COST-BENEFIT ANALYSIS OF COOPERATIVES TO MITIGATE ARTISANAL SMALL-SCALE GOLD MINING EXTERNALITIES IN GHANA

WISDOM AKPALU

Dean, School of Research and Graduate Studies
Ghana Institute of Management and Public Administration (GIMPA)

NATIONAL DEVELOPMENT PLANNING COMMISSION

COPENHAGEN CONSENSUS CENTER

GHANA PRIORITIES

COPENHAGEN CONSENSUS CENTER

info@copenhagenconsensus.com
www.copenhagenconsensus.com

This work has been produced as a part of the Ghana Priorities project.

PRELIMINARY DRAFT AS OF JUNE 8, 2020

Cost-Benefit Analysis of Cooperatives to Mitigate Artisanal Small-Scale Gold Mining Externalities in Ghana

Ghana Priorities

Wisdom Akpalu[¥]

Dean, School of Research and Graduate Studies

Ghana Institute of Management and Public Administration (GIMPA)

Brad Wong

Chief Economist, Copenhagen Consensus Center

[¥] The lead researcher is grateful to his Research Assistant, Dictus A. Azorliade, for his invaluable contribution to this report.

Abstract

Artisanal and small-scale (ASM) gold miners in Ghana employ mining and processing technologies that generate substantial environmental, economic and health opportunity costs as well as elevate the risks of mortality and morbidity. The government's attempt at formalizing small-scale mining operations, may increase employment within the sector but it is unlikely to mitigate the negative externalities if complementary measures are not taken. This paper investigates the costs and benefits of forming mining cooperatives within all mining communities. Using data obtained from local sources and drawing on findings from the literature, it was found that the intervention has a BCR around 1.2.

Keywords: Artisanal Small-Scale Mining; Externalities; Co-operatives; Ghana

Policy Abstract

The Problem

Artisanal and Small-Scale gold Mining (ASM) is an important economic activity in several gold-rich developing countries around the world (Kahhat *et al*., 2019). In Ghana, ASM has provided jobs and supported the livelihoods of many rural communities for over a century (Mantey *et al*., 2016). It is estimated that over 1.1 million people are currently engaged in it (McQuilken and Hilson, 2016). Since Ghana implemented the mineral sector reforms in the 1980s to attract foreign direct investment into the large-scale mining sector, the contribution of ASM to total gold production has been rising steadily. In 1989, it accounted for 2.2 percent of total production. By 2014 and 2018, the figure rose to 34.4 and 41.1 percent, respectively, (Ghana Chamber of Mines, 2014 and 2019).

Despite the clearly laid out formalization process in the Ghana's Mineral and Mining Act (Act 703), bureaucratic bottlenecks and prohibitive licensing costs are compelling between 60 and 80 percent of miners to operate illegally. To minimize production cost, the miners employ technologies that are harmful to the environment, negatively impacting the health of those involved, directly or indirectly, in the mining activities. These environmental opportunity costs are not fully internalized. It is striking that the environmental damages (e.g., land and rainforest degradation, air pollution and mercury pollution of water bodies in the mining communities), occur regardless of whether (or not) the mining operation is formalized. Moreover, owing to weak resource governance institutions, mining laws and regulations are hardly enforced. Over 200 water bodies within mining districts were found to be heavily polluted by alluvial gold mining operations in Ghana. Based on the survey of the existing literature on gold mining externalities, this study proposes and analyses an intervention that could mitigate the environmental impacts, namely the formalization of illegal mining through mining cooperatives.

The Intervention

Overview

Mining cooperatives have proven to improve efficiency, reduce environment impacts and minimize social conflicts, and are currently present in many countries including Rwanda and Democratic Republic of Congo. Operating as a cooperative facilitates access to financial resources and procurement of improved mining technologies, hence ensuring increased production efficiency. In addition, cooperatives ensure collective environmental compliance, which reduces enforcement costs and diminishes the administrative burden otherwise required to manage individual operators. It is assumed that the formation of co-operatives leads to more efficient production processes as noted in Alves et al (2019). This increases costs, since co-operatives will use more expensive, improved technology. However, it is assumed to lead to improved revenue, safer production processes and fewer environmental externalities.

Implementation Consideration

Of the total number of 1.1m ASM operators in Ghana, 60 percent (660,000 operators) are illegal or unregistered, and therefore must be targeted to form co-operatives. One thousand one hundred and twenty (1120) co-operatives, representing approximately one per community, in 40 mining districts across seven (7) mining regions will be registered co-operative unions for five (5) years under the Co-operative Societies decree of 1968 (NLCD 252) and Co-operative Societies Regulations, 1968 (L.I. 604). Each co-operative will include 590 ASM operators. According to Ghana's Minerals and Mining Acts 2006, a license issued to a co-operative shall last for a period of five years and is renewable for a further period to be determined by the Minister. Furthermore, a co-operative society shall be granted a mineralized land not exceeding 25 acres to be mined for 5 years at a time. For the purpose of the cost-benefit analysis, it is assumed that the mining co-operatives will operate for a period of 5 years.

Costs and Benefits

Costs

The cost elements related to the establishment of mining co-operatives comprise both one-time set up costs as well as ongoing operational and administrative costs. The largest one-time set up cost relates to sensitization of mining communities to the opportunities of co-operatives. Here we assume a fixed cost of GHs 500,000 per cooperative, which is intended to cover promotion materials, grassroots outreach and community level seminars. Additional minor costs of set up including fees for legal registration, crafting by laws are estimated at GHS 2,130 in the first year. Total one off set up costs across 1120 co-operatives are therefore around GHS 562,000,000.

