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Fiscal Spending and the Environment: Theory and Empirics

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Abstract

During economic crises, governments often increase fiscal spending to stimulate the economy. While the fiscal spending surge is sometimes temporary, recessions are opportunities to revise the spending composition often in favor of expenditures in social programs and other public goods which tend to persist over time. We model and measure the impact of fiscal spending patterns on the environment. The model predicts that a reallocation of government spending composition towards public goods reduces pollution while increasing total government spending has an ambiguous effect on pollution. We find consistent empirical results for various air and water pollutants.

Keywords: Government Spending, Public Goods, Pollution
JEL codes: H11, H20, O13,Q53

1. Introduction

In most countries, a large fraction of the national income is directly spent by the government. Government spending varies from 20% to 45% of Gross Domestic Product (GDP). Many governments expand and revise fiscal spending priorities to stimulate the economy during deep economic crises. While the increased government spending may be temporary, the changes in the composition of fiscal spending are likely permanent.[1] Given the importance and the economic impact of the level and composition of fiscal spending for most areas of the economy it is surprising that the connection between fiscal spending policy and the environment has not yet been addressed in a systematic manner.

This article fills this gap in the literature by developing a theoretical and empirical model of the mechanisms by which the level and composition of fiscal spending may affect certain air and water pollutants. Given the enormous variety of items in which governments spend, it is important to develop a taxonomy of expenditures that is both simple enough to be theoretically and empirically tractable and at the same time conceptually meaningful. We use a taxonomy proposed by López and Galinato [López and Galinato, 2007] which distinguishes between government expenditures that are directed to areas where the private sector under-invests as a consequence of market failure, and government expenditures that cannot be justified on these grounds. The former can be referred to as "expenditures in public goods" and the latter as

[1] The share of expenditures in health care, education, energy and environmental protection in total government outlays in the USA is projected to rise from 27% in 2008 to 31% in 2014 as a consequence of the new fiscal policies implemented to mitigate the most recent financial crisis [Office of Management and Budget, 2009]. Similarly, almost all affected countries during the 1997 Asian crisis made drastic changes in the fiscal spending composition which subsequently became permanent. In Korea, fiscal spending in social security and welfare increased from 7.8% of the total government expenditures in years prior to the 1997 Asian crisis to 9.7% during the crisis and averaged 13.5% by 2003-2005, several years after the crisis subsided [Asian Development Bank.,2009]. Social security and welfare expenditures in Thailand rose from less than 4% of the government outlays in the pre-crisis years to 6% during the crisis and accounted for almost a 9% average in 2003-2005. Many social programs in both advanced and developing countries were established in response to deep crises and remained in place for many years thereafter. For example, massive conditional cash transfer programs in Mexico emerged in the aftermath of the Peso crisis of 1995 and still remain in place today. Similarly, several social security programs which emerged during the Great Depression in the USA became a permanent and important component of government spending.

"expenditures in private goods." The key distinction between expenditures in public goods and expenditures in private goods is that the former may alleviate the negative effects of market failure, while the latter may not.

We develop a stylized theoretical model that provides testable predictions for the relationship between government spending allocation and the environment using the above taxonomy. We then empirically test such predictions for air and water pollutants using a large panel data set on pollutant concentrations measured in a large number of monitoring sites spanning across many countries over several years.[2]

We broadly define government expenditures in public goods to include direct subsidies to households (education, health and other social transfers), expenditures in conventional public goods, environmental protection, research and development (R&D), and knowledge diffusion. These expenditures may mitigate the effects of market failure and complement rather than substitute private spending. Direct household subsidies diminish the impact of liquidity constraints often affecting a large number of households as a consequence of credit market imperfections [Attanasio et. al., 2008; Grant, 2007; Jappelli, 1990; Zeldes, 1989] and subsidize education and health investments which tend to have large positive externalities [Miguel and Kremer, 2004; Moretti, 2004; Moretti, 2004b, Watson, 2006]. Thus, direct household subsidies may ameliorate the tendency to under-invest in education and other forms of knowledge by households [López et. al., 2008]. Similarly, spending in R&D and knowledge diffusion subsidizes activities which are often affected by considerable market failures [Hoff and Stiglitz, 2000]. Also, environmental protection is an area where the private sector has little incentives to invest as a consequence of market failures [Dasgupta, 1996]. Finally, conventional public goods

[2] We neither model nor measure the determinants of budget composition. Interested readers may refer to a number of studies that have investigated such a relationship [Beasley and Coate, 1998; Cremer et. al,2008; Dreher and Sturm, 2008; Gemmell and Kneller, 2008].

such as institutions and law and order are considered to be essential areas of investment for the government as the private sector does not have incentives to invest in them at optimal levels [Polinsky and Shavell, 2000; , Williamson, 2000].

Expenditures in private goods tend to exacerbate the distortions caused by market failure. They include subsidies to fossil fuel production, input subsidies, subsidies to energy consumption, farm programs, commodity-specific subsidy programs, government grants to corporations, and other subsidies targeting specific industries or firms. In fact, many studies have shown that government expenditures in private goods are largely ineffective in promoting productivity and private investment and tend to substitute rather than complement private expenditures [Bergstrom, 1998; Bregman et. al., 1999; Estache, 1995; Fakin, 1995; Harris, 1991; Lee, 1996]. Moreover, any increase of spending in private goods causes a reduction of spending in public goods given a fiscal budget constraint.

The reallocation of government spending towards public goods may affect pollution via the proximate factors similar to those identified in the trade and environment literature [Antweiler et. al., 2001]: scale, composition, and technique effects. López and Islam [2008] showed that restructuring government spending in favor of public goods causes more economic growth. This means that such a restructuring may cause a scale effect which should increase environmental pressures, *ceteris paribus*. On the other hand, this reallocation of government spending may favor human capital-intensive activities to the detriment of physical capital-intensive industries, which tend to be among the most polluting industries [Antweiler et. al, 2001; Mani and Wheeler, 1997]. Thus, a reallocation from expenditures in private goods to public goods causes an output composition effect that is likely to improve environmental quality.

Government expenditures in public goods may also induce a technique effect that could be pro-environment. The technique effect refers to a reduction in the pollution-output ratio. A greater provision of public goods is associated with higher labor efficiency due to increased human capital. To the extent that human capital and pollution-generating dirty inputs are substitutes in production, we can expect that a greater provision of human capital would induce cleaner production that reduce the pollution-output ratio. Also, more R&D and technological diffusion through expenditures in public goods could lead to the development and use of cleaner technologies under certain conditions. In addition, expenditures in public goods can also induce an income effect where increased income raises the population's demand for cleaner environment and more environmental regulation, which in turn may reduce pollution.

The theoretical analysis shows the conditions under which the reallocation of government spending from private goods to public goods may result in lower pollution-output intensity and lower total production-generated pollution.[3] It turns out that these conditions are sufficiently weak and plausible to allow us to hypothesize that this may indeed be the case. We empirically test this hypothesis and find that increasing the government share of expenditure in public goods reduces certain production-generated air and water pollutants, holding aggregate GDP constant. Moreover, we also show that expanding total fiscal spending is neutral for the environment.

Our results are potentially very significant especially given that the U.S. and other governments are using fiscal stimulus to mitigate the current economic crisis and address certain structural long term problems, including reducing the dependence on fossil fuels, widening access to health care, improving education, and reducing poverty through social programs. This may entail a major shift in the composition of fiscal expenditures towards these areas, which

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[3] It must be noted that we focus our analysis on production pollution only and not consumption-generated pollution. The mechanisms by which government expenditure size and composition affect consumption pollution is likely to differ compared to production pollution.

roughly correspond to what we call expenditures in public goods. If our central hypothesis that shifting the composition of government expenditures reduces pollution is empirically corroborated, then it could mean that achieving environmentally sustainable growth in a renovated fiscal context could be much less costly than currently believed. Also, if aggregate government expenditure has no significant impact on the environment, then the current fiscal spending surge may not necessarily be deleterious to the environment.

Despite the large number of studies that have used various specifications to derive the structural determinants of pollution, we know of only one study that empirically looks at one particular aspect of fiscal policy focusing on only one pollutant. Using an *ad-hoc* empirical model, Bernauer and Koubi [2006] estimate the effect of the aggregate level of fiscal expenditures on sulfur dioxide air concentrations but neglects the role of fiscal spending composition.

The remainder of this paper is organized as follows: Section 2 formulates the theoretical model. Section 3 presents the empirical model. Section 4 describes the data used in the paper. Section 5 summarizes the results of the empirical analysis. Section 6 concludes the study.

2. The Conceptual Model

The conceptual model captures three important stylized facts. First, production pollution is mostly generated by the industrial sector (which includes manufacturing, mining, agriculture and related industries), while the service and human capital-producing sectors are relatively clean [Mani and Wheeler, 1997]. Second, the industrial sector (henceforth called the "dirty sector") is more capital-intensive and fossil fuel-intensive than the service sector (henceforth called the "clean sector") and the human capital-producing sector (henceforth called the "knowledge sector") [Antweiler et. al., 2001]. Finally, while government expenditures in private goods can target any of the three sectors, most of them are often directed to the industrial sector [López and Islam, 2008].

Consistent with the above stylized facts the model considers three productive sectors: the clean sector (y_c), the dirty sector (y_d), and the knowledge sector which produces an intermediate good called human capital (h). Human capital is an input in the production of all three sectors and augments labor efficiency measured by hl_i where l_i is raw labor in the i^{th} sector and h is assumed to be greater than 1. Thus hl_i is effective labor (in efficiency units) used by sector i. The dirty sector also uses private capital (k) and a dirty input, e.g. fossil fuel, which is the source of production pollution (Z). All three productive sectors benefit from government-provided goods. The government spends part of its budget, G, in public goods (g), which are generally complementary with private inputs, and in private goods (x) that may be perfect substitutes to private capital. The government budget is $G=g+x$.

Consumers derive utility from the consumption of final goods and suffer disutility from pollution such that the utility function is specified as $u(c)-v(Z)$ where c is per capita consumption. Aggregate consumption is $\tilde{C} = Nc$ where N is the total number of consumers. Without loss of generality, we assume $N=1$ so that $\tilde{C} = c$ assuming a fixed population.

