \) and \( C \) are likely to be much greater than disinvestment. Then \( D \) increases with \( I, E \) and \( C \) so long as

\[
\alpha p_E > \beta p_I
\]

or

\[
\alpha / p_I > \beta / p_E
\]

which is to say that the productivity of surplus of infrastructural investment relative to its price is greater than that of environmental protection.

Because we can operationally measure state capacity, we focus discussion on this term. The larger the stock of state capacity \( C \), the lower the level of environmental quality at time t = 2 so long as the productivity of infrastructural investment relative to its price is greater than the productivity of environmental investment relative to its price. If we assume additionally that at relatively low levels of development infrastructural investment is typically more productive of ruler surplus than environmental investment:

H1: Other things equal, the higher the level of state capacity the lower the level of environmental quality in authoritarian systems at relatively low levels of development.

The mechanism behind this result is as follows. Constraints are assumed slack so the ruler equates the marginal productivity of surplus across his possible investments at the optimum. Moreover the marginal productivity of factors is declining, because of the ‘Cobb-Douglas’ production function. The larger \( C \) is the lower is marginal productivity of state capacity before investment/disinvestment. So investment in infrastructure and the environment is pushed further in equilibrium the larger \( C \) is. A greater stock of state capacity increases both infrastructural investment and environmental protection, but the investment gap grows if
infrastructural investment grows more in relative terms, which it will if it is relatively more productive of surplus.\(^5\)

Notice that the magnitude of \(D\) increases with the size of the selectorate, \(s\), as the larger the value of \(s\) the smaller the value of \(\gamma(s)\). In the typical case where \(\alpha/p_I > \beta/p_E\), \(D\) gets bigger and environmental quality gets worse the larger the size of the selectorate, \(s\). The mechanism at work here again relates to equating productivity of investments at the margin. The larger \(s\) is, the lower the productivity state capacity in terms of producing surplus. At the optimum both investments in infrastructure and environmental regulation are pushed further as a consequence of larger \(s\), because of this suppressing effect on the productivity of state capacity and because of the declining marginal productivity of infrastructural and environmental investments.\(^6\)

H2: Other things equal, the larger the size of the selectorate the lower the level of environmental quality in authoritarian systems at relatively low levels of development.

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**Data and Measurement**

*Air and Water Pollution:* In order to test the impacts of the size of the selectorate and the capacity of the state on the environment, we choose to focus on three major types of air and water pollution with available data covering enough countries and years: Sulphur dioxide (SO\(_2\)), carbon dioxide (CO\(_2\)), and bio-chemical oxygen demand (BOD).\(^7\) Sulphur dioxide is a serious air pollutant, implicated in ground-level smog and haze, particularly in urban areas. It is associated with damage to human health and it reduces agricultural productivity and. It often results in acid-deposition, which damages vulnerable aquatic and forest ecosystems and buildings (Hill 2004). Around two-thirds of emissions result from fossil fuel-burning electricity generation. In developed countries the trend has been towards reductions in emissions due to changes to less sulphurous fossil fuels, deindustrialization, domestic legislation such as the US Clean Air Act of 1973, pollution control technologies encouraged by regional arrangements like the 1988 EU Large Combustion Plant Directive, and the international Convention of Long-Range Transboundary Air Pollution. However, emissions are still increasing in rapidly growing developing countries many of which are authoritarian regimes. We measure sulphur dioxide emissions in kilograms per-capita per year.\(^8\)

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\(^5\) However there may be atypical cases of highly polluted systems where it is more productive of surplus at the margin for a ruler to invest in environmental protection (i.e. \(\alpha/p_I < \beta/p_E\)). We return to this possibility in the conclusion.

\(^6\) Again this effect reverses if low environmental quality becomes a drag on national income.

\(^7\) We choose not to model environmental policies and regulations because recent studies have shown that even with stringent laws on the books, governments can and often cut enforcement budgets, reduce penalties for enforcement violations, and adopt administrative policies, all of which undermine enforcement effectiveness of policies (Cao and Prakash forthcoming). And we expect that the gap between law on paper and environmental outcomes is likely to be large especially for developing countries.

\(^8\) See Stern 2005.
Carbon dioxide is the most significant anthropogenic forcing factor for climate change. Hence it is also implicated in an enormous range of problems, including potential food scarcity, health, development, security, and loss of biodiversity. It has been under intense discussion since the late 1980s, primarily under the umbrella of the 1992 Framework Convention on Climate Change. Despite the entering into force of the 1997 Kyoto Protocol in 2005, regional action such as the EU Emissions Trading Scheme, and action at state and local scales, policy has had little impact to date. We use CO$_2$ emissions in metric tonnes per capita from the World Bank’s Development Indicators. Emissions have fallen in some countries since the 1980s partly as a consequence of shifts in fuel or closing polluting heavy industry.

Bio-chemical oxygen demand (BOD) is an important indicator of water pollution and it measures the amount of oxygen required to decompose a given amount of organic pollutant. Organic matter entering rivers and lakes is decomposed by micro-organisms, and their activity depletes the oxygen dissolved in the water. Beside natural flows of organic matter, there are flows from sewage discharge and from industrial processes like paper production. These flows push up bio-chemical oxygen demand, and in the extreme can lead to the water becoming hypoxic and unable to support life (Hill 2004). The measure we draw from World Bank Development Indicators is based on the standard test for this form of environmental stress, bio-chemical oxygen demand in kilograms per-day, per-capita. This is, then, a measure of anthropogenic organic pollution of waterways.

