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Impact of growth and tax on pollution in the presence of corruption

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Abstract. *In the context of international environmental agreements, where both developed and developing countries commit to mitigating ecological risks, this paper develops a theoretical model to examine the growth-pollution nexus in the presence of rent-seeking behavior by a self-interested government and a firm. We analyze two cases: (1) when lobbying transfers are unilaterally determined by the firm, and (2) when they are jointly determined through a Nash bargaining framework. Furthermore, when tax revenues are endogenously allocated to stimulate growth, we find that higher environmental taxes may paradoxically increase pollution in the Nash bargaining case.*

Keywords: Pollution; Lobby payment; Corruption; Pollution tax; Economic growth.

JEL Classification: Q52, D72, O44.

1. Introduction

The relation between economic growth and environmental pollution was quite straightforward since the 1970s. Initially, the conventional path opted by both developed and developing nations dependent on non-renewable resources like coal, fossil fuel etc. as these were the cheapest means of achieving economic growth. Hence, with the increase in productive activities environmental degradation via rise in pollution also became inevitable. This view was challenged during the 1990s and more complexities of this relationship were explored by scholars both empirically and theoretically. There is a huge part of literature that deals with the growth pollution nexus. Understanding all aspects of this relationship is important in controlling the greenhouse emissions to combat with the climate change and to put the economy in a sustainable growth path.

Many studies have examined the growth-pollution nexus through the lens of the Environmental Kuznets Curve (EKC). The EKC hypothesis suggests an inverted U-shaped relationship between economic output and environmental degradation (Grossman and Krueger 1995; Selden and Song 1994; Shafik 1994; Stern 2004; Sharma 2011). At lower levels of development, countries prioritize material growth over environmental concerns, leading to higher pollution. However, as economies grow and reach a turning point, increased awareness and demand for environmental quality reduce pollution, making development more environmentally sensitive. Empirical evidence provides mixed results. For instance, Apergis and Ozturk (2015) confirm the inverted U-shaped EKC for 14 Asian countries, finding carbon emission initially rise with GDP but later decline. Similarly, Dogan and Seker (2016) validate the EKC for OECD countries, showing that real income increases CO_2 emission while squared GDP reduces them in the long run. In contrast, Ozcan (2013) reports a U-shaped relationship for 12 Middle Eastern countries, indicating that emissions initially decline with growth but rise again at higher income levels. Moreover, they find different country-level results, while some economies exhibit inverted U-shaped patterns, others U-shaped, and some show no significant link at all.

Another strand of EKC related literature focuses on broader growth-pollution relationship, often using different pollutants or energy use as proxies for environmental degradation (Copeland Taylor, 2003; Bese et al., 2018). A key finding in this line of research is the role of renewable energy in mitigating pollution. For instance, Marques et al. (2010) and Ito (2016) show that renewable energy consumption significantly reduces emissions, particularly in developed countries, highlighting the importance of clean energy in supporting sustainable growth.

While many empirical studies confirm the inverted U-shape of the EKC, they often focus on selected pollutants. However, conventional EKC pattern does not always hold, and a strand of literature challenges its validity. Some studies (Clausen and York 2008; Lee and Lee 2009; Coondoo and Dinda 2008) find no evidence of the EKC, showing instead that pollutant emissions continue to rise with higher income levels. In the case of Malaysia, Begum et al. (2015) and Go et al. (2021) also reject the EKC hypothesis, particularly for pollution-intensive sectors. Similarly, Masron and Subramaniam highlight instances where the relationship takes the opposite from the conventional EKC, indicating a direct rather than inverted U-shaped link between income and certain pollutants. The shape of EKC

depends on another factor apart from concerned pollutant, is the socio-political and institutional structures of the economy. The turning point of the inverted U-shaped EKC comes at a high-income level but that also depends on how environmental awareness is internalized by producers, consumers and governments. For producers, adopting cleaner technologies or abating pollution is often costly, while consumers face a trade-off: reduced pollution improves environmental quality but can increase price of goods previously produced with cheaper, polluting inputs. Governments, acting as a social planner, intervene through policies aimed at balancing growth with sustainability. These measures range from market-based mechanisms such as pollution taxes and cap-and-trade schemes to non-market-based approaches like command-and-control regulations and the promotion of green technologies.

International agreements such as the Kyoto Protocol (1992), the Paris Agreement (2015), and successive COP summits have reinforced the role of such measures. Yet, their success in curbing emissions varies significantly across countries depending on many factors like the nature of pollutants targeted, the technological capacity to adopt cleaner production, and political-economic factors such as corruption and lobbying. In this regard, the political economy of climate policy has drawn increasing attention. While corruption and bribery are often associated with developing countries, lobbying is more prevalent in developed nations, where firms attempt to influence environmental regulations in their favor.

The role of lobbying was particularly evident during COP28, held in November 2023 in the UAE(1). The summit witnessed an unprecedented number of fossil-fuel lobbyists, many representing major oil and gas companies such as Shell, Total and ExxonMobil. Climate activists argued that these summits ere increasingly becoming platforms for greenwashing, allowing corporations to present a façade of climate action while obstructing meaningful progress. Although the primary aim of COP28 was to secure a commitment to phasing out fossil fuel use, negotiations were hindered by the resistance of major polluting nations(2). This raises broader concerns about the EKC logic- where higher growth supposedly leads to environmental improvements-remains valid when political and lobbying pressure distort climate policy outcomes.

Thus, it is clear that relationship between growth and pollution might change when we consider other political economic factors which have an impact on this relationship. The theoretical evaluation of the impact of growth on pollution in the presence of lobbying has not been done extensively. Although there are empirical papers that have attempted to understand the impact of corruption on environmental efforts. There exists a small set of literature that deals with corruption and environment. Masron and Subramaniam (2018) find the direct and indirect impacts of corruption on environmental degradation using the panel data of 64 developing countries. Using the generalized method of moments (GMM) technique, this study shows that corruption exhibits a positive impact on pollution and there is also evidence that the level of pollution tends to be higher in countries with a higher level of corruption, eliminating the effectiveness of the role of income in creating environmental consciousness. Their results also suggest that environmental degradation is monotonically increasing with higher corruption and invalidate the presence of the conventional shape of EKC in the presence of corruption in case of a developing country. With the help of

simulation, they show that corruption tends to worsen environmental standards at the higher level of income and instead of going downward after the threshold income it moves upward for both carbon emission and ecological footprint.

