Associations between mining projects and socio-economic determinants of health in sub-Saharan Africa

INAUGURALDISSERTATION

zur

Erlangung der Würde eines Doktors der Philosophie

vorgelegt der

Philosophisch-Naturwissenschaftlichen Fakultät

der Universität Basel

von

Raogo Hyacinthe ZABRE

Basel, 2022

Genehmigt von der Philosophisch-Naturwissenschaftlichen Fakultät der Universität Basel auf Antrag von PD Dr. Mirko Winkler, Prof. Dr. Günther Fink und Prof. Dr. Jürgen Maurer

Basel, den 22.06.2021

Prof. Dr. Marcel Mayor,
Dekan der Philosophisch-
Naturwissenschaftlichen Fakultät

Summary

Background: Natural resource extraction projects (NREPs) have the potential to improve socio-economic determinants of health and hence contribute to the achievement of the Sustainable Development Goals (SDGs) of the 2030 Agenda. Since most natural resource deposits are located in remote tropical areas, NREPs have considerable potential to create employment and other opportunities for socio-economic development, along with the strengthening of local health systems and improving public infrastructures. However, there is a large body of evidence showing that instead of improving public health, NREPs often have negative effects on environmental, social and economic determinants of health, leading to alterations in the disease burden in affected communities. Thus, related economic hardship may increase, imposing additional health expenditures. Hence, there is the risk that NREPs counteract efforts made by the public sector to work towards the SDG 2030 Agenda. From a health economics perspective, SDG1 (no poverty), SDG3 (good health and wellbeing), SDG8 (employment and economic growth) and SDG10 (reduced inequalities) are of particular concern. The situation is particularly relevant in Sub-Saharan Africa (SSA), where economic underdevelopment coexists with natural resource abundance. For promoting effective collaboration between the public sector and extractive industry companies, a better understanding is needed of how health systems and local economies develop in a resource extraction environment, including the economic interests that motivate each party involved.

Objectives: The overarching objective of this PhD thesis was to contribute to a better understanding of the economic impacts of NREPs on health systems in African countries. The specific objectives pursued under this PhD thesis were: (i) to systematically review the inclusion of economic analysis in impact assessments of natural resource extraction projects; (ii) to assess the overall