Gold Mining and Mercury Pollution in Colombia:

Policy Recommendations to Reduce the Tradeoff between Economic Growth and Sustainability

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Colombia is the top mercury polluter per capita in the world and the main cause of this pollution is artisanal gold mining. Even though the current government has restricted the use of mercury in mining, the problem goes beyond regulations: eighty-seven percent of the country's gold production comes from small-scale, informal (unlicensed) mining. Furthermore, market restrictions on mercury for mining activities have created a window of opportunity for organized crime. Illegal armed groups control the illicit trafficking of mercury into the country and its commercialization among small-scale miners.

This article discusses different policies aimed at mitigating the externalities of gold mining in Colombia and considers the tradeoff between the economic benefits and external costs to human health. The main conclusion is that heavy regulations on mining activities have not been helpful in reducing mercury pollution, and that alternative policies based on lessons from behavioral economics can be more useful tools for reducing the environmental hazards associated with gold mining.

BACKGROUND ON MERCURY POLLUTION AND GOLD MINING IN COLOMBIA

Gold mining has long been one of the main economic activities in Colombia. After the emergence of the Colombian state in the 19th century, gold mining was one of the primary economic activities and the country became the largest global producer of this metal (Sarmiento et al. 2013). Current official statistics suggest that the production of gold represents less than 1 percent of the country's gross domestic product (GDP) (author's calculation based on Colombian Central Bank data, 2018). Although this indicates a considerable decrease in the importance of gold for the Colombian economy, this figure may be misleading because most gold production happens in the informal sector. According to Sarmiento et al. (2013), a combination of high levels of regulation and low enforcement capacity by environmental institutions explains these high levels of informality.

The use of mercury in mining can also be traced back to the 16th century, when Spanish colonists introduced the amalgamation technique (Veiga, Maxon, & Hylander 2006). This method uses mercury to separate gold and other metals from minerals collected during the mining process. The collected minerals are mixed with mercury, which absorbs the gold. Then, the mercury and gold are separated through a boiling and centrifugation process. This technique is commonly used in artisanal or small-scale mining, in which miners typically collect minerals from riverbanks and then mix them with a mercury solution to extract the gold. This process generates pollution when miners pour mercury directly into the rivers, and during the boiling process, which releases mercury gases into the environment.

The problem of mercury pollution in Colombia's rivers has been well documented. The Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) consider 0.5 μg/g to be the maximum safe limit of mercury concentration in fish for human consumption (FAO and WHO 2015) and various studies have identified exposure levels beyond this threshold in Colombia. Some of these studies are based on human hair samples collected along the two main rivers in the country, the Cauca and the Magdalena (Olivero-Verbel, Caballero-Gallardo, & Negrete-Marrugo 2011; Palacios-Torres, Caballero-Gallardo, & Olivero-Verbel 2017), and other bodies of water located in gold mining areas (Olivero, Johnson, & Arguello 2002; Olivero-Verbel, Caballero-Gallardo, & Turizo-Tapia 2015). Other studies have found fish muscle samples that surpass the WHO threshold (Olivero & Solano 1998; Marrugo-Negrete et al. 2008; Marrugo-Negrete et al. 2010; Álvarez et al. 2012; Marrugo-Negrete, Ruiz-Guzmán, & Ruiz-Fernández 2018). The same pattern has also been documented in turtles in the area (Zapata, Bock, & Palacio 2014). There is also empirical evidence demonstrating the correlation between high levels of fish consumption and high mercury concentration in human hair samples found in mining areas in Colombia (Salazar et al. 2017), demonstrating that continuous consumption of even low levels of mercury poses harm to humans (Marrugo-Negrete, Norbeto Benítez & Olivero-Verbel 2008).