A number of theoretical studies (Lopez and Mitra 2000; Fredriksson et al. 2004; Sheng et al. 2016) show the possibility that higher levels of corruption tend to reduce the stringency of environmental rules and regulations. Pellegrini and Gerlagh (2006) empirically analyze the relative impact of corruption, democracy, and environmental policies in 41 countries and show a positive relationship between income and environmental policy stringency (lower corruption). Furthermore, Cole (2007) finds that corruption attracts environmental pollution and a higher degree of corruption which, in turn, can speed up per capita emissions and, hence, affect the dynamics of environmental performance. Lopez and Mitra (2000) indicate that government institutions in developing nations are often weaker and less efficient than in developed countries and hence imposition of environmental policies become less stringent. Leitao (2010) assert that higher corruption will delay governmental concern for and control of environmental quality and may result in postponing environmental laws and restricting the enforcement of these laws.

Now when it comes to lobbying in the literature it is either studied together with corruption or separately. Harstad and Svensson (2011) distinguish lobbying from the mere act of bribery by stating that when a firm faces a regulation it has three options, to comply, bribe the regulator or lobby the government to relax it. It is dependent on the developmental status of the economy. According to them when the level of development is low, firms are more prone to pay bribe and 'bend the rule' but it switches to lobbying when development level becomes sufficiently high. Unlike bribery, lobbying is generally perceived as a lumpsum transfer to the government by firms collectively. Harstad and Svensson (2011) argue that this lumpsum transfer is jointly paid by the several firms but the burden of each firm is determined via Nash bargaining. Even though the common narrative that prevails is lobbying helps 'bending the rules' for the big firms and eventually harming the environmental quality, there is a different view that shows how lobbying specifically green lobbying can sometime be helpful for achieving environmental goals too (Hu et. al. ,2020, Binder and Neumayer, 2005, Fredriksson et al. ,2005). Anger et al. (2015) explain how lobbying efforts affect energy tax differentiation, showing that sectors with more lobbying, driven by inelastic energy demand, tend to face lower energy tax rates. Empirical studies on environmental tax reforms in Germany support these theoretical findings.

In this backdrop, this paper theoretically investigates the impact of increase in growth factor of an economy on the environmental pollution in the presence of lobby payment made by a polluting firm to a non-benevolent self-motivated government. In this paper we consider two cases of decision making. First, where firm is the sole decision maker the impact of growth on both pollution and corruption depends on the output elasticity of pollution. Second, when firm and self motivated government jointly decide the amount of lobby payment, increase in growth reduces both lobby payment and pollution. Finally, we consider a case where the semi-benevolent government invests the tax revenue collected from the polluting firm to boost the economic growth rate. In this case, we try to find the impact of increase in pollution tax on lobby payment and pollution. When the firm is the

sole decision maker with increase in pollution tax it reduces lobby payment and pollution while in case of Nash bargaining solution where the firm and the government jointly decide the lobby payment, with an increase in environmental tax, the firm pays higher lobby payment and pollute more. If government assigns higher weight on lobby payment that will also cause a rise in lobby payment, increase in pollution, increase in tax revenue and that will cause a rise in growth factor. Lastly, higher the weight of pollution in welfare, it will cause lowering the level of lobby payment as well as lowering the level of pollution.

As we have already mentioned, the impact of growth on pollution in the presence of corruption has been done empirically but theoretical work in this particular issue is scarce except a few (Lopez Mitra ,2000). Our work deviates from Lopez and Mitra (2000) in a number of ways like first, besides updating on the recent literature, we have complemented their work by considering a tax rate imposed on environmental pollution. The firm is assumed to make a lobby payment to reduce the tax rate. Self- interested (semi-benevolent) government's objective is to maximize the weighted sum of welfare of the society (as it helps to get the government votes), bribe amount and the tax revenue. In Lopez and Mitra (2000) though welfare and bribe amount are parts of government's objective function but, the tax revenue is not. We have also considered a separate section where the tax revenue is spent to enhance the growth rate which is not considered in Lopez Mitra (2000). Our findings are also different from their work. When the firm solely decides the lobby amount, we get through- out upward rising or downward sloping relationship between growth factor and pollution. When lobby amount is decided by the firm and the government jointly by Nash bargaining solution the relationship between growth factor and pollution is negative instead of an inverted U-shaped curve like conventional EKC, which has been found by Lopez Mitra (2000).

The rest of the paper is organized as follows: Section 2 talks about the theoretical model that we have mentioned above, the Section 3 discusses the impact of pollution tax when Government uses the tax revenue to boost the growth rate, Section 4 discusses the findings of the model and finally Section 5 concludes the paper.

2. The model

We build up a model where the firm produces output Y using two factors, namely, environmental pollution, x and external effect generated from economic growth (growth factor), $g^{(3)}$. Note that, we assume that this is a free input. The logic underlying including the economic growth rate as input in the production function is that firm in a fast-growing economy will be more productive than the same in a low growth economy.

Thus, the firm's production function can be written as

$$Y = x^{\lambda} g^{1-\lambda} \qquad (1)$$

λ is the output elasticity of pollution and $0 \leq \lambda \leq 1$

The government imposes a per unit environmental tax τ on the pollution used by the firm. The firm makes a lobby payment 'c' to the government for reducing the tax rate on pollution. Higher the amount of lobby payment, lower is the tax rate imposed on pollution.

When the firm makes the lobby payment, the profit function of the firm is assumed to take the following form:

$$\Pi = x^{\lambda} g^{1-\lambda} - \frac{\tau}{c} x - c, \qquad c \geq 1 \tag{2}$$

where π is the profit level of the firm, c is the amount of rent or lobby payment and τ is the environmental tax. The higher the amount of c, lower is the tax burden on the firm.

However, when lobby payment is equal to zero, it is assumed that tax rate imposed on polluting inputs becomes fixed.

Therefore, when the lobby payment is zero, the firm's profit function is

$$\pi^{*} = X^{\lambda} g^{1-\lambda} - \tau X \tag{3}$$

Where X denotes the amount of polluting input used in case of no bribe.

First, we consider the case when the firm is the sole decision maker of how much lobby it would pay to maximize its profit. Second, following Lopez and Mitra (2000), in this model we consider the case where the firm and the government decide pollution and lobby payment through a Nash bargaining solution.

