Tanneries in Kanpur and pollution in the Ganges: a theoretical analysis

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by

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Abstract

We study pollution in the Ganges river caused by tanneries in the city of Kanpur in India. Two tanneries, A and B, are located on the same bank of the Ganges in Kanpur. Both produce leather and the production of leather requires the use of chemicals that are toxic to humans. Tannery A is located upstream from tannery B. Tannery $A's$ leather production depends directly only on labor use but tannery $B's$ leather production depends on labor use, the chemical waste generated by tannery A, and the natural pollution absorbing capacity of the Ganges. In this setting, we accomplish three tasks. First, we determine the equilibrium production of leather by both tanneries in the benchmark case in which there is no pollution. Second, we ascertain how the benchmark equilibrium is altered when tannery B accounts for the negative externality imposed on it by tannery A. Finally, we analyze what happens to leather production and to labor use when the two tanneries merge and then we discuss some policy implications emanating from our research.

Keywords: Ganges River, Leather, Merger, Pollution, Tannery

JEL Codes: Q52, Q53

1. Introduction

1.1. Preliminaries

The longest and most important river in India is the Ganges. This river is also frequently referred to by its Hindi name---Ganga. As noted by Hammer (2007), Conaway (2015), and Batabyal and Beladi (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) point out 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 over one billion people by the year 2030. The significance of the Ganges on economic life in northern India can be gauged by recognizing that there are approximately 52 cities, 48 towns, and several thousand villages in its basin. What is important for our purpose is the fact that almost all the waste from these 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).

Menon (1988) and Tare *et al*. (2003) note that the first serious attempt at cleaning up pollution in the Ganges was the so-called Ganga Action Plan (GAP) which was launched in 1985. The GAP was largely the outcome of the personal interest shown by Indira Gandhi---who was the Prime Minister of India in the early 1980s---in improving water quality in the Ganges. A staggeringly large amount of money was set aside to implement the GAP. In this regard, Markandya and Murty (2004) note that the final investment cost of the GAP was, using 1995-1996 prices, approximately Indian rupees 7,657.37 million during the 1985-1986 to 1996-1997 time period. Using the Indian rupee-US$ exchange rate prevalent then, these authors point out that over

US$300 million was allocated to pollution cleanup expenditures. The basic objective behind the allocation and expenditure of such a vast sum of money was to raise water quality in the Ganges so that one could bathe in the river. With regard to the GAP, it is important to bear in mind that although large-scale river basin cleanup programs have been implemented in a number of nations, none of these programs "has the full spectrum of geographical, ecological, and socio-ciultural complexities which faced the Indian government duringimplementation of the GAP" (Markandya and Murty (2004, p. 62).

Black (2016) points out that more than a billion gallons of waste enters the Ganges every day. Although the problem of waste deposition into the Ganges occurs at various points along the river, Gallagher (2014) and Black (2016) maintain that with regard to pollution in the Ganges, two problems are paramount. The first problem is pollution from the tannery industry which is centered in the city of Kanpur. The second problem is waste deposited into the Ganges in Varanasi, a city that is located two hundred miles downstream from Kanpur. Now, the tannery industry in Kanpur is almost entirely owned by Muslims. In contrast, a lot of the pollution in Varanasi---the spiritual center of Hinduism---is the outcome of Hindu religious activities. In this regard, Dhillon (2014) points out that 32,000 bodies are cremated every year in Varanasi and that this process results in 300 tons of ash and 200 tons of half burnt human flesh being deposited into the Ganges. This state of affairs tells us that ridding the Ganges of pollution is a challenging task because in addition to environmental and economic considerations, this task plays directly into India's charged caste and religious politics.

That said, the problem of cleaning up pollution in the Ganges at Varanasi now 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.[3] 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 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 pollution and rejuvenate the Ganges. [4]

1.2. Literature review

Recently, the problem of cleaning up pollution in the Ganges at Varanasi has been studied theoretically from a variety of deterministic and stochastic perspectives by researchers. For instance, Batabyal and Beladi (2017) first point out that there are no theoretical studies of the cleanup of the Ganges and its connection to tourism and then they proceed to construct and analyze a stochastic model of pollution cleanup in the Ganges.