In terms of ongoing costs, the largest cost category relates to the costs of improved technology, estimated at a marginal cost of GHS 510,000 per cooperative. Across 1120 cooperatives this equates to GHS 574,000,000 per year. Another large cost category is the cost of grants provided by the government to support cooperatives, which we estimate as GHS 192,000 per organization, totaling GHS 216,000,000 per year. Remaining costs include mining concession fees, office and utilities costs, and monitoring and evaluation are estimated at GHS 162,000 per cooperative or GHS 182,000,000 per year.

In total the costs are therefore estimated at GHS 1,534,000,000 in the first year and then GHS 917,000,000 every year after that. At an 8% discount rate over 10 years the total cost of the intervention is therefore GHS 7,040 million.

Benefits

There are several benefits that we assume arise from the formation of cooperatives. They include increased revenue from improved production practices, reduced environmental damages, reduced deaths and injuries from accidents, and reduced in-utero exposure to mercury from harmful production practices. Additionally, the grant transfer is also considered a benefit. Mechanised investments yields an annual revenue boost of GHS 593,000 per operator in 2018, or GHS 664,000,000 per year across all cooperatives. The benefit from reduced environmental impacts was estimated at GHS 19,000,000 annually. In addition, the values of water for the industrial sector and household consumptive use were estimated based on current usage and market prices, which summed up to GHS 136,000,000 per year. The total value of benefits from reduced fatalities yield around GHS 132,000,000 per year with the vast majority of benefits coming from avoided injuries, while avoided mercury exposure yields an annual benefit of approximately GHS 64,000,000. Lastly, the government grant is also considered a benefit, since it is a transfer to miners under the cooperatives. Total benefits are therefore GHS 8,265 million with most of the benefit coming from improved revenue

BCR Summary Table

Intervention	Discount Rate	Benefit (GHs million)	Cost (GHs million)	BCR
Establishment of Mining Cooperatives	5%	9,512	8,037	1.2
	8%	8,265	7,040	1.2
	14%	6,424	5,561	1.2

Introduction

Artisanal and Small-Scale gold Mining (ASM) is an important economic activity in several gold-rich developing countries around the world (Kahhat *et al*., 2019). In Ghana, ASM has provided jobs and supported the livelihoods of many rural communities for over a century (Mantey *et al*., 2016). It is estimated that over 1.1 million people are currently engaged in it (McQuilken and Hilson, 2016). Since Ghana implemented the mineral sector reforms in the 1980s to attract foreign direct investment into the large-scale mining sector, the contribution of ASM to total gold production has been rising steadily. In 1989, it accounted for 2.2 percent of total production. By 2014 and 2018, the figure rose to 34.4 and 41.1 percent, respectively, (Ghana Chamber of Mines, 2014 and 2019).

"Artisanal Small-scale Mining" is a combination of two terms: 'small-scale mining' and 'artisanal mining'. The former denotes a formalized and a more mechanized mining operation, whiles artisanal mining is done on a smaller-scale, purely manual and typically informal or illegal basis (Hilson, 2012). However, in Ghana, the difference is mainly due to operating either formally or illegally, hence the two terms are used interchangeably or put together as "Artisanal Small-scale Mining". According to Ghana's Minerals and Mining Act 2006 (Act 703), small-scale gold mining is the mining of gold by an individual or group of persons not exceeding nine in number or by a co-operative society made up of 10 or more persons, using any effective and efficient method that does not involve substantial expenditure. Mineralized land (of 25 acres or less) that is mined by small-scale operators have secured tenure over a given period (5 years or less) (Aryee et al., 2003; Iddirisu and Tsikata, 1998).

ASM, as currently practiced in Ghana, generates negative externalities. Technologies used in ASM are often obsolete, and lead to significant environmental damages that are not fully internalized. Damages, including land and rainforest degradation, air pollution and mercury pollution of water bodies in the mining communities (Tuokuu *et al*., 2018), occur regardless of whether or not the mining operation is formalized. Other factors include weak resource governance institutions and poor enforcement of mining laws and regulations (Hilson and Vieira, 2007). Also, in the quest to minimize production costs, some artisanal miners employ harmful technologies that risk negatively impacting the health of those involved, directly or indirectly, in the mining activities.

Ample evidence exists on the environmental damages caused by ASM in Ghana. For example, alluvial gold mining operations have been found to heavily pollute over 200 water bodies within mining districts in Ghana (Ghana Business News, 2011). Also, the mining operations damage riverbanks and divert rivers and streams from their natural courses. Not only does this contribute to the incidence of floods in some mining communities, it has also resulted in irreversible damages to aquatic and terrestrial ecological systems. Furthermore, there is evidence that miners are exposed to injuries and death resulting from cave-ins of mine shafts (see e.g., Bansah *et al*., 2016; Ibrahim, 2018).

