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Research note:
A note on tanneries in Kanpur, water pollution in the Ganges, taxation, and tax shifting

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Abstract: In this note, we provide the first game-theoretic analysis of taxation and tax shifting when tanneries in Kanpur, India, which produce leather and pollute the Ganges River are taxed. We model the $n \geq 2$ tanneries as a Cournot oligopoly and a specific tax $\tau > 0$ is imposed on each unit of leather produced by the polluting tanneries. We first determine the symmetric Nash equilibrium output of leather and its price with the tax. Second, we show that the rate of tax shifting by the polluting tanneries is constant. Third, we discuss how increasing either the number of tanneries or the price elasticity of demand affects the tax shifting that takes place. Finally, we comment on the policy implications of constant tax shifting such as the predictability of the incidence of the tax burden.

Keywords: Ganges river, tannery, specific tax, tax shifting, water pollution

Introduction

The Ganges River, a vital water resource for millions in South Asia, faces severe contamination due to untreated or partially treated effluents from the city of Kanpur's tannery industry. Kanpur, a major leather-processing hub in India, hosts over 400 tanneries that discharge toxic chemicals, including chromium, sulfides, and heavy metals, into the river (Khwaja et al., 2001; Mallet, 2017).

Several studies report that these effluents have drastically reduced dissolved oxygen levels, harmed aquatic ecosystems, and made the water unsafe for human use (Dwivedi et al., 2018; Markandya & Murty, 2004; Tare et al., 2003; Trivedi, 2010). Despite numerous laws and regulations that are currently in place, weak enforcement and inadequate wastewater treatment infrastructure perpetuate pollution caused by tanneries in the Kanpur region (Batabyal et al., 2023).

The environmental and public health impacts of pollution caused by tanneries are profound. Studies indicate that hexavalent chromium {Cr (VI)}, a carcinogen found in tannery waste, accumulates in fish and enters the food chain, posing long-term health risks (Sharma et al., 2012). Local communities relying on the Ganges for

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drinking and bathing report high incidences of skin diseases, respiratory disorders, and gastrointestinal illnesses (Chaudhary & Walker, 2019).

The continuing pollution of the Ganges in and around Kanpur remains an urgent public policy problem that requires a comprehensive solution, involving more stringent regulation, improved waste treatment technologies, and greater accountability on the part of the tanneries contributing to the pollution. Even though the Ganges water pollution problem in Kanpur is acute (Singh & Rao, 2013), there are very few studies in the literature that have rigorously analyzed this problem *theoretically*. Recently, Batabyal (2023), Batabyal et al. (2023), and Batabyal and Beladi (2024) have theoretically studied aspects of the Ganges water pollution control problem in Kanpur. The first two papers maintain that one way to ensure higher water quality in the Ganges is by unitizing or merging the polluting tanneries under study. The last paper analyzes the circumstances in which water pollution control ought to be centralized or decentralized.

Even though the underlying problem with tanneries in Kanpur is the external diseconomy (water pollution in the Ganges) that their leather production gives rise to, to the best of our knowledge, there is no research on how pollution taxation and tax shifting affects the behavior of these tanneries. Therefore, in this note, we provide the first game-theoretic analysis of taxation and tax shifting when the tanneries in Kanpur that produce leather and pollute the Ganges River are taxed. Section 1 describes the theoretical framework in which we model the $n \geq 2$ tanneries as a Cournot oligopoly and a specific tax $\tau > 0$ is imposed on each unit of leather produced by the polluting tanneries. Section 2 determines the symmetric Nash equilibrium output of leather and its price with the tax. Section 3 demonstrates that the rate of tax shifting by the polluting tanneries is constant. Section 4 discusses how increasing either the number of tanneries or the price elasticity of demand influences tax shifting. The last section concludes and then suggests two ways in which the research delineated in this note might be extended.

Before proceeding to the theoretical framework, we would like to point out that the regulation of water pollution in the Ganges River caused by tanneries in Kanpur has lessons for river water pollution regulation in Europe. In general, the regulation of water pollution in the Ganges River caused by tanneries in Kanpur highlights the critical importance of strict enforcement, industrial accountability, and the challenges of balancing economic interests with environmental protection—lessons that are equally relevant for Europe.

In Kanpur, the leather industry has been a major source of toxic pollutants, particularly chromium and other heavy metals, which have severely degraded water quality. Despite existing environmental laws, lax enforcement and inadequate treatment infrastructure have allowed these pollutants to enter the Ganges for decades. The Indian government's eventual crackdown—including shutting down non-compliant tanneries and mandating zero liquid discharge systems—

demonstrated that effective regulation requires not just legislation, but also robust monitoring, political will, and technological investment.

