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Elections and Water Pollution Cleanup in the Ganges River in India [1]

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Abstract

We analyze the role of regular elections in ensuring water pollution cleanup in the Ganges river in a north Indian city. Our central result is that, in the absence of elections, politicians have no incentive to undertake pollution cleanup, leading to poor environmental outcomes. In contrast, when elections are present, retrospective voting by a representative voter, who re-elects incumbents only if observed cleanup exceeds a threshold, can effectively discipline politicians. We show that this threshold strategy induces politicians to choose positive levels of pollution abatement in equilibrium. By explicitly characterizing the optimization problems of the politician, the voter, and the resulting equilibrium, we demonstrate that electoral accountability can serve as a powerful mechanism for improving water quality in the Ganges. Our findings highlight the critical role of democratic institutions in mitigating environmental externalities in developing country contexts.

Keywords: Election, Ganges River, Pollution Cleanup, Retrospective Voting

JEL Codes: C72, D72, Q53

1. Introduction

1.1. Preliminaries

The struggle to clean the Ganges river (Ganga in Hindi) in its most polluted urban stretches---Kanpur, a leather-tanning industrial hub, and Varanasi, the spiritual heart of India---is a battle fought on physical, technological, and political terrain (Batabyal 2023, 2024; Batabyal and Beladi 2024).[4] At its core, it poses a profound governance question: is the cyclical pressure of regular central and state elections a vital catalyst for action, or a disruptive force that prioritizes short-term spectacle over long-term systemic change? The evidence suggests that while elections are an indispensable mechanism for generating political will and public accountability, their effectiveness is heavily mediated by deeper institutional weaknesses and the complex trade-offs inherent in India's developmental politics (Das and Tamminga 2012).

Regular elections, particularly at the central and state levels, are fundamentally important because they create the primary arena for agenda-setting and accountability. The Ganga is not merely a river; it is a powerful national symbol, a religious lifeline, and a public health concern (Dwivedi *et al.* 2018). Its condition has become a potent electoral issue,

[4] The Ganges river can meaningfully be viewed as a jointly determined ecological-economic system. The study of such systems sometimes requires one to make use of mathematical simulation models. See Braat *et al.* (1986) for an example of such a study.

especially in constituencies like Varanasi, where Prime Minister Narendra Modi's own parliamentary seat lies. The launch and continuation of the flagship *Namami Gange* mission, with its budget of thousands of crores[5] of rupees, is a direct product of political commitment forged in the crucible of electoral competition (Mathur 2021). Without the threat of electoral repercussion, it is unlikely that such a massive, cross-jurisdictional program would maintain its prominence or funding. Elections force political parties to articulate their stance, make promises, and subsequently face scrutiny over their performance. The media and public discourse that accompany elections repeatedly shine a spotlight on the gap between promise and reality, preventing the issue from being entirely buried by bureaucratic inertia.

The constitutional division of powers in India makes state elections in Uttar Pradesh, a key north Indian state through which the Ganges flows, equally critical. Water supply, sanitation, and the regulation of industries—the very sources of pollution in the Ganges—are state subjects (Jha 2010). The commitment of a state Chief Minister and the state cabinet determines the vigor with which pollution control boards act against illegal industrial discharge in Kanpur's tannery clusters, or how effectively state agencies coordinate with municipal bodies (Hussain 2024). A state government that is indifferent to environmental enforcement can sabotage even the best-funded central government scheme.

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One crore equals ten million.

Therefore, state elections provide a vital check, allowing voters to punish or reward the political leadership most directly responsible for on-the-ground implementation (Weschle 2016).

Despite the documented significance of both central and state elections for the cleanup of water pollution in the Ganges river in India, to the best of our knowledge, there are *no* theoretical studies in the literature that clearly demonstrate the nexus between regular elections and water pollution cleanup in the Ganges. That said, there are two related papers that we would like to briefly comment on.

Batabyal and Beladi (2020) use a game-theoretic model of local elections to show that there exist circumstances in which an insincere politician, who pays lip service to Ganges water pollution cleanup in Varanasi, can nonetheless persuade voters to elect him to office. Batabyal and Beladi (2025) examine the implications of two kinds of taxation and majority voting for the cleanup of water pollution in the Ganges. We emphasize that *neither* of these papers focus on connecting the regular occurrence of elections with water pollution cleanup in the Ganges.