State Capacity: In order to capture the concept of the capacity of the state, we use two different fiscal measures of state capacity from Arbetman-Rabinowitz and Johnson (2007): the state’s tax revenue as a ratio of GDP (Tax ratio) and relative political capacity (RPC). Tax ratio measures state’s ability to extract resources from individuals and groups in society; it is the conventional gauge of the state’s extractive capacity (Campbell 1993; Cheibub, 1998; Centeno, 2002; Thies, 2005 and 2010). Relative political capacity (RPC) further conceptualizes state’s relative political capacity as the “the ability of a government to extract resources from a population given their level of economic development” (Arbetman-Rabinowitz and Johnson 2007, 2). It is a measure of the strength of the state compared to other states with similar levels of development and resource endowments.

RPC is an index that compares the actual level of tax revenue extraction to a predicted level of extraction. Predicted revenues are estimated as a function of per capita income, the share of agriculture in the economy, the share of mining in the economy, and major oil production.

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9 Even though other pollutants have greater forcing potential per-unit.

10 Inorganic pollution, for instance, that due to run-off of nitrates and phosphates from agriculture, may also deplete oxygen by generating algal blooms, but BOD is not a direct measure of this, and we know of no internationally comparable data.

11 Other measures of state capacity are also often used in the literature, such as government consumption and government total revenue. However, we think these alternative measures are problematic for our purposes. Government consumption is a measure of the amount of a society’s resources consumed by government. It measures expenditures, rather than revenue gathering activity. Total government revenue is a measure of the government’s income that includes both tax and non-tax revenue. It is not typically seen as the best measure of revenue extraction, since it contains non-tax revenue.
A state that scores 1 on the RPC indicator is extracting exactly as one would expect compared to other states with similar conditions, while those that score higher than 1 are extracting more than expected and those that score lower than 1 are extracting less than expected. The relative political capacity score was originally developed by Organski and Kugler (1980) as a proxy for states’ relative ability to wage war, and has proven useful in conflict studies (Ties 2010) and in recent work on carbon emissions (Sprinz et al. 2009).

**Authoritarian Regime Type as Proxy for Selectorate Size:** The size of the selectorate is another variable in our theoretical story. However, it is hard to empirically measure this directly, especially across countries. Bueno de Mesquita et al. 2003 use index variables that they themselves describe as crude. These indexes use general characteristics of political systems that are assumed to be correlated with the sizes of the selectorate, but they are also highly correlated with other important concepts such as the level of political competition and the level of political rights. Their efforts to separate the effects of selectorate (and winning coalition) from measures of these other concepts have drawn criticism (Hanson 2007; Gallagher and Hanson 2009). For example, Clarke and Stone 2008 present a detailed analysis of the statistical findings in Bueno de Mesquita et al. 2003 and argue that the empirical evidence does not support the theory because the effects ascribed to winning coalition size are indeed attributable to democracy.

We follow a different approach in the recent literature (Peceny and Butler 2004, Chang and Golden 2010, and Pickering and Kisangani 2010), that is, rank authoritarian regime types by the size of selectorate, and use regime type dummy variables to test the effects of the size of the selectorate on pollution. It is worth noting that this approach is not without controversy. Scholars seem to have different rankings of authoritarian regime types by the size of winning coalition (W) and selectorate (S). For example, Chang and Golden 2010 assume that W is more or less the same in all polities and the variation comes from S in the following order: military juntas and monarchies < single-party dictatorships < personalistic regimes. But Pickering and Kisangani 2010 argue that the selectorate is roughly the same (the citizenry) and variation of W follows the order of personalistic<=military<=single-party (Geddes 2006; Peceny and Butler 2004). In the following, we derive our ranking orders of regime types based on a theoretical definition of the selectorate.

The selectorate refers to individuals who can theoretically be part of the leadership selection process and whose endowments include the qualities or characteristics institutionally required to gain access to private benefits doled out by the government’s leadership (Bueno de Mesquita et al. 2003, p 42). In a single-party regime, the distinction between the disenfranchised and the selectorate might be that between party members and others. Moreover, the whole military machinery is likely to be included in the selectorate because authoritarian rulers need to rely on the repressive capacity of the military to deal with potential revolutionary threats from the disenfranchised or from coup attempts by rival factions within the selectorate. Indeed, it is likely to be true that in all four types of authoritarian regimes, the military is included in the selectorate and receives private goods distributed by the ruler. Therefore, in addition to the military, the selectorate of the single-

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12 In the context of authoritarian states, the existence of disenfranchised population seems to cast serious doubt on Pickering and Kisangani’s (2010) assumption that the selectorate is roughly the whole citizenry.
party regime would include party members;\textsuperscript{13} in addition to the military, the selectorate of a monarchy might include all members of the extended royal family; in a military regime, the selectorate is the military apparatus itself. Thus, on average the ranking for these three types of regimes by size of the selectorate is roughly the following if we can assume that a dominant party in a single party regime includes a larger proportion of the population than a typical extended royal family in a monarchy:\textsuperscript{14}

\[
\text{single-party regime} \geq \text{monarchy} \geq \text{military regime.}
\]

The case of personalistic regimes is more complicated because this might depend on the way that the leader came to power: Geddes argues that they often do so as an officer in a military coup or as the leader of a single-party government, and they are in the process marginalizing other officers’ influence and/or reducing the influence and functions of the party after having consolidated control (Geddes 1999). Therefore, if the leader came into power from a single-party, the selectorate is the military plus a marginalized party; if the leader came to power as an officer in a military coup, the selectorate is more likely to be the marginalized military. For the former case, the size of the selectorate would be somewhere between the single-party regime and the military regime: whether the size is larger than that of a monarchy depends on the extent of marginalization of the party. For the latter case, the size of the selectorate would be more likely to be the smallest among all regime types: smaller than the military regime because the military has been marginalized. Therefore, there are three possible rankings for all of which single-party regimes are expected to have the largest selectorate:

1). \text{single-party regime} \geq \text{personalistic} \geq \text{monarchy} \geq \text{military regime};
2). \text{single-party regime} \geq \text{monarchy} \geq \text{personalistic} \geq \text{military regime};
3). \text{single-party regime} \geq \text{monarchy} \geq \text{military regime} \geq \text{personalistic}.