Batabyal and Beladi (2019) extend the previous analysis by studying two probabilistic approaches to the cleanup of pollution in the Ganges in Varanasi. The first approach models the idea that because resources are scarce and cleanup is costly, not all pollutants in the Ganges can be remioved. Therefore, a cleaning agency first establishes a benefit-cost ratio rule and then it uses this rule to remove from the Ganges only those pollutants whose removal satisfies the ratio rule. The second approach concentrates on removing all pollutants from the Ganges but the emphasis

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See Gettleman *et al.* (2019) and Slater and Masih (2019) for additional details on this election victory.

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Go to Namami Gange Programme| National Portal of India for additional details on this program. Accessed on 23 August 2022.

now is on the frequency of cleanup given that pollutants accumulate and therefore water quality diminishes over time.

Batabyal and Beladi (2020) look at the Ganges pollution cleanup problem in Varanasi with a political-economy lens. In their model, voters elect politicians and elected politicians decide how much pollution to clean up. Politicians are of two possible types; they are either sincere about cleaning up pollution or they are insincere about cleaning up pollution. The model studies the conditions under which one or the other type of politician gets elected to office and the resulting pollution clean up that arises.

Finally, Xing and Batabyal (2019) focus on two Ganges pollution cleanup questions in Varanasi. First, these researchers introduce the notion of a safe-minimum-standard (SMS) into the analysis and then then they discuss the insights emanating from a probabilistic model that explicitly accounts for the SMS. Second, for a representative citizen of Varanasi, these researchers study how the magnitude of the elasticity of substitution between a composite consumption good and water quality in the ganges influences the tradeoff between consumption and water quality maintenance. Given the existence of these prior studies on the Varanasi specific aspects of pollution cleanup in the Ganges, we shall not dwell any further on this facet of the water pollution cleanup problem.

Instead, we shall focus on pollution in the Ganges caused by the tannery industry in Kanpur. In this regard, the work of Khwaja *et al*. (2001), Gowd *et al*. (2010), and Bhatnagar *et al*. (2013) clearly tells us that many of the pollutants---such as chromium---that are deposited into the Ganges by the tanneries are extremely injurious to human health and hence the problem of regulating the deposition of these pollutants is a serious matter. Singh (2006) notes that a key problem here is that the growth of tanneries has not been matched by an increase in the capacity of the pertinent effluent treatment plants. For instance, in 2006, of the 220 chrome tanning units in Kanpur, 110 units were supposed to install their own chrome recovery plants (CRPs). This notwithstanding, only 88 units had actually undertaken this task. As Singh (2006) explains, even existing CRPs are often not operated as they should because of high operating costs. More generally, we learn that the GAP has failed in important ways in the Kanpur area because the lives oif many villagers in and around Jajmau---the industrial suburb of Kanpur where most of the tanneries are located---have been upended by their inability to continue farming with wastewater irrigation, something that they did before the implementation of the GAP in 1986.

The fact that the GAP appears to have done little to improve water quality in the Ganges in the vicinity of Kanpur has been noted by other resaerchers as well. For instance, Srivastava (2010) observes that in Kanpur, water in the Ganges stinks even during the monsoon season when the river is flooded. He adds (2010, p. 155) that "river water quality has deteriorated in a big way in Kanpur since the GAP was launched. The amount of filth in the river and along its banks continues to rise unabatedly" In this regard, it should be noted that the government of the state of Uttar Pradesh---where Kanpur is located---periodically takes "stern" actions such as closing down some tanneries in Kanpur in advance of important events such as the Kumbh Mela in the city of Prayagraj but these actions have had little, long-term impact on reducing the discharge of toxic pollutants into the Ganges.[5]

1.3. Objectives of this paper

There is no gainsaying the fact that the seriousness of the underlying problem involving the discharge of noxious pollutants into the Ganges by tanneries in Kanpur has been recognized by a

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See Anonymous (2019) for additional details on this point.

number of researchers including, but not limited to, Ansari *et al*. (2000) and Sinha *et al*. (2006). Even so, despite the seriousness of the underlying problem, to the best of our knowledge, there are *no* theoretical studies in either economics or regional science that have rigorously analyzed the control of pollution in the Ganges caused by the tannery industry in Kanpur. Given this lacuna in the literature, we provide what we believe is the *first* theoretical analysis of pollution in the Ganges arising from the activities of the tannery industry in Kanpur.