For Europe, where many countries have more developed regulatory frameworks under directives like the EU Water Framework Directive[1], the Kanpur case underscores that even well-crafted policies can fall short without consistent enforcement and compliance mechanisms. It also shows the need for strong integration between industrial policy and environmental sustainability. European regulators can draw from the Kanpur example by ensuring that industries, particularly those with high pollution potential, are held to strict discharge standards and are incentivized or compelled to adopt cleaner technologies. Furthermore, public pressure and legal action—as seen in India—can play a powerful role in driving compliance and transparency in pollution control, a strategy that can strengthen environmental governance in Europe's own industrial river basins.

1. The theoretical framework

Consider a stylized version of the Kanpur tannery economy in which the leather manufacturing industry consists of $n \geq 2$ tanneries. In game-theoretic terms, the leather manufacturing industry can be thought of as a Cournot oligopoly (see Tirole 1988, pp. 218-221). The quantity of leather produced by the ith tannery is $q_i, i = 1, \ldots, n$. Aggregate production of leather is given by $Q = \sum_{i=1}^{n} q_i$ and it is understood that $Q \geq 0$. The demand for leather in our n tannery leather manufacturing industry is given by $p(Q) = Q^{-1/\beta}$, where $\beta > 0$.

The total cost of producing leather for the ith tannery is given by $C(q_i) = cq_i$, where $c > 0$. A specific tax denoted by $\tau > 0$ is levied by a regulator on each unit of leather produced by the individual tanneries. With this description of the theoretical framework in place, our next task is to ascertain the equilibrium output and price of leather in the symmetric Cournot-Nash equilibrium.

2. The Cournot-Nash equilibrium

Without loss of generality, let us focus on the profit maximization problem faced by tannery 1. Denoting the profit function by $\Pi(\cdot)$, this tannery solves:

$$max_{\{q_1\}} \Pi_1 = p(\cdot)q_1 - C(q_1) - \tau q_1 = \left[\{q_1 + \sum_{i=2}^{n} q_i\}^{-\frac{1}{\beta}} - c - \tau \right] q_1. \quad (1)$$

The first-order necessary condition for an optimum is (the second-order sufficiency condition is satisfied):

[1] Go to https://environment.ec.europa.eu/topics/water/water-framework-directive_en for additional details.

$$\frac{\partial \Pi_1}{\partial q_1} = -\frac{1}{\beta}\{q_1 + \sum_{i=2}^{n} q_i\}^{-\frac{1}{\beta}-1} q_1 + \{q_1 + \sum_{i=2}^{n} q_i\}^{-\frac{1}{\beta}} - c - \tau = 0. \quad (2)$$

In a symmetric Cournot-Nash equilibrium, the output of leather produced by tannery 1 is given by $q_1 = (1/n)Q$. Substituting this last finding in equation (2) and then rewriting, we get:

$$-\frac{1}{\beta} Q^{-\frac{1}{\beta}-1} \frac{Q}{n} + Q^{-\frac{1}{\beta}} - c - \tau = 0 \Rightarrow Q^{-\frac{1}{\beta}}\left(1 - \frac{1}{\beta n}\right) = c + \tau. \quad (3)$$

Simplifying the right-hand-side (RHS) of equation (3) for the total output of leather or Q gives us:

$$Q = \left\{\frac{\beta n - 1}{\beta n(c+\tau)}\right\}^{\beta} \Rightarrow q_1 = \frac{1}{n}\left\{\frac{\beta n - 1}{\beta n(c+\tau)}\right\}^{\beta}. \quad (4)$$

Substituting the value of Q from equation (4) into the equation for the demand function given in section 1 gives us the expression for the equilibrium price. That expression is:

$$p = Q^{-1/\beta} \Rightarrow p = \frac{\beta n(c+\tau)}{\beta n - 1}. \quad (5)$$

So, in the symmetric Cournot-Nash equilibrium, replacing 1 with i, the ith tannery's output of leather is given by the RHS of equation (4), total output of leather produced by all n tanneries is given by the left-hand-side (LHS) of equation (4), and the equilibrium price of leather is given by equation (5), on the assumption that $\beta n > 1$. Let us now study the extent to which tax shifting occurs in our stylized Kanpur tannery economy.