Our expectation that on average, single-party regimes have the largest selectorate (mainly party members plus the military) is consistent with Bueno de Mesquita et al. 2003’s observation that associates single-party regimes with large selectorates.\textsuperscript{15} More importantly,

\textsuperscript{13} However, there is often an overlap between the party, the military, and the bureaucracy: the party often penetrates even the ranks and files of the military; and it often requires party membership not only for important posts of the bureaucracy, but also for lower-ranked jobs in the civil service.

\textsuperscript{14} The reason why we assume that single-party regimes are associated with larger selectorates than monarchies is that with some exceptions such as Taiwan and Mexico, most single-party states have been socialist regimes; communist/socialist parties in these states are often large. Notoriously, the PRI in Mexico included quite large groups of farmers and trade-unions in the movement, so maybe it had quite big \(S\) as well. For example, there are about 77.9 million (in 2009) members of the Chinese Communist Party, which is roughly 6\% of the population; the Communist Party of Vietnam has 3.6 million members: roughly 4\% of the population. It is hard to estimate the exact size of the extended royal family in a monarchy; however, it is unlikely that this will be 4\%–6\% of the population: this would mean 1 to 1.5 million for Saudi Arabia which has a total population of 25.7 million.

\textsuperscript{15} They also consider personalistic dictatorships to have large selectorates. We think this is likely to be the case if the dictator in a personalistic regime came to power as a leader of a party.
by having the largest selectorate among all four regime types, single-party regimes should be associated with bad environmental outcomes.

We use an extended version of Geddes’ typology of authoritarian regimes (Wright 2008). There are some hybrid regimes coded in the data (e.g., military-personalist and single-party-military). These hybrid regimes might exhibit characteristics of two or more of the two pure regime types. Therefore, we choose to focus on the four pure types of authoritarian regime types to capture the effects of the size of the key constituencies on the environment.

**Socialist/Communist Legacies:** Communist regimes have often adopted a progressivist perspective based on Marx and Engels’ idea that the road to communism lies through the development of the forces of production. In practice, communist regimes tended to develop forces of production by investment in heavy industry, mining, and massive irrigation and hydro-electric projects. While the case-study literature on communist regimes finds it difficult to disentangle this ideology from other variables such as relative under-development, it is frequently held to be one factor lying behind such problems as heavy air and water pollution in the Soviet Union (Oldfield 2005, 21-42). Beside ideology, it is commonly held that Soviet central planning was wasteful of resources, because inputs and use of pollution sinks came un-priced to enterprises bent on plan fulfillment, and led to under-investment in cleaner plant, because of short-term pressures to maximize production (Ericson 1991).

Another reason to control for communist legacies is that many single-party regimes are associated with communist/socialist experience; we need to tease out the effect of communist legacies in order to make it a convincing case that it is the size of the constituencies (and state capacity) that impact the environment. We therefore add a dummy variable indicating whether a country has ever been a communist or socialist regime.

**Further Control Variables:** We include both GDP per capita (in purchasing power parity) and its squared term in the model to capture the possibility that there is a curvilinear relationship between wealth and environmental protection. This is to test the Environmental Kuznets Curve argument that there is a U shape relationship between economic development and the environment.

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16 Note that Geddes originally offered a straightforward classification of regimes as military, personalist, and single-party: in military regimes, a group of officers decides who will rule and influence policy; in single party regimes, one party dominates access to political office and controls policy; in personalist regimes, access to office and the fruits of office depends on the discretion of an individual leader. The original data spanned from 1950 to 2000, but did not include monarchies and only included data on regimes that endured more than three years. Wright 2008 updated the Geddes data to include monarchies, such as Saudi Arabia, Morocco, and Kuwait.

17 Between 1946 and 2003, roughly 22% of the total observations are coded hybrid regimes; so we are not losing too many observations.

18 The correlation between communist legacies and single-party regime is indeed 0.45 in our data.

19 Countries that have been coded 1 for this dummy variable and potentially enter the empirically analysis after deletion of missing data are Albania, Bulgaria, China, Hungary, Mongolia, Poland, Laos, Mozambique, Angola, Cambodia, Vietnam, Somalia, and Afghanistan.
and environmental protection. Moreover, rapid economic growth may generate forms of environmental damage that are hard to cope with in the short-term. We therefore include \textit{GDP growth rate}. Our model also includes the share of industrial production in GDP (\textit{Industry}) because the industrial production is often associated with higher levels of pollution compared to the service and agricultural sectors. We further control for \textit{Fuel exports} (as a percentage of merchandise exports) given the negative environmental impacts associated with the exploration, drilling, and extraction of fossil fuels (O’Rourke and Connolly 2003).