We emphasize that our objective in this paper is to conduct a *theoretical* analysis of water pollution in the Ganges caused by the activities of tanneries in Kanpur and thereby make a *theoretical* contribution to the existing literature on this subject. That said, at various points in what follows, we point to connections between our theoretical analysis and actual issues concerning tannery generated pollution in the Ganges.

The remainder of this paper is organized as follows: Section 2 describes our model of pollution in the Ganges caused by the tanneries in Kanpur. In particular, there are two tanneries, denoted by A and B, that are located on the same bank of the Ganges in Kanpur. Both tanneries produce leather and the production of leather requires the use of chemicals that are toxic to humans. Tannery A is located upstream from tannery B. Tannery $A's$ leather production depends directly only on labor use but tannery $B's$ leather production depends on labor use, the chemical waste generated by tannery A, and what we can think of as the natural pollution absorbing capacity of the Ganges. Section 3 determines the equilibrium production of leather by the two tanneries in the benchmark case in which there is no pollution. Section 4 focuses on the ways in which the benchmark equilibrium is altered when tannery B accounts for the external diseconomy imposed on it by tannery A. Section 5 first analyzes what happens to leather production and to labor use when the two tanneries merge and then comments on a couple of policy implications stemming from the present paper's research. Section 6 concludes and then suggests two ways in which the research delineated in this paper might be extended.

2. The Theoretical Framework

Consider two tanneries, denoted A and $B,$ that are located on the same bank of the Ganges river in the Jajmau industrial suburb of Kanpur. Many of Kanpur's tanneries are present in Jajmau which is a small area located just a few miles from the city center. The two tanneries under study produce leather and the production of leather requires the use of chemcials that are injurious to the health of humans. Tannery A is located upstream of tannery B.

Tannery $A's$ production function for leather is given by

$$\alpha = 1000L_A^{1/2}, \tag{1}$$

where $L_A > 0$ is the amount of labor used to produce leather and $\alpha > 0$ is the amount of leather produced. Tannery B has a very similar production function but the leather it produces can be negatively impacted by the chemical waste generated by tannery A. Using this last piece of information, we can write tannery $B's$ production function as

$$\beta = \begin{pmatrix} 1000L_B^{1/2}\{\alpha - \alpha_0\}^{-\zeta}, \alpha > \alpha_0 \\ 1000L_B^{1/2}, \alpha < \alpha_0 \end{pmatrix}, \tag{2}$$

where $L_B > 0$ is the amount of labor used to produce leather, $\beta > 0$ is the amount of leather produced, $\alpha_0 > 0$ is the natural capacity of the Ganges for absorbing pollution, and $\zeta \geq 0$ is an externality parameter whose meaning is discussed in greater detail in sections 3 and 4 below. We shall normalize the price of a unit of leather so that its price $p = 1$ and we suppose that the wage paid per unit of labor is $w = 50$. It is understood that both the tanneries under study are profit maximizers.

It is important to point out that our choices of $p = 1, w = 50,$ and the numerical value of 1000 for the coefficients of the two production functions in equations (1) and (2) are without loss of generality. This means that if, instead of working with these numbers, we had worked with a variable then there would be greater algebraic clutter in the mathematical analysis we undertake below but there would be *no* substantive change in our results. With this description of the theoretical model out of the way, we are now in a position to solve for the equilibrium production of leather by the two tanneries in the benchmark case in which, by assumption, there is no pollution to contend with.

3. The Benchmark Case

The profit function of tannery A is given by

$$\pi_A = p\alpha - wL_A = 1000L_A^{1/2} - 50L_A. \tag{3}$$

The first-order necessary condition for an optimum---the second-order sufficiency condition is satisfied---is given by

$$\frac{d\pi_A}{dL_A} = 500L_A^{-1/2} - 50 = 0. \tag{4}$$

Manipulating equation (4), the optimal solution we seek is given by

$$L_A^* = 100 \quad and \quad \alpha^* = 10000.$$

(5)

In words, to maximize profit from leather production, tannery A ought to hire 100 laborers and use this hired labor to produce 10000 units of leather.