We assume the government is engaged in rent seeking behavior and receives a lobby payment 'c' from the firm to reduce the tax rate on pollution. When firm is the sole decision maker it chooses the quantity of polluting inputs and lobby amount to pay to the government simultaneously by maximizing profit level. In the Nash bargaining solution, the firm considers 'c' to be given and takes the decision regarding how much polluting inputs to use by maximizing its profit level. Then, the lobby amount is decided jointly by the firm and the government by Nash bargaining solution. There are two possibilities in this model, either the firm strikes a deal with the government or the firm fails to strike a deal. So, in the first case, profit function is given by equation (2) and in the second case profit function is given by equation (3).

When firm makes a lobby payment profit maximizing level of pollution is obtained by maximizing (2) with respect to x,

$$x = \left(\frac{\tau}{\lambda c}\right)^{\frac{1}{\lambda-1}} g \tag{4}$$

When no lobby payment is made, maximizing π^{*} given by (3) with respect to X gives,

$$X = \left(\frac{\tau}{\lambda}\right)^{\frac{1}{\lambda-1}} g \tag{5}$$

Substituting this X given by (5) in the profit function π^{*} given by (3) yields

$$\pi^{*} = \left(\frac{\tau}{\lambda}\right)^{\frac{\lambda}{\lambda-1}} g - \tau \left(\frac{\tau}{\lambda}\right)^{\frac{1}{\lambda-1}} g \tag{6}$$

In presence of lobby payment, we define the social welfare function as follows

$$W = \alpha\Pi - \beta x, \quad 1 \geq \alpha \geq 0, \; 1 \geq \beta \geq 0 \tag{7}$$

Where α is the weight assigned to profit (economic output) in economic welfare, and β is the weight associated to pollution in it. Economic agents derive gain from economic output but dislikes the level of pollution as it harms the environmental quality they enjoy.

It is the existing political party that makes the government in any economy. In the presence of lobby payment, self-motivated government (existing political party) is assumed to have the following objective function,

$$G = (1 - a - b)(\alpha\Pi - \beta x) + bx\frac{\tau}{c} + ac\,, \qquad 0 \le a \le 1, 0 \le b \le 1 \qquad (8)$$

G is a weighted average of social welfare, tax revenue and lobby payments. As the welfare of the economy increases, people are more likely to choose the existing political party to rule. Though not modelled, it is assumed that the government spends the tax revenue for different welfare programs that would enhance welfare of the agents of all section of the society (Lopez Mitra 2000)[4]. Therefore, the popularity or vote bank of the ruling party is more when the tax revenue increases. The objective function also depends on the amount of lobby payment collected because officers who are direct beneficiaries of lobby payments are also assumed to form a large part of the vote bank. If the government's motive is to getting re-elected it should take care of both welfare of the society along with the tax revenue collected and the lobby payments received.

2.1. Firm is the sole decision maker

In this sub-section, it is assumed that the firm is the sole decision maker. The firm simultaneously chooses the quantity of polluting inputs to employ and the lobby to be paid to the government by maximizing its profit. The profit maximizing level of pollution is given by equation (4). Maximizing profit given by equation (2) with respect to c gives,

$$c = \sqrt{x\tau} \qquad (9)$$

Now we try to derive the relation between growth and pollution as well as growth and lobby payment. Using (4) and (9) we get,

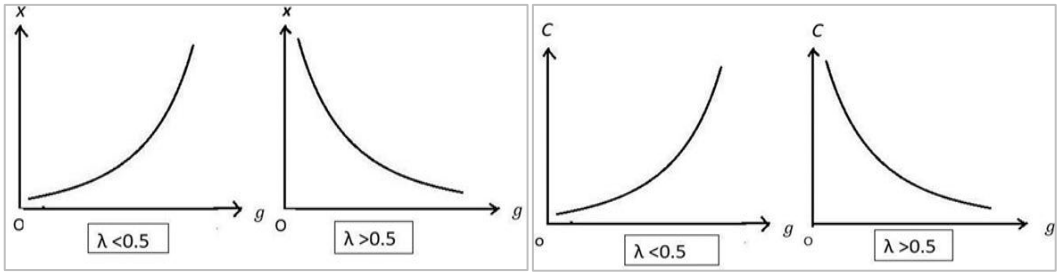
$$x = \lambda^{\frac{2}{1-2\lambda}} g^{\frac{2(1-\lambda)}{1-2\lambda}} \tau^{\frac{1}{2\lambda-1}} \qquad (10)$$

$$c = \tau^{\lambda/(2\lambda-1)} g^{(1-\lambda)/(1-2\lambda)} \lambda^{1/(1-2\lambda)} \qquad (11)$$

From equation (10), we observe that the relationship between g and x depends upon the factor $(\frac{2(1-\lambda)}{1-2\lambda})$ which in turn depends on λ (output elasticity of polluting inputs in production function). If λ is less than 0.5 pollution rises with growth and if λ is greater than 0.5, with rise in growth, pollution falls.

From equation (11), we can infer that at low level of λ with rise in g the level of corruption goes up and the result reverses when λ crosses 0.5. When λ is less than 0.5, output elasticity of g is high. With rise in g gain from using x that is the marginal product of polluting input goes up and outweighs the cost burden from using higher x for paying higher tax and higher lobby payment. When λ is greater than 0.5, the cost burden from using high x outweighs the gain from using higher x and paying higher lobby payment. So, it is optimal for the firm to use lesser x and pay less lobby payment as g rises.

Figure 1: *Impact of growth on pollution and lobby payment when the polluting firm is the sole decision maker*



***Proposition 1*:** When a firm solely decides how much lobby amount to be paid so as to reduce the tax burden on polluting input, the impact of growth on both pollution and corruption depends on the output elasticity of pollution. If the output elasticity of pollution is less than 0.5, both pollution levels and lobby payments increase with growth; if it exceeds 0.5, this relationship reverses.

Though in this section we have considered the entire range of lambda. Kalaitzidakis (2008) Finds the lambda to be on average 0.008 for OECD nations, so it is fair to assume its value to be lower than 0.5, Thus, now onwards we will consider the value of lambda to be less than 0.5.