We include two demographic variables, \textit{Population density} (population divided by land area) and \textit{Urban population} (as a share of total population) to control for demographic influences on pollution levels. Countries with high population density might prioritize development at the expense of environmental protection. Large urban population might also increase the environmental burden on the country; but urban population is also likely to be associated with environmental activism and protection.\footnote{We controls for \textit{Trade openness} (the sum of imports and exports as a percentage of GDP) which has been used extensively in the trade-environment literature to capture the effect of overall trade \textit{openness} (de Soysa and Neumayer 2005).}

Finally, any account of environmental politics will be incomplete without taking into account societal demands for more/less environmental protection. We, like many previous studies, have implicitly assumed that the public demands a cleaner environment. However, how strong that demand is and to what extent people are willing to give up part of their income for environmental protection is largely unknown, especially for many authoritarian states. It is therefore important to control for relative demand for environmental public goods. However, data on public opinion concerning environmental demand are limited, especially for developing countries.\footnote{Income is probably the best available proxy. Indeed, this is another justification for including GDP per capita and its square term.}

Another important societal demand is associated with the energy intensive sectors and the common assumption is that these sectors prefer less stringent environmental regulations. For example, Ward and Cao forthcoming have shown that in the OECD context, the larger the size of the sectors, the lower the level of environmental taxation in a country. Energy intensive sectors can be identified, for instance by reference to those included in the EU’s CO2 emissions trading scheme such as electricity generation, cement production, and glass making. In principle, the power of such sectors could be measured by their contribution to GDP, but available breakdowns of GDP are not fine enough to make this practicable. Things are more straightforward on the production side. We used World Development Indicators (WDI) data on national energy production in ktonnes of oil equivalent and divided by real GDP. This gives energy production per unit of real gross domestic product (\textit{Energy production}). Table 1 presents the correlation statistics for the variables used in the paper.

\footnote{Data on GDP per capita, GDP growth rate, industrial production, oil exports, population density, and urban population are from the World Development Indicators (World Bank 2008).}

\footnote{The World Values Survey and European Value Survey are the best sources for public opinion data on environmental demand in terms of country and year coverage. These surveys have a number of questions relating to the environment, depending on wave and country concerned (World Values Survey 2009). However, the number of authoritarian country/years covered by these surveys is very limited.}
Empirical Findings

We first model air and water pollution in a country random effects model with a first-order autoregressive process to capture the within-country serial correlation of the data. While the random-effects in our model are conceptually analogous to the country-fixed effects usually employed in Time-Series-Cross-Sectional data (TSCS) analyses, they have certain statistical advantages. Unlike random effects models, fixed effects models use one degree of freedom for each unit. Such loss of information inflates the standard errors and makes the estimates of the coefficients less precise. This is important for our analysis because missing data (on RPC and Tax ratio, for example) already reduces the number of countries to 39-46 (time period 1980-2003). More importantly, the authoritarian regime type variables are often slow-moving or even time-invariant. It is well known that estimating country fixed effects with slow-moving and time-invariant variables is often problematic.\(^{22}\)

The model can be written as \( y_{i,t} = \beta_0 + \beta_1 + X\beta + \xi_{i,t} \), where \( \beta_0 \) is the population intercept, \( \beta_1 \) represents mean-zero random unit intercepts and is normally distributed. \( X\beta \) is the linear covariates and an estimate of their impact on the dependent variable. Residuals are further decomposed as \( \xi_{i,t} = \rho \xi_{i,t-1} + \epsilon_{i,t} \), where \( \rho \) is the first order autoregressive correlation term (AR1), and \( \epsilon_{i,t} \) follows the normal distribution \( N(0, \sigma^2) \). We also include year fixed effects to control for common trend and region dummy variables to control any potential regional effects that might not be captured by the explanatory variables.\(^{23}\)

We present the empirical findings in Table 2-4 with one table for each type of pollutant; for each pollutant, we present two model specifications: we have two measures for state extractive capacity here. Each model specification includes basic social-economic control variables from GDP per capita to energy production, communist/socialist legacies, and region variables. We take the logarithm of all three dependent variables to rescale extreme values and approximate a normal distribution.

The results from SO\(_2\) regressions (Table 2) best support our theoretical expectations. With military regime as the baseline regime type, single-party regimes are associated with higher levels of SO\(_2\) per capita emission. Not only is the association statistically significant across both model specifications, but also the magnitude of the association is substantively important. A coefficient around 0.8 suggests that a single-party regime on average emits 0.8 kilograms per-capita in logarithm of SO\(_2\) per capita per year --- the average of SO\(_2\) per capita emission in the sample is 1.474 kilograms per-capita in logarithm. State extractive capacity, either measured by RPC or Tax ratio, is also associated with a higher level of SO\(_2\) per capita emission. GDP per capita and its square term are significantly associated with emission and

\(^{22}\) Even though recent literature has proposed statistical tools to deal with this (Plümper and Troeger 2007), there is still debate on whether the proposed estimators indeed solve the problem and about which estimator(s) outperform the others (Greene 2010, but also see Plümper and Troeger 2011).

\(^{23}\) The region dummies are East Asia, Eastern Europe & post-Soviet, Latin America, North Africa & Middle East, South-East Asia, South Asia, and Sub-Saharan Africa.
the signs of coefficients indicate an inverted U-shaped environmental Kuznets curve: per capita SO2 emission goes up with wealth until reaching a threshold after which increasing wealth decreases emission. Urban population and energy production are also positively associated with SO2 emission.

Insert Table 2-4 about here.

Table 3 presents the empirical findings for CO2 emission. Different from the case of SO2 emission, we do not find evidence for an inverted U-shaped environmental Kuznets curve though the negative impacts of urban population and energy production are still statistically significant. In terms of the effects of regime types, the relationship between single-party regimes and emission is not significant. Moreover, similar to the case of SO2 emission, both RPC and Tax ratio increase CO2 emission significantly. In terms of the regional effects, with the baseline region being East Asia, we find that South Asia emits significantly less CO2.

Different from findings of two major air pollutants, those from BOD regressions suggest that few covariates in our model actually have any impact on this type of water pollution. GDP growth reduces and urban population increases BOD per capita. However, state extractive capacity as measured as both RPC and Tax ratio still increases BOD per capita. We might simply need better quality data for BOD discharges: for the same time period and same set of countries, the available observations for the BOD regressions are almost one third lower than those in the SO2 and CO2 regressions.

Insert Table 5 about here.