1.2. Our objective

We study the role of regular elections in ensuring the cleanup of water pollution in the Ganges. To this end, we first analyze a stylized model of an election in which a

representative voter in a city such as Kanpur or Varanasi, that lies on the Ganges, elects a politician to office. Second, we delineate the equilibrium of the voting model when the representative voter uses a cutoff strategy to re-elect an elected politician but only if the observed amount of water pollution cleaned up by this elected politician exceeds this cutoff. Third, we describe the optimization problem faced by politicians. Fourth, we delineate the optimization problem faced by the representative voter. Fifth, we show that if there are no elections then there is *no* cleanup of water pollution. Finally, we demonstrate that if there are elections, then by using retrospective voting, our voter can ensure that elected politicians clean up water pollution.

The rest of this paper is organized as follows. Section 2 formulates our theoretical model of elections and Ganges water pollution cleanup that is adapted from Ferejohn (1986). Section 3 describes the equilibrium of the voting model when the representative voter uses a threshold strategy to re-elect a politician but only if the observed amount of pollution cleaned up by the elected politician surpasses this threshold. Section 4 explains the maximization problem faced by politicians. Section 5 discusses the maximization problem faced by the representative voter. Section 6 points out that if there are no elections then there is no cleanup of water pollution. Section 7 notes that if there are elections, then by using retrospective voting, our voter can confirm that elected politicians will clean up water

pollution. Section 8 concludes and then suggests three extensions of the research delineated in this paper.

2. The Theoretical Framework

Consider a city along the Ganges river such as Kanpur, Prayagraj, or Varanasi in the northern state of Uttar Pradesh in India. There are an infinite number of discrete time periods denoted by $t = 0, 1, 2, \ldots, \infty$. There is a set of identical politicians and a single representative voter in the city under study. At the end of each time period, there is an election which, for our purpose, can be either a central or a state election. In this election, the incumbent politician responsible for cleaning up water pollution in the Ganges is confronted with a challenger. This challenger is randomly drawn. To keep the subsequent mathematical analysis straightforward, we suppose that an incumbent politician who is voted out cannot run again for election.[6]

In any time period t, the incumbent politician privately observes the realization of a random pollution shock $\zeta_t \in [\zeta^L, \zeta^H]$. He cleans up $w_t \in \mathbb{R}_+$ units of water pollution. The random pollution shock is distributed in accordance with a smooth and increasing cumulative distribution function $F(\zeta)$ with probability density function $f(\zeta) > 0, \forall \zeta$. When in elected office the politician receives a per time period net payoff or Π_1 denoted

[6] We discuss this supposition in greater detail section 8 below.

by

$$\Pi_1 = B - c(e_t), \tag{1}$$

where $B \in \mathbb{R}_+$ is the per time period gross benefit from being in elected office and $c(e_t)$ is the cost of applying e_t units of effort to the task of water pollution cleanup. By "effort," we mean the actual work done to clean up water pollution and things like the ability to build coalitions across sectors, environmental literacy, and communication skills. We assume that the cost function $c(\cdot)$ is strictly increasing and strictly convex and that it passes through the origin. In symbols, this means that $c'(\cdot) > 0, c''(\cdot) > 0,$ and $c(0) = 0.$ When unelected and hence not in office, a politician receives a net payoff of 0.

The representative voter's utility is increasing in the amount of water pollution cleaned up by the elected politician or w_t and this is denoted by

$$w_t = e_t \zeta_t. \tag{2}$$

This voter observes only the outcome, i.e., number of units of water pollution cleaned up or $w_t.$ She does not observe either the amount of effort applied by the elected politician e_t or the pollution shock $\zeta_t.$ Both the voter and the politicians have a common per time period discount rate denoted by $\delta \in (0, 1).$

The reader should note that our "identical politicians" assumption means that the candidates for political office are all essentially the same in the sense that they have the

same preferences and abilities and this feature is common knowledge among all the agents (voter and politicians). In this way of modeling the water pollution cleanup problem, the voter's task is *not* to elect the more competent politicians to office but, instead, to police moral hazard stemming from the fact that an elected politician is able to apply varying amounts of effort to the task of cleaning up water pollution and this fact is *hidden* from the voter.