2.2. Nash bargaining solution and environmental pollution

In the Nash bargaining solution, the firm chooses how much polluting input to use by maximizing profit level then taking this into account the firm and the government jointly decide the amount of lobby payment given a level of pollution tax by bargaining with each other. The maximand of Nash bargaining solution can be written explicitly as

$$H = [\,\Pi - \pi^*]\left[(1-a-b)(\alpha\Pi - \beta x) + \frac{b\tau x}{c} + ac - (1-a-b)(\alpha\pi^* - \beta X) - b\tau x\right] \tag{12}$$

Using equations (2), (4), (6) and (8) we get,

$$H = \left[\left(\frac{\tau}{\lambda c}\right)^{\frac{\lambda}{\lambda-1}} g - \frac{\tau}{c}\left(\frac{\tau}{\lambda c}\right)^{\frac{1}{\lambda-1}} g - c - \left(\frac{\tau}{\lambda}\right)^{\frac{\lambda}{\lambda-1}} g - \tau\left(\frac{\tau}{\lambda}\right)^{\frac{1}{\lambda-1}} g\right]$$

$$\left[(1-a-b)\left\{\alpha\left(\frac{\tau}{\lambda c}\right)^{\frac{\lambda}{\lambda-1}} g - \alpha\frac{\tau}{c}\left(\frac{\tau}{\lambda c}\right)^{\frac{1}{\lambda-1}} g - \alpha c - \beta\left(\frac{\tau}{\lambda c}\right)^{\frac{1}{\lambda-1}} g\right\} + b\frac{\tau}{c}\left(\frac{\tau}{\lambda c}\right)^{\frac{1}{\lambda-1}} g + ac\right.$$
$$\left. - (1-a-b)\left\{\alpha\left(\frac{\tau}{\lambda}\right)^{\frac{\lambda}{\lambda-1}} g - \tau\alpha\left(\frac{\tau}{\lambda}\right)^{\frac{1}{\lambda-1}} g\right\} - b\tau\left(\frac{\tau}{\lambda}\right)^{\frac{1}{\lambda-1}} g\right] \tag{12'}$$

H is maximized with respect to c. As solving the non-linear equation analytically is not possible and also getting empirical observation on these parameters which are consistent with this model is outside the scope of this paper, we have done our analysis numerically

by taking hypothetical values of the parameters. To operationalize the model, we calibrate the parameters to values that are both theoretically consistent and empirically grounded in literature. The calibration reflects political economy of developing countries, where economic growth is prioritized, environmental regulation is relatively weak, and government behavior is shaped by both fiscal needs and corruption incentives. Table 1 summarizes the chosen parameter values, along with their rationale and supporting literature. These values are not intended to replicate a single country but to capture stylized features common in developing economies, thereby ensuring that the model outcomes are realistic and comparable to existing findings. The environmental tax rate is fixed at 0.2, consistent with evidence that such economies typically impose modest environmental taxes (OECD,2010). In the welfare function, economic profit receives a weight of 0.6, while pollution is weighted at 0.2, mirroring the prioritization of growth over environmental quality in developing contexts (Dasgupta et al. 2002). Within the government's objective function, tax revenue is assigned a weight of 0.2, whereas lobby payment receives a higher weight of 0.6, reflecting findings that corrupt governments value rent extraction more than fiscal gains (Shleifer and Vishny, 1993; Frederiksson & Svensson, 2003).

Table 1. *Variable description and baseline values*

Variables/ Parameters	Baseline value	Justification	Supporting Literature
Output elasticity of polluting input (λ)	0.2	A 1% rise in output raises pollution by 0.2%. Reflecting that production relies less on polluting inputs due to partial adoption of cleaner technologies, and regulation. This is especially relevant in developing countries transitioning toward greener growth.	Antweiler, Copeland & Taylor (2001); Brock & Taylor (2010); Cole (2004); Kalaitzidakis (2008)
Environmental tax (τ)	0.2	Developing countries generally set modest environmental taxes due to political resistance, weak enforcement capacity, and concerns about growth slowdown.	OECD (2010); Eskeland & Harrison (2003)
Weight assigned to lobby payment by self-motivated Government (a)	0.6	Corrupt governments derive higher utility from lobbying rents than from public tax revenue.	Shleifer & Vishny (1993); Ades & Di Tella (1999); Frederiksson & Svensson (2003)
Weight assigned to tax revenue by self-motivated Government (b)	0.2	Fiscal mobilization plays a limited role in rent-seeking states.	Tanzi & Davoodi (1997); Bird et al. (2008)
Weight assigned to economic profit in welfare (α)	0.6	Growth and industrial profitability are prioritized over environmental concerns in early stages of development.	Dasgupta et al. (2002); Lopez & Mitra (2000)
Weight associated to pollution in welfare (β)	0.2	Environmental quality is considered but plays a secondary role compared to growth and jobs, reflecting trade-offs in policy priorities.	Dasgupta et al. (2002); Lopez & Mitra (2000)

Table 2. *Impact of growth on the amount of lobby payment and pollution level*

g	c	x
0.01	1.294538272*10^12	1.380840823*10^13
0.02	8.090864198*10^10	8.630255144*10^11
0.03	1.598195398*10^10	1.704741758*10^11
0.04	5.056790132*10^9	5.393909476*10^10
0.07	5.391663028*10^8	5.751107252*10^9
0.1	1.294538361*10^8	1.380840942*10^9
0.15	2.557113521*10^7	2.727587992*10^8
0.5	207134.6845	2.209459464*10^6

Baseline values: λ = 0.2, $\tau = 0.2$, a = 0.6, b = 0.2, $\boldsymbol{\alpha}$ = 0.6, $\boldsymbol{\beta}$= 0.2

In Table 2, we observe that increase in growth factor reduces both the amount of lobby payment and pollution. We have considered growth level to vary from 1% to 50%. It is observed that with increase in growth rate, there is monotonous fall in the amount of lobby payment from 1.294538272*10^12 to 207134.6845 but interestingly corresponding pollution level also falls throughout from 1.380840823*10^13 to 2.209459464*10^6. Thus, in our framework- where firm and government jointly determine lobbying through Nash bargaining- growth exerts a dual effect: it reduces pollution and lowers lobby payment. A plausible explanation is that higher growth increases output substantially, reducing the incentive for firms to pay government in exchange for pollution tax cuts. Existing literature supports our finding that, government corruption is higher in countries with lower growth. Mocan (2004) empirically tested that the correlation between per capita GDP and "gifts" to public officials for several countries and it is found to be negative. Triesman (2000) also finds that growth has negative impact on corruption. Bai et. al. (2013) has studied the growth corruption relation both theoretically and empirically for Vietnam) and has found that economic growth (of firms) reduces corruption (bribery) and prescribe that corruption is not needed to be rooted out rather growth subsides corruption. In our study we have built this theoretical model to understand the impact of growth on environmental pollution in the presence of corruption. Our finding is shown in Table 2 where we see that with the rise in growth factor, the endogenously determined amount of lobby payment falls which might be due to the fact that growth factor improves the institutional quality (Acemoglu, Johnson, and Robinson, 2005; Glaeser, La Porta, Lopez-de Silanes, and Shleifer, 2004) and polluting inputs becomes less important. Moreover, in this model, as the polluting inputs are taxed while growth factor is free, polluting inputs are relatively expensive. Therefore, the firm might take the decision to use lesser polluting inputs. Our finding is in same line of this literature where it is observed that lobby payment is lower when an economy is experiencing growth. In our model the firm and a corrupt government are coming to a co-operative solution via Nash bargaining.