Our strongest finding is the positive effect of state capacity on pollution. In order to test whether this result is robust to other empirical models, we run OLS regressions with lagged dependent variable and country and year fixed effects. Adding country fixed effects essentially makes our estimation rely exclusively on temporal variation in the data. A country’s state capacity, at least for those two measures in our data, does not change much over time. Therefore, we think this is a stronger test for the state capacity argument. Moreover, we choose not to include regime type variables and the dummy variable for communist/socialist regime because they are almost time-invariant. The results are reported in Table 5. Here, except for one out of the six model specifications --- using RPC for SO2, we find that both measures of state capacity are still positively associated with pollutions at reasonably high statistical significance levels.

Conclusion and Discussion on Future Research

In this paper, we present a model of environmental politics in the authoritarian world. We show that it is typically the case that the larger state capacity, the worse environmental quality: while both infrastructural investment and environmental protection increase with higher state capacity, the former increases at a faster rate, which enlarges the environmental investment gap. Furthermore we show that the larger the size of the selectorate the bigger the environmental investment gap will be. Our theoretical model predicts that large key
constituencies plus strong state capacity should be associated with bad environmental outcomes in the authoritarian regimes. We test our theory for three types of major air and water pollutants (SO₂, CO₂, and BOD). We find that state capacity is associated with higher levels of all three types of pollutants. Single-party regimes, which we assume to have the largest key constituencies among four types authoritarian regimes (single-party, military, personalistic, and monarchy), are positively associated with SO₂ emissions.

Our model predicts that environmental problems will get worse as a function of state capacity as long as infrastructural public goods investment is more productive of surplus than investment in environmental regulation. If there came a point where environmental regulation mattered more, the relationship reverses, though. This may shed some light on recent developments in China where the five year plan for the period 2011 to 2015 has a strong environmental focus (BBC News, 3rd March 2011) and Premier Wen Jiabao announced a reduction in target growth rates from 7.5% to 7% partly to address environmental concerns (BBC News, 28th February 2011). There is no doubt that China faces enormous environmental challenges (World Bank 2001), partly due to its very rapid economic development over the last two decades. Some believe that poor environmental quality and resource shortages will increasingly constrain China’s economic growth, while increasing environmental protest will generate strains for the regime (Economy 2004; Grumbine 2007). It may be that China is on the cusp at which its considerable state capacity will turn to an advantage from the environmental point of view, reducing the environmental investment gap if it grows.

There are many assumptions in our model that require further investigation. Not all authoritarian regimes can be plausibly characterized as pure rent-seekers (Wintrobe 1990). If a leader was purely concerned to maximize his chances of retaining tenure, increasing state capacity and increasing size of the selectorate might be associated with worse environmental quality, but for different reasons to the ones we suggest. If the leader had to pay some attention to all members of the selectorate by paying them off with private goods, and if this necessitated building state capacity through time, we would expect greater pressure on the profits of enterprises not in the state sector, damaging their ability to invest in cleaner technology. We might also expect direct environmental effects due to a bias towards current consumption and further attempts to suppress dissent among the general population, including environmental dissent. Although there is certainly evidence from large scale social surveys and from other sources for environmental concern in authoritarian systems (World Values Survey 2009), it is plausible that the degree of concern varies. If authoritarian leaders have to pay attention to dissent both within the selectorate and (to some extent) among the wider citizenry, environmental demand should matter to their behaviour, too, if they have the capacity to meet it. This suggests an interaction between demand and state capacity. As it is the case that a variety of causal mechanisms could explain our empirical results, detailed empirical work will be required to tell which are the most plausible.²⁴

²⁴ A more direct test of our causal story is look at the correlations between state capacity and regimes types on the one hand, and government spending patterns across different types of public goods on the other hand. More specifically, the differences between government spending on economic affairs (e.g., on mining, mineral resources, manufacturing and construction) and the environment can be operationalized as the environmental investment gap variable. However, data on government environmental spending (e.g., from IMF’s Government Financial Statistics) are often missing, especially for developing countries and for the pre-1990s period.
Moreover, we need to better understand the differences between different types of pollutants. We test our theory for three types of pollutants. The results regarding selectorate size vary across pollutant types. What explains these differences in addition to data quality? Industries and activities that generate one type of pollutant might be different from those generating other types of pollutants, and politics connecting these groups to authoritarian rulers’ calculation might be different. Cao and Prakash forthcoming have shown that the effects of trade competition and domestic political constraints on pollution intensity indeed vary across pollutants, more likely as a function of visibility associated with each pollutant (which in turn affects the level of mobilization of pro-environmental groups). In the context of authoritarian states, whether it is visibility or some other factors that can explain these differences across pollutant types can only be settled by more detailed studies on this in the future.

Finally, we use regime types to approximate the size of key constituencies. Our ranking of regime types by the constituency sizes is largely based on the expectations derived from the theoretical definitions of the selectorate. Also based on anecdotal evidence, we are confident that single-party regimes tend to have the largest selectorate than other three types of regimes. However, it is always an empirically challenge to measure the winning coalition and selectorate directly. We think comparative case studies might help us to better establish the causal relationships. For example, many authoritarian governments have a tendency to include more and more people into the selectorate (often by giving them public employment) either intentionally to buy out support or as a function of the “natural” growth of bureaucracy and party organizations. Future research might be able to take advantage of such comparative cases (over time) to see whether differences in size of the key constituencies make a difference in environmental outcomes.

References:


Indeed, this is the most serious empirical challenge for the Selectorate theory as problematic proxies of W and S limit the validity of any test associated with the theory.


Gulbrandsen LH, Andresen S. 2004. NGO influence in the implementation of the Kyoto protocol: compliance, flexibility mechanisms, and sinks. Global Environmental Politics 4:54–75.