According to the U.S. Environmental Protection Agency (EPA), high levels of exposure to mercury through fish consumption can cause health problems such as speech and hearing impairment, loss of vision, and lack of physical coordination. In children, this exposure can have more severe long-term consequences affecting cognitive thinking, memory, language, and fine motor skills (EPA 2017). International agencies including the WHO (2017) and the United Nations Environment Programme (UNEP) (2013) have also identified hazardous effects of mercury exposure including kidney failure and neurological damage, especially in young children.

In Colombia, empirical evidence indicates the prevalence of health risks associated with mercury exposure in gold mining areas. Health problems reported in these areas include: high incidence of paresthesia among informal gold miners and non-miners (Gasca 2000), neurological damage in gold miners (Tirado et al. 2000), and developmental deficiencies during pregnancy and in young children's cognitive skills as a result of consumption of contaminated fish (Álvarez n.d.). Furthermore, the Colombian government indicates that there were 1,126 cases reported of mercury poisoning between 2013 and 2015, and that these cases were concentrated in the main gold mining regions (Departamento Nacional de Planeación 2016).

According to official estimates, the health costs associated with mercury-related cognitive damages in Colombia amount to US$310 million annually (DNP 2016). This corresponds to about 29 percent of the total value of gold exports in the country, which is estimated at over $1 billion in 2015 (Colombian Ministry of Mines 2016b). Because cognitive damage is not the only health issue associated with exposure to mercury, and many related health issues are underreported in rural areas due to limited access to care (Ministry of Health and Social Protection 2018), the total costs are likely to be higher.

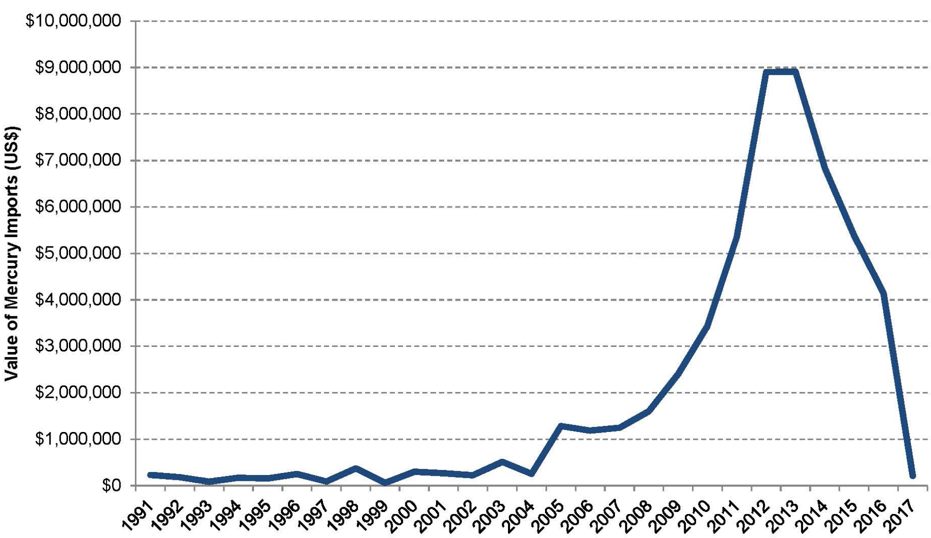
Abatement costs to mitigate mercury pollution in gold mining units—midsized production areas with machinery such as backhoes and processing plants—vary depending on the type of technology implemented to clean the waste from mining. However, low-cost solutions are available for small-scale miners. For example, a retort device is one technology available in Colombia that can capture between 75 and 95 percent of the total mercury used in gold mining activities, with a total cost that ranges between $5 and $50 per mining unit (Telmer & Stapper 2012). The Colombian Ministry of Mines (2016a) estimates that there are 543 basic gold mining units in the country—of which 70 percent are unlicensed. Multiplying the number of gold mining units by the highest cost of the cleaning technology yields $27,150. This amount does not take into consideration additional costs such as workshops to teach miners how to use the technology and the labor needed to apply the retort technique. However, it seems cheap compared to the health costs of mercury exposure, which are more than 11,000 times higher than the calculated abatement costs. Furthermore, it is important to note that health costs recur annually, while costs related to abatement processes using retort devices (such as the purchase of these devices) are much less frequently incurred.