2.1. Assumptions and Functional Forms

Assumptions:

A1. The economy is small and open which freely trades in the international markets for final goods implying exogenous output prices, and all domestic factor and output markets are perfectly competitive.

A2. By their very nature, the government-provided public goods, such as institutions, infrastructure and education, are difficult to allocate to specific sectors, so we assume that they benefit all sectors of the economy but allow for differing productivity effects on each sector. By contrast, government expenditures in private goods can be directed to specific sectors. Based on the third stylized fact, we assume that all government expenditures in private goods go to the dirty sector and that such goods are perfect substitutes with private physical capital.

A3. We define the output elasticities of g in the clean sector and dirty sector as Ω and η, respectively. We assume that $\Omega \geq \eta$.

A4. The utility function is increasing and concave in c such that $u'(c)>0$ and $u''(c)<0$ and the elasticity of the marginal utility of consumption, $a(c) \equiv -cu''(c)/u'(c)$, is greater or equal to 1.

Assumption *A3* may *a priori* seem arbitrary. However, under certain conditions we show that this assumption can be empirically tested and is supported by the empirical analysis. Assumption *A4* is solidly based on empirical evidence. Majority of the vast volume of empirical measurements of $a(c)$ in many countries around the world have obtained values above. We tabulate a summary of the studies that estimate $a(c)$ across different countries in Table AI in the appendix.

To reduce algebraic clutter and to increase the clarity of the results, we use Cobb-Douglas production functions.[4] The clean sector's production function uses human capital, labor (l_c) and the government-provided public input such that the production function is:

(1) $$y_c = Ahl_c g^{\Omega},$$

where A is the total factor productivity index and $\Omega > 0$ is a parameter representing the output elasticity of g in the clean sector.[5]

[4] This functional form is commonly used in the literature. Most results and all the ensuing theoretical predictions that we test in the empirical analysis are still valid if we use general neo-classical production functions instead of the Cobb-Douglas function. The use of Cobb-Douglas functional forms merely sharpens the results. Proof is available from the authors upon request.

The dirty sector uses (quasi-fixed) physical capital, human capital, two variable inputs, namely labor (l_d,) and the dirty input which can be pollution itself,[6] the government-provided public good and government-provided private good. The production function is:

(2) $$y_d = D(hl_d)^{\alpha} Z^{\beta}(x+k)^{1-\alpha-\beta} g^{\eta},$$

where D is a total factor productivity index and $\alpha>0$, $\beta>0$, $\alpha + \beta < 1$, and $\eta>0$ is the output elasticity of g in the dirty sector.

Production of human capital uses labor (l_r), human capital, and the government-provided public good such that the production function can be presented as $h = \bar{B}(hl_r)^{\nu} g^{\bar{\mu}}$, where ν, $\bar{\mu}$, and $\bar{B}$ are positive parameters. Assuming that ν=1/2, the production function is simplified to:[7]

(3) $$h = Bl_r g^{\mu},$$

where $B \equiv \bar{B}^2$ and $\mu \equiv 2\bar{\mu}$. Thus, B can be interpreted as a total factor productivity index, and $\mu>0$ is a fixed parameter representing the output elasticity of g in the knowledge sector.

Finally, we have two additional market clearing conditions. The labor market competitive equilibrium is:

(4) $$\bar{L} = l_c + l_d + l_r,$$

where $\bar{L}$ is the total supply of labor in the economy which is assumed to be fixed. Equilibrium in the economy's budget implies that the total consumption is equal to the total,

(5) $$c = py_d + y_c,$$

where p is the price of the dirty good and the price of the clean good has been normalized to one.

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[5] We could allow the clean sector to also use physical capital, but as long as this sector is less physical capital-intensive than the dirty sector the qualitative results are not affected. The algebra would however be more complex subtracting from the clarity of the presentation.
[6] Representing pollution as an input in production is quite common in the literature. See, for example, Baumol and Oates [1988] and Copeland and Taylor [1994].
[7] Assuming ν=1/2 reduces simplifies the algebra but does not alter the qualitative results. This also yields a reduced-form production function for h which is linearly homogenous in private inputs.

Producers in the dirty sector minimize the cost of production by choosing labor, and the dirty input, Z, given g, h, x and k,

(6) $$C(w,\tau;y_d,k+x,g)=\min_{(hl_d),Z} whl_d+\tau Z: \qquad D(hl_d)^{\alpha}Z^{\beta}\left(x+k\right)^{1-\alpha-\beta}g^{\eta}=y_d,$$

where w is the wage rate per unit of efficiency labor (hl_d) and τ is the unit tax rate on pollution. We note that since w is the wage rate per efficiency labor units the actual wage rate per unit of labor time is hw.[8]

The implicit cost function in (6) is

(7) $$C=\tilde{\phi}w^{\frac{\alpha}{\alpha+\beta}}\tau^{\frac{\beta}{\alpha+\beta}}y_d^{\frac{1}{\alpha+\beta}}\left(x+k\right)^{\frac{\alpha+\beta-1}{\alpha+\beta}}g^{-\frac{\eta}{\alpha+\beta}},$$

where $\tilde{\phi}=D^{-\frac{1}{\alpha+\beta}}(\alpha/\beta)^{\frac{\beta}{\alpha+\beta}}(1+\beta/\alpha)$. Using Shepherd's Lemma, the dirty input demand is,

(8) $$\frac{\partial C}{\partial\tau}=Z=D^{-\frac{1}{\alpha+\beta}}(\alpha/\beta)^{-\frac{\alpha}{\alpha+\beta}}(w/\tau)^{\frac{\alpha}{\alpha+\beta}}y_d^{\frac{1}{\alpha+\beta}}\left(x+k\right)^{\frac{\alpha+\beta-1}{\alpha+\beta}}g^{-\frac{\eta}{\alpha+\beta}}.$$

2.2. Competitive equilibrium

We derive the equilibrium levels for the relevant endogenous variables w, y_d, y_c and τ. The assumption of competitive equilibrium means that the marginal value products of labor in all three sectors equalize. Equating the marginal products of labor in the clean sector and knowledge sector using (1) and (3) yield unique equilibrium levels for h and w consistent with competitive labor markets:[9]

(9) $$h=\frac{B}{A}g^{\mu-\Omega},$$

(10) $$w=Ag^{\Omega}.$$

[8] Firms choose l_d taking hw as given. Equivalently, we can regard firms picking the level of efficiency labor hl_d (by selecting l_d) with reference to the wage for efficiency effort, w, as we do in (6).

[9] In deriving (9) we used the fact that the marginal product of raw labor in the human capital producing sector is equal to the wage rate per unit of raw labor time, hw. Thus, using (3) we have that $\partial h/\partial l_r=Bg^{\mu}=hw$. Then using (1) we have $\partial y_c/\partial(hl_c)=Ag^{\Omega}=w$ which combined with the previous equation leads to (9).

Thus, from (10) the equilibrium wage rate per efficiency labor is increasing in the government-provided public good. Moreover, the level of human capital is non-decreasing in the government-provided public good if $\mu \geq \Omega$. This latter result is plausible; the direct positive effect of increasing expenditures in public goods on human capital dominates the indirect negative effect associated with the increased wage rate per efficiency labor.

A competitive economy behaves as if it maximizes its total output revenue subject to the economy remaining on the production possibility frontier. This maximization yields the equilibrium level of the dirty output, y_d. To derive the production possibility frontier, we substitute the demand for labor from each sector into the labor constraint (4). Using (9) in (1), (2) and (3), we obtain expressions for l_c, l_d and l_r, respectively. Using these expressions in (4) the labor market clearing condition can be written as a function of y_c and y_d,

(11) $$\bar{L} = g^{-\Omega}/A + y_c g^{-\mu}/B + y_d^{\frac{1}{\alpha}} D^{-\frac{1}{\alpha}} (A/B) Z^{-\frac{\beta}{\alpha}} (x+k)^{\frac{\alpha+\beta-1}{\alpha}} g^{\frac{\alpha(\Omega-\mu)-\eta}{\alpha}} .$$

The economy's total revenue, $py_d + y_c$, is maximized with respect to y_d and y_c subject to (11) and yields the condition $\frac{\partial y_c}{\partial y_d} = -p$ implying that,

(12) $$\frac{\partial y_c}{\partial y_d} \equiv -\frac{\frac{1}{\alpha} y_d^{\frac{1-\alpha}{\alpha}} D^{-\frac{1}{\alpha}} (A/B) Z^{-\frac{\beta}{\alpha}} (x+k)^{\frac{\alpha+\beta-1}{\alpha}} g^{\frac{\alpha(\Omega-\mu)-\eta}{\alpha}}}{g^{-\mu}/B} = -p \ .$$

Solving (12) we obtain an explicit expression for y_d,

(13) $$y_d = (p\alpha D/A)^{\frac{\alpha}{1-\alpha}} D^{\frac{1}{\alpha}} Z^{\frac{\beta}{1-\alpha}} (x+k)^{\frac{1-\alpha-\beta}{1-\alpha}} g^{\frac{\eta-\alpha\Omega}{1-\alpha}} .$$

Using (11) and (13) the equilibrium level of y_c can also be obtained.

We now turn to the determination of τ. The optimal pollution tax rate or optimal tax-equivalent pollution regulation is equal to the marginal rate of substitution between income and pollution [López, 1994],

$$\tau^* = \frac{v'(Z)}{u'(c)}. \tag{14}$$

Recall that $v(Z)$ is the disutility from pollution. We assume that v is linear and increasing in Z such that $v'(Z) \equiv \gamma$.[10]

We distinguish between the optimal pollution tax rate (or the optimal tax-equivalent regulation) that fully internalizes the production pollution costs, τ^*, and the actual pollution tax rate (or tax-equivalent pollution regulation) chosen by the government, τ. Depending on institutional and social conditions, the government may choose a level of τ below the optimal tax rate, τ^*. We assume that the actual pollution tax rate is proportional to the optimal tax, $\tau = \varsigma(I)\tau^*$, where $\varsigma \leq 1$ and I is a vector of politico-institutional conditions that may affect the effectiveness of the environmental policy. Finally, using (5) and evaluating y_c and y_d at their respective equilibrium values yields the actual pollution tax rate,

$$\tau = \frac{\gamma\varsigma(I)}{u'\left(y_c^* + p y_d^*\right)}. \tag{15}$$

2.3. The Effect of Increasing the Budget Share of Government Expenditures in Public Goods

We now derive the effect on pollution from an increase in expenditures in public goods that is entirely financed through a concomitant reduction of expenditures in private goods. This corresponds to increasing the budget share of expenditures in public goods given a fixed government budget. Using $x = G - g$, logarithmic differentiation of (8) with respect to g yields,

[10] If $v(Z)$ is strictly convex instead of linear, the ensuing results are reinforced.