Our finding also sheds light on the intertwined growth-pollution nexus which over the period of time has been investigated in a more complex manner. Initially, it was believed that growth increases pollution. This prompted discussions regarding the feasibility of achieving sustainable economic growth at regional, national, and global levels (Adebayo 2020; Adebayo & Odugbesan, 2021). Central to this discourse is the environmental Kuznets curve (EKC) theory, which suggests an inverted-U-shaped relationship between per capita GDP and per capita pollutant emissions, based on empirical observations (Grossman & Krueger, 1991). Historically, many developed countries followed a "Treatment after Pollution" approach during early economic development, eventually reaching a decline in pollutant emissions by the end of the 20th century. However, lessons from their environmental governance may not be directly applicable to developing countries, which are still ascending along the EKC curve and have yet to reach its turning point (Panayotou, 2000). This divergence reflects differing stages of economic development between developed and developing nations, resulting in distinct economic-environmental relationships (Lu et al., 2007).

The EKC hypothesis has garnered significant scholarly interest and has been applied to study various economies and time periods (Apergis & Ozturk, 2015; Destek et al., 2018).

However, while the EKC has been supported in some cases, evidence suggests it does not universally hold true (Perman & Stern, 2003; Stern, 2004; Robalino-Lopez et al., 2014; Lorente & Herranz, 2016). Studies on the relationship between economic growth and environmental pollution often use various curve shapes (inverted-U, N-shaped, inverted N-shaped, U-shaped), focusing on inflection points but not fully explaining the underlying dynamics.

3. Impact of pollution tax when Government uses the tax revenue to boost the growth rate

In this section, we consider the case where semi-benevolent government invests the tax revenue collected from the polluting firm to boost the economic growth rate, g. In the previous sections, we took the value of g as exogenously given and determined its impact on lobby payment and pollution level. But, in this section growth rate (g) is determined endogenously along with the value of lobby payment and pollution level. Here, we are interested in evaluating the impact of change in tax rate on corruption, pollution and the growth rate.

We assume that g takes the following form,

$$g = \delta\sqrt{\frac{x\tau}{c}}, \quad 0 \le \delta \le 1 \qquad When\ c > 1 \tag{13}$$

3.1. Firm is the sole decision maker

Similar to subsection 2.1 here also the firm simultaneously chooses the quantity of polluting inputs to employ and the lobby to be paid to the government by maximizing its profit.

Substituting g from equation (13) in equation (2) and maximizing it with respect to lobby payment (c) and pollution (x) gives us the first order conditions,

$$\frac{\lambda+1}{2}x^{\frac{\lambda-1}{2}}\left(\frac{\tau}{c}\right)^{\frac{1-\lambda}{2}}\delta^{1-\lambda} - \frac{\tau}{c} = 0 \tag{14}$$

$$\frac{1-\lambda}{2}x^{\frac{\lambda+1}{2}}\left(\frac{\tau}{c}\right)^{-\left(\frac{\lambda+1}{2}\right)}\frac{\tau}{c^2}\delta^{1-\lambda} - \frac{\tau x}{c^2} + 1 = 0 \tag{15}$$

Solving equation (14) and equation (15) we determine the expression for c and x in terms of τ. Substituting these values of c and x in equation (13) we determine g in terms of τ. Since g is endogenously determined, the only exogenous variable here is the tax rate (τ) and we try to see the impact of change in tax rate on lobby payment (c) growth factor (g) and pollution (x). Due to non-linearity of the equations, it cannot be done analytically. Therefore, we have taken the benchmark value of output elasticity of pollution (λ) to be 0.2 and for different possible values of tax rate ranging from 0.004 to 0.36 tried to see the impact of it on these three endogenously determined variables. The results are shown in Table 3.

Table 3. *Impact of change in tax rate on lobby payment (c) growth factor (g) and pollution (x) when firm is the sole decision maker and tax revenue is used to boost growth*

τ	c	g	x
0.004	2.160000001	1.203732549	39.12224534
0.006	1.439999998	1.087695143	21.29545298
0.008	1.079999999	1.012214385	13.83180246
0.01	0.8639999998	0.9572932615	9.897232189
0.08	0.10799	0.5692099784	0.4373999986
0.1	0.08639999992	0.5383255611	0.3129779622
0.2	0.04320000000	0.4526760345	0.1106544198
0.28	0.03085714281	0.4161553610	0.06680003821
0.36	0.02400000002	0.3908133374	0.04582051944

Output elasticity of pollution (λ) is assumed to be 0.2

From Table 3 we see that when the firm is taking the decision solely and government reinvest the collected tax revenue to boost growth factor, with the rise in tax rate all the three variables (growth factor, lobby payment and pollution) are falling. With higher tax rate, firms will prefer to pay less lobby payment and rather it would pollute less to avoid the tax burden. For this particular set of values, we observe that when tax rate is fairly less (less than 0.01) firms will be willing to pay lobby payment as $c > 1$ and beyond that if tax rate rises further $c < 1$, implying there will be no lobby payment. It is interesting to observe that with rise in tax rate, growth factor is also decreasing which means that even though tax revenue is reinvested in growth factor, when firm is the sole decision maker the reduction in pollution is higher in magnitude to dampen the impact of higher tax rate on growth factor by reducing the tax revenue in total.

3.2. The Nash bargaining solution

Like subsection 2.2 here again we consider the case where firm and the semi-benevolent government jointly decides the lobby payment via Nash bargaining and consequently the growth factor and pollution level are determined too. In this case the objective of the government changes from previous case since government no longer incorporates the tax revenue in its own objective function but uses it to enhance growth as described in equation (13).