To reduce mercury pollution, the Colombian government has focused on increasing regulations and promoting the formalization of small-scale miners—meaning getting them registered in the formal market system. In 2013, Colombian officials signed the Minamata Convention on Mercury, a global treaty to protect human health signed by 128 countries (UNEP 2019). That same year, the National Congress approved Law 1658, banning the use of mercury in mining starting in 2018. Furthermore, the Ministry of Mines implemented a strategic plan to strengthen the rule of law in order to formalize unauthorized miners, and to raise their awareness of the negative health effects of mercury exposure (Ministry of Mines 2016a). However, difficulties remain for small-scale miners to meet formal requirements (Sarmiento et al. 2013), which may contribute to the persistence of informality in the mining sector. Legal registration would also subject small-scale miners to environmental regulations, potentially increasing their production costs. The cost of registration fees and environmental permits combined would reach at least $25,000 for a small mining unit in the country (Echavarria 2014).

Beyond the high registration costs, the government's approach, which has entailed banning the use of mercury in mining, does not consider the internal dynamics of the gold economy and the strong incentives for miners to use mercury. Even though artisanal mining practices do not require mercury to extract gold from rivers, the use of this chemical element significantly increases productivity by speeding up the extraction process, thereby providing an incentive for its continued illegal use.

Colombia is a net importer of mercury and prohibiting its use in mining could create incentives for illegal trade due to the prevalent informality of this sector. The following graph shows the trend of mercury imports in Colombia from 1991 to 2018:

Figure 1. Value of Legal Mercury Imports by Year in Colombia, US$



Source: Author's calculations based on United Nations data (United Nations 2018).

In 2004, legal mercury imports started to increase steadily, until they began to decline in 2013. This drop is likely an anticipatory effect of Law 1658, approved the same year. However, the decrease in legal imports of mercury did not result in a decrease in its use. According the Colombian Minister of Environment, a bigger challenge is controlling the illegal trafficking of mercury into the country; approximately 50 percent of the mercury found in Colombia is not legal (El País 2016). Therefore, it is possible that illegal imports of mercury increased since 2013 when legal imports decreased. However, there are no official estimates of illegal mercury imports in Colombia and further research is required to understand the drop in legal imports.

The lack of government control in rural areas of the country has also opened an opportunity for armed groups to take advantage of the informal mining economy and further drive up costs. According to an Organization for Economic Cooperation and Development (OECD) report on gold mining in Colombia, small-scale informal miners are vulnerable to the influence of illegal armed groups. (Massé & Munevar 2016) There is already an existing relationship between informal miners and paramilitary groups, who are gaining control over the gold mining economy (Bargent 2013). The expansion of paramilitary groups in rural areas that lack state control has resulted in the extortion of small-scale miners who are forced to pay a fee in order to continue mining and maintain their business. This fee can be understood as an illegal tax enforced by paramilitary groups that control the territory. Furthermore, government reports suggest that gold mining is replacing drug trafficking as the main source of income for criminal groups, and empirical evidence shows a direct relationship between gold mining activities and violence measured in homicide rates, human displacement, and massacres (Rettberg & Ortiz-Riomalo 2016).

Recent political events also explain the expansion of paramilitary groups in mining areas. In 2016 the Colombian government signed a peace treaty ending a 50-year war with the main guerrilla group in the country, Revolutionary Armed Forces of Colombia (FARC). The government has also been moving forward in peace talks with a secondary guerrilla movement, National Liberation Army (ELN). However, as guerrillas retreat from mining areas, paramilitary groups are replacing them, filling the vacuum they left (Acosta & Murphy 2018).