(16) $$\frac{d\ln Z}{d\ln g} = -\frac{\eta}{\alpha+\beta} + \frac{1}{\alpha+\beta}\frac{\partial \ln y_d}{\partial \ln g} + \frac{\alpha}{\alpha+\beta}\frac{\partial \ln w}{\partial \ln g} + \frac{(1-\alpha-\beta)}{(\alpha+\beta)}\pi_g - \frac{\alpha}{\alpha+\beta}\frac{d\ln \tau}{d\ln g},$$

where $\pi_g \equiv \frac{g}{k+x}$ is the ratio of the government-provided public good over the total capital used by the private sector.

Equation (16) decomposes the impact of a change in the composition of government expenditures towards public expenditures on pollution into five partial effects: First, the *direct effect* is negative. This implies that the same level of the dirty output can be produced with fewer dirty inputs when g increases holding all other factors constant. Second is the *dirty output scale* effect. A higher g increases labor productivity which, in turn, may affect the level of the dirty output holding all other factors constant. The dirty output level does not necessarily increase because a rise in g increases labor productivity in all sectors of the economy not just the dirty sector. If this effect causes production of the dirty output to increase (decrease), this effect will be pollution-increasing (decreasing). Third is the *pollution-labor substitution* effect. A higher g raises the economy's wage rate which increases pollution since labor and pollution are substitutes. Fourth is the *government's budget* effect. An increase in g reduces x which implies a lower level of total capital used in production. Given a constant output level, the fall in total capital must be compensated with an increase in all variable inputs including pollution. Fifth is the *environmental regulation* effect. An increase in g leads to higher income which induces a higher pollution tax and reduces pollution, *ceteris paribus*.

We can now derive the total impact of g on Z and y_d by using (10), (13), (15) and (16),

(17) $$\frac{d\ln Z}{d\ln g} = \frac{[1-a(c)(1-\alpha)\Lambda_d]\eta - [\alpha + a(c)(1-\alpha)\Lambda_c]\Omega}{1-\alpha-\beta} - \pi_g,$$

(18) $$\frac{d\ln y_d}{d\ln g} = \frac{[1-a(c)\beta\Lambda_d]\eta - [\alpha + a(c)\beta\Lambda_c]\Omega}{1-\alpha-\beta} - \pi_g ,$$

where $\Lambda_c \equiv y_c^*/(y_c^*+py_d^*)$ is the share of clean output in total income and $\Lambda_d \equiv py_d^*/(y_c^*+py_d^*)$ is the share of dirty output in total income such that $\Lambda_c + \Lambda_d = 1$. The first term on the right-hand of (17) condenses the direct effect, the pollution-labor substitution effect, part of the dirty output scale effect that accounts for the change in y_d keeping x constant and the environmental regulation effect. The second right-hand-term in (17) incorporates the effect of the fall in dirty output caused by a lower level of x, plus the direct government's budget effect.

From (17) we derive the fundamental result of this section: the necessary and sufficient condition for pollution to be non-increasing in government expenditures in public goods is

(17') $$\Omega + \frac{(1-\alpha-\beta)}{(\alpha+(1-\alpha)a(c)\Lambda_c)}\pi_g \geq \eta\frac{(1-a(c)(1-\alpha)\Lambda_d)}{(\alpha+a(c)(1-\alpha)\Lambda_c)} .$$

Thus, pollution must be decreasing in g as long as assumptions *A3* and *A4* hold ($\Omega \geq \eta$ and $a(c) \geq 1$). More generally, if the output elasticity of g in the clean sector plus the weighted government budget effect is larger than the weighted output elasticity of g in the dirty sector then pollution is decreasing in share of expenditures in public goods. Even if assumption *A3* does not hold such that $\Omega < \eta$, pollution can still be decreasing in the share of expenditure in public goods as long as the government's budget effect is significant. The following proposition then follows,

Proposition *1. If assumptions A3 and A4 hold, i.e.if $\Omega \geq \eta$ and $a(c) \geq 1$, then increasing government expenditures in public goods entirely financed by decreasing expenditures in private goods reduces pollution.* ⊗

Pollution Intensity

Using (17) and (18), the effect of g on the pollution intensity of the dirty output is,

(19) $$\frac{d\ln\left(\mathrm{Z}/y_{\mathrm{d}}\right)}{d\ln\mathrm{g}} = \frac{d\ln\mathrm{Z}}{d\ln\mathrm{g}} - \frac{d\ln\mathrm{y}_{\mathrm{d}}}{d\ln\mathrm{g}} = -a(c)\left(\Lambda_{\mathrm{c}}\Omega + \Lambda_{\mathrm{d}}\eta\right) < 0\,.$$

Thus, the effect of increasing the fiscal budget share of expenditures in public goods is to decrease the pollution intensity of the dirty sector. We note that unlike the effect on total pollution shown above, this unambiguous result is not dependent on assumptions *A3* and *A4*. Thus we have the following proposition,

Proposition 2. *Increasing government-provided public goods financed by a concomitant reduction of expenditures in private goods reduces pollution intensity of the dirty sector making the dirty sector cleaner.* ⊗

2.4. The Effect of Increasing Total Fiscal Spending on Pollution

We now consider the effect on pollution of an increase in total government spending that is financed by government borrowing instead of the effect of expenditure reallocation as we derived in the previous section.[11] We examine the effect of a neutral increase in total fiscal spending where both *g* and *x* are increased by the same proportion. From (17) it follows that the pollution effect of an increase in *g* holding *x* constant is,

(20) $$\frac{d\ln Z}{d\ln g} = \frac{[1-a(c)(1-\alpha)+a(c)(1-\alpha)\Lambda_c]\eta - [\alpha + a(c)(1-\alpha)\Lambda_c]\Omega}{1-\alpha-\beta}$$

Note that given that $\Omega \geq \eta$ the sign of (20) is negative if the first term in square brackets in the numerator is smaller than the second square bracket term. This is true as long as $a \geq 1$. The partial effect of *x* on pollution can be derived in a similar way as the effect of *g*,

(21) $$\left.\frac{\partial \ln Z}{\partial \ln x}\right|_{dg=0} = \left(1 - a(c)(1-\alpha)\Lambda_d\right)\pi_x\,,$$

[11] Here, we neglect the possible indirect effects associated with government borrowing itself on pollution.

where $\pi_x \equiv \frac{x}{x+k}$ is the share of government-provided private goods in total capital used by the dirty sector.

From (20) and (21) we derive the net effect of increasing total fiscal spending keeping the spending composition constant,

$$\frac{d\ln Z}{d\ln G} = \frac{[1-a(c)(1-\alpha)\Lambda_{\mathrm{d}}]\left(\eta+(1-\alpha-\beta)\pi_x\right)-[\alpha+a(c)(1-\alpha)\Lambda_{\mathrm{c}}]\Omega}{1-\alpha-\beta}. \tag{22}$$

The net effect of a fiscal spending expansion on pollution is, in general, ambiguous. A neutral increase of G raises both g and x by the same proportion. When the share of physical capital in the dirty sector (1-α-β) and the share of the government-provided private good in total capital (π_x) are both small, it is more likely that pollution will be decreasing in total fiscal spending. This is intuitively plausible because the partial pollution-increasing effect of the x component of G is small in this case. Also, G is less likely to be pollution increasing when there is greater divergence between the output elasticity of the public good in the clean and dirty sectors. If Ω is large and η is small, it is more likely that the pollution-reducing effect of increasing g could off-set the pollution-increasing effect of increasing x.

These results are summarized in the following proposition,

Proposition 3. *A borrowing-financed increase in aggregate fiscal spending that keeps the expenditure composition constant has an ambiguous effect on pollution. Aggregate fiscal spending is more (less) likely to raise pollution when the share of capital in the production of the dirty good and the share of the government-provided private goods in the total private capital in the dirty sector are high (low) while the divergence between the elasticity of the public good in the clean and dirty sectors is small (large).* ⊗

In addition we have the following corollary to proposition 3,

Corollary to Proposition 3. *An increase in total public spending while keeping expenditure composition constant necessarily increases pollution if assumptions A3 and A4 do not hold.*

This Corollary is important because it suggests a way to empirically validate assumptions *A3* and *A4* used elsewhere throughout the theoretical model.

3. The Empirical Model

We estimate the effect of government spending on pollution levels by specifying an empirical model that controls for various economy-wide factors and uses proxy measures to control for the scale effect and (imperfect proxies) for the tax-equivalent pollution regulations. The empirical model specification is derived by using Equations (10), (13) and (15) in (8). This yields the following specification for an empirical pollution equation,

(23) $$Z = \mathrm{F}(g, x, p, I, k, c)\,.$$

We postulate that the vector I that determines the proportional wedge between τ and τ^{*} from (15) is dependent on political economy factors and institutions, *Pol*, the growth rate of GDP, *R*, and consumption per capita, *c*. Wealthier countries that are democratic and have more efficient political institutions are likely to establish pollution regulations close to the optimal pollution tax level, τ^*. Also, we hypothesize that the speed of economic growth (the growth rate of GDP) may have an impact on the ability of regulations to adjust to pollution levels. Countries that grow too fast may not have time to adjust environmental regulations to the increasing pressures on the environment that economic growth entails. Thus, we postulate that the vector *I* is determined by *Pol, R* and c. We also use trade policy (*T*) as a factor that affects the relative price, p, as well as productivity [Melitz, 2003].