The profit function of tannery B is given by

$$\pi_B = p\beta - wL_B = \begin{cases} 1000L_B^{1/2}\{\alpha - \alpha_0\}^{-\zeta} - 50L_B, \alpha > \alpha_0 \\ 1000L_B^{1/2} - 50L_B, \quad \alpha < \alpha_0 \end{cases}. \tag{6}$$

The first-order necessary conditions for an optimum---the second-order sufficiency conditions are satisfied---are

$$\frac{d\pi_B}{dL_B} = \begin{cases} 500L_B^{-1/2}\{\alpha - \alpha_0\}^{-\zeta} - 50 = 0, \alpha > \alpha_0 \\ 500L_B^{-1/2} - 50 = 0, \alpha < \alpha_0 \end{cases}. \tag{7}$$

Manipulating the above first-order necessary conditions and then solving for the optimal values of the two decision variables of interest, we get

$$L_B^* = \begin{cases} 100\{\alpha - \alpha_0\}^{-2\zeta}, \alpha > \alpha_0 \\ 100, \alpha < \alpha_0 \end{cases}. \tag{8}$$

and

$$\beta^* = \begin{cases} 10000\{\alpha - \alpha_0\}^{-2\zeta}, \alpha > \alpha_0 \\ 10000, \alpha < \alpha_0 \end{cases}. \tag{9}$$

In other words, if tannery B would like to maximize its profit from leather production then it ought to hire the quantity of labor indicated by equation (8) and then use this labor to produce an amount of leather given by equation (9).

We are now in a position to answer the question about optimal leather production when there is no pollution to contend with. Specifically, if tannery $A's$ production of leather leads to no pollution in the Ganges river then this tannery imposes *no* costs on tannery B. Put differently, tannery $A's$ leather production does *not* lead to an external diseconomy for tannery B. In our model, the existence of this external diseconomy is captured by the externality parameter ζ. If there is no pollution and hence no negative externality then we can set the value of this parameter $\zeta = 0$. Doing this in equation (9) and then using equation (5), we get

$$\alpha^* = \beta^* = 10000. \tag{10}$$

In sum, in this benchmark case in which there is no pollution and therefore no negative externality to account for, the fact that tannery B is located downstream from tannery A does not disadvantage it in any way as far as the production of leather is concerned. Our next task is to ascertain how the benchmark equilibrium studied in this section is altered when tannery A pollutes and tannery B accounts for the negative externality imposed on it by tannery A.

4. The Negative Externality

We begin by supposing that $\alpha_0 = 9000$ and that $\zeta = 1/10$. The reader will understand that these two numerical values of α_0 and ζ do *not* in any way change the profit maximizing amount of leather produced by tannery A. Therefore, as in equation (10), once again we obtain $\alpha^* = 10000$. To obtain the optimal value β^*,we use equations (9) and (10) together. This tells us that

$$\beta^* = 10000\{10000 - 9000\}^{-0.2} = 2511.89. \quad (11)$$

Comparing equations (10) and (11) we see that when $\zeta = 1/10 > 0,$ there is an external diseconomy imposed by tannery A on the ability to produce by tannery B. In particular, the parameter ζ measures the strength of the external diseconomy. In other words, a higher value of ζ means that the external diseconomy tannery A imposes on tannery B is stronger and hence has a greater impact on leather production by B. Tannery A basically ignores this negative externality and therefore it hires too many laborers and produces *more* leather than is socially optimal.

Observe that in our analysis thus far, we have only required the "strength of the negative externality parameter" to be non-negative. This allows us to easily compare the benchmark case in section 3 in which there is no pollution $(\zeta = 0)$ with the case in the present section in which there is pollution $(\zeta > 0)$. That said, we have *not* picked a particular value for this parameter because doing so would make all our results in this and in the subsequent sections depend on this specific value and thereby *limit* the scope of our analysis. To this end, observe that by varying the numerical value of $\zeta,$ we can readily analyze, for instance, how worsening water pollution in the Ganges (a higher value of ζ) influences the hiring of labor and the production of leather by the affected tannery B. Our final task in this paper is to analyze what happens to labor use and to leather production when tanneries A and B merge.