We outline these features of ASM in Ghana, not to assign culpability or make any claims on the net social value of ASM broadly, but merely to make clear the current situation in the country, and what benefits might accrue if interventions could be introduced to address these externalities. Formalization seems to be an important part of the policy discussion, as evidenced by the recent formation of the Multi-Sectoral Mining Integrated Project. However, despite a clearly laid out formalization process in Ghana's Mineral and Mining Act (Act 703), bureaucratic bottlenecks and prohibitive licensing costs compel a significant number of miners (between 70 and 80 percent) to operate illegally (Crawford and Botchwey, 2016; McQuilken and Hilson, 2016). Additionally, favoritism towards large-scale operators has come at the expense of small-scale miners for example, with respect to land for mining activities (Hilson, 2019). The 18 month ban on ASM has arguably, also left diggers with little choice but to engage in 'illegal' mining activities.

In this paper we focus on the costs and benefits of establishing mining co-operatives. According to the Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (IGF), (2017) and the International Monetary Fund (IMF), (2017), mining co-operatives have proven to be an effective way of formalizing small-scale mining to improve efficiency, reduce environment impacts and minimize social conflicts: they appear to have successfully improved small-scale mining activity in many countries including India, Brazil, Bolivia, Rwanda, Australia, Venezuela, and Eastern Democratic Republic of Congo. Co-operatives may have advantages over individual mining operations. Operating as a co-operative facilitates the procurement of improved mining technologies, hence increased production efficiency, owing to easier access to financial resources. This, in turn, increases output and earnings (Alves et al., 2019; Ghose, 2002). Mining co-operatives in Brazil, for example, are at the frontier of deploying modern mining technologies and benefitting from economies of scale (Alves et al., 2019). Massaro and de Theije (2018) noted that the use of innovative and improved mining technologies promotes cleaner gold production.

Furthermore, in Rwanda, mining co-operatives' financial model of shared savings resulted in greater capital accumulation, from which loans are given to members to help advance personal or household goals (Perks, 2012). Also, there is ease of enforcement as members of a mining co-operatives can be held collectively liable for causing environmental damages. In some countries, co-operatives are issued an environmental compliance certificate and are required to engage the services of a pollution control officer (PCO) and a mines safety officer to monitor mining operations. This self-monitoring mechanism reduces enforcement costs and diminishes the administrative burden otherwise incurred by individual operators (Verbrugge and Besmanos, 2016). As stipulated by Act 703 (section 89), the Minister of Mines, in consultation with the Minerals Commission, can designate an area for small scale mining operations if the area is of public interest. Such areas can be allocated to co-operatives rather than to individual operators.

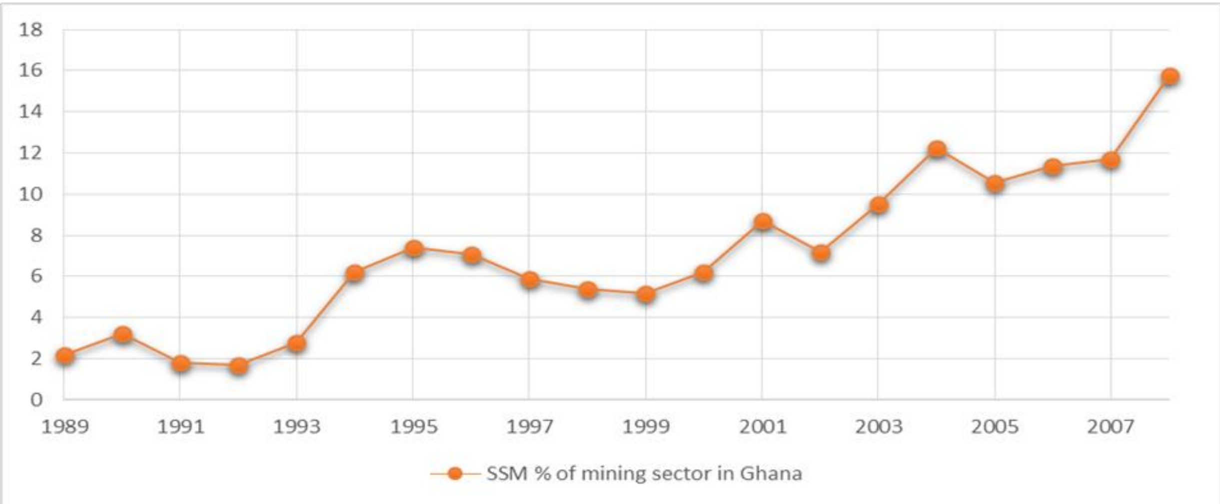
It is important to note at the outset that the evidence for mining co-operatives is not strong, in the sense of having been evaluated using rigorous methods such as randomized controlled trials. To the best of our knowledge, these types of analyses do not exist for the ASM sector. As outlined above, the impacts of co-operatives appear to be beneficial, but these effects have been exclusively noted in qualitative focus-group style analyses. This paper therefore makes assumptions about the potential impacts from the formation of cooperatives, and then proceeds to estimate the monetized benefits of these impacts and compare them against the costs. The headline result is that the benefits outweigh the costs by a factor of 1.2 to 1 at an 8% discount rate. The results of the paper must be seen in light of the weakness in the underlying body of evidence. If for example, co-operatives do not lead to the impacts assumed, then the benefit-cost ratio would be lower.

Artisanal Small-Scale Mining (ASM) in Ghana

Gold extraction and trade in Ghana date back to the fifteenth century (Akpalu and Normanyo, 2017). Prior to the nation's independence when mineral resources of the state were controlled by the British, ASM was undertaken using simple implements for extraction, and mercury for processing the gold. After independence, the state took over the ownership of the resources but implemented policies over the years, especially from the 1980s, to attract foreign capital into the sector. Overall, government involvement in controlling Ghana's mining industry has been increasing since independence, crowding-out foreign control (Akabzaa and Darimani, 2001).