The aforementioned objective function of the government, (8) changes to,

$$G = (1 - a)(\alpha \Pi - \beta x) + ac \tag{16}$$

So now the Nash bargaining maximand will become,

$$H = [\Pi - \pi^*][(1 - a)(\alpha \Pi - \beta x) + ac - (1 - a)(\alpha \pi^* - \beta X)] \tag{17}$$

Substituting Π , x , X , $\pi^*$and g from equation (2), equation (4), equation (5), equation (6) and equation (13) in equation (17), then maximizing it with respect to *c*, we determine the Nash bargaining solution of lobby payment. Using that *c* in the new profit maximizing level of pollution and equation (13) respectively we obtain x and g , given τ . As g is endogenously determined, here we have tried to investigate the impact of change in the other exogenous parameters of our model like tax rate (τ), weight assigned to lobby payment in Government's objective function (a) and weight of pollution in welfare function (β) on lobby payment (c), government expenditure (g) and pollution level (x).

With the baseline values of $\lambda = 0.2$, $\tau = 0.2$, a = 0.6, b = 0.2, $\boldsymbol{\alpha}$ = 0.6, $\boldsymbol{\beta}$= 0.2, $\boldsymbol{\delta}$=*1* the impact of change in τ, a and β on lobby payment, growth rate and pollution are shown in Table 4,5 and 6 respectively. With the rise in environmental tax from 0.08 to 0.36, firms are paying high lobby payment from 0.514 to 8.723 and using higher polluting inputs from 5.019 to 33.2621. Here the results are completely opposite of what we got in the case of firm being the sole decision maker. Here for lower tax rates, firm will not pay any lobby payment ($c > 1$) but if tax rate is sufficiently high, firm will start paying lobby payment ($c < 1$) and that will keep on increasing as tax rate goes up and that results in continuous increase in growth factor too. May be due to rise the tax revenue outweighs the amount of lobby it eventually increases the growth factor of the economy from 0.841 to 1.171. If government assigns higher weight on lobby payment that will obviously cause a rise in c and a rise in growth factor. The third finding is intuitively obvious, where higher negative weight assigned to pollution in welfare function (government value the quality of environment they enjoy more) will cause lowering the level of lobby payment as well as optimum level of pollution. But in this case, growth rate will also fall might be because the fall is tax revenue will dominate over the fall in lobby payment.

Table 4. *Impact of change in τ*

τ	c	g	x
0.08	0.5140461072	0.8407504041	5.01945083
0.1	0.6868344215	0.8548739352	7.01654830
0.2	2.032964326	0.9428964561	9.037072554
0.28	4.462665463	1.055110969	17.74322568
0.36	8.723362242	1.171613627	33.26214369

Baseline values: $\lambda = 0.2$, $\tau = 0.2$, a = 0.6, b = 0.2, $\boldsymbol{\alpha}$ = 0.6, $\boldsymbol{\beta}$= 0.2, $\boldsymbol{\delta}$=*1*

Table 5. *Impact of change in a*

a	c	g	x
0.6	2.032964326	0.9428964561	9.037072554
0.7	5.625868455	1.216127075	41.60231444
0.75	10.15800590	1.409722655	100.9359381
0.8	19.72226038	1.664066723	273.0663370

Baseline values: $\lambda = 0.2$, $\tau = 0.2$, a = 0.6, b = 0.2, $\boldsymbol{\alpha}$ = 0.6, $\boldsymbol{\beta}$= 0.2, $\boldsymbol{\delta}$=*1*

Table 6. *Impact of change in β*

β	c	g	x
0.1	6.340611817	1.253038328	49.77713321
0.08	9.546475278	1.388009143	91.95973492
0.07	12.25553170	1.477456161	133.7615735
0.06	16.40598631	1.589213150	207.1746669

Baseline values: $\lambda = 0.2$, $\tau = 0.2$, a = 0.6, b = 0.2, $\boldsymbol{\alpha}$ = 0.6, $\boldsymbol{\beta}$= 0.2, $\boldsymbol{\delta}$=*1*

4. Result and discussion

The major focus of this paper is to determine the impact of growth factor on pollution in the presence of corruption, specifically lobby payment. Lopez, Mitra (2000) has investigated the same and has concentrated on the shape of EKC in the presence of corruption. In their paper EKC is conventional shaped but the maximum point is shifted in

rightward direction because of corruption. However, in the present paper, unlike the conventional inverted U-shaped EKC we get a throughout upward or downward sloping curve, depending on how the decision on lobby payment is made. In the presence of lobby payment, we study the behavior of pollution level and lobby payment amount with the rise in growth level in two cases: firstly, when firm is the sole decision maker, secondly, in the case when firm and government are engaged in Nash bargaining. In the first case results depend on the output elasticity of pollution. If the output elasticity of pollution is less than 0.5 growth increases both the lobby payment as well as the pollution level and the result reverses when elasticity is over 0.5. Second, if the self-motivated government and firm jointly decides the amount of lobby payment by Nash bargaining solution, growth will have a negative impact on pollution and lobby payment. Next, we consider the case where self-motivated government invests back the tax revenue it receives into the growth factor. Here also we have examined the two cases, one where firm is the sole decision maker regarding the amount of lobby payment and polluting input. We investigate the impact of tax rate, (τ), for both cases. When firm is the sole decision maker at low level of tax rate, firm pays lobby payment. But, with rise in tax rate, eventually the amount of lobby payment, amount of polluting input and growth factor falls. But in case of Nash bargaining solution with the rise in environmental tax, firms are paying high lobby payment and polluting more. Therefore, rise in the tax revenue outweighs the effect of higher lobby payment and eventually increases the growth factor of the economy. In case of Nash bargaining, we have examined the impact of change in weight of lobby payment received (a) and weight of pollution in welfare function (β), that are included in the Government's objective function, on pollution, lobby payment and growth factor. If the government imposes higher weight on lobby payment that will cause not only a rise in c but a rise in growth factor. The third finding is in line with the literature, where higher the weight of pollution in welfare will cause lowering the level of lobby payment as well as the level of pollution. But in this case, growth factor will also fall because of a decrease in tax revenue. So, a country run by dishonest government may have higher growth rate while a country run by honest government who really cares for environment may have lower growth rate! This finding strengthens "grease the wheels" hypothesis. When the government is dishonest and assigns more weight to lobby payment, it is obvious that lobby payment would increase but at the same time pollution also increases. The increase in pollution increases the tax revenue and increases the growth rate too. On the contrary, when the government cares more for environment, it accepts less lobby payment to reduce tax cut. As a result, the firm has to reduce the pollution level that in turn reduces the tax revenue and consequently the growth rate.