Aside from their vulnerability to security threats, miners also face insecurity as a result of a lack of social services in mining regions. According to Echavarria (2014), 54 percent of gold mining workers are affiliated with health insurance programs subsidized by the government and 20 percent do not have access to any healthcare coverage. Individuals are only eligible for health insurance programs if they fall below a certain income threshold, underscoring the reality that most gold mining workers live in poor conditions. Furthermore, it is important to mention here that gold mining activities represent the main source of income for rural communities in Colombia. It is estimated that over 340,000 people—of a population of 45 million—in the country solely depend on gold mining (Ibid). This reality highlights the tradeoff noted in the title of this paper: gold mining presents both a health threat and an economic opportunity for vulnerable people.

The following pages elaborate on alternative policy recommendations to reduce mercury pollution, considering the main characteristics of the Colombian mining sector described above. The two alternative policies are based on 1) pollution taxes and 2) lessons from behavioral economics.

POLLUTION TAXES

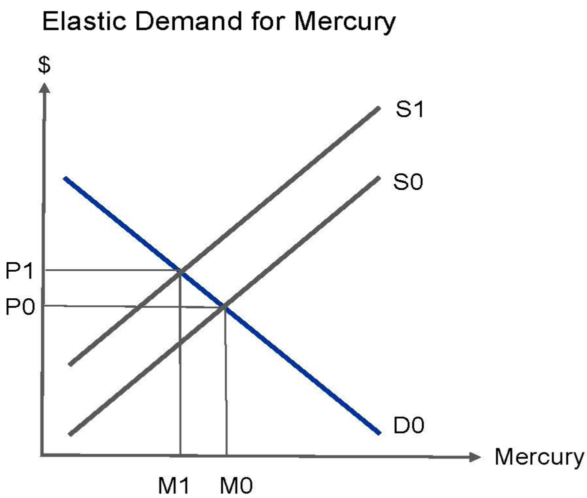
A tax on pollution is one possible policy lever considered in the literature and by policymakers to mitigate environmental hazards. For example, Marron and Toder (2014) discuss the feasibility of setting carbon taxes to discourage greenhouse emissions. The authors argue that these taxes would increase the adoption of cleaner technologies. However, there are challenges in implementing this solution, including determining the appropriate tax rates. According to the Pigouvian approach described by the authors, the pollution tax should be equal to the marginal social cost of carbon; this means the tax would equal the clean-up costs that accrue to society with an additional unit of carbon. Nonetheless, it is not easy to determine that marginal social cost.

With respect to mercury pollution in Colombia, one possible way of calculating the average cost would be to divide the estimated total cost of mercury-related cognitive damage by total gold mining production. However, this calculation does not reflect how much an additional unit of mercury pollution affects the total social cost (as in a marginal cost estimation). For example, an additional unit of gold would likely have a low marginal social cost in cases of low mercury pollution, but a very high marginal social cost in instances of high pollution. Additionally, this calculation does not take into consideration all the possible long-term social costs beyond cognitive damage.

In Colombia, an additional challenge in implementing pollution taxes is the informal nature of the gold mining economy, which operates outside of government law enforcement. In their discussion, Marron and Toder (2014) note that an alternative approach to direct pollution taxes is to identify proxies for pollution emissions that could be easier to tax. In Colombia, this would translate to taxing the mercury inputs used in gold mining. As Figure 1 shows, Colombia is a net importer of mercury, making this solution feasible. A tax on mercury imports, holding everything else constant, should increase the total costs of current gold mining production, thereby incentivizing the adoption of alternative technologies that do not use mercury, such as concentration methods, panning, and sluicing (EPA 2019). However, in the real world, “holding everything else constant” usually does not apply. A tax on mercury imports in Colombia could lead to increased illegal mercury imports, as importers try to circumvent the tax. Furthermore, the import tax would violate international free trade agreements already signed by Colombia, making this solution politically impractical.