Mining sector reforms in the 1980s revived the industry and spurred the growth of the sector, elevating its attractiveness to foreign investors. Following the promulgation of the Small-Scale Gold Mining Law, PNDC Law 218 of 1989, the number of ASM miners has increased by 941.73% from 1984 to 2004 (Bansah *et al.*, 2016). Also, the contribution of ASM to total gold production rose from 2.2% in 1989 to 15.7% by 2008. Fig. 1 depicts the evolution of the production and contribution of small-scale mining to total gold production in Ghana over the 19-year period (1989 – 2008). In 2014, ASM share to total production was 34.4%. This rose to 41.4% in 2018, according to Ghana Chamber of Mines (2019). It is obvious from the trends that ASM contribution to economic development and transformation can no longer be ignored. The rapid increase in ASM gold production over the years implies a rise in employment of indigenous labour, the retention of additional revenue within the local and national economy, and an enhanced potential for the nation to absorb commodity price shocks (Aragon and Rud, 2015; Billon and Good, 2016).

Figure 1: ASM % of mining sector in Ghana



Historically, the technologies employed in extracting the mineral deposits include the dig and wash, the chisel and hammer, the anomabo and the underground ghetto methods. As more foreign nationals invaded the sector, improved technologies such as excavators, crushers, dredging machines and trucks have been adopted, scaling up the mining operations (Bansah *et al.*, 2016). Both the obsolete and improved technologies used by the ASM operators generate huge environmental opportunity costs (Banchirigah, 2008; Ako et al., 2014). The environmental damages generated by the ASM operators include surface and underground water pollution (with heavy metals), air pollution, soil pollution, and noise pollution, as well as ecosystem damages. Among the chemicals used is mercury, which affects the nervous system when inhaled (Babi et al., 2016). Gold amalgam is burnt in the open air and the particles get transported by the wind during the production process exposing those directly and indirectly involved in the mining to the dangers of mercury inhalation. In addition, as mercury and other suspensions are discharged frequently into streams and rivers during alluvial mining, human and aquatic lives are threatened. Owing to the persistent exposure of miners to its harmful effects, environment agencies in Ghana have indicated that mercury presents one of the greatest environment threats. A study found high concentrations of mercury and toxic elements in water, soil and sediment samples at ASM areas in Ghana.

Since the miners typically discharge their effluents directly into adjacent land and surface water bodies, they generate excessive levels of heavy metal concentration. Ecotoxicological studies have found heavy metal (e.g., arsenic, iron, mercury, zinc and lead) deposits in water bodies in some mining communities within the catchment areas (Obiri 2007). Besides water pollution, the open-pit ASM mining activities generate high volumes of dust that cause upper respiratory tract disorders, including cardiovascular diseases (see e.g., Franchini, & Mannucci, 2007, 2009, and 2012; and Pope III et al., 2004).

The Basic Methodology

Benefit-Cost Ratio (BCR)

The study adopted the BCR model as one of the Social Cost Benefit Analysis (SCBA) metrics to appraise the interventions proposed to help mitigate the negative impact of ASM operations. The SCBA is the ratio of the present value of annualized benefits (B) of the small-scale gold mining intervention relative to the present value of annualized costs (C) associated with the intervention. Basically, the BCR compares the relative benefits and costs of a given intervention over time to determine whether it constitutes a good investment from society's point of view (Boardman, Greenberg, Vining, & Weimer, 2017).

To compute the present values, the benefits and the costs of the interventions are discounted at annual rates, 5%, 8% and 14% based on the prescription of the Copenhagen Consensus Center. Thus, using the conventional formula, the benefit cost ratios are calculated as:

$$BCR = \frac{PV_0\left(Benefits\right)}{PV_0\left(\text{Cos}\,ts\right)} \tag{1}$$

where $PV_0 = \sum_{t=0}^{T} FV_t\left(1+r\right)^{-t}$, PV is the present value, FV is the future value, r is the discount rate and t is the time. If the BCR for an intervention is greater (less) than 1, then the society gains (losses) from the intervention and it is therefore rational to consider implementing (discarding) the intervention. In this study, the benefit cost analysis is assessed over a five-year time frame. In the following section, the elements of social costs and benefits of each intervention are explained and the BCR computed. All costs and benefit figures are denominated in 2018 Ghanaian cedi unless otherwise specified.

Cost-Benefit Analysis

Mining co-operatives are associations created by miners to support mining activities, from extraction to commercialization of mining products (Alves et al., 2017). As noted earlier, mining co-operatives have been found to successfully promote efficient and less environmentally harmful mining practices in many countries, including Brazil, Democratic Republic of Congo (DRC), and Rwanda (Alves et al., 2019). According to IGF (2017) and IMF (2017), mining co-operatives have proven to be an effective way of formalizing small-scale mining to reduce environment impacts and reduce social conflicts. ASM activities in Ghana, including alluvial mining, generate significant environmental opportunity costs. With limited public budget to enforce mining regulations, community level self-enforcement strategies are expected to yield better outcomes. Thus, we surmise that by easing the formalization process and making miners form mining co-operatives, the environmental damages could be internalized, and the risk of mortality and morbidity reduced at a minimized cost. A mining co-operative may provide a better organizational structure for ASM thereby making it easy for members to pool their skills and financial resources together to acquire improved mining technologies, and access technical support to improve and sustain mining activities (Alves *et al*., 2017).