Using these considerations and after dividing and multiplying *g* and *x* by *G*, where $G \equiv g+x$, and then normalizing *G* by the economy's income, we obtain the following, (23’) $Z = \mathrm{F}(s, 1-s, \tilde{G}, T, Pol, R, k, c)$,

where $s \equiv g/G$ is the share of government expenditures in public goods in total government expenditure and $\tilde{G} \equiv G/c$ is total government expenditure in total income of the economy.

From (23’), we derive the following empirical relationship:

(24) $\ln Z_{ijt} = \psi_1 \ln s_{jt} + \psi_2 \ln \tilde{G}_{jt} + \psi_4 \ln Y_{jt} + \psi_3 \ln T_{jt} + \psi_5 Pol_{jt} + \psi_6 R_{jt} + \psi_7 \ln k_{jt} + \psi_8 \ln c_{jt} + \vartheta_{ij} + \zeta_t + \varepsilon_{ijt}$,

where subscript *i*, *j* and *t* represents site station where pollution is monitored, country and time, respectively and ψ_j (j=1,..,8) are fixed parameters. Thus Z_{ijt} is pollution concentration measured from site *i* in country *j* at year *t*; s_{jt} is the share of public goods expenditure in total government expenditure in country j at time t; $\tilde{G}_{jt}$ is government consumption expenditure over GDP;[12] T_{jt} is an index of trade policy openness; Y_{jt} is total GDP per land area; Pol_{jt} is a vector of political economy variable that include an index of democracy, years of democratic stability and a dummy for freedom of press; R_{jt} is GDP growth rate; k_{jt} is the share of investment over GDP (as a proxy for capital stock); c_{jt} is the household income per capita; ϑ_{ij} is a site effect corresponding to site i in country j which can be fixed or random, ζ_t is a time effect common to all countries, and ε_{ijt} is a random disturbance with the usual desirable properties.

We test two parts of our theoretical model: Proposition 1 and the corollary to Proposition 3. For Proposition 1 to hold, ψ_1 needs to be negative and significant. For the corollary to proposition 3 to hold, ψ_2 needs to be non-positive.

3.1. Interpretation issues

[12] We use total government consumption since government investment is already included in the share of investment over GDP. Thus we avoid double counting.

The theoretical model used to derive the empirical model is relevant for production-generated pollution so we focus on air pollutants generated as a by-product from production as opposed to consumption of goods. We calculate the percentage distribution of sources of pollution by air pollutant type and identify if the majority are from production sources, such as electricity generation or industrial processes, or consumption sources, such as road vehicle use and residential wood combustion (see Appendix Table AII).

There are six air pollutants for which there is consistent data on concentrations levels measured in several monitoring stations for a number of countries: sulfur dioxide (SO_2), nitrogen dioxide, lead, ozone, volatile organic compounds and carbon monoxide. Nitrogen dioxide, carbon monoxide and volatile organic compounds mainly come from road vehicle use and are more likely to be consumption pollutants based on the distribution of sources shown in Table AIII.[13] Since the combination of nitrogen dioxide and volatile organic compounds produce ozone, ozone can also be considered a consumption pollutant. On the other hand, the majority of SO_2 and lead come from electricity generation and industrial process. We note that during the late 1970s and early 1980s the main source of lead was from road vehicles using leaded gasoline. However, by the mid-1980s, lead in gasoline was partially or even totally banned in the majority of our sample of countries. The remaining lead concentrations are mainly due to production processes within our sample period which starts in the late 1980s. Thus, we focus the study of air pollution on SO_2 and lead.

The measure of water pollution used is biological oxygen demand (BOD). The majority of BOD emissions come from the food industry (on average 44%) followed by textiles (on

[13] In general, emissions from road vehicles may be classified as production-generated or consumption-generated. However, majority of vehicles are passenger vehicles so we classify pollutants associated with their use as consumption pollution.

average 16%) [Gurluk, 2009]. In general BOD can be regarded as primarily a production-generated pollutant although a modest fraction of it is originated in consumption processes.

Since we control for measures of aggregate output and institutional factors as determinants of the implemented tax-equivalent pollution regulation, τ, the coefficients of the government spending variables are capturing the sum of the *direct effect*, the *pollution-labor substitution effect* and the g*overnment's budget effect*. However, as indicated earlier it is likely that the proxies that we use for τ are imperfect and incomplete, so we can expect that the government variables also capture some of the unobserved *environmental regulation effects*. To put it in terms of the usual nomenclature used to classify the pollution effects in the trade literature, the coefficients of the government expenditure variables mainly capture the output composition and input composition effects and part of the technique effect.

3.2. Econometric issues

The impact of government expenditure may not occur instantaneously. For this reason, we use the lagged share of expenditure in public goods and lagged share of government consumption expenditure which also may mitigate bias from reverse causality. However, other biases may persist if the lagged values of the government spending variables are correlated with omitted variables that affect pollution but which may not be causally related to government spending variables. The use of fixed site effects may control for time-invariant omitted variables but the problem of time-varying omitted variables remains.

Omitted time-varying variables could bias the coefficients of the government variables if they are correlated with the government spending variables. We are particularly concerned with omitted time-varying environmental regulations that are difficult to measure and may be positively correlated with expenditures in public goods, which may cause an upward bias to the coefficients of such expenditures. Environmental regulation changes over time are also driven by factors other than the government spending variables that may be correlated with the government spending variables. For example, one could speculate that governments that are more responsive to social welfare may spend more in public goods and may also be inclined to implement tighter environmental regulation leading to lower pollution.

To deal with this possibility we use *time-varying country-specific effects* (TVC) as part of the sensitivity analysis. We exploit the fact that we have several site observations per country and year and, thus we augment equation (24) by substituting the common-to all-countries time effect, ζ_t, with the TVC effects that allow for country-idiosyncratic time varying effects. That is, we use country-year interaction effects or a_{jt} effects.[14] This allows us to control for biases due to unobserved economy-wide, time-varying omitted variables that differ for each country. Since most of the unobserved environmental regulations apply to the whole country and since the government variables are also economy-wide, this procedure should be quite effective in removing potential biases affecting the coefficients of the government spending variables. While the TVC procedure prevents biases due to time-varying country specific unobserved variables, it may entail costs as a consequence of having to estimate a large number of additional parameters.[15] For this reason we use the TVC procedure mainly as a sensitivity analysis to check the robustness of the coefficients associated with the government spending variables.

We also employ a frequently used procedure that can be called *Added Controls Approach* (ACA) to deal with the general issue of time-varying omitted variables. ACA enhances the controls by using a large set of additional institutional, political and economic time-varying

[14] Given that Equation (24) already controls for the fixed or random site-country effects ϑ_{ij} the additional a_{jt} dummies are defined for $\tilde{T}$-1 periods where $\tilde{T}$ is the total number of periods.

[15] Out of a total of 1910 site observations in 38 countries for SO_2, we need to estimate 246 additional coefficients associated with the a_{jt} dummies. For lead and BOD we estimate 153 and 310 a_{jt} dummies, respectively, using a total of 664 observations in 28 countries and 3584 site observations in 40 countries, respectively.

control sets in sequence. These added controls may be correlated with unobserved time-varying variables that could bias the effect of the government variables. If a large number of control sets are used and the sign and significance of the coefficients of interest do not change, it is less likely that time-varying omitted variables affect the estimates. The ACA sensitivity analysis that we use follows a procedure used by Altonji *et al.* [2005], which consists of verifying whether adding variables that increase the goodness-of-fit of the estimation affect the coefficients in question.

4. The Data

Water and air pollution concentration measures are derived from the Global Environmental Monitoring System (GEMS) dataset which is the most consistent data source for cross-country pollution. The air quality measures were compiled by the WHO Automated Meteorological Information System (AMIS) program. In this study, we use only the WHO-AMIS dataset from 1986 – 1999 for air pollution.[16]

For the case of water quality we are able to use a more updated dataset for the years 1980-2005 from GEMS-Water. These data are actual measurement of water quality from various groundwater, wetland, rivers or lakes in fixed sites. There are 47 countries in our sample that measure water quality. For the air pollution data, the total number of countries included in the sample is 38 of which half are low and middle income according to the World Bank classification. Taking SO_2 as an example, there are about 1900 observations distributed in 120 cities with about 2.5 measurement sites per city per year on average.

[16] The air quality database is sponsored by the World Health Organization (WHO) and maintained by the Environmental Protection Agency (EPA) while the water quality database is maintained by GEMSWater. The original air quality dataset utilized by Grossman and Krueger [1995] has been updated to GEMS/AIRS resulting in two GEMS datasets which were cleaned and combined by Harbaugh *et al*. [2000] for the years 1971 to 1992. However, in their study they do not explicitly explain how they combine the data when both datasets have differing observations. Thus, we did not combine the older dataset with the most recent dataset from the WHO.

Government expenditures data is obtained from the Government Financial Statistics database compiled by the IMF and, in some cases, we use data from the Asian Development Bank. Expenditures in public goods include spending in education, health, social welfare, transport, communications, public order and safety, research and development, environment, recreation and culture, and social housing.[17] We include social welfare as part of the expenditures in public goods because it includes housing, unemployment, sickness and disability, care for the elderly, survivors, family and children, and R&D for social protection. These social welfare programs allow the poor to invest in education and health which corrects underinvestment in human capital in part due to credit market imperfections and positive spillovers associated with education and health. However, we check the robustness of the results to the exclusion of social welfare expenditures from the public good component. Table AIII in the appendix presents summary statistics of the data. Data source and descriptions are in Table AIV in the appendix.

5. The Results

We present Ordinary Least Squares (OLS), Fixed Site Effects (FSE), Random Site Effects (RSE) and Hausman Taylor Random Site Effects (HTRE) estimates of air and water pollutants based on the specification in (23). FSE and RSE models take into consideration the heterogeneous characteristics across sites. The HTRE method allows for some of the explanatory variables to be correlated with individual effects [Baltagi et. al., 2003].

5.1. The Econometric Estimates

Tables I and II present the coefficient estimates of the determinants of the production-generated pollutants. The goodness-of-fit of the models are satisfactory as shown by the adjusted

[17] One obvious hypothesis to test is the impact of environmental expenditure on pollution concentration. Unfortunately, many countries in our sample do not provide values for this subcategory in the data.