Putting these challenges aside, the effectiveness of a tax on mercury imports to reduce mercury pollution depends most directly on the elasticity of demand for mercury.

Figure 2. Response to a Pollution Tax Based on the Elasticity of Demand



Source: Author's rendering.

The graphs in Figure 2 demonstrate the effectiveness of a pollution tax to reduce mercury emissions depending on the elasticity of the demand curve for mercury. If the demand is relatively elastic (Graph A), or responsive to changes in price, a tax on mercury would increase miners' production costs and therefore reduce demand. However, if the demand is relatively inelastic (Graph B), a tax on mercury would increase production costs with a minimum effect on decreasing the demand. This translates into a minimum marginal effect of the tax on reducing mercury pollution. The elasticity of demand for mercury depends on the availability of mercury substitutes. Alternative technologies in gold mining exist, but their desirability as a substitute for mercury depends on their output levels and their price compared to using mercury. An alternative, cleaner technology may be comparatively cheaper, but requires more time to achieve the same output with the same amount of labor.

Ecuador, a country with similar geographic and economic characteristics as Colombia, has had positive results associated with a rise in the price of mercury following a government intervention that capped mercury imports. After the price increase, there was a 60-percent decrease in mercury use alongside a 30-percent increase in cyanide use between 2013 and 2015 (Gonçalves et al. 2017). This suggests that the relatively cleaner cyanidation method could be an effective substitute for mercury use in gold mining. Nevertheless, it is important to note that cleaner does not imply optimal. According to the EPA, "Cyanide is highly toxic and great care must be taken when using it. However, in contrast to mercury, cyanide does not persist in the environment" (EPA 2019). Though there is a clear advantage to the use of cyanide over mercury because it reduces the environmental threats posed by gold mining, it still represents a health hazard for miners. An alternative to a change in mercury prices would be to offer a subsidy on cyanide, however a careful consideration of the side effects of this policy is required to understand the impact that it could have on other industries and on uses of cyanide.

Evidence suggests that a mercury tax in Colombia may also be effective in reducing contraband mercury. In early 2017, a local newspaper found a network of companies that legally imported mercury, which was then distributed illegally to informal gold miners (El Tiempo 2017). Therefore, illicit networks could be bolstered by increased prices resulting from a tax on mercury imports.

LESSONS FROM BEHAVIORAL ECONOMICS TO MITIGATE MERCURY POLLUTION

Informal gold miners are one of the primary groups that fall victim to mercury exposure, suffering from health issues such as kidney failure and cognitive damage (WHO 2017). Nonetheless, these harmful effects do not dissuade them from using mercury. One lens through which to view these decisions is behavioral economics, which analyzes situations in which individuals make poor economic judgments because of an inadequate assessment of the tradeoff between current benefits and future costs. This is known as present bias (Laibson & List 2015). The following equation could be used to represent the total cost assessment of an individual gold miner regarding her economic activity.

*Total Cost (K, L, M) = Production Costs (K(M), L) + Φ*PV Future Health Costs (M, t)*

Where, Φ=11+kt and k ∈ [0,1]

The total cost of gold mining is the sum of the miner's current production costs and the present value (PV) of future health costs. The production costs depend on capital (K) and labor (L). Mercury (M) inputs are included within capital (K). The PV of future health costs depends on the total amount of M inputs used, with expected negative health effects over time (t). The PV of health costs is multiplied by a coefficient that represents the hyperbolic discount rate—impatience level—of the gold miner. The parameter k in this discount rate corresponds to the present bias. If the miner has a large present bias, then k should be close to one and the result should be a very low valuation of possible future health costs. This equation illustrates that the average informal gold miner in Colombia is not risk averse and has a very low valuation of future health costs.