Recent policy targets of the government of Ghana include promoting community mining to minimize the social costs as well as increase the social benefits from the mining activities. Incentives include a cash grant to newly formed mining co-operatives. By legally formalizing collective decision making and sharing of responsibilities, mining co-operatives as a community-based management strategy may generate significant social net returns. In view of the potential benefits, the government of the Democratic Republic of Congo, for example, forces ASM operators into mining co-operatives, as part of the country's formalization policies (de Haan and Geenen, 2016).

To make mining co-operatives a part of the formalization of ASM operations in Ghana, the minerals commission and the district assemblies may have to play key roles. Of the total number of 1.1m ASM operators in Ghana, 60 percent (660,000 operators) are illegal or unregistered (McQuilken and Hilson, 2016), and therefore must be targeted to form co-operatives. One thousand one hundred and twenty (1120) co-operatives, representing approximately one per community, in 40 mining districts across seven (7) mining regions will be registered co-operative unions for five (5) years under the Co-operative Societies decree of 1968 (NLCD 252) and Co-operative Societies Regulations, 1968 (L.I. 604). Each co-operative will include 590 ASM operators. According to Ghana's Minerals and Mining Acts 2006, a license issued to a co-operative shall last for a period of five years and is renewable for a further period to be determined by the Minister. Furthermore, a co-operative society shall be granted a mineralized land not exceeding 25 acres to be mined for 5 years at a time. For the purpose of the cost-benefit analysis, it is assumed that the mining co-operatives will operate for a period of 5 years.

It is assumed that the formation of co-operatives leads to more efficient production processes as noted in Alves et al (2019). This increases costs, since co-operatives will use more expensive, improved technology. However, it is assumed to lead to improved revenue, safer production processes and fewer environmental externalities.

Costs

The cost elements related to the establishment of mining co-operatives comprise both one-time set up costs as well as ongoing operational and administrative costs. The largest one-time set up cost relates to sensitization of mining communities to the opportunities of co-operatives. Here we assume a fixed cost of GHs 500,000 per cooperative, which is intended to cover promotion materials, grassroots outreach and community level seminars. This figure is imprecise, but at a cost of around GHS 900 per miner, should be sufficient to cover the necessary activities. Additional set up costs include fees for legal registration, crafting of by laws and setting up correspondence channels. Using information obtained from the Registrar General's Department, Ghana Post Company Limited, and sector experts, we estimate these minor costs of establishing a mining co-operative are GHS 2,130 in the first year. Total one off set up costs across 1120 co-operatives are therefore around GHS 562,000,000.

In terms of ongoing costs, the largest cost category relates to the costs of improved technology. To estimate this we use figures provided in Opoku-Antwi (2010) who surveyed 57 mining operations in the Bibiani, Bolgatanga, Dunkwa and Tarkwa districts of Ghana. Those estimates suggest that moving from manual to mechanized tools generated a marginal cost of GHS 130,000 per year in 2010 figures. This translates to almost GHS 510,000 per cooperative in 2018 terms, a value we apply to each cooperative as an estimate of increased technology costs. Across 1120 cooperatives this equates to GHS 574,000,000 per year.

Another large cost category is the cost of grants provided by the government to support cooperatives, which we estimate as GHS 192,000 per organization. These are based on actual grants paid by the Minerals Commission to Talensi-Nabdam Cooperative in Bolgatanga, Ekomyeya Cooperative in Bibiani, the Konongo Cooperative and Smith Cooperative in Winneba (Africa Minerals Development Center, 2017). These grants would form part of the incentive structure to miners to form and maintain cooperatives. The total estimated cost of these grants is GHS 216,000,000 per year.

The remaining costs are estimated from various sources including documents from the Minerals Commission and other cooperative structures such as the Komfo Anokye Teaching Hospital Co-operative Credit Union Limited (KATHCCU). These costs include mining concession fees, office and utilities costs, and monitoring and evaluation. These sum to around GHS 162,000 per cooperative or GHS 182,000,000 per year (see appendix for detail).

In total the costs are therefore estimated at GHS 1,534,000,000 in the first year and then GHS 917,000,000 every year after that (see Table 1). At an 8% discount rate over 10 years the total cost of the intervention is therefore GHS 7,040 million.

Table 1: Summary of costs

Cost Category	Value (GHS)	Source
Set up costs	562,000,000 (one-off)	Limited data; we speculate GHS 500,000 per cooperative sensitization cots
Improved mining technology	574,000,000	Adapted from Opoku-Antwi (2010)
Government grant	216,000,000	Africa Minerals Development Center (2017)
Operations and administration	182,000,000	Minerals Commission; KATHCCU

Benefits

There are several benefits that we assume arise from the formation of cooperatives. They include increased revenue from improved production practices, reduced environmental damages, reduced deaths and injuries from accidents, and reduced in-utero exposure to mercury from harmful production practices. Additionally, the grant transfer is also considered a benefit.