Repetto, Robert, Dale Rothman, Paul Faeth, and Duncan Austin. 1996. Has environmental protection really reduced productivity growth? We need unbiased measures. World Resources Institute.


Appendix A: Derivation of Conditions in Formal Model

The Lagrangian for the ruler’s programme is
\[ L = L' + \lambda_2 p + \lambda_3 (I - \Delta I) + \lambda_4 (E - \Delta E) + \lambda_5 (C - \Delta C) \]
where
\[ L' = S_1 - p - p_I \Delta I - p_E \Delta E - p_C \Delta C + \Pi(p)S_2((I + \Delta I), (E + \Delta E), (C + \Delta C)) \]
\[ + \lambda_1 (S_1 - p - p_I \Delta I - p_E \Delta E - p_C \Delta C) \]

Assume that all C1-C4 are satisfied as strict inequalities. Then by the Kuhn-Tucker conditions, \( \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = 0 \), and the programme is equivalent to \( L' \).

Assuming that the ruler always takes some positive rent at \( t = 1 \). Then C5 is slack, so \( \lambda_1 = 0 \) by complementary slackness.

Then for an optimum,
\[ \frac{\delta L'}{\delta \Delta I} = 0 \rightarrow -p_I + \Pi \frac{\delta S_2}{\delta \Delta I} = 0 \]
\[ \frac{\delta L'}{\delta \Delta E} = 0 \rightarrow -p_E + \Pi \frac{\delta S_2}{\delta \Delta E} = 0 \]
\[ \frac{\delta L'}{\delta \Delta C} = 0 \rightarrow -p_C + \Pi \frac{\delta S_2}{\delta \Delta C} = 0 \]
(As C5 is slack, \( \Pi(\cdot) \) is not a function of \( \Delta I, \Delta E \) or \( \Delta C \).) Then as \( \Pi(\cdot) > 0 \)

\[ \frac{\delta S_2}{\delta \Delta I} = \frac{p_I}{p_E} = \frac{\alpha (E + \Delta E)}{\beta (I + \Delta I)} = \alpha E' \]  \( (1) \)

\[ \frac{\delta S_2}{\delta \Delta E} = \frac{p_E}{p_C} = \frac{\beta (I + \Delta I)}{\gamma(s) I'} \]  \( (2) \)

\[ \frac{\delta S_2}{\delta \Delta C} = \frac{p_C}{p_E} = \frac{\gamma(s) I'}{\gamma(s) E'} \]  \( (3) \)

Suppose that the ruler’s total investment in infrastructure, environment and state capacity is \( k \), so that
\[ p_I \Delta I + p_E \Delta E + p_C \Delta C = k \]
or

\[ p_{I}(I' - I) + p_{E}(E' - E) + p_{C}(C' - c) = k \]  \hspace{1cm} (4)

Then solving (1) through (4) simultaneously,

\[ I' = \frac{\alpha (k + p_{I}I + p_{E}E + p_{C}C)}{p_{I}(\alpha + \beta + \gamma(s))} \]

\[ E' = \frac{\beta (k + p_{I}I + p_{E}E + p_{C}C)}{p_{E}(\alpha + \beta + \gamma(s))} \]

\[ C' = \frac{\gamma(s) (k + p_{I}I + p_{E}E + p_{C}C)}{p_{C}(\alpha + \beta + \gamma(s))} \]

And as \( D = (I' - E') \)

\[ D = \frac{(\alpha p_{E} - \beta p_{I}) (k + p_{I}I + p_{E}E + p_{C}C)}{p_{I}p_{E}(\alpha + \beta + \gamma(s))} \]
### Table 1. Correlation among covariates

<table>
<thead>
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<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
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<td>0.10</td>
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<td>0.07</td>
<td>0.12</td>
<td>0.12</td>
<td>-0.13</td>
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<td>2: Tax ratio</td>
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<td>0.04</td>
<td>0.19</td>
<td>0.31</td>
<td>0.30</td>
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<tr>
<td>3: Personalist</td>
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<td>-0.15</td>
<td>1.00</td>
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<td>-0.31</td>
<td>-0.23</td>
<td>-0.29</td>
<td>-0.25</td>
<td>-0.11</td>
<td>-0.09</td>
<td>-0.19</td>
<td>-0.09</td>
<td>-0.15</td>
<td>-0.13</td>
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<tr>
<td>4: Single party</td>
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<td>0.04</td>
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<td>5: Military</td>
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<td>-0.02</td>
<td>0.02</td>
<td>-0.24</td>
<td>-0.06</td>
<td>-0.07</td>
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<td>6: Monarchy</td>
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<td>7: Socialist/Communist legacies</td>
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<td>-0.03</td>
<td>-0.03</td>
<td>-0.04</td>
<td>-0.03</td>
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<tr>
<td>8: GDP per capita</td>
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<td>-0.05</td>
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<td>9: Industry (% of GDP)</td>
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<td>10: GDP growth rate</td>
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<td>11: Population density</td>
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<td>-0.09</td>
<td>0.15</td>
<td>-0.02</td>
<td>-0.07</td>
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<td>0.31</td>
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<td>12: Urban population (% pop.)</td>
<td>0.07</td>
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<td>-0.19</td>
<td>-0.02</td>
<td>0.02</td>
<td>0.26</td>
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<td>0.66</td>
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<td>1.00</td>
<td>0.26</td>
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<td>13: Trade openness</td>
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<td>0.30</td>
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<td>14: Fuel export (% of exp)</td>
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<td>15: Energy production (% GDP)</td>
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<td>-0.07</td>
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<td>0.32</td>
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Table 2. Models on SO2 per capita emission: using RPC and tax ratio for state capacity.