3. Tax shifting

The notion of tax shifting is concerned with who bears the burden of a particular tax. Normally, we would expect the burden of the pollution tax to be shared by the tanneries and the consumers of the produced leather. Even so, in principle, a tax may be shifted forward or backward. In our case, forward shifting takes place when the burden of the tax falls entirely on the purchasers of leather and not on the tanneries themselves. Backward shifting occurs when the price of the taxed leather is unchanged, but the burden of the tax is borne entirely by the tanneries.

To determine the extent or the rate of tax shifting by the oligopolistic tanneries, we partially differentiate the equation for the equilibrium price $p(\cdot)$ in equation (5) with respect to the specific tax τ. The partial derivative of interest is given by:

$$\frac{\partial p(\cdot)}{\partial \tau} = \frac{\beta n}{\beta n - 1}. \tag{6}$$

Because the demand function is of the isoelastic form, it is straightforward to confirm that the price elasticity of demand is given by $-\beta$ or, in absolute value, equals β. In either case, this price elasticity of demand is constant. Similarly, the number of tanneries in the economy under study or n is also constant. Therefore, the RHS of equation (6) tells us that the rate of tax shifting by the polluting tanneries is *constant*.

Before concluding this section, we would like to make the reader aware of a key point about the above constancy result. In our model, the marginal cost of producing leather or $c > 0$ is constant. The combination of the constant elasticity inverse demand function and the constant marginal cost of producing leather together gives us the "constant tax shifting" result. If, in contrast, the marginal cost of producing leather was linear and increasing then raising the tax would reduce the equilibrium output of leather which, in turn, would give rise to an endogenous change in the marginal cost with output, and the resulting tax shifting would be *non-constant*. Our final task in this note is to discuss how increasing either the number of tanneries (n) or the price elasticity of demand $(-\beta)$ influences tax shifting.

4. Impacts of tax shifting

In an oligopoly, the rate of tax shifting is generally greater than one (Hindriks and Myles, 2013, p. 271). This means that the equilibrium price of leather increases by more than the amount of the tax τ. In our case, differentiating the RHS of equation (6) with respect to n gives us $-\beta/(\beta n - 1)^2$, which is clearly negative. This means that as the number of tanneries in the Kanpur tannery industry increases, the rate of tax shifting *falls*. It is easy to confirm that the same negative result arises when the price elasticity of demand increases. In other words, in both instances, the market power of each individual tannery declines and, therefore, the Kanpur tannery economy gets closer to a competitive economy.

We now discuss some of the policy implications of constant tax shifting to regulators in both India and European nations. First, the incidence of the tax burden is predictable. In other words, when tax shifting is constant, policy makers can predict precisely how much of the tax will be paid by consumers, through higher prices, versus the tanneries, through reduced net revenue. For instance, if the RHS of equation (6) equals 0.6 then 60 percent of any tax increase would be passed on to consumers and 40 percent would be absorbed by the tanneries.

Second, the impact on consumers across tax levels is stable. This means that because the "pass-through rate" or the tax shifting rate does not change with the level of the tax, doubling the tax will double the price increase borne by the consumers of leather. This stability helps regulators in long-term tax planning and in evaluating the distributional effects of tax changes.

Third, efficiency and welfare analysis becomes easier. In other words, constant pass-through simplifies welfare calculations by regulators, especially when comparing the deadweight loss or the consumer surplus across different tax levels. This means that policy makers can model the effects of tax changes more transparently.

Fourth, there is policy neutrality as far as scale is concerned. This means that the effects of tax changes are scale independent. Therefore, whether the tax is 100 Rupees or 1000 Rupees per unit of leather produced, the proportion passed through to consumers remains the same. This feature allows for "linear policy design," such as phased tax increases.

Let us now briefly contrast the constant tax shifting result in this note with non-constant shifting. In many real-world instances, tax pass-through varies with output level, elasticity, or the cost structure of the taxed firms. This feature makes tax policy outcomes less predictable, requiring more complex analytic models. In contrast, constant pass-through gives regulators a simple and robust tool. In sum, constant tax shifting simplifies tax policy design by making the effects on prices and tax incidence predictable and linear. It enables clearer forecasts of who bears the burden of a tax and how markets respond, which is valuable for crafting efficient, equitable, and transparent tax interventions. This completes our discussion of a game model of tanneries in Kanpur, water pollution in the Ganges, taxation, and tax shifting.