R-squared and significant coefficients. We use the Huber / White / Sandwich estimator of variance to estimate the standard error of the coefficients to account for any potential autocorrelation and heteroskedasticity. All estimates yield negative and statistically significant effects for the share of public goods regardless of the method used. If these estimates are corroborated by the sensitivity analysis, it means that the key prediction of the model in Proposition 1 is empirically supported. Moreover, with the exception of the OLS estimates which are likely to be biased, the magnitudes of the estimated coefficients are remarkably similar for each of the three pollutants across the three methods of estimation. For SO_2 they range between -0.36 and -0.44. The ranges for lead and BOD coefficients vary between -0.61 and -0.74 and -0.21 and -0.26, respectively. We can use any of the estimates that allow for heterogeneous site characteristics as a benchmark because government expenditure variables are lagged and, therefore, not endogenous. Here, we use the RSE estimates as benchmarks for the sensitivity tests and the simulation.[18]

The estimates imply that increasing the share of government expenditures in public goods by 10%, holding total government expenditure constant, may result in a 4% reduction of SO_2 concentration and a 7% decrease in lead concentrations. A similar reallocation of government expenditures may induce a 2% decrease in BOD. To see the importance of these effects it is convenient to look at relative changes within the sample. Increasing the share of expenditures in public goods by one standard deviation (about 27% of the sample mean) reduces SO_2 concentrations by 10% of its standard deviation (or 12% of the sample mean), lead by 15% of its standard deviation (or 21% of the sample mean), and BOD concentration by 1% of its standard

[18] The Hausman test suggests that some of the explanatory variables used in the RSE estimation may be endogenous. The test uses random effects as the maintained assumption and tests whether the explanatory variables are truly exogenous. Since the government spending variables are lagged, they are not endogenous. Thus, the Hausman test in our specification may mainly indicate that some of the control variables that are not lagged are endogenous.

deviation (or 6% of the sample mean). Thus, it appears that the quantitative impact of changes in the composition of government spending is quite large especially for the air pollutants.

The size of the government, as measured by the share of total government consumption expenditure in GDP, has no significant impact in any of the pollutants in all three estimators that allow for heterogeneous site characteristics. In fact, there is a surprising degree of correspondence on these results. Thus, changing the total level of government consumption expenditure without changing its composition is likely to be pollution neutral. If this finding is robust to the ensuing sensitivity analyses it means that by the Corollary to Proposition 3, assumptions *A3* and *A4* used in the theoretical analysis are not jointly rejected by the empirical evidence.

Most of the signs and significance of the coefficients associated with the other controls are generally plausible and consistent with the literature. We find that per capita household income has a consistent negative and significant effect on water pollution across all methods of estimation. For SO_2 the household income effect is negative although mostly insignificant in all cases except for OLS. For lead the income effect is positive, a result for which we do not have an explanation. The literature finds much more definitive and robust income effects [Antweiler et. al., 2001] than our estimates. To the extent that government public expenditure share is positively correlated with household income [López and Islam, 2008], the omission of the former in the regression could bias the income estimates from the literature when the effect of government expenditure composition is not controlled for. The output scale effect, represented by the GDP per land area variable, is positive and significant in most of the estimates. This is quite consistent with studies that have separated the effects of output scale from per capita income [Antweiler et. al., 2001; Grossman and Krueger, 1995].

The political economy variables generally have a significant negative effect on pollution with the exception of freedom of the press and polity for BOD. This is generally consistent with the notion that political economy factors may be important in determining the emergence of institutions that regulate pollution levels. Particularities of the political system, the degree of participation of the civil society in monitoring governments [Dollar and Kray, 2007; Li et. al, 1998; Lundberg and Squire, 2003; White and Anderson, 2001] and freedom of the press [Arimah, 2004; Chong and Grandstein, 2004] are some of the politico-economy factors that appear to play a role in improving social welfare and subsequently improving environmental quality.

5.2. Sensitivity Analysis

The reliability of the reported estimates depend on the assumption that there are no underlying time-varying omitted variables, such as institutional development and environmental policies that may lead to lower pollution levels and which may be correlated with but not caused by the fiscal variables. If we do not control for these variables, spurious correlation between pollution and public expenditure may exist. We check the robustness of our results from these types of omitted variables by using the ACA and TVC approaches.

ACA Sensitivity Analysis. Several studies have found that governance [Barro, 2003], government finance [Borensztein et. al., 1995], human capital and income distribution [López et. al., 2008], and demographics [Gallup et. al., 1999], are correlated with economic development which, in turn, may induce institutional changes that may affect environmental policies. We add a set of variables representing each of the determinants listed above in sequence into the RSE regressions for each pollutant.

Table III shows how the estimated coefficient of lagged share of expenditure in public goods on pollution changes as we alternatively add various sets of time-varying control variables to the base model. A set of added control variables raises the explanatory power to the basic model if the adjusted R-squared increases relative to the base level. Adding the set of variables representing human capital and income distribution and the set of government finance variables both increase explanatory power for the SO_2 model. Despite this, the sign and significance of the lagged share of public goods expenditure coefficients are largely unaffected. For BOD, the results are even more robust. All set of covariates, except government finance, adds explanatory power to the model. However, even with the inclusion of these sets of variables, the sign and significance of our coefficient of interest does not change. The results for lead are not as robust. While the government share of public expenditures remains negative in all cases, the coefficient becomes insignificant in majority of the cases. A possible reason for the lack of complete robustness of the results for lead may be due to the relatively small number of observations that are available for this pollutant.

Similar sensitivity checks were implemented to ascertain the robustness of the finding that total government consumption expenditures had non-positive effects on pollution. As shown in Table III this result is robust to the sensitivity checks implemented. The coefficient of government consumption expenditure is either insignificant or negative and significant for BOD, SO_2 and lead in all specifications but never positive and significant.

TVC Sensitivity Analysis. Table IV presents the TVC estimates using the augmented RSE model as well as RSE with fixed country effects for comparison. The coefficient of the share of public goods remains significant and negative for all pollutant models in both cases. Since the fixed country effect model is nested in the TVC model we can test the former using a Likelihood

Ratio (LR) test. As shown in Table IV the LR test rejects the fixed country effect model in favor of the TVC at a 1% level of significance. The TVC estimates show that the coefficients of the government share of public expenditures remain negative and highly significant for all pollutants. While the coefficients for SO_2 and lead become larger in absolute magnitude than those in the base regressions, the magnitude of the coefficient for BOD is remarkably similar to the size of the coefficient estimated with the RSE base model reported in Table II.

The coefficient for total government consumption expenditure is consistently insignificant for SO_2 and BOD. However, the same coefficient is now negative and significant for lead when the TVC approach is used. By the Corollary to Proposition 3 this implies that assumption *A3* and *A4* made in the theoretical model are consistent with the empirical findings.

Dominance Tests. A test for extreme observation dominance of the share of public goods was conducted by estimating the model without the top and bottom 1% of the share of public goods expenditure data. A similar analysis was also conducted with the pollutant measures themselves. Signs, significance and magnitudes of the parameter estimates from the models are robust as shown in Table V. To test for the effect of potential country outliers, we dropped countries one at a time if they have less than 5% of the total number of observations and checked whether they altered the parameter estimates of the share of public goods. There is no significant country dominance. It appears that the results are not driven by a small number of observations.[19]

Additional Sensitivity checks. We also conduct a series of additional robustness checks related to the variables included in the regression analyses. First, the expenditure in social welfare category may not all be used to correct underinvestment in human capital. We exclude this

[19] We also implement bootstrapping procedures to verify robustness of standard errors and check for country dominance to see whether results are driven by a small number of observations. We calculate standard errors using nonparametric bootstrap with 10,000 sampling repetitions. Bias-corrected confidence intervals are generated from the bootstrap procedure to test the significance of the coefficient of interest. Table V shows the standard error and significance level using the bootstrap procedure are very close to the original benchmark.

subcategory in the construction of the share of public goods variable and re-estimate the regressions. We find that the sign and significance of the share of public goods remains robust in the SO_2 and BOD regressions but it becomes insignificant for the lead regression as shown in Table VI. One potential explanation is that lead pollution may have a disproportionate effect on lower income populations who rely on social welfare.

Second, we include an index of political constraints used in Henisz [2000], an index of globalization used in Dreher [2006] and different democracy indicators used in [Cheibub and Gandhi, 2010] and find that our results are robust to the addition of these variables across all pollutants. We summarize the results in Tables VII and VIII.

Lastly, we estimated a dynamic panel model with a lagged dependent variable as an added regressor in Table IX. Results are also robust for all pollutants.

5.3 Summary of the Results

The results render empirical support not only to the main empirically testable prediction of the theoretical model shown in Proposition 1 but they are also consistent with the key assumptions used by the model as shown in the Corollary to Proposition 3. The finding that shifts in the composition of fiscal spending in favor of public goods causes a reduction in pollution is very robust for SO_2 and BOD. While the negative effect of public good expenditure share on lead is not as robust, the coefficient remains negative in all cases.

The finding that the effect of total government consumption expenditure is non-positive is also robust. In fact, the coefficient associated with the government consumption expenditures variable is either insignificant or negative and significant for all three pollutants, but never positive and significant. This finding validates two key assumptions made in the theoretical model: the output elasticity of public goods in the clean sector is larger than that in the dirty sector and the elasticity of the marginal utility of consumption is greater or equal to 1. Thus, the theoretical model developed in this paper appears to be robust when its key prediction and assumption are confronted with empirical evidence.

6. Conclusion

This paper presents the first comprehensive theoretical and empirical examination of the effects of the level and composition of fiscal spending on the environment. We have shown that reallocating government expenditure towards a greater provision of public goods reduces air and water pollution. An increase in the share of government spending in public goods in total government spending decreases significantly the concentration of BOD and SO_2 in the atmosphere. These results pass extremely demanding sensitivity tests and do not seem to be driven by biases originated in neither fixed nor time-varying omitted variables. The evidence for lead is less robust but it hints at a possible pollution-decreasing effect as well. Another finding is that total government spending is neutral for pollution, holding government expenditure composition unchanged. An interpretation of this is that when increasing government expenditure in public goods and private goods by the same proportion, the pollution-reducing effects of increasing the former tends to offset pollution-increasing effects of the latter.