5. Conclusion

This paper examines the impact of growth and pollution tax on pollution in the context of corruption, specifically lobby payments. We build a model based on the previous research that explored the shape of the Environmental Kuznets Curve (EKC) under corruption, revealing that, unlike the conventional inverted U-shape, we can observe consistently upward or downward sloping curves based on who decides on lobby payments and

pollution levels. If the polluting firm is the sole decision maker, output elasticity of pollution is a key factor. When a self-motivated government and firm jointly determine lobby payments through Nash bargaining, growth negatively affects both pollution and lobby payments. We also analyze scenarios where the semi-benevolent government reinvests tax revenue to enhance the growth factors. The impact of change in tax rate here also depends on how the amount of lobby payment and pollution level is decided.

When growth factor is exogenous, bargaining power to decide the lobby amount should not be concentrated to firm only. If it is inevitable, it should be jointly decided through Nash bargaining solution. However, when growth rate is no longer exogenous, we cannot recommend such set up to decide the lobby payment. In this case, we find that when the firm is the sole decision maker, increase in pollution tax reduces both pollution and corruption but when lobby payment is decided by Nash bargaining solution increase in tax increases lobby payment and pollution.

Competing interests

The authors declare none.

Notes

(1) https://www.theguardian.com/environment/2023/dec/05/record-number-of-fossil-fuel-lobbyists-get-access-to-cop28-climate-talks

(2) https://www.bbc.com/news/science-environment-58982445

(3) This type of production function is used in Mitra Lopez (2000). Pollution is treated as an input also in Copeland Taylor (2003).

(4) Tax revenue enhances people's confidence in the government by improving the budgetary position of the government. Spending the tax revenue for improving welfare is not modelled in this section. Modelling that would not change our results.

References

Acemoglu, D. (2005). Institutions as the Fundamental Cause of Long-Run Growth. In P. Aghion & S. Durlauf (Eds.), *Handbook of Economics Growth*. (Vol. 1, pp. 385–472). Elsevier.

Ades, A., and Di Tella, R. (1999). Rents, competition, and corruption. *American Economic Review, 89*(4), 982–993.

Al-Mulali, U., and Ozturk, I. (2016). The investigation of environmental Kuznets curve hypothesis in the advanced economies: the role of energy prices. *Renewable and Sustainable Energy Reviews*, *54*, 1622-1631.

Al-Mulali, U., Weng-Wai, C., Sheau-Ting, L., and Mohammed, A.H. (2015). Investigating the environmental Kuznets curve (EKC) hypothesis by utilizing the ecological footprint as an indicator of environmental degradation. *Ecological indicators*, *48*, 315-323.

Antweiler, W., Copeland, B.R., and Taylor, M.S. (2001). Is free trade good for the environment? *American Economic Review, 91*(4), 877–908.

Apergis, N., and Ozturk, I. (2015). Testing environmental Kuznets curve hypothesis in Asian countries. *Ecological indicators*, *52*, 16-22.

Begum, R.A., Sohag, K., Abdullah, S.M.S., and Jaafar, M. (2015). CO2 emissions, energy consumption, economic and population growth in Malaysia. *Renewable and Sustainable Energy Reviews*, *41*, 594-601.

Bernauer, T., Engel, S., Kammerer, D., and Sejas Nogareda, J. (2007). Explaining green innovation: ten years after Porter's win-win proposition: how to study the effects of regulation on corporate environmental innovation? *Politische Vierteljahresschrift*, *39*, 323-341.

Ben Jebli, M., Ben Youssef, S., and Ozturk, I. (2015). The role of renewable energy consumption and trade: Environmental Kuznets curve analysis for sub-Saharan Africa countries. *African Development Review*, *27*(3), 288-300.

Beşe, E., and Kalayci, S. (2021). Environmental Kuznets curve (EKC): empirical relationship between economic growth, energy consumption, and CO2 emissions: evidence from 3 developed countries. *Panoeconomicus*, *68*(4), 483-506.

Bird, R.M., Martinez-Vazquez, J., and Torgler, B. (2008). Tax effort in developing countries and high-income countries: The impact of corruption, voice and accountability. *Economic Analysis and Policy, 38*(1), 55–71.

Brock, W.A., and Taylor, M.S. (2010). The green Solow model. *Journal of Economic Growth, 15*(2), 127–153

Candau, F., and Dienesch, E. (2017). Pollution haven and corruption paradise. *Journal of environmental economics and management*, *85*, 171-192.

Clausen, R., and York, R. (2008). Economic growth and marine biodiversity: influence of human social structure on decline of marine trophic levels. *Conservation Biology*, *22*(2), 458-466.

Cole, M.A. (2004). Trade, the pollution haven hypothesis and the environmental Kuznets curve: Examining the linkages. *Ecological Economics, 48*(1), 71–81.

Cole, M.A. (2007). Corruption, income and the environment: an empirical analysis. *Ecological economics*, *62*(3-4), 637-647.

Coondoo, D., and Dinda, S. (2008). Carbon dioxide emission and income: A temporal analysis of cross-country distributional patterns. *Ecological Economics*, *65*(2), 375-385.

Copeland, B.R., and Taylor, M.S. (2004). Trade, growth, and the environment. *Journal of Economic literature*, *42*(1), 7-71.

Dasgupta, S., Laplante, B., Wang, H., and Wheeler, D. (2002). Confronting the environmental Kuznets curve. *Journal of Economic Perspectives, 16*(1), 147–168.

Destek, M.A., Ulucak, R., and Dogan, E. (2018). Analyzing the environmental Kuznets curve for the EU countries: the role of ecological footprint. *Environmental Science and Pollution Research*, *25*(29), 29387-29396.

Dogan, E., and Seker, F. (2016). Determinants of CO2 emissions in the European Union: the role of renewable and non-renewable energy. *Renewable Energy*, *94*, 429-439.

Eskeland, G.S., and Harrison, A.E. (2003). Moving to greener pastures? Multinationals and the pollution haven hypothesis. *Journal of Development Economics, 70*(1), 1–23.

Feng, T., Du, H., Lin, Z., and Zuo, J. (2020). Spatial spillover effects of environmental regulations on air pollution: Evidence from urban agglomerations in China. *Journal of Environmental Management*, *272*, 110998.

Fredriksson, P.G., and Svensson, J. (2003). Political instability, corruption and policy formation: the case of environmental policy. *Journal of public economics*, *87*(7-8), 1383-1405.