Our next task is to describe the equilibrium of our voting model when the representative voter uses a cutoff strategy to re-elect a politician but only if the observed amount of pollution cleaned up by the elected politician exceeds this cutoff.

3. The Voting Equilibrium

Let us denote the representative voter's stationary or time independent cutoff or threshold level of water pollution cleanup amount by $\bar{w}$. Then, in the game between the representative voter and the politician, this voter employs the just described stationary cutoff voting rule and she re-elects the incumbent politician in period t if and only if the actual amount of water pollution cleaned up is either equal to or greater than this threshold $\bar{w}$ or, mathematically, as long as

$$w_t = e_t \zeta_t \geq \bar{w}. \tag{3}$$

The politician's strategy can be denoted by $e(\bar{w}, \zeta)$ which is the choice of effort

applied for any given re-election cutoff $\bar{w}$ and pollution shock ζ. Now, in the game equilibrium denoted by the pair (e^*, w^*), the effort applied by the politician is the optimal response to the voter's cutoff rule and, similarly, the representative voter is satisfied with her choice of the cutoff given the politician's optimal response in terms of the application of effort.

With this description of the voting equilibrium out of the way, we now proceed to explain the maximization problem faced by politicians.

4. The Politicians

The incumbent politician at any time t observes the pollution shock ζ_t and chooses either the minimum amount of effort that is required to get re-elected $e = \bar{w}/\zeta_t$ or no effort at all which means that $e = 0$. The net payoff to the politician from applying just enough effort or Π_2 is given by

$$\Pi_2 = B - c(\bar{w}/\zeta_t) + \delta V, \tag{4}$$

where V is the continuation payoff or the expected value of being in office again in time period $t + 1$. In addition, the gross payoff to the politician for applying no effort is simply B.

This line of reasoning tells us that the incumbent politician will apply a positive amount of effort if and only if

$$\delta V \geq c(\bar{w}/\zeta_t). \tag{5}$$

The weak inequality in (5) can also be written as

$$\zeta \geq \zeta^{\circ} = \frac{\bar{w}}{c^{-1}(\delta V)}. \tag{6}$$

Equations (5) and (6) together make the politician's optimal choice of effort transparent. This optimal choice can be expressed as

$$e(\bar{w}, \zeta) = \begin{cases} 0, \forall \zeta < \zeta^{\circ} \\ \bar{w}/\zeta, \ \forall \zeta \geq \zeta^{\circ} \end{cases}. \tag{7}$$

Finally, the incumbent politician's expected continuation payoff can be expressed as

$$V = BF(\zeta^{\circ}) + \int_{\zeta^{\circ}}^{\zeta^{H}} \{B - c(\bar{w}/\zeta) + \delta V\} f(\zeta) d\zeta. \tag{8}$$

The expression on the right-hand-side (RHS) of equation (8) can be simplified further. This simplification gives us

$$V = \frac{B - \int_{\zeta^{\circ}}^{\zeta^{H}} c(\bar{w}/\zeta) f(\zeta) d\theta}{1 - \delta\{(1 - F(\zeta^{\circ})\}}. \tag{9}$$

We have now completed the description of the maximization problem faced by the politicians. Next, let us delineate the maximization problem faced by the representative voter.

5. The Representative Voter

Let us begin by considering the voter's problem in time period t. We suppose that our voter uses the cutoff rule $\bar{w}$ in all future time periods as well. In addition, suppose that the voter is considering whether to deviate in time period t and to use some other cutoff

rule $\widehat{w} \neq \overline{w}$. When the incumbent politician sees this deviation, he will alter the effort he applies to cleaning pollution in time period t to $e(\widehat{w}, \zeta)$ and will apply effort $\hat{e} = \widehat{w}/\zeta$ if and only if $\zeta \geq \widehat{w}/c^{-1}(\delta V)$.