5. A Merger

The profit function of the newly merged tannery is

$$\pi = \pi_A + \pi_B = p(\alpha + \beta) - w(L_A + L_B). \quad (12)$$

Making the relevant algebraic substitutions, the above profit function can be written as

$$\pi = -50(L_A + L_B) + \begin{bmatrix} 1000\left\{L_A^{1/2} + L_B^{1/2}\left(1000L_A^{1/2} - \alpha_0\right)^{-\zeta}\right\}, \ L_A > \left(\frac{\alpha_0}{1000}\right)^2 \\ 1000\{L_A^{1/2} + L_B^{1/2}\}, \qquad L_A < \left(\frac{\alpha_0}{1000}\right)^2 \end{bmatrix}. \quad (13)$$

The two inequalities on the right-hand-side (RHS) of equation (13) follow because $\alpha \gtrless \alpha_0$ implies from equation (1) that $1000L_A^{1/2} \gtrless \alpha_0$ and this last expression, in turn, implies that $L_A \gtrless (\alpha_0/1000)^2$.

The first-order necessary conditions for an optimum---the second-order sufficiency conditions are satisfied---are

$$\frac{\partial \pi}{\partial L_A} = -50 + \begin{bmatrix} 500L_A^{-1/2}\left\{1 - 1000\zeta L_B^{1/2}\left(1000L_A^{1/2} - \alpha_0\right)^{-(\zeta+1)}\right\}, L_A > \left(\frac{\alpha_0}{1000}\right)^2 \\ 500L_A^{-1/2}, L_A < \left(\frac{\alpha_0}{1000}\right)^2 \end{bmatrix}, \quad (14)$$

and

$$\frac{\partial \pi}{\partial L_B} = -50 + \begin{bmatrix} 500L_B^{-1/2}\{1000L_A^{1/2} - \alpha_0\}^{-\zeta}, L_A > \left(\frac{\alpha_0}{1000}\right)^2 \\ 500L_B^{-1/2}, L_A < \left(\frac{\alpha_0}{1000}\right)^2 \end{bmatrix}. \quad (15)$$

Using equations (14) and (15), we can determine the equilibrium labor demand functions. In particular, manipulating these two sets of equations, we can deduce the equilibrium demand for labor. The two demand functions we seek are given by

$$L_A^e = \begin{cases} 100\left\{1 - \zeta L_B^{1/2}\left(1000(L_A^e)^{1/2} - \alpha_0\right)^{-(\zeta+1)}\right\}^2, L_A^e > \left(\frac{\alpha_0}{1000}\right)^2 \\ 100, L_A^e < \left(\frac{\alpha_0}{1000}\right)^2 \end{cases}, \tag{16}$$

and

$$L_B^e = \begin{cases} 100\left\{\left(1000(L_A^e)^{1/2} - \alpha_0\right)^{-\zeta}\right\}^2, L_A > \left(\frac{\alpha_0}{1000}\right)^2 \\ 100, L_A < \left(\frac{\alpha_0}{1000}\right)^2 \end{cases}. \tag{17}$$

Let us now focus on the equilibrium labor demand functions in equations (16) and (17) and the corresponding expressions for L_A^* and L_B^* in equations (5) and (8). Comparing these two sets of equations, we infer that

$$L_A^e < L_A^* \ \ for \ \ L_A^e > \left(\frac{\alpha_0}{1000}\right)^2 \Rightarrow L_B^e > L_B^*. \tag{18}$$

In words, the newly merged tannery employs *less* labor than the original tannery A and *more* labor than the original tannery B. The clear implication of this finding is that the newly merged tannery has an incentive to reallocate labor from the original tannery A to the original tannery B. This outcome arises because the newly merged tannery effectively *internalizes* the external diseconomy that is present and, as a result, it reduces the labor input and the output of leather from the original tannery A. This reduction makes it profitable to increase the labor input and the output of leather from the previous tannery B.

Chitnis (2017) points out that even though many industries are responsible for pollution in the Ganges, tanneries in Kanpur are among the worst polluters. As such, tanneries clearly deserve greater regulatory scrutiny. In this regard, a straightforward policy implication of our analysis is that the many, often small, tanneries in Kanpur that both pollute the Ganges and impose costs on each other ought to be merged into larger entities. *Inter alia*, such an action is likely to ameliorate water quality in the Ganges river. In a standard textbook, Hartwick and Olewiler (1998, p. 194) point out that this kind of merger activity is sometimes called *unitization* in the natural resource and environmental economics literature.

