The representative Kanpur tannery's Ganges water pollution problem

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by

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Abstract

In this research note, we focus on a representative, leather producing tannery in Kanpur, India, and shed light on two specific questions that, to the best of our knowledge, have *not* been studied previously in the literature. First, what is the deadweight loss from water pollution caused by this tannery? Second, how might an effluent fee be used to ensure that the socially optimal amount of leather is produced by this same tannery? Our linear model provides answers to these two questions and also shows how our results can be used to guide pollution regulation policy.

Keywords: Deadweight Loss, Effluent Fee, Ganges River, Pollution, Representative Tannery

JEL Codes: Q53, R11

1. Introduction

The longest and the most significant river in India, without a doubt, is the Ganges. This storied river is also often referred to by its Hindi name---Ganga. As pointed out by Hammer (2007), Conaway (2015), and Batabyal and Beladi (2019, 2020), the Ganges occupies a central place in the Hindu religion in the sense that most Hindus consider this river to be sacred. Markandya and Murty (2004) observe that the Ganges is 2510 kilometers long and, in addition, it has a basin that covers 861,404 square kilometers. At the present time, almost ten percent of the world's population lives within the Ganges basin and this population is expected to rise to over one billion people by the year 2030.

The significant role of the Ganges on economic life in northern India can be gauged by understanding that there are roughly 52 cities, 48 towns, and many thousand villages in its basin. That said, what is salient for our purpose in this research note is the fact that almost all the waste from these myriad populations goes directly into the Ganges. This waste adds up to "1.3 billion litres per day along with a further 260 million litres of industrial waste, runoff from the 6 million tons of fertilisers and 9000 tons of pesticides used in agriculture within the basin…" (Markandya and Murty, 2004, p. 62).

The problem of cleaning up pollution in the Ganges at Varanasi now certainly appears to have a champion and that champion is the current Prime Minister Mr. Narendra Modi. Mr. Modi is a devout Hindu and his Bharatiya Janata Party (BJP) won a second five-year term in the 2019 national elections. It is important to understand that Mr. Modi's parliamentary constituency in 2014---the earlier year in which a national election was held---and in 2019 was and remains Varanasi. Therefore, it is perhaps not surprising to observe that Mr. Modi has initiated an ambitious, multi-year plan to clean the Ganges called the "Namami Gange Program" and that he has also promised to convert Varanasi into a vibrant city for religious and other tourists. This program is an integrated conservation mission that was approved by the Government of India as a "flagship program" in June 2014 with a budgetary outlay of Indian rupees 20,000 crore (1 crore equals 10 million). Specifically, the goal of the program was to control water pollution and rejuvenate the Ganges.[3]

Even though research on cleaning up pollution in the Ganges has been burgeoning in recent times---see, for instance, Khwaja *et al*. (2001), Markandya and Murty (2004), Katiyar (2011), Batabyal and Beladi (2017), Xing and Batabyal (2019), Batabyal and Yoo (2022), and Batabyal *et al*. (2023)---there are *gaps* in the existing literature in the sense that two specific questions remain *unanswered* thus far. First, what is the deadweight loss from water pollution caused by a representative, leather producing tannery in Kanpur? Second, how might an effluent fee[4] be used to ensure that the socially optimal amount of leather is produced by this tannery? Given this *lacuna* in the literature, our objective in this research note is to use a linear model to shed light on these two questions. We use this linear model because of three reasons. First, it is straightforward to work with and the algebra involved in obtaining the solutions of interest is uncomplicated. Second, the model provides clear and easily interpretable answers to the preceding two questions. Finally, the model demonstrates how our results can be used to guide pollution regulation policy. That said, we would like to point out that it is possible to study the two questions of interest to us in this research note with a more "general model" that does not use explicit functional forms.

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3 Go to Namami Gange Programme| National Portal of India for additional details on this program. Accessed on 9 May 2023.

4 See Beladi *et al.* (2013) for an alternate approach to pollution control.

2. Analysis

We begin by considering a representative tannery in Kanpur that produces leather but also deposits chemical waste into the Ganges. For every unit of leather produced, this tannery deposits one unit of waste into the Ganges. The demand function for leather is given by

$$p^d = \alpha - q. \tag{1}$$

The reader should think of this demand function as the marginal benefit function where $q > 0$ is the quantity of leather purchased by consumers by paying price $p^d > 0$.

The supply function or the marginal private cost (MPC) of producing leather by the tannery is given by

$$MPC = \beta + q. \tag{2}$$

The marginal external cost (MEC) stemming from leather production can be written as

$$MEC = \gamma q, \tag{3}$$

when the tannery under study deposits q units of waste into the Ganges. The marginal social cost (MSC) from waste deposition into the Ganges is the sum of the two expressions given in equations (2) and (3). In other words, the MSC can be written as

$$MSC = MPC + MEC = \beta + q + \gamma q = \beta + (1 + \gamma)q. \tag{4}$$

With this straightforward theoretical framework in place, our first task is to compute the equilibrium market price (p^m) and the quantity of leather produced (q^m) when there is no correction for the negative externality arising from the chemical waste deposited into the Ganges. To obtain these two values, we set the demand from equation (1) equal to the marginal private cost (MPC) from equation (2). This gives us the ratios

$$p^d = MPC \Rightarrow \alpha - q^m = \beta + q^m \Rightarrow q^m = \frac{\alpha-\beta}{2} \;\; and \;\; p^m = \frac{\alpha+\beta}{2}. \qquad (5)$$