The largest benefit is the gain in mining revenue associated with improved technologies. Again we refer to the detailed survey by Opoku-Antwi (2010). That analysis indicated mechanized investments yields an annual revenue boost of GHS 152,000 per operator in 2010 figures. This translates to a GHS 593,000 per operator in 2018, or GHS 664,000,000 per year across all cooperatives. Note that the private return to mechanization implied by these figures (based on costs presented above) is 15% per year, well within the expected range for a private investment in an arena such as gold mining.

The second benefit is associated with reduced environmental impacts. These include provision of potable water for household and for industrial consumption, and a reduction in the lost non-timber forest benefit because of a decrease in ecosystem degradation or changes in biodiversity. The decline in the loss of non-timber forest benefits -- which is the sum of the value of product such as bushmeat, snails, spices, herbs, fruits, and mushrooms from the forest that could have been lost -- was calculated assuming that yield loss ranges from 25% to 50%. Following Schep et al. (2016), the figure amounted to GHS 19,000,000 annually. In addition, the values of water for the industrial sector and household consumptive use were estimated based on current usage and market prices, which summed up to GHS 136,000,000 per year.

The third benefit is reduced fatalities and injuries associated with dangerous mining practices. It is assumed the cooperatives would mitigate unsafe practices leading to a reduction in 5 deaths per year, as well as avoiding 86,000 abrasions, 28,000 fractures and 76,000 lacerations. These values were obtained from the following estimation approach. According to Nakua et al., (2019), the annual incidence rate of mining related injury among small-scale gold miners in Ghana is 289 per 1000 workers, equivalent to 190,740 injuries in this intervention. According to AngloGold Ashanti Limited Integrated Report 2018, AngloGold Ashanti's operation in Obuasi gold mine, the annual all injury frequency rate in 2018 was 0.62 per million hours worked which is equivalent to 786 mining injuries under best practice. The difference in these two figures is the assumed benefit of the intervention or roughly 190,000 avoided injuries. This total figure is apportioned according the statistics in Nakua et al. (2019) 45.5% for abrasions, 14.7% for fractures and 39.8% for lacerations. The benefit is estimated using the cost-of-illness approach with a focus on lost productivity from these injuries. Following Nakua et al. (2019) we assume abrasions require one week away from work, 8 weeks for fractures and 10 days off for lacerations. These absences are valued at 100% of mining wages - approximately GHS 40 per day (Bansah et al., 2016). The total value of benefits is therefore around GHS 132,000,000 per year with the vast majority of benefits coming from avoided injuries.

The last substantive benefit is that of avoided mercury exposure in utero. Mercury has been shown to reduce IQ, and Trasande et al. (2016) estimate a reduction of 0.18 IQ points per 1 ug/g exposure in maternal hair. Kwaansa-Ansah et al. (2019) found baseline mercury exposure to be 6.59 ug/g in the hair of those from mining communities. While the relationship between IQ and wages is not particularly well established, a longitudinal study of individuals within the context of a breastfeeding promotion strategy in Brazil noted that each IQ point was associated with a 6% increase in wages over the lifetime (Victora et al. 2015). In this study we apply 4.4% since Victora et al. (2015) note that only 72% of the wage boost was associated with IQ improvements. We assume that forming cooperatives leads to a 30% reduction in mercury exposure which is the mid-point of the upper and lower bound of reported impacts from safety training garnered from a review of 22 studies (Zolnikov and Ortiz, 2018). This suggests forming cooperatives would lead to a 1.5% boost to income for the children of female miners who avoid mercury exposure. Lastly, we assume that 50% of miners are women (Yakovleva 2007), and that each woman has on average 0.143 children per year (DHS, 2014). The assumed pathway of income follows standard projections under the *Ghana Priorities* project (Wong and Dubosse, 2019). The benefit per child is estimated at GHS 1,343 (8% discount rate) and each year roughly 47,190 children would be borne to the beneficiary population. This implies an annual benefit of approximately GHS 64,000,000.

Lastly, the government grant is also considered a benefit, since it is a transfer to miners under the cooperatives. Total benefits are therefore GHS 8,265 million with most of the benefit coming from improved revenue (Table 2)

Table 2 – Summary of Benefits

Benefit Category	Value (GHS)	Source
Improved production efficiency	664,000,000	Adapted from Opoku-Antwi (2010)
Government grant	216,000,000	Africa Minerals Development Center (2017)
Reduced environmental degradation	155,000,000	Based on Schep et al. (2016)
Avoided fatality and injuries	132,0000	Nakua et al (2019); AshantiGold (2018).
Avoided exposure to mercury in utero	64,000,000	Transade et al. (2016);

Results and Discussion

Forming cooperatives is expected to yield a cost of 7,040 million over 10 years, while generating a benefit of GHS 8,265 million. The BCR is 1.2. Table 3 provides a summary of costs and benefits at different discount rates. The BCR is not sensitive to choice of discount rate.

Table 3. Costs and Benefits Summary

Intervention	Discount Rate	Benefit (GHS millions)	Cost (GHS millions)	BCR
Establishment of Mining Co-operatives	5%	9,512	8,037	1.2
	8%	8,265	7,040	1.2
	14%	6,424	5,561	1.2

Extraction and processing of gold in Ghana, especially by small-scale artisanal miners, comes with large externalities – environmental, health and economic, many of which are hardly internalized. Owing to a raft of factors ASM find it difficult to formalize. Based on the limited evidence in other countries we proposed cooperatives as a potential avenue for formalization. The results suggest positive net benefits, but a relatively low BCR compared to other interventions within the Ghana Priorities project.