Conclusions

In this note, we provided the first game-theoretic analysis of taxation and tax shifting when tanneries in Kanpur, India, which produced leather and polluted the Ganges River, were taxed. Let us now briefly connect the taxation of the output of leather to water pollution in the Ganges River. First, note that taxing the output of leather produced by the Kanpur tanneries would likely reduce water pollution in the Ganges, since the tax would raise production costs and thereby discourage leather production. Because the volume of the pollutants discharged into the Ganges is closely tied to the level of leather production, lower output would translate into less total waste released. In addition, to the extent that the tanneries pass the tax onto consumers, higher leather prices would reduce demand, thereby amplifying the reduction in production and pollution. In this way, an output tax can indirectly curb the environmental damage caused by the tanneries, even if it does not target the effluent or effluents directly.

The analysis here can be extended in several ways. Here are two examples. First, it would be interesting to analyze the time profile of the pollution tax in a dynamic setting in which the tanneries and a regulator interact repeatedly over time. Second, and, once again, in a dynamic setting, it would be instructive to analyze whether social welfare is higher when a tax is used to regulate water pollution in the Ganges or when a quantity restriction---such as a temporary ban on leather production---is used to improve water quality. Studies that analyze these aspects of the underlying problem will provide additional insights into water quality in the Ganges, which is a function of the outcome of the strategic interactions between polluting tanneries and regulators.

References

Batabyal, A.A. (2023). Tanneries in Kanpur and pollution in the Ganges: A theoretical analysis. *Regional Science Policy and Practice*, *15*, 1114-1124. https://doi.org/10.1111/rsp3.12593

Batabyal, A.A., & Beladi, H. (2024). Decentralized vs. centralized water pollution cleanup in the Ganges in a model with three cities. *Networks and Spatial Economics*, *24*, 383-394. https://doi.org/10.1007/s11067-024-09620-8

Batabyal, A.A., Kourtit, K., & Nijkamp, P. (2023). Polluting tanneries and small farmers in Kanpur, India: A theoretical analysis. *Environmental Modeling and Assessment*, *28*, 331-336. https://doi.org/10.1007/s10666-022-09865-y

Chaudhary, M., & Walker, T.R. (2019). River Ganga pollution: Causes and failed management plans (correspondence on Dwivedi et al. 2018. Ganga water pollution: A potential health threat to inhabitants of Ganga basin, Environment International 117, 327-338). *Environment International*, *126*, 202-206. https://doi.org/10.1016/j.envint.2019.02.033

Dwivedi, S., Mishra, S., & Tripathi, R.D. (2018). Ganga water pollution: A potential health threat to inhabitants of Ganga basin. *Environment International*, *117*, 327-338. https://doi.org/10.1016/j.envint.2018.05.015

Hindriks, J., & Myles, G.D. (2013). *Intermediate Public Economics* (2nd ed.). Cambridge: MIT Press.

Khwaja, A.R., Singh, R., & Tandon, S.N. (2001). Monitoring of Ganga water and sediments vis-a-vis tannery pollution at Kanpur (India): A case study. *Environmental Monitoring and Assessment*, *68*, 19-35. https://doi.org/10.1023/A:1010790705006

Mallet, V. (2017). *River of Life, River of Death*. Oxford: Oxford University Press.

Markandya, A., & Murty, M.N. (2004). Cost-benefit analysis of cleaning the Ganges: Some emerging environment and development issues. *Environment and Development Economics*, *9*, 61-81. https://doi.org/10.1017/S1355770X03001013

Sharma, P., Bihari, V., Agarwal, S.K., Verma, V., Kesavachandran, C.N., Pangtey, Mathur, N., Singh, K.P., Srivastava, M., & Goel, S.K. (2012). Groundwater contaminated with hexavalent chromium [Cr (VI)]: A health survey and clinical examination of community inhabitants (Kanpur, India). *PLoS One*, *7*, e47877. https://doi.org/10.1371/journal.pone.0047877

Singh, A.P., & Rao, D.P. (2013). Assessment of tannery effluent: A case study of Kanpur in India. *European Chemical Bulletin*, *2*, 461-464.

Tare, V., Gupta, S., & Bose, P. (2003). Case studies on biological treatment of tannery effluents in India. *Journal of the Air and Waste Management Association*, *53*, 976-982. https://doi.org/10.1080/10473289.2003.10466250

Tirole, J. (1988). *The Theory of Industrial Organization*. Cambridge: MIT Press.

Trivedi, R.C. (2010). Water quality of the Ganga river - An overview. *Aquatic Ecosystem Health and Management*, *13*, 347-351. https://doi.org/10.1080/14634988.2010.528740

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