Fredriksson, P.G., Vollebergh, H.R., and Dijkgraaf, E. (2004). Corruption and energy efficiency in OECD countries: theory and evidence. *Journal of Environmental Economics and management*, *47*(2), 207-231.

Glaeser, E.L., La Porta, R., Lopez-de-Silanes, F., and Shleifer, A. (2004). Do institutions cause growth? *Journal of Economic Growth, 9*(3), 271–303.

Go, Y.H., Lau, L.S., Liew, F.M., and Senadjki, A. (2021). A transport environmental Kuznets curve analysis for Malaysia: exploring the role of corruption. *Environmental Science and Pollution Research*, *28*(3), 3421-3433.

Grossman, G.M., and Krueger, A.B. (1995). Economic growth and the environment. *The quarterly journal of economics*, *110*(2), 353-377.

Harstad, B., and Svensson, J. (2011). Bribes, lobbying, and development. *American political science review*, *105*(1), 46-63.

Jebli, M.B., Youssef, S.B., and Ozturk, I. (2016). Testing environmental Kuznets curve hypothesis: The role of renewable and non-renewable energy consumption and trade in OECD countries. *Ecological indicators*, *60*, 824-831.

Jin, Y., Andersson, H., and Zhang, S. (2016). Air pollution control policies in China: a retrospective and prospects. *International journal of environmental research and public health*, *13*(12), 1219.

Kalaitzidakis, P., Mamuneas, T., and Stengos, T. (2008). The Contribution of Pollution to Productivity Growth.

Krishnan, S., Teo, T.S., and Lim, V.K. (2013). Examining the relationships among e-government maturity, corruption, economic prosperity and environmental degradation: A cross-country analysis. *Information & Management*, *50*(8), 638-649.

Lau, L.S., Choong, C.K., and Eng, Y.K. (2014). Investigation of the environmental Kuznets curve for carbon emissions in Malaysia: do foreign direct investment and trade matter? *Energy policy*, *68*, 490-497.

Lee, C.C., Chiu, Y.B., and Sun, C.H. (2009). Does one size fit all? A reexamination of the environmental Kuznets curve using the dynamic panel data approach. *Applied Economic Perspectives and Policy*, *31*(4), 751-778.

Leitão, A. (2010). Corruption and the environmental Kuznets curve: empirical evidence for sulfur. *Ecological economics*, *69*(11), 2191-2201.

Lopez, R., and Mitra, S. (2000). Corruption, pollution, and the Kuznets environment curve. *Journal of environmental economics and management*, *40*(2), 137-150.

Lorente, D.B., and Álvarez-Herranz, A. (2016). Economic growth and energy regulation in the environmental Kuznets curve. *Environmental Science and Pollution Research*, *23*, 16478-16494.

Martinez-Zarzoso, I., and Bengochea Morancho, A. (2003). Testing for an environmental Kuznets curve in Latin-American countries. *Revista de Análisis Económico*, *18*(1).

Masron, T.A., and Subramaniam, Y. (2018). The environmental Kuznets curve in the presence of corruption in developing countries. *Environmental science and pollution research*, *25*, 12491-12506.

OECD. (2010). *Taxation, innovation and the environment*. OECD Publishing.

Ozcan, B. (2013). The nexus between carbon emissions, energy consumption and economic growth in Middle East countries: a panel data analysis. *Energy policy*, *62*, 1138-1147.

Panayotou, T. (1993). Empirical Tests and Policy Analysis of Environmental Degradation at Different Stages of Economic Development.

Pellegrini, L., and Pellegrini, L. (2011). Corruption, democracy, and environmental policy: an empirical contribution to the debate. *Corruption, Development and the Environment*, 75-99.

Perman, R., and Stern, D.I. (2003). Evidence from panel unit root and cointegration tests that the environmental Kuznets curve does not exist. *Australian Journal of Agricultural and Resource Economics*, *47*(3), 325-347.

Porter, M.E., and Linde, C.V.D. (1995). Toward a new conception of the environment-competitiveness relationship. *Journal of economic perspectives*, *9*(4), 97-118.

Robalino-López, A., García-Ramos, J.E., Golpe, A.A., and Mena-Nieto, Á. (2014). System dynamics modelling and the environmental Kuznets curve in Ecuador (1980–2025). *Energy Policy*, *67*, 923-931.

Rjoub, H., Odugbesan, J.A., Adebayo, T.S., and Wong, W.K. (2021). Sustainability of the moderating role of financial development in the determinants of environmental degradation: evidence from Turkey. *Sustainability*, *13*(4), 1844.

Selden, T.M., and Song, D. (1994). Environmental quality and development: is there a Kuznets curve for air pollution emissions? *Journal of Environmental Economics and management*, *27*(2), 147-162.

Shafik, N. (1994). Economic development and environmental quality: an econometric analysis. *Oxford economic papers*, *46* (Supplement_1), 757-773.

Sharma, S.S. (2011). Determinants of carbon dioxide emissions: empirical evidence from 69 countries. *Applied energy*, *88*(1), 376-382.

Sheng, J., Han, X., Zhou, H., and Miao, Z. (2016). Effects of corruption on performance: Evidence from the UN-REDD Programme. *Land Use Policy*, *59*, 344-350.

Shleifer, A., and Vishny, R.W. (1993). Corruption. *Quarterly Journal of Economics, 108*(3), 599–617.

Soytas, U., Sari, R., and Ewing, B.T. (2007). Energy consumption, income, and carbon emissions in the United States. *Ecological Economics*, *62*(3-4), 482-489.

Stern, D.I. (2004). The rise and fall of the environmental Kuznets curve. *World development*, *32*(8), 1419-1439.

Tanzi, V., and Davoodi, H. (1997). Corruption, public investment, and growth. *IMF Working Paper* No. 97/139. International Monetary Fund.

Treisman, D., 2000, The causes of corruption: a cross-national study, Journal of public economics, 76(3): 399458

Vivanco, D.F., McDowall, W., Freire-González, J., Kemp, R., and van der Voet, E. (2016). The foundations of the environmental rebound effect and its contribution towards a general framework. *Ecological Economics*, *125*, 60-69.

Walter, I., and Ugelow, J.L. (1979). Environmental policies in developing countries. *Ambio*, 102-109.

Welsch, H. (2004). Corruption, growth, and the environment: a cross-country analysis. *Environment and Development Economics*, *9*(5), 663-693.