Our second task is to ascertain how much leather ought to be produced (q^o) and its price (p^o) in the social optimum. To undertake this task, we use equations (1) and (4) and then perform some algebraic simplifications. This process gives us

$$p^d = MSC \Rightarrow \alpha - q^o = \beta + (1+\gamma)q^o \Rightarrow q^o = \frac{\alpha-\beta}{2+\gamma} \Rightarrow p^o = \frac{\alpha(1+\gamma)+\beta}{2+\gamma}. \qquad (6)$$

Equation (6) provides us with closed-form expressions for the optimal quantity and price (q^o, p^o) and this equation also shows us exactly how the optimal quantity and price depend on the parameters of the various functions in our linear model.

Having computed the market outcome (p^m, q^m) and the social optimum (p^o, q^o), we are now in a position to determine the deadweight loss from the deposition of chemical waste into the Ganges by the representative tannery. Observe that this deadweight loss (DWL) is the difference between the welfare level at the social optimum (the sum of consumer and producer surplus) and the welfare level in the market equilibrium (the sum of the consumer surplus, producer surplus, and the difference between the total social and the total private cost). Mathematically, we need to compute

$$DWL = \int_{q^o}^{q^m} [MSC(q) - p^d\,(q)]dq = \int_{q^o}^{q^m} [\{\beta + (1+\gamma)q\} - \{\alpha - q\}]dq. \qquad (7)$$

Now, let A = $(\beta - \alpha)$ and B = $(2+\gamma)/2$. Then, using these last two substitutions to simplify the integral on the right-hand-side (RHS) of equation (7), we get an explicit expression for the deadweight loss. That expression is

$$DWL = \mathrm{A}\left\{\left(\frac{\alpha-\beta}{2}\right) - \left(\frac{\alpha-\beta}{2+\gamma}\right)\right\} + \mathrm{B}\left\{\left(\frac{\alpha-\beta}{2}\right)^2 - \left(\frac{\alpha-\beta}{2+\gamma}\right)^2\right\}. \quad (8)$$

Using the results for the endogenous variables q^m and q^o in equations (5) and (6), we can rewrite the above expression for the deadweight loss in equation (8). This gives us

$$DWL = q^m(\mathrm{A} + \mathrm{B}q^m) - q^o(\mathrm{A} + \mathrm{B}q^o). \quad (9)$$

The policy implication stemming from equation (9) is clear. Specifically, we see that as the market equilibrium level of leather production or q^m increases, so does the deadweight loss from the unaccounted negative externality resulting from the deposition of chemical waste into the Ganges. In contrast, as the socially optimal level of leather production or q^o rises, the deadweight loss declines.

In our analysis thus far, we have not accounted for how one or more shocks to the value chain leading up to the production of leather would impact the actual production of this final good and the deposition of chemical waste into the Ganges. If these shocks lead to an increase (decrease) in the cost of producing leather then, *ceteris paribus*, we can expect leather production and pollution in the Ganges to fall (rise).

Our last task in this research note is to determine how large an effluent fee[5] must be if it is to ensure that the representative tannery produces the socially optimal amount of leather. Let us

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An effluent fee is a price control instrument. In principle, a quantity control can also be used to ensure that the representative tannery produces the socially optimal amount of leather.

denote the effluent fee by F. Then, with this fee in place, using equations (1) and (2), the market equilibrium is given by

$$\alpha - q = \beta + q + F \Rightarrow q = \frac{\alpha-\beta}{2} - \frac{F}{2}. \tag{10}$$

Now, setting the output of leather or q on the RHS of equation (10) equal to the socially optimal level of leather production or q^o and then simplifying the resulting expression tells us that

$$F = \alpha - \beta - \frac{2(\alpha-\beta)}{2+\gamma}. \tag{11}$$

In other words, an effluent fee F set at the level given in equation (11) will ensure that the representative tannery effectively internalizes the external cost it imposes on society by polluting the Ganges with discharges of chemical waste.

3. Extensions

The analysis in this research note can be generalized in a number of ways. Here are three potential generalizations. First, to explicitly account for uncertainty, it would be useful to analyze the case where the chemical waste discharge by the representative tannery is stochastic and not deterministic. Second, it would be helpful to analyze the ways in which this probabilistic discharge of chemical waste interacts with the Ganges river's natural capacity to cleanse itself of the detrimental impacts of one or more pollutants. Finally, our analysis was conducted with a linear model in which the focus was on a single pollutant (chemical waste) or, alternately, this single pollutant could be interpreted as a composite pollutant that reflected all the pollutants present in the Ganges. As such, it would be interesting to analyze an alternate model in which there are interaction effects between dissimilar polluters (leather producers) and the the different pollutants that they deposit into the Ganges. Such a model may well need to be game-theoretic in nature with multiple equilibria potentially replacing the unique equilibrium in the linear model under study here. Analyses along the lines suggested here are sure to increase our comprehension of the complex interactions between polluting tanneries and the many ecosystem services provided by the Ganges river.

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