Nudging is one policy approach that economists have identified as a way to help individuals overcome present bias in their personal decision-making with minimal interference (Thaler & Sunstein 2009). For example, the nudge of educating miners on the risk of mercury exposure may trigger rational thinking, inducing miners to decrease their current exposure or change to cleaner technologies. These alternative technologies could be more expensive in the short term but less expensive when looking at long-term health costs. In the current Colombian gold mining scenario, it is possible to think that most of the miners maximize their utility function without taking into consideration possible future health hazards.

Related literature identifies music as one way to raise awareness among small-scale miners about current hazards to help them lower their present bias. Veiga and Marshall (2017) argue that traditional government policies to reduce mercury pollution have proven unsuccessful, and that education could play a more effective role. In particular, the authors indicate that the use of humor and parodies in songs may be a compelling way to engage miners and educate them about the negative consequences of mercury pollution. The authors also argue that this approach should be accompanied by technical assistance to provide the miners with alternative, cleaner technologies. Even though the authors do not explicitly discuss present bias, their argument hinges on the benefits of a nudge approach to provide miners with additional information, encouraging them to change their current decision-making.

Other nudge policies could include showing documentaries on the health hazards related to mercury exposure in gold mining towns or hanging banners and posters around towns with photographs demonstrating the health consequences of mercury exposure. Education programs broadcast on local radio stations could also raise awareness about the hazards of mercury use.

To the author's knowledge, there currently are no evaluations of the effectiveness of educational programs aimed at decreasing the use of mercury in informal gold mining in Colombia. Nonetheless, this approach could be a low-cost solution and prove valuable as part of a broader push to transition from mercury amalgamation to cleaner technologies in gold mining.

CONCLUSION

This paper discussed two policy recommendations to mitigate mercury pollution caused by gold mining in Colombia that take into consideration the persistent informality of the mining sector and the current political atmosphere: a tax on pollution and nudging through education. Currently, the Colombian government has focused its efforts on implementing legal prohibitions and encouraging informal miners to enter the formal market. In particular, the ban on mercury could contribute to a criminalization of informal gold mining activities, and consequentially, create a greater window of opportunity for illegal armed groups to control them.

Two major political processes have made these policy recommendations more relevant. First, Colombia recently signed a peace treaty with FARC, yet still needs to recover control over the areas once ruled by the guerrilla group. Second, Colombia recently elected a new president, creating an opportunity to rethink the effectiveness of government policies to mitigate environmental hazards. The new president, Iván Duque, has indicated interest in promoting mining activities in a sustainable way. This interest reflects the ideas laid out in this paper, recognizing the importance of gold mining for local economies but also the environmental and health hazards derived from this activity. Nonetheless, current policies still emphasize regulation and formalization as the main mechanisms to promote a sustainable mining economy. As shown in this paper, the enforcement of these regulations is beyond the capacity of the Colombian government, creating an opening for criminal actors to control mining areas.

The two policies recommended in this paper are not mutually exclusive and could be implemented in tandem. Taxes on mercury inputs could work as an incentive to discourage use of the chemical in amalgamation processes; simultaneously, educational programs could motivate informal miners to engage in cleaner practices. As Veiga and Marshall (2017) mention, educational programs should be accompanied by technical assistance to facilitate the transition from mercury to alternative technologies.

Additionally, other practical measures could help integrate informal gold miners into the legal economy. The reduction of paperwork, legal requirements, and delays in the approval of production permits could work as effective mechanism in that regard. According to previous research findings, these excessive legal requirements discourage the formalization of small-scale miners (Echavarria 2014).

The complexity of the mining sector in Colombia and government efforts to reduce externalities while fostering national economic growth demonstrate the importance of designing policy based on empirical facts rather than wishful thinking enforced through laws and regulations. Finally, it is important to remember that gold mining activities represent a valuable source of income for the vulnerable rural communities of Colombia. Instead of criminalizing this activity through the regulation of necessary inputs, the government should support these communities in their economic development while guiding their decision-making to account for future hazards related to mercury pollution.

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