The advantage of a merger or unitization is that it is typically done through market mechanisms. In other words, at least in principle, a costly regulatory process does not have to be put in place to impose penalties on a polluting tannery, it is not necessary to pay compensation to the negatively impacted party or parties, and it is also not necessary to monitor pollution. It should be noted that when a merger takes place, it may make sense for one of the merging tanneries to stop producing leather completely. As noted by Singh and Gundimeda (2021), this would be entirely consistent with existing regulatory approaches in Kanpur that sometimes involve shutting down the operations of one or more polluting tanneries. [6] Singh and Gundimeda (2021, p. 73) go on to point out that environmental regulations in the Indian leather industry are restricted to command-and-control policies "with mandatory uniform pollution control norms across all the tanneries." The available evidence---see the case study based work of Singh and Gundimeda (2020)---shows that the uniformity of these policies combined with high monitoring and

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Go to https://www.freepressjournal.in/india/uttar-pradesh-closure-of-94-tanneries-ordered-for-polluting-river-ganga for a more detailed discussion of this point. Accessed on 24 August 2022.

enforcement costs have *failed* to successfully control pollution caused by tanneries in Kanpur. Therefore, our position is that it is now time to consider alternate approaches such as mergers/unitization that certainly have the potential to efficaciously deal with the Ganges river water pollution problem caused by tanneries in Kanpur.

The reader should note that there is a lot of research support for our thesis---see Sankar (2004), Chakraborty and Chakraborty (2007), and Singh and Gundimeda (2021)---that if not regulated then tanneries in the Jajmau region of Kanpur and elsewhere in India will generally not clean up the noxious effluents they discharge either into a water body such as the Ganges or into the atmosphere as a byproduct of their production of leather. In this regard, consider the work of Singh and Gundimeda (2021, p. 73) that is based on field work involving the collection of primary data from 61 leather producing firms "in the Jajmau region and Unnao-Banthar leather cluster of Kanpur city in the state of Uttar Pradesh in India." These researchers point out clearly that the many, small tanneries operating in and around Kanpur frequently do *not* comply with extant regulatory standards and emit excessive amounts of toxic effluents because the penalty for non-compliance is not only low but also independent of the actual emission of the effluents.

Finally, extant empirical evidence provides a rationale for our decision to study how upstream polluting tanneries negatively impact tanneries and other entities located downstream from them. In this regard, Khwaja *et al*. (2001) study the impact of emitted wastes on the physico-chemical characteristics of the Ganges. They focus on two sampling sites in Kanpur, the first before and the second after the point at which the tanneries are typically located. Their analysis demonstrates that there is significant leakage of toxic chromium into the Ganges at the downstream site. In particular, there is a tenfold increase in chromium in the downstream site as compared to the upstream site. These findings are corroborated by Katiyar (2011) who shows that there are negative impacts from tannery pollution in the form of elevated levels of chromium in upstream versus downstream points along the Ganges in Jajmau, Kanpur. This completes our theoretical analysis of tanneries in Kanpur and pollution in the Ganges river.

6. Conclusions

In this paper, we studied pollution in the Ganges river caused by tanneries in the city of Kanpur in India. We focused on two tanneries, denoted by A and $B,$ that were located on the same bank of the Ganges in Kanpur. Both produced leather and the production of leather required the use of chemicals that were toxic to humans. Tannery A was located upstream from tannery B. Tannery $A's$ leather production depended directly only on the number of laborers employed but tannery $B's$ leather production depended on the number of laborers employed, the chemical waste generated by tannery $A,$ and the natural pollution absorbing capacity of the Ganges. In this setting, we accomplished three tasks. First, we determined the equilibrium production of leather by both tanneries in the benchmark case in which there was no pollution by assumption. Second, we ascertained how the benchmark equilibrium was altered when tannery B explicitly accounted for the negative externality imposed on it by tannery A. Finally, we analyzed what happened to leather production and to labor use when the two tanneries merged and then we commented on some policy implications arising from our research.

Here are two suggestions for extending the research described in this paper. First, it would be useful to analyze an intertemporal model in which, as a result of the repeated deposition of pollutants, the natural capacity of the Ganges to absorb pollution is diminished over time. Second, it would also be helpful to study a scenario in which upstream polluters, such as leather producing tanneries in Kanpur, cooperate with downstream polluters, such as religious and other tourists in

Varanasi, to attenuate water pollution over a much longer stretch of the Ganges river. Studies of pollution prevention in the Ganges that incorporate these aspects of the problem into the analysis will provide additional perspectives on the ways in which, to paraphrase Mallet (2017), the Ganges can be made a river of life and not a river of death.

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