These results may have important implications given the current emphasis on fiscal spending as a means to palliate the effects of the current world economic crisis. It appears that many countries, including the USA, have started a program that entails not only increasing government spending in a dramatic way but also increasing the emphasis in the expansion of public goods, especially social spending including education and health care, along with green initiatives. Given our results, the expansion of government spending with greater emphasis in public goods may have an unexpected silver lining: It could make reducing pollution easier to achieve entailing much lower costs than what is usually assumed.

This implication is particularly important because the source of the effect of government spending composition on pollution is not likely to be related to environmental regulation as shown by the robustness of the results to time-varying omitted variables related to economy-wide environmental regulation. Even if environmental regulation remains unchanged, the change in the composition of government spending towards public goods is likely to reduce air and water pollution at each level of GDP.

In closing, we have been able to develop a simple model which is not only powerful enough to yield an important empirically testable prediction but also exposes two of its key assumptions to empirical falsification. Both the prediction and the theoretical assumption of the model are supported by the empirical evidence. Theoretical parsimony and powerful testable predictions corroborated by empirical evidence seem to conform well to the scientific ideal.

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Table I
Pollution Estimates using Ordinary Least Squares (OLS) and Fixed Site Effects (FSE)

	OLS			FSE		
	Air		Water	Air		Water
	Log SO_2	Log Lead	Log BOD	Log SO_2	Log Lead	Log BOD
Log Share of expenditures in public goods (as % of total government exp) lagged	-1.452*** [0.100]	-1.026*** [0.177]	-0.296*** [0.041]	-0.363*** [0.079]	-0.611*** [0.112]	-0.260*** [0.044]
Log total government cons exp over GDP lagged	0.303** [0.125]	-1.168*** [0.253]	-0.397*** [0.108]	-0.005 [0.177]	-0.498 [0.486]	0.238 [0.196]
Log total Investment over GDP lagged	0.035 [0.095]	-1.090*** [0.152]	-0.383*** [0.061]	0.162 [0.100]	-0.033 [0.204]	-0.185* [0.109]
Log Household final consumption expenditure per capita (2000 US$) average of current and previous two years	0.203*** [0.033]	0.234*** [0.064]	-0.081** [0.032]	-0.605* [0.344]	2.032** [0.909]	-0.439** [0.208]
Log Total GDP (2000 US$) over land area (sq. km)	0.201*** [0.020]	-0.207*** [0.037]	0.292*** [0.015]	0.923*** [0.278]	0.528 [0.677]	0.583*** [0.160]
Growth rate of GDP	-1.354** [0.639]	2.940** [1.193]	-2.219*** [0.524]	0.636* [0.385]	1.875* [1.107]	-0.840** [0.361]
Trade openness Index	-0.001 [0.001]	-0.002 [0.002]	0.008*** [0.001]	0.0005 [0.001]	0.013*** [0.004]	0.005*** [0.002]
Dummy Freedom of Press	-0.588*** [0.068]	0.096 [0.154]	0.128** [0.056]	-0.169*** [0.039]	-0.134 [0.099]	0.118*** [0.044]
Index of Democracy	-0.085*** [0.007]	-0.025* [0.014]	0.0004 [0.005]	-0.011 [0.012]	-0.074*** [0.017]	0.013** [0.006]
Years of Democratic Stability	-0.066*** [0.007]	-0.121*** [0.016]	-0.119*** [0.005]	-0.004 [0.036]	0.116** [0.052]	-0.191*** [0.041]
Constant	-0.23 [0.361]	-5.104*** [0.601]	-4.019*** [0.321]	-3.305* [1.778]	-24.751*** [2.984]	-2.416 [1.539]
Adjusted R-squared	0.44	0.31	0.47	0.32	0.69	0.11
Observations	1910	664	3584	1910	664	3584

Note: * significant at 10%; ** significant at 5%; *** significant at 1%*. Robust standard errors are in brackets. Estimations for OLS include dummies for socialist and formerly socialist economies as well as site characteristic dummies for air pollutants (city center, other urban, rural, and traffic) and water pollutants (groundwater, lake, river, and water temperature). Estimations for FSE also include common to the countries year dummies.

Table II
Pollution Estimates using Random Site Effects (RSE) and Hausman-Taylor Random Site Effects (HTRE)

	RSE			HTRE		
	Air		Water	Air		Water
	Log SO_2	Log Lead	Log BOD	Log SO_2	Log Lead	Log BOD
Log Share of expenditures in public goods (as % of total government exp) lagged	-0.443*** [0.061]	-0.741*** [0.123]	-0.216*** [0.031]	-0.397*** [0.072]	-0.693*** [0.123]	-0.231*** [0.029]
Log Total government cons exp over GDP lagged	-0.167 [0.165]	-0.324 [0.277]	0.056 [0.123]	-0.037 [0.133]	-0.073 [0.265]	0.138 [0.156]
Log of total Investment over GDP lagged	0.117 [0.090]	-0.413** [0.167]	-0.239*** [0.071]	0.247*** [0.082]	-0.004 [0.181]	-0.239*** [0.082]
Log Household final consumption expenditure per capita (2000 US$) average of current and previous two years	-0.065 [0.056]	0.279*** [0.105]	-0.127*** [0.048]	-0.128 [0.089]	1.136*** [0.304]	-0.110* [0.066]
Log Total GDP (2000 US$) over land area (sq. km)	0.198*** [0.042]	-0.044 [0.057]	0.324*** [0.034]	0.281*** [0.074]	0.459** [0.232]	0.356*** [0.048]
Growth rate of GDP	0.894*** [0.323]	0.865 [0.606]	-0.811** [0.338]	1.089*** [0.290]	1.365** [0.605]	-0.756** [0.305]
Trade openness Index	0.0004 [0.001]	0.003 [0.002]	0.007*** [0.001]	0.0005 [0.001]	0.011*** [0.003]	0.006*** [0.001]
Dummy Freedom of Press	-0.263*** [0.039]	-0.216** [0.093]	0.084** [0.038]	-0.206*** [0.036]	-0.152* [0.082]	0.092** [0.039]
Index of Democracy	-0.026*** [0.008]	-0.054*** [0.013]	0.007 [0.005]	-0.018* [0.009]	-0.075*** [0.016]	0.010* [0.006]
Years of Democratic Stability	-0.071*** [0.013]	-0.100*** [0.024]	-0.118*** [0.011]	-0.053** [0.021]	0.022 [0.045]	-0.144*** [0.016]
Hausman Test (P-value)	0.000	0.000	0.000	0.952	-	-
Adjusted R-squared	0.41	0.26	0.45			
Observations	1910	664	3584	1910	664	3584
No. of Sites	292	123	488	292	123	488

Note: * significant at 10%; ** significant at 5%; *** significant at 1%*. Robust standard errors are in brackets for RSE. Both sets of estimations include common year dummies as well as site characteristic dummies for air pollutants (city center, other urban, rural, and traffic) and water pollutants (groundwater, lake, river, and water temperature). HTRE uses the mean and deviation from the mean of all variables except expenditures in public goods as instruments in the estimation. The Hausman tests for HTRE using lead and BOD yield a negative test statistic.

Table III
ACA Robustness Checks for the Coefficients of the Share of Public Goods and of total Government Spending

Specification	SO2 – RSE			LEAD - RSE			BOD - RSE		
	Share of expenditures in public goods	Total government cons exp over GDP	Adjusted R-Squared	Share of expenditures in public goods	Total government cons exp over GDP	Adjusted R-Squared	Share of expenditures in public goods	Total government cons exp over GDP lagged	Adjusted R-Squared
Base	-0.443*** [0.061]	-0.167 [0.165]	0.41	-0.741*** [0.123]	-0.324 [0.277]	0.26	-0.216*** [0.031]	0.056 [0.123]	0.45
Governance Presidential System Dummy Quality of Government Index Corruption Proportional Representation	-0.293*** [0.076]	-0.499*** [0.161]	0.40	-0.118 [0.151]	-0.831*** [0.224]	0.47	-0.197*** [0.040]	0.229 [0.162]	0.49
Government Finance Tax over GDP Foreign Direct Investment over total Investment	-0.412*** [0.073]	-0.273* [0.159]	0.45	-0.048 [0.148]	-1.089*** [0.256]	0.43	-0.252*** [0.033]	-0.216 [0.151]	0.43
Demographics Log of level of Population between 15 and 64 Population Density	-0.465*** [0.064]	-0.186 [0.169]	0.41	-0.797*** [0.125]	-0.274 [0.261]	0.32	-0.207*** [0.032]	-0.110 [0.129]	0.47
Human Capital and Income Distribution Initial Income Gini Initial Primary School	-0.270*** [0.100]	-0.19 [0.188]	0.48	-0.267 [0.190]	-0.003 [0.271]	0.59	-0.159*** [0.030]	0.131 [0.157]	0.55

Completion Rate
Life Expectancy

Note: * significant at 10%; ** significant at 5%; *** significant at 1%. Data for the additional covariates used are available from the authors.