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<td>p(&gt;</td>
<td>t</td>
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<td>(Intercept)</td>
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<td>0.040</td>
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<td>-0.0893</td>
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<td>Industry (% of GDP)</td>
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<td>0.004</td>
<td>0.723</td>
<td>0.0004</td>
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<td>Fuel export (% of exp)</td>
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</tr>
<tr>
<td>Energy production (% GDP)</td>
<td>0.1459</td>
<td>0.090</td>
<td>0.106</td>
<td>0.1886</td>
</tr>
<tr>
<td>Socialist/Communist legacies</td>
<td>-0.6193</td>
<td>0.793</td>
<td>0.441</td>
<td>0.0958</td>
</tr>
</tbody>
</table>

**State Capacity:**
- RPC: 0.1194 0.044 0.007
- Tax ratio (of GDP): 0.7060 0.275 0.011

**Region (baseline: East Asia):**
- East Europe & post-Soviet: 0.0332 0.643 0.959
- Latin America: -0.6884 0.852 0.426
- North Africa & Middle East: -0.6831 0.864 0.435
- South-East Asia: -0.6096 0.871 0.490
- South Asia: -1.7929 1.256 0.164
- Sub-Saharan Africa: -0.5898 0.912 0.523

- AR1: 0.971 0.969
- StdDev(Intercept): 0.0002 0.0003
- StdDev(Residual): 0.731 0.725

N of countries: 39 46
N of Observations: 370 390

Year fixed effects are estimated for all models but not reported because of space limit.
Table 3. Models on CO2 per capita emission: using RPC and tax ratio for state capacity.

<table>
<thead>
<tr>
<th></th>
<th>Model 3</th>
<th>Model 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coef.</td>
<td>$\hat{\sigma}$</td>
</tr>
<tr>
<td>(Intercept)</td>
<td>-4.3460</td>
<td>2.492</td>
</tr>
<tr>
<td>GDP per capita</td>
<td>0.3748</td>
<td>0.515</td>
</tr>
<tr>
<td>GDP per capita$^2$</td>
<td>0.0175</td>
<td>0.029</td>
</tr>
<tr>
<td>Industry (% of GDP)</td>
<td>-0.0016</td>
<td>0.003</td>
</tr>
<tr>
<td>GDP growth rate</td>
<td>-0.0017</td>
<td>0.002</td>
</tr>
<tr>
<td>Population density</td>
<td>0.0353</td>
<td>0.124</td>
</tr>
<tr>
<td>Urban population (% pop.)</td>
<td>0.0082</td>
<td>0.005</td>
</tr>
<tr>
<td>Trade openness</td>
<td>0.0579</td>
<td>0.051</td>
</tr>
<tr>
<td>Fuel export (% of exp)</td>
<td>0.0942</td>
<td>0.007</td>
</tr>
<tr>
<td>Energy production (% GDP)</td>
<td>0.1830</td>
<td>0.082</td>
</tr>
<tr>
<td>Socialist/Communist legacies</td>
<td>-0.8809</td>
<td>0.772</td>
</tr>
<tr>
<td>Regime (baseline: Military):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monarchy</td>
<td>0.3145</td>
<td>0.547</td>
</tr>
<tr>
<td>Personalist</td>
<td>-0.3390</td>
<td>0.410</td>
</tr>
<tr>
<td>Single party</td>
<td>0.1958</td>
<td>0.385</td>
</tr>
<tr>
<td>State Capacity:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RPC</td>
<td>0.1299</td>
<td>0.036</td>
</tr>
<tr>
<td>Tax ratio (of GDP)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Region (baseline: East Asia):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>East Europe &amp; post-Soviet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latin America</td>
<td>-0.8429</td>
<td>0.841</td>
</tr>
<tr>
<td>North Africa &amp; Middle East</td>
<td>-0.3564</td>
<td>0.858</td>
</tr>
<tr>
<td>South-East Asia</td>
<td>-0.3679</td>
<td>0.868</td>
</tr>
<tr>
<td>South Asia</td>
<td>-2.5810</td>
<td>1.187</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>-1.0789</td>
<td>0.890</td>
</tr>
<tr>
<td>AR1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>StdDev(Intercept,)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>StdDev(Residual)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N of countries</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>N of Observations</td>
<td>422</td>
<td></td>
</tr>
</tbody>
</table>

Note: Year fixed effects are estimated for all models; not reported because of space limit.
Table 4. Models on BOD per capita emission: using RPC and tax ratio for state capacity.