References

African Minerals Development Centre (2017). Report on Artisanal & Small-scale mining in Africa selected countries policy profile review on ASM. Retrieved from https://knowledge.uneca.org/ASM/sites/default/files/docs/ASMStudyReport2017.pdf

Akabzaa, T., & Darimani, A. (2001). Impact of mining sector investment in Ghana: A study of the Tarkwa mining region. *Third World Network*.

Ako, T. A., Onoduku, U. S., Oke, S. A., Adamu, I. A., Ali, S. E., Mamodu, A., & Ibrahim, A. T. (2014). Environmental impact of artisanal gold mining in Luku, Minna, Niger state, North Central Nigeria. *Journal of Geosciences and Geomatics*, *2*(1), 28–37.

Akpalu, W., & Normanyo, A. K. (2017). Gold mining pollution and the cost of private healthcare: the case of Ghana. *Ecological Economics*, *142*, 104–112.

Alves, W, Ferreira, P., & Araújo, M. (2017). Mining cooperatives in Brazil: an overview. *Procedia Manufacturing*, *13*, 1026–1033.

Alves, Wellington, Ferreira, P., & Araújo, M. (2019). Mining co-operatives: A model to establish a network for sustainability. *Journal of Co-Operative Organization and Management*, *7*(1), 51–63.

AngloGold Ashanti Limited (2018). Integrated report for the Year ended December 31, 2018**:** Integrated Report 2018**.** Retrieved from http://www.aga-reports.com/18/ir#home

Aragon, F., & Rud, J. P. (2012). Mining, pollution and agricultural productivity: evidence from Ghana.

Aryee, B.N.A., Ntibery, B.K., Atorkui, E., 2003. Trends in the small-scale mining of precious minerals in Ghana: a perspective on its environmental impact. Journal of Cleaner Production 11 (2), 131–140

Banchirigah, S. M. (2008). Challenges with eradicating illegal mining in Ghana: A perspective from the grassroots. *Resources Policy*, *33*(1), 29–38.

Bansah, K. J., Yalley, A. B., & Dumakor-Dupey, N. (2016). The hazardous nature of small scale underground mining in Ghana. *Journal of Sustainable Mining*, *15*(1), 8–25.

Boardman, A. E., Greenberg, D. H., Vining, A. R., & Weimer, D. L. (2017). *Cost-benefit analysis: concepts and practice*. Cambridge University Press.

Crawford, G., & Botchwey, G. (2016). Conflict, collusion and corruption in small-scale gold mining in Ghana: Chinese miners and the state. In *Global Governance/Politics, Climate Justice & Agrarian/Social Justice: Linkages and Challenges. An International Colloquium* (pp. 4–5).

de Haan, J., & Geenen, S. (2016). Mining cooperatives in Eastern DRC The interplay between historical power relations and formal institutions. *The Extractive Industries and Society*, *3*(3), 823–831.

Franchini, M, & Mannucci, P. M. (2007). Short-term effects of air pollution on cardiovascular diseases: outcomes and mechanisms. *Journal of Thrombosis and Haemostasis*, *5*(11), 2169–2174.

Franchini, Massimo, & Mannucci, P. M. (2009). Particulate air pollution and cardiovascular risk: short-term and long-term effects. In *Seminars in thrombosis and hemostasis* (Vol. 35, pp. 665–670). © Thieme Medical Publishers.

Franchini, Massimo, & Mannucci, P. M. (2012). Air pollution and cardiovascular disease. *Thrombosis Research*, *129*(3), 230–234.

Ghana Chamber of Mines (2014). Performance of the Mining Industry in Ghana: Annual Report 2014.

Ghana Chamber of Mines (2019). Performance of the Mining Industry in Ghana: Annual Report 2019

Ghose, M. K. (2003). Indian small-scale mining with special emphasis on environmental management. *Journal of Cleaner Production*, *11*(2), 159–165.

Hilson, G. (2001). A contextual review of the Ghanaian small-scale mining industry. *Mining, Minerals and Sustainable Development*, *76*, 1–29.

Hilson, G. (2012). Corporate Social Responsibility in the extractive industries: Experiences from developing countries. *Resources Policy*, *37*(2), 131-137.

Hilson, G. (2019). Why is there a large-scale mining ‘bias’ in sub-Saharan Africa? *Land Use Policy*, *81*, 852–861.

Hilson, G., & Vieira, R. (2007). Challenges with minimising mercury pollution in the small-scale gold mining sector: Experiences from the Guianas. *International Journal of Environmental Health Research*, *17*(6), 429–441.

Ibrahim, I. (2018). Gold Exports and Cost Implications of Illegal Gold Mining in Ghana. *British Journal of Economics*, *15*, 1.

Iddirisu, A. Y. and F. S. Tsikata (1998) 'Mining Sector Development and Environment Project.Regulatory Framework Study to Assist Small Scale Miners'. Study prepared for the Minerals Commission. Accra: Minerals Commission

Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development

(IGF) (2017). Global Trends in Artisanal and Small-Scale mining (ASM): A review of key

numbers and issues. Retrieved fromhttp://www.iisd.org/sites/default/files/

publications/igf-asm-global-trends.pdf.

IMF - International Monetary Fund (2017). World economic outlook: Gaining momentum?

World economic outlook April 2017. Retrieved fromwww.imfbookstore.org.