Table IV
Robustness Check of the effect of share of expenditures in Public Goods and Total government spending on pollution: TVC vs Fixed country effects

	Fixed Country Effects			TVC: Variable Country-specific Effects		
	Air		Water	Air		Water
	Log SO_2	Log Lead	Log BOD	Log SO_2	Log Lead	Log BOD
Log Share of expenditures in public goods (as % of total government exp) lagged	-0.471*** [0.097]	-1.737*** [0.115]	-0.319*** [0.042]	-0.691** [0.334]	-1.594*** [0.414]	-0.240*** [0.068]
Log Log Total government consumptions exp over GDP lagged	0.283 [0.175]	0.499 [0.341]	0.264 [0.177]	0.234 [0.451]	-1.505*** [0.524]	-0.163 [0.245]
Log of Share of Investment over GDP lagged	0.370*** [0.102]	1.378*** [0.245]	-0.139 [0.0846]	0.258 [0.313]	-1.161*** [0.314]	-0.167 [0.166]
Log Household final consumption expenditure per capita (2000 US$) average of current and previous two years	-0.817** [0.364]	5.364*** [1.011]	-0.738*** [0.198]	0.0135 [0.099]	0.401** [0.161]	-0.075 [0.0570]
Log Total GDP (2000 US$) over land area (sq. km)	0.131 [0.288]	-5.098*** [0.763]	0.651*** [0.141]	0.254*** [0.061]	-0.165** [0.067]	0.298*** [0.036]
Growth rate of GDP	0.612 [0.398]	6.868*** [1.224]	-0.985*** [0.327]	-0.694 [2.841]	15.57*** [4.442]	2.671** [1.179]
Trade openness Index	-0.005*** [0.002]	0.011*** [0.004]	0.003** [0.001]	0.0002 [0.003]	0.004 [0.004]	0.009*** [0.001]
Dummy Freedom of Press	-0.066* [0.038]	-0.135 [0.116]	0.078* [0.042]	-0.736* [0.384]	0.303 [1.143]	0.606*** [0.187]
Index of Democracy	-0.035** [0.017]	-0.065*** [0.017]	0.019*** [0.006]	-0.055 [0.036]	-0.095 [0.087]	-0.040*** [0.014]
Years of Democratic Stability	-0.292*** [0.027]	-0.143*** [0.051]	-0.219*** [0.031]	-0.0005 [0.021]	0.040 [0.035]	-0.101*** [0.017]
LR test for Country-Year Dummies				0.000	0.000	0.000
Adjusted R Squared	0.69	0.72	0.52	0.57	0.51	0.49
Number of Observations	1910	664	3584	1910	664	3584

Number of sites	292	123	488	292	123	488

Note: * significant at 10%; ** significant at 5%; *** significant at 1%*. Robust standard errors are in brackets. Estimates also include site characteristic dummies for air pollutants (city center, other urban, rural, and traffic) and water pollutants (groundwater, lake, river, and water temperature). LR tests the null hypothesis that the country fixed effects estimator is valid.

Table V
Dominance Tests of the estimates on the effect of share of Government Expenditure in Public Goods on Pollutants and Bootstrapping estimates

Sensitivity Test	SO2 (RSE)	Lead (RSE)	BOD (RSE)
Dominance Test			
Bottom 1% of Share of Expenditures in Public Good dropped	-0.456*** [0.073]	-0.696*** [0.133]	-0.224*** [0.066]
Top 1% of Share of Expenditures in Public Good dropped	-0.445*** [0.061]	-0.694*** [0.125]	-0.217*** [0.031]
Top and Bottom 1% of Share of Expenditures in Public Good dropped	-0.460*** [0.073]	-0.647*** [0.136]	-0.227*** [0.066]
Bottom 1% of Pollutant	-0.438*** [0.061]	-0.770*** [0.120]	-0.136*** [0.030]
Top 1% of Pollutant	-0.467*** [0.061]	-0.709*** [0.125]	-0.223*** [0.030]
Top and Bottom 1% of Pollutant	-0.462*** [0.061]	-0.738*** [0.122]	-0.144*** [0.029]
Bootstrap			
Benchmark	-0.443*** [0.061]	-0.741*** [0.123]	-0.216*** [0.031]
Bootstrap Bias-Corrected	-0.447*** [0.059]	-0.787*** [0.111]	-0.219*** [0.041]

significant at 10%; ** significant at 5%; *** significant at 1%

TABLE VI:
Robustness Check with the Removal of the Social Welfare Component from the share of Public Good spending

	RSE		
	Air		Water
	Log SO_2	Log Lead	Log BOD
Log Share of expenditures in public goods excludes Social Welfare (as % of total government exp) lagged	-0.217***	-0.111	-0.232***
	[0.060]	[0.129]	[0.067]
Log Total government cons exp over GDP lagged	-0.216	-0.489*	0.024
	[0.172]	[0.264]	[0.131]
Log of total Investment over GDP lagged	0.084	-0.606***	-0.232***
	[0.095]	[0.184]	[0.074]
Log Household final consumption expenditure per capita (2000 US$) average of current and previous two years	-0.138**	0.187*	-0.205***
	[0.058]	[0.102]	[0.049]
Log Total GDP (2000 US$) over land area (sq. km)	0.212***	-0.033	0.338***
	[0.043]	[0.054]	[0.037]
Growth rate of GDP	1.053***	0.671	-1.434***
	[0.337]	[0.636]	[0.354]
Trade openness Index	0.00002	0.001	0.007***
	[0.001]	[0.002]	[0.001]
Dummy Freedom of Press	-0.265***	-0.273***	0.084**
	[0.040]	[0.094]	[0.038]
Index of Democracy	-0.037***	-0.074***	0.006
	[0.008]	[0.013]	[0.005]
Years of Democratic Stability	-0.066***	-0.093***	-0.110***
	[0.013]	[0.024]	[0.012]
Hausman Test (P-value)	0.000	0.000	0.000
Adjusted R-squared	0.37	0.25	0.46
Observations	1863	642	3584
No. of Sites	284	123	488

Note: * significant at 10%; ** significant at 5%; *** significant at 1%*. Robust standard errors are in brackets for RSE. Both sets of estimations include common year dummies as well as site characteristic dummies for air pollutants (city center, other urban, rural, and traffic) and water pollutants (groundwater, lake, river, and water temperature).

TABLE VII
Robustness Checks with Added Political Constraints and Regime Change.

	RSE		
	Air		Water
	Log SO_2	Log Lead	Log BOD
Log Share of expenditures in public goods (as % of total government exp) lagged	-0.441*** [0.063]	-0.705*** [0.127]	-0.076*** [0.027]
Log Total government cons exp over GDP lagged	-0.164 [0.167]	-0.369 [0.278]	-0.238* [0.127]
Log of total Investment over GDP lagged	0.121 [0.091]	-0.447*** [0.170]	-0.217*** [0.067]
Log Household final consumption expenditure per capita (2000 US$) average of current and previous two years	-0.061 [0.056]	0.278*** [0.105]	-0.145*** [0.052]
Log Total GDP (2000 US$) over land area (sq. km)	0.197*** [0.043]	-0.055 [0.056]	0.258*** [0.031]
Growth rate of GDP	0.903*** [0.325]	0.818 [0.607]	-0.746** [0.332]
Trade openness Index	0.001 [0.001]	0.003 [0.002]	0.006*** [0.001]
Dummy Freedom of Press	-0.268*** [0.039]	-0.201** [0.095]	0.064 [0.040]
Index of Democracy	-0.026*** [0.009]	-0.067*** [0.016]	0.002 [0.009]
Years of Democratic Stability	-0.071*** [0.013]	-0.114*** [0.027]	-0.125*** [0.010]
Political Constraint V	-0.054 [0.126]	-0.013 [0.203]	0.12 [0.099]
Regime Change	-0.037 [0.185]	-0.355 [0.275]	-0.088 [0.104]

Hausman Test (P-value)	0.000	0.000	0.000
Adjusted R-squared	0.40	0.27	0.47
Observations	1910	664	3443
No. of Sites	292	123	484

Note: * significant at 10%; ** significant at 5%; *** significant at 1%*. Robust standard errors are in brackets for RSE. Both sets of estimations include common year dummies as well as site characteristic dummies for air pollutants (city center, other urban, rural, and traffic) and water pollutants (groundwater, lake, river, and water temperature).

TABLE VIII
Robustness Checks with Index of Globalization

	RSE		
	Air		Water
	Log SO_2	Log Lead	Log BOD
Log Share of expenditures in public goods (as % of total government exp) lagged	-0.441*** [0.061]	-0.765*** [0.123]	-0.222*** [0.031]
Log Total government cons exp over GDP lagged	-0.178 [0.163]	-0.304 [0.281]	0.262** [0.132]
Log of total Investment over GDP lagged	0.096 [0.091]	-0.415** [0.165]	-0.234*** [0.072]
Log Household final consumption expenditure per capita (2000 US$) average of current and previous two years	-0.068 [0.055]	0.292*** [0.104]	-0.201*** [0.048]
Log Total GDP (2000 US$) over land area (sq. km)	0.196*** [0.039]	-0.082 [0.055]	0.445*** [0.032]
Growth rate of GDP	0.883*** [0.319]	0.915 [0.601]	-0.712** [0.336]
KOF Index of Globalization	0.004 [0.006]	-0.014 [0.010]	-0.014*** [0.005]
Dummy Freedom of Press	-0.269*** [0.039]	-0.211** [0.092]	0.055 [0.038]
Index of Democracy	-0.028*** [0.008]	-0.049*** [0.013]	0.007 [0.005]
Years of Democratic Stability	-0.072*** [0.012]	-0.103*** [0.024]	-0.135*** [0.012]
Hausman Test (P-value)	0.000	0.000	0.000
Adjusted R-squared	0.41	0.28	0.43
Observations	1910	664	3584

No. of Sites	292	123	488

Note: * significant at 10%; ** significant at 5%; *** significant at 1%*. Robust standard errors are in brackets for RSE. Both sets of estimations include common year dummies as well as site characteristic dummies for air pollutants (city center, other urban, rural, and traffic) and water pollutants (groundwater, lake, river, and water temperature).

TABLE IX: Robustness Check with Dynamic Panel Estimation using GMM.