<table>
<thead>
<tr>
<th></th>
<th>Model 5</th>
<th></th>
<th>Model 6</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coef.</td>
<td>σ</td>
<td>p(&gt;</td>
<td>t</td>
</tr>
<tr>
<td>(Intercept)</td>
<td>-5.6892</td>
<td>3.969</td>
<td>0.153</td>
<td>-2.7238</td>
</tr>
<tr>
<td>GDP per capita</td>
<td>-0.4822</td>
<td>0.900</td>
<td>0.593</td>
<td>-1.1398</td>
</tr>
<tr>
<td>GDP per capita²</td>
<td>0.0518</td>
<td>0.054</td>
<td>0.336</td>
<td>0.0902</td>
</tr>
<tr>
<td>Industry (% of GDP)</td>
<td>-0.0065</td>
<td>0.005</td>
<td>0.219</td>
<td>-0.0088</td>
</tr>
<tr>
<td>GDP growth rate</td>
<td>-0.0054</td>
<td>0.003</td>
<td>0.035</td>
<td>-0.0065</td>
</tr>
<tr>
<td>Population density</td>
<td>0.0609</td>
<td>0.134</td>
<td>0.649</td>
<td>0.1553</td>
</tr>
<tr>
<td>Urban population (% pop.)</td>
<td>0.0199</td>
<td>0.009</td>
<td>0.922</td>
<td>0.0185</td>
</tr>
<tr>
<td>Trade openness</td>
<td>-0.0508</td>
<td>0.114</td>
<td>0.657</td>
<td>-0.0346</td>
</tr>
<tr>
<td>Fuel export (% of exp)</td>
<td>-0.0046</td>
<td>0.015</td>
<td>0.765</td>
<td>-0.0009</td>
</tr>
<tr>
<td>Energy production (% GDP)</td>
<td>-0.0865</td>
<td>0.156</td>
<td>0.579</td>
<td>-0.2120</td>
</tr>
<tr>
<td>Socialist/Communist legacies</td>
<td>-1.3459</td>
<td>0.792</td>
<td>0.100</td>
<td>0.0521</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Regime (baseline: Military):</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Monarchy</td>
<td>-0.9937</td>
<td>0.541</td>
<td>0.077</td>
<td>-0.7696</td>
</tr>
<tr>
<td>Personalist</td>
<td>-0.6383</td>
<td>0.388</td>
<td>0.111</td>
<td>-0.6370</td>
</tr>
<tr>
<td>Single party</td>
<td>-0.2321</td>
<td>0.369</td>
<td>0.534</td>
<td>-0.1083</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>State Capacity:</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>RPC</td>
<td>0.1396</td>
<td>0.067</td>
<td>0.039</td>
<td></td>
</tr>
<tr>
<td>Tax ratio (of GDP)</td>
<td>0.7596</td>
<td>0.434</td>
<td>0.082</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Region (baseline: East Asia):</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>East Europe &amp; post-Soviet</td>
<td>0.3859</td>
<td>0.620</td>
<td>0.538</td>
<td></td>
</tr>
<tr>
<td>Latin America</td>
<td>-0.5239</td>
<td>0.800</td>
<td>0.518</td>
<td>-0.8466</td>
</tr>
<tr>
<td>North Africa &amp; Middle East</td>
<td>-0.4746</td>
<td>0.810</td>
<td>0.563</td>
<td>-0.9369</td>
</tr>
<tr>
<td>South-East Asia</td>
<td>0.4594</td>
<td>0.808</td>
<td>0.574</td>
<td>-0.0768</td>
</tr>
<tr>
<td>South Asia</td>
<td>1.0031</td>
<td>1.213</td>
<td>0.415</td>
<td>-0.4098</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>-0.3502</td>
<td>0.867</td>
<td>0.689</td>
<td>-1.0370</td>
</tr>
</tbody>
</table>

| AR1                           | 0.917   |                       | 0.856   |                       |
| StdDev(Intercept,)            | 0.358   |                       | 0.492   |                       |
| StdDev(Residual)              | 0.597   |                       | 0.472   |                       |

| N of countries                | 39      | 43                     |        |                       |
| N of Observations             | 302     | 300                    |        |                       |

Note: Year fixed effects are estimated for all models; not reported because of space limit.
Table 5. OLS with lagged dependent variable and country and year fixed effects: using RPC and tax ratio as state capacity.

<table>
<thead>
<tr>
<th></th>
<th>SO2 per capita</th>
<th>CO2 per capita</th>
<th>BOD per capita</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coef.</td>
<td>σ</td>
<td>p(&gt;</td>
</tr>
<tr>
<td>Intercept</td>
<td>-0.903</td>
<td>2.558</td>
<td>0.724</td>
</tr>
<tr>
<td>Lagged DV</td>
<td>0.778</td>
<td>0.039</td>
<td>0.000</td>
</tr>
<tr>
<td>GDP per capita</td>
<td>0.069</td>
<td>0.588</td>
<td>0.906</td>
</tr>
<tr>
<td>GDP per capita²</td>
<td>-0.001</td>
<td>0.033</td>
<td>0.968</td>
</tr>
<tr>
<td>Industry (% of GDP)</td>
<td>-0.000</td>
<td>0.002</td>
<td>0.989</td>
</tr>
<tr>
<td>GDP growth rate</td>
<td>-0.000</td>
<td>0.001</td>
<td>0.888</td>
</tr>
<tr>
<td>Population density</td>
<td>0.266</td>
<td>0.225</td>
<td>0.236</td>
</tr>
<tr>
<td>Urban population (% pop.)</td>
<td>0.007</td>
<td>0.005</td>
<td>0.132</td>
</tr>
<tr>
<td>Trade openness</td>
<td>0.037</td>
<td>0.047</td>
<td>0.437</td>
</tr>
<tr>
<td>Fuel export (% of exp)</td>
<td>-0.009</td>
<td>0.006</td>
<td>0.152</td>
</tr>
<tr>
<td>Energy production (% GDP)</td>
<td>-0.047</td>
<td>0.085</td>
<td>0.582</td>
</tr>
</tbody>
</table>

|                   | Coef.          | σ              | p(>|t|)         | Coef.          | σ              | p(>|t|)         | Coef.          | σ              | p(>|t|)         |
| State Capacity:   | 0.045          | 0.034          | 0.181          | 0.088          | 0.028          | 0.002          | 0.130          | 0.068          | 0.061          |
| RPC               | 0.527          | 0.187          | 0.005          | 0.776          | 0.461          | 0.094          |
| Tax ratio (of GDP)| 0.378          | 0.209          | 0.072          | 39             | 46             | 39             | 39             | 46             | 33             |
| N of countries    | 368            | 389            | 420            | 389            | 389            | 259            | 265            |
| N of Observations | 0.979          | 0.980          | 0.991          | 0.989          | 0.989          | 0.935          | 0.943          |

Note: Year and country fixed effects are estimated for all models but not reported because of space limit.