Kahhat, R., Parodi, E., Larrea-Gallegos, G., Mesta, C., & Vázquez-Rowe, I. (2019). Environmental impacts of the life cycle of alluvial gold mining in the Peruvian Amazon rainforest. *Science of The Total Environment*, *662*, 940–951.

Kwaansa-Ansah, E. E., Armah, E. K., & Opoku, F. (2019). Assessment of total mercury in hair, urine and fingernails of small–scale gold miners in the Amansie West District, Ghana. *Journal of Health and Pollution*, *9*(21), 190306.

Le Billon, P., & Good, E. (2016). Responding to the commodity bust: Downturns, policies and poverty in extractive sector dependent countries. *The Extractive Industries and Society*, *3*(1), 204–216.

Mantey, J., Nyarko, K., & Owusu-Nimo, F. (2016). Costed reclamation and decommissioning strategy for galamsey operations in 11 selected MDAs of.".

Marshall, B. G., & Veiga, M. M. (2017). Formalization of artisanal miners: stop the train, we need to get off! *The Extractive Industries and Society*, *4*(2), 300–303.

Massaro, L., & de Theije, M. (2018). Understanding small-scale gold mining practices: An anthropological study on technological innovation in the Vale do Rio Peixoto (Mato Grosso, Brazil). *Journal of Cleaner Production*, *204*, 618–635.

McQuilken, J., & Hilson, G. (2016). Artisanal and small-scale gold mining in Ghana. *Evidence to Inform an 'Action Dialogue'. IIED, London*.

Nakua, E. K., Owusu-Dabo, E., Newton, S., Koranteng, A., Otupiri, E., Donkor, P., & Mock, C. (2019). Injury rate and risk factors among small-scale gold miners in Ghana. *BMC Public Health*, *19*(1), 1368.

Obiri, S. (2007). Determination of heavy metals in water from boreholes in Dumasi in the Wassa West District of western region of Republic of Ghana. *Environmental Monitoring and Assessment*, *130*(1–3), 455–463.

Opoku-Antwi, G. L. (2010). Three essays on small-scale gold mining operations in Ghana: An integrated approach to benefit-cost analysis.

Perks, R. (2012). Mining cooperatives: re-invigorating small-scale mining participation and benefit in Rwanda. *Unpublished Draft)*.

Pope III, C. A., Burnett, R. T., Thurston, G. D., Thun, M. J., Calle, E. E., Krewski, D., & Godleski, J. J. (2004). Cardiovascular mortality and long-term exposure to particulate air pollution: epidemiological evidence of general pathophysiological pathways of disease. *Circulation*, *109*(1), 71–77.

Schep, S., Guzman, A., van Beukering, P., de Moel, H., Eiselin, M., Ayesu, S., Birikorang, G., & Ansah, K. B. (2016). The economics of the Atewa Forest Range, Ghana. Amsterdam, Netherlands: IUCN

Trasande, L., DiGangi, J., Evers, D. C., Petrlik, J., Buck, D. G., Šamánek, J., … Regan, K. (2016). Economic implications of mercury exposure in the context of the global mercury treaty: hair mercury levels and estimated lost economic productivity in selected developing countries. *Journal of Environmental Management*, *183*, 229–235.

Verbrugge, B., & Besmanos, B. (2016). Formalizing artisanal and small-scale mining: Whither the workforce? *Resources Policy*, *47*, 134–141.

Victora, C. G., Horta, B. L., De Mola, C. L., Quevedo, L., Pinheiro, R. T., Gigante, D. P., … Barros, F. C. (2015). Association between breastfeeding and intelligence, educational attainment, and income at 30 years of age: a prospective birth cohort study from Brazil. *The Lancet Global Health*, *3*(4), e199–e205.

Yakovleva, N. (2007). Perspectives on female participation in artisanal and small-scale mining: A case study of Birim North District of Ghana. *Resources Policy*, *32*(1–2), 29–41.

Zolnikov, T. R., & Ortiz, D. R. (2018). A systematic review on the management and treatment of mercury in artisanal gold mining. *Science of the Total Environment*, *633*, 816–824.

The Ghanaian economy has been growing swiftly, with remarkable GDP growth higher than five per cent for two years running. This robust growth means added pressure from special interest groups who demand more public spending on certain projects. But like every country, Ghana lacks the money to do everything that citizens would like. It has to prioritise between many worthy opportunities. What if economic science and data could cut through the noise from interest groups, and help the allocation of additional money, to improve the budgeting process and ensure that each cedi can do even more for Ghana? With limited resources and time, it is crucial that focus is informed by what will do the most good for each cedi spent. The Ghana Priorities project will work with stakeholders across the country to find, analyze, rank and disseminate the best solutions for the country.

FOR MORE INFORMATION VISIT WWW.GHANAPRIORITIES.COM

Copenhagen Consensus Center is a think tank that investigates and publishes the best policies and investment opportunities based on social good (measured in dollars, but also incorporating e.g. welfare, health and environmental protection) for every dollar spent. The Copenhagen Consensus was conceived to address a fundamental, but overlooked topic in international development: In a world with limited budgets and attention spans, we need to find effective ways to do the most good for the most people. The Copenhagen Consensus works with 300+ of the world's top economists including 7 Nobel Laureates to prioritize solutions to the world's biggest problems, on the basis of data and cost-benefit analysis.