	RSE		
	Air		Water
	Log SO_2	Log Lead	Log BOD
Log Share of expenditures in public goods (as % of total government exp) lagged	-0.243** [0.110]	-0.454*** [0.159]	-0.212** [0.093]
Log Total government cons exp over GDP lagged	0.702*** [0.195]	-0.089 [0.364]	0.396 [0.289]
Log of total Investment over GDP lagged	-0.107 [0.116]	-0.092 [0.214]	0.285** [0.126]
Log Household final consumption expenditure per capita (2000 US$) average of current and previous two years	-1.011** [0.515]	0.283 [0.897]	-2.923*** [0.443]
Log Total GDP (2000 US$) over land area (sq. km)	1.294*** [0.408]	1.126 [0.751]	1.281*** [0.322]
Growth rate of GDP	-0.153 [0.479]	0.391 [1.015]	-1.884*** [0.440]
Trade openness Index	-0.002 [0.002]	0.005 [0.004]	0.006*** [0.002]
Dummy Freedom of Press	-0.094* [0.050]	-0.042 [0.097]	0.253** [0.119]
Index of Democracy	0.005 [0.018]	-0.056*** [0.017]	0.005 [0.009]
Years of Democratic Stability	0.053 [0.051]	0.059 [0.052]	-0.423*** [0.056]
Lag of ln(SO2)	0.234*** [0.053]		
Lag of ln(Lead)		0.243*** [0.065]	
Lag of ln(BOD)			0.175*** [0.034]
Hansen Test (P-value)	0.000	0.000	0.000
Observations	1377	458	2775

No. of Sites	261	98	432

Note: * significant at 10%; ** significant at 5%; *** significant at 1%*. Robust standard errors are in brackets for RSE. Both sets of estimations include common year dummies as well as site characteristic dummies for air pollutants (city center, other urban, rural, and traffic) and water pollutants (groundwater, lake, river, and water temperature).

APPENDIX

Table AI.
Measures of Elasticity of Marginal Utility of Consumption or Income

	Study	Elasticity of marginal utility of consumption/ income	Median Value	Absolute ranges	USA values	Countries studied and year period
1	Layard (2008)	1.26	Not indicated	1.19-1.34	Not indicated	50 countries (1972-2005)
2	Evans (2005)	1.4	Not indicated	1.21-1.51	1.15-1.45	20 OECD countries (has the estimates for each individual country)
3	Kula (2004)	1.64	Not indicated	Not indicated	none	India (1965-1995)
4	Lopez (2008)	1.5	Not indicated	Not indicated	none	9 Latin American Countries (has the estimates for each individual country)
5	Percoco (2008)	1.347 (Personal Tax) 1.282 (CEM)	Not indicated	Not indicated	none	Italy
6	Kula (1984)	1.89 (US) 1.56 (Canada)	Not indicated	Not indicated	1.89	USA and Canada
7	Evans and Saez (2005)	1.1-1.8 across countries	Not indicated	Not indicated	none	19 EU countries
8	Cowell and Gardiner, 1999	1.41 (income tax only) 1.28 (Tax +NICs)	Not indicated	Not indicated	none	UK (1999-2000)
9	Evans and Sezer, 2004	Ranges from 1.4 to 1.7 across countries	Not indicated	Not indicated	1.4	6 major countries: Australia, France, Germany, Japan, US, UK
10	Evans (2004)	1.35	Not indicated	Not indicated	none	France
11	Azar (2007)	4.5	Not indicated	Not indicated	4.5	USA
12	Stern (1977)	1.97				UK (1973-1974)
13	Mera (1969, pg 469)	1.5			1.5	US (1948-1965)
14	Blundell et al., 1994	1.20-1.40 0.35-1.05 (this last estimate is because a dummy was used in 1980s to capture				UK (1970-86)

		high interest rate)				
15	Pearce and Ulph (1995)	0.8-0.9				UK
16	Barsky et al., 1995	4.2			4.2	US middle aged ages 51- 61 (1992)
17	Brown and Deaton (1972, pg 1206)	2.8				UK (1900-1970)
18	Kula (1985)	0.71				UK
19	Amiel et al., 1999	0.2-0.8				Student surveys in Australia and Israel
	EXPERT OPINIONS					
20	Eckstein (1958)	0.5-2.0				USA
21	Feldstein (1965)	1.0-2.0				USA
22	Cline (1993)	1.5				USA
23	Boscolo et. al. (1998)	1.0-2.0				USA
24	Arrow (1995)	1.5-2.0				USA
25	Scott (1977, 1989)	1.5				UK
26	Little and Mirrlees (1974)	1.0-3.0				UK

Table AII
Sources of Air Pollutants (%), 2002

Sources of pollution	Sulfur Dioxide	Carbon Monoxide	Lead	Nitrogen Oxides	Volatile Organic Compound
Production sources (Includes Electricity Generation and Industrial Process)	80	3	56	27	9
Consumption sources (Includes Road Vehicles and Residential Wood Combustion)	2	60	0	38	30
Both production and consumption (Includes Fuel Combustion, Non Road Equipment, Solvent Use, Fires, Waste Disposal and Miscellaneous)	18	37	44	34	61

Note: Figures are in percentage distribution.
Source: Authors' calculation from EPA's Air Emissions Sources site located at: http://www.epa.gov/air/emissions/.

Table AIII
Summary Statistics of the Data Used in Regressions

Variables	Mean	Std. Dev	Min	Max
Share of public goods (as % of total government expenditure)	0.54	0.15	0.21	0.88
Share of Govt. cons. Exp. over GDP	0.22	0.08	0.08	0.39
Share of total Investment over GDP	0.20	0.076	0.029	0.441
Household final consumption expenditure per capita (2000 US$) moving average of current and previous two years	5,380	5,296	158	22,223
GDP growth (2000 US$)	0.04	0.04	-0.13	0.14
GDP Per Square Km (000)	1,429	2,408	32.1	11,900
Sulfur Dioxide	39	47	0.5	460
Lead	0.3	0.4	0.005	4.5
Biological Oxygen Demand	4.2	19	0.01	604.0

Table AIV
Description of Variables

Variable	Description	Years Available	Source
Sulfur Dioxide (SO2)	SO2 concentration, micrograms per cubic meter	1986-1999	GEMS
Lead	Lead, micrograms per cubic meter	1986-1999	GEMS
Biological Oxygen Demand	Quantity of oxygen necessary for biological and chemical oxidation of water-borne substances (in milligrams per liter).	1980-2003	GEMSWater
Household final consumption expenditure per capita (2000 US$) (3 year moving average)	Household final consumption expenditure (formerly private consumption) is the market value of all goods and services, including durable products (such as cars, washing machines, and home computers), purchased by households. It excludes purchases of dwellings but includes imputed rent for owner-occupied dwellings. It also includes payments and fees to governments to obtain permits and licenses. Here, household consumption expenditure includes the expenditures of nonprofit institutions serving households, even when reported separately by the country.	1980 – 2004	World Development Indicators (World Bank)
GDP growth (2000 US$)	Real GDP per Capita growth (Constant US$ 2000)	1980 – 2004	World Development Indicators (World Bank)
Share of Government Expenditure in Public Goods	This is the share of government expenditure on public goods. Public goods are defined as a total of Public Goods is the total of: i) Education ii) Health iii) Social security iv) Transport v) Communication vi) Public order and safety vii) Housing and community amenities viii) Environmental Protection ix) Religion and Culture	1980 – 2004	Government Financial Statistics (IMF), Asian Development Bank, Country data Level of government: Consolidated central government is the level of government used apart from: Budgetary: Bangladesh, Ecuador, Greece Jordan New Zealand, Philippines Consolidated General: India

Trade Openness	Sati index which is the residual of the regression of Trade on population, area, gdp per capita, dummy for industrialized country, dummy for oil exporter, and imports over export prices. A positive residual implies a more open economy	1980-2001	Pritchett, Lant. 1996. Updated by López and Galinato [2007]
GDP Per Square Km	Total GDP (2000 US$) over land area	1980-2004	World Development Indicators (World Bank)
Foreign Direct Investment over GDP	Foreign direct investment are the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments. This series shows net inflows in the reporting economy and is divided by GDP.	1980-2005	World Development Indicators (World Bank)
Share of Government consumption Expenditure over GDP		1980 – 2004	Penn World Tables [2006]
Share of Investment over GDP		1980 – 2004	Penn World Tables [2006]
Index of Democracy	Score that indicates how democratic is a country	1980-2003	Polity IV www.cidcm.umd.edu
Years of Democratic Stability	Square root of Durability of Polity if Polity 2>0	1980-2005	From Polity IV and updated to 2005 www.cidcm.umd.edu
Dummy Freedom of Press	1 if print media is considered free	1980-2005	www.freedomhouse.org
Political Constraint V	This index measures the feasibility of policy change, i.e. the extent to which a change in the preferences of any one political actor may lead to a change in government	1960-2004	Henisz [2000]

	policy. The index scores are derived from a simple spatial model and theoretically ranges from 0 to 1, with higher scores indicating more political constraint and thus less feasibility of policy change.		
Regime Change	Coded 0 if democracy; 1 if dictatorship. A regime is considered a dictatorship if the chief executive is not elected, the legislature is not elected, there is no more than one party, or there has been no alternation in power. Transition years are coded as the regime that emerges in that year.	1946-2002	Cheibub and Gandhi [2004]
KOF Index of Globalization	Index of globalization considers three main sub-indices: (i) Index of economic integration (actual flows: e.g. trade, FDI, restrictions: e.g. mean tariff trade, taxes on international trade) (ii) Index of political integration (embassies in country, membership in international organizations) (iii) Index of social integration (Personal Contact: e.g. outgoing telephone traffic, foreign population, Information Flows: e.g. daily newspapers, radios, telephone mainlines, Cultural Proximity: e.g. No. of McDonald's restaurants per capita. Higher values imply a more globalized country.	1970-2007	Dreher [2007] http://globalization.kof.ethz.ch/

Note: Data for additional covariates are available from the authors.

COUNTRY LIST OF POLLUTION DATA AVAILABILITY

Countries with Air Pollution Data: Argentina, Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, China, Costa Rica, Croatia, Denmark, Ecuador, Estonia, Finland, France, Germany, Greece, Hungary, India, Japan, Latvia, Lithuania, Mexico, New Zealand, Philippines, Portugal, Republic of Korea, Romania, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, United Kingdom, United States, Uruguay.

Countries with Water Quality Data
Argentina, Australia, Austria, Bangladesh, Belgium, Brazil, Canada, Chile, China, Colombia, Denmark, Egypt, Fiji, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Iran, Italy, Japan, Malaysia, Mexico, Morocco, Netherlands, New Zealand, Norway, Pakistan, Panama, Peru, Philippines, Poland, Portugal, Republic of Korea, Russia, Spain, Sweden, Switzerland, Thailand, Tunisia, Turkey, United States, United Kingdom, Uruguay