As such, the ensuing utility to the representative voter in time period t or U_p will be

$$U_p = \{1 - F(\widehat{w}/c^{-1}(\delta V))\}\widehat{w}. \tag{10}$$

Note that the continuation payoff or V in equation (10) is independent of the one time deviation $\widehat{w}$. Therefore, the optimal deviation for the voter solves

$$\overline{w} = argmax_{\{\widehat{w}\}}[1 - F(\widehat{w}/c^{-1}(\delta V))]\widehat{w}. \tag{11}$$

Differentiating the RHS of equation (11) with respect to $\widehat{w}$ gives us the first-order necessary condition (FONC) for an optimum. The condition we seek is

$$1 - F\left\{\frac{\widehat{w}}{c^{-1}(\delta V)}\right\} = \frac{\widehat{w}}{c^{-1}(\delta V)} f\left\{\frac{\widehat{w}}{c^{-1}(\delta V)}\right\}. \tag{12}$$

Now substituting $\zeta^{\circ} = \overline{w}/c^{-1}(\delta V)$ from (6) into the FONC in equation (12) and then rewriting, we get an expression for the optimal cutoff. That expression is

$$\overline{w} = \frac{c^{-1}(\delta V)\{1 - F(\zeta^{\circ})\}}{f(\zeta^{\circ})}. \tag{13}$$

With this solution to the representative voter's maximization problem out of the way, let us now demonstrate that if there are no elections then there is no cleanup of water pollution in the Ganges.

6. The Impact of No Elections

If there are no elections then our game model becomes essentially a static or one time period model. We know that the gross payoff to an incumbent politician from applying no effort is simply B. This tells us that given the representative voter's cutoff rule $\bar{w}$---see equation (13)---this incumbent politician will apply effort to cleaning up water pollution in the Ganges if and only if

$$\delta V \geq e(\bar{w}/\zeta_t). \tag{14}$$

Now, without any elections, there is no value to an incumbent politician from being re-elected. In other words, the continuation payoff from being re-elected or $\delta V = 0$. Therefore, this politician will apply *no* (or zero) effort to clean up water pollution in the Ganges river.

Our final task in this paper is to demonstrate how this negative result changes when there are elections. Specifically, we want to show that by using retrospective voting, our voter can induce elected politicians to apply a positive amount of effort and thereby clean up water pollution in the Ganges.

7. The Impact of Elections

With elections and in contrast to the scenario analyzed in section 6, our game model becomes a dynamic or multiple time periods model. Retrospective voting is the notion in

political science---see Healy and Malhotra (2013)---that voters make their decision in a given election by reflecting on the performance of the politician in power over the relevant election cycle. In our case, "performance" refers to the amount of water pollution cleaned up by the politician in power. If water pollution cleanup is proceeding well meaning that the amount of cleanup either equals or exceeds the voter's cutoff or threshold then retrospective voting theory dictates that the representative voter will re-elect the incumbent politician. On the other hand, if the actual amount of pollution cleanup is less than the voter's threshold then this voter will vote for a change.

We contend that when there are elections, by using retrospective voting, the representative voter can induce the incumbent politician to apply effort to the task of cleaning up water pollution in the Ganges.

To see this, observe that the election constraint puts some restraint on the politician's behavior. In particular, this restraint depends on the gross benefit from holding elected office B and the discount rate δ. The value to the politician from being re-elected is δV and this value is increasing in both the gross benefit B and the discount factor or measure of patience δ. The game-theoretic equilibrium of interest is the solution to a system of three equations in the three unknown variables ζ°, V, and $\overline{w}$. From (6), the first equation for ζ° that we use is

$$\zeta^{\circ} = \frac{w}{c^{-1}(\delta V)}. \tag{15}$$

Next, using equation (9), the second equation for V is

$$V = \frac{B - \int_{\zeta^{\circ}}^{\zeta^{H}} c(w/\zeta) f(\zeta) d\zeta}{1 - \{1 - F(\zeta^{\circ})\}\delta}. \tag{16}$$

Finally, using equation (13) we obtain our third equation for $\bar{w}$ that is given by

$$\bar{w} = \frac{c^{-1}(\delta V)\{1 - F(\zeta^{\circ})\}}{f(\zeta^{\circ})}. \tag{17}$$

Let us now solve this system of three equations in the three unknowns in four steps. However, before we do this, observe that a good approach to solving this system is to reduce everything to a single unknown, namely ζ°, and to then recover the desired values of V and $\bar{w}$. In step 1, we use equation (15) and observe that

$$\zeta^{\circ} = \frac{\bar{w}}{c^{-1}(\delta V)} \Rightarrow \bar{w} = \zeta^{\circ} c^{-1}(\delta V). \tag{18}$$

In step 2, we substitute the value of $\bar{w}$ from equation (18) into the left-hand-side (LHS) of equation (17). This gives us

$$\zeta^{\circ} c^{-1}(\delta V) = c^{-1}(\delta V) \frac{1 - F(\zeta^{\circ})}{f(\zeta^{\circ})} \Rightarrow \zeta^{\circ} = \frac{1 - F(\zeta^{\circ})}{f(\zeta^{\circ})}. \tag{19}$$

The RHS of equation (19) can be interpreted as the inverse hazard rate condition.[7]

[7] The inverse hazard rate function is the reciprocal of the hazard rate, which itself measures the instantaneous likelihood of an event occurring at time t given that it has not yet occurred. If the hazard rate is $h(t) = f(t)/\{1 - F(t)\}$, where $f(t)$ is the probability density function and $F(t)$ is the cumulative distribution function, then the inverse hazard rate is $1/h(t) = \{1 - F(t)\}/f(t)$. It represents the expected remaining time until the event occurs, conditional on survival up to time t, and is widely used in economics and reliability theory. See Shaked and Shanthikumar (2007) for an authoritative account of the inverse hazard rate function.

Therefore, we infer that the threshold pollution shock ζ° has the property that it equals the inverse hazard rate at $\zeta = \zeta^{\circ}$. In the third step, we solve for V using equation (16). Specifically, substituting $\bar{w} = \zeta^{\circ} c^{-1}(\delta V)$ into the RHS of equation (16) gives us

$$V = \frac{B - \int_{\zeta^{\circ}}^{\zeta^{H}} c\left(\frac{\zeta^{\circ} c^{-1}(\delta V)}{\zeta}\right) f(\zeta) d\zeta}{1 - \delta\{1 - F(\zeta^{\circ})\}}. \tag{20}$$

Equation (20) is a fixed-point equation in V.[8] After solving for V, we can substitute this value into equation (18) to obtain $\bar{w}$.

Four points are now worth emphasizing. First, the RHSs of equations (18), (19), and (20) give us the optimal values of $\bar{w}, \zeta^{\circ}$, and V respectively. Second, equation (19) tells us that we can determine the threshold pollution shock purely from the cumulative distribution function $F(\cdot)$ via the inverse hazard rate and that this threshold does *not* depend on the cost function $c(\cdot)$, the per period gross benefit from holding elected office B, or the discount rate δ. Third, V is determined from a non-linear fixed point problem and the cost function $c(\cdot)$ and the discount rate δ only scale the levels of the threshold level of water pollution cleaned up $\bar{w}$ and the politician's continuation payoff V. Finally, observe that our theoretical framework assumes that all politicians are the same. Therefore, voters

[8] A fixed-point equation is an equation in which a variable is defined in terms os a function of itself. Formally, it has the form $x = g(x)$ where a fixed point is a value x^* such that applying the function does not change it. In other words, $g(x^*) = x^*$. In economic models, fixed-point equations often arise when an equilibrium variable (like the value V) depends on expectations or outcomes that themselves depend on that same variable.

are indifferent about a water pollution cleanup threshold *ex post* because they are indifferent *ex post* about replacing the incumbent politician with a challenger.

7.1. An example

Let us now demonstrate the working of our game-theoretic model in the special case in which the random pollution shock is uniformly distributed on the closed interval $[0, 1]$ and the cost of applying effort function is quadratic, i.e., $c(e_t) = e_t^2/2$. In this case, $F(\zeta) = \zeta, f(\zeta) = 1,$ and $c'(e_t) = e_t$.

Let us first solve for ζ°. From the inverse hazard condition in equation (19), we get

$$\zeta^\circ = \frac{1-F(\zeta^\circ)}{f(\zeta^\circ)} = 1 - \zeta^\circ \Rightarrow \zeta^\circ = \frac{1}{2}. \tag{21}$$

Second, using equation (18), we get

$$\bar{w} = \zeta^\circ c^{-1}(\delta V) = \frac{1}{2}\sqrt{2\delta V}. \tag{22}$$

Third, we need to simplify the integral in the numerator of the ratio on the RHS of equation (20). Integrating between the lower and upper limits, we get

$$\int_{\zeta^\circ}^{1} c\left(\frac{\bar{w}}{\zeta}\right) f(\zeta) d\zeta = \int_{1/2}^{1} \frac{1}{2}\left(\frac{\bar{w}}{\zeta}\right)^2 d\zeta. \tag{23}$$

Substituting $\bar{w}^2 = (1/4)(2\delta V) = \delta V/2$ into the above equation gives us

$$\int_{1/2}^{1} \frac{1}{2}\frac{\delta V}{2}\frac{1}{\zeta^2} d\zeta = \frac{\delta V}{4}\int_{1/2}^{1} \zeta^{-2}\, d\zeta. \tag{24}$$

Integrating the expression on the RHS of equation (24), we get

$$\int_{1/2}^{1} \zeta^{-2} d\zeta = \left[-\frac{1}{\zeta}\right]_{1/2}^{1} = 1, \tag{25}$$

which implies that the integral in the numerator of the ratio on the RHS of equation (20) is equal to $\delta V/4$.

Finally, we need to solve for V. Using the above result in equation (20), we get

$$V = \frac{B - \delta V/4}{1 - \delta\{1 - F(1/2)\}}. \tag{26}$$

Since $F(1/2) = 1/2$, we infer that the denominator on the RHS of equation (26) equals $1 - \delta\{1 - F(1/2)\} = 1 - \delta/2$. Using this last result in equation (26), we obtain

$$V = \frac{B - \delta V/4}{1 - \delta/2}. \tag{27}$$

Isolating B on one side of the equation and keeping all other terms on the other side allows us to write equation (27) as

$$V = \frac{B}{1 - \delta/4}. \tag{28}$$

In our last step, using equation (28), we get

$$\overline{w} = \frac{1}{2}\sqrt{2\delta V} = \frac{1}{2}\sqrt{\frac{2\delta B}{1 - \delta/4}} \Rightarrow \overline{w} = \sqrt{\frac{\delta B}{2(1 - \delta/4}}. \tag{29}$$

Equation (21) clearly shows that the pollution shock threshold ζ° depends *only* on the hazard rate of the distribution function and in the case of the uniform distribution, we get a clean interior solution at one-half. The reason for the solution being at one-half is that for the uniformly distributed pollution shock on the closed interval [0, 1], the probability

density function is constant, the uniform distribution is symmetric, and hence there is no skew towards either low or high pollution shock values.

Equation (28) tells us that V or the continuation payoff balances a flow benefit and the expected future payoff that is discounted by δ. In our model, two forces reduce the future value of being in office. The first force is the discounting which means that future payoffs matter less to our politician and the second force stems from the fact that it makes sense to apply effort only for half the values of the pollution shock since $\zeta^{\circ} = 1/2$. These two forces together look like a discount factor of $\delta/4$ and not δ and this gives rise to the denominator $1 - \delta/4$. Inspectiong equation (28), we see that a higher B raises V, one-for-one. Higher patience or δ also raises V but at a diminishing rate.

Equation (29) reveals that a higher gross benefit from being in elected office or $B \uparrow$ raises the representative voter's cutoff pollution cleanup amount. Second, higher patience or $\delta \uparrow$ also increases the representative voter's cutoff pollution cleanup amount. More generally, water pollution cleanup responds to incentives but slowly. In this regard, the square root in equation (29) can be thought of as reflecting either technological or bureaucratic limits.

We close this section with a brief discussion of the nexuses between regular elections, water pollution cleanup, and the spatial effects of this cleanup by focusing on, for example,

pollution cleanup in the city of Kanpur. As far as the connection between elections and pollution cleanup is concerned, we have already shown that if there are elections, then by using retrospective voting, our voter in Kanpur can ensure that elected politicians clean up water pollution effectively.

Moving on to the spatial effects, cleaning up water pollution in the Ganges in Kanpur can generate significant positive spatial spillovers that extend well beyond the immediate locality. Improved water quality upstream reduces the transmission of contaminants to downstream settlements, benefiting cities such as Varanasi by lowering health risks, enhancing agricultural productivity through safer irrigation, and improving fisheries. Cleaner river conditions can also raise land values and stimulate economic activity along the riverbanks, including tourism and religious activities that depend on the river's cultural significance (Batabyal and Beladi 2019). Moreover, reduced pollution enhances ecosystem connectivity, allowing aquatic species to recover and migrate more freely, which strengthens regional biodiversity. These spatial benefits reinforce each other, creating a broader corridor of environmental and economic revitalization along the Ganges river basin. This concludes our analysis of elections and water pollution cleanup in the Ganges river in India.

8. Conclusions

In this paper, we developed a dynamic game-theoretic model to analyze how regular

elections affect incentives for water pollution cleanup in cities such as Kanpur, Prayagraj, and Varanasi that are located on the Ganges river in north India. Politicians derived benefits from holding office but incurred convex costs when applying effort to cleanup water pollution, while voters observed only cleanup outcomes, not effort or pollution shocks. In the absence of elections, politicians optimally applied zero effort, leading to no pollution cleanup. With elections, however, a representative voter used a retrospective voting rule, re-electing incumbents only if observed cleanup exceeded a particular threshold. This cutoff strategy disciplined politicians by linking future electoral prospects to current performance, thereby inducing positive cleanup effort in equilibrium. Our analysis characterized the equilibrium behavior of voters and politicians, showed how the optimal cleanup threshold depended on the distribution of pollution shocks through the inverse hazard rate, and demonstrated that democratic accountability can overcome moral hazard in environmental governance even when politicians are identical.

The empirical implications of the research described in this paper are clear and testable. First, the model predicts a systematic positive relationship between electoral accountability and observed water pollution cleanup: jurisdictions or time periods with more competitive or salient elections should exhibit higher levels of pollution abatement. Second, cleanup efforts should display electoral-cycle effects, increasing prior to elections when

incumbents seek re-election and declining when electoral pressure weakens. Third, cross-regional variation in water quality outcomes should reflect differences in institutional strength, voter responsiveness, and the distribution of pollution shocks, rather than purely technological constraints. Fourth, policies that improve transparency—such as better monitoring of water quality—should enhance voter ability to engage in retrospective voting and thereby lead to measurable improvements in environmental performance. Finally and more broadly, the results suggest that strengthening transparency, measurability of cleanup outcomes, and voter capacity for retrospective evaluation can enhance environmental performance, reinforcing the view that democratic institutions play a central causal role in mitigating environmental externalities in developing-country contexts.

The analysis in this paper can be extended in a number of different directions. Here are three suggestions for extensions. First, following the work of Manjon and Crutzen (2022), and Wang *et al.* (2025), it would be useful to study the nexuses between regular elections and water pollution cleanup in smart cities that use information and communication technologies (ICT) extensively to generate green innovations. Second, it would be instructive to analyze a scenario in which the politicians under study are heterogeneous in that they differ in terms of their ability to apply effort to cleaning up water pollution and a defeated politician in time period t is able to stand for elected office in time periods $t+1$ and

beyond. In this scenario, *inter alia*, the representative voter's task would be to elect the more capable politicians to office and not just police moral hazard. Finally, it would be instructive to analyze the circumstances in which the voter's optimal cutoff rule is not stationary but declining in stringency over time. Studies of elections and water pollution cleanup in the Ganges that incorporate these aspects of the problem into the analysis will provide further insights into the vital role played by regular elections in ensuring the cleanup of water pollution in one of the most salient rives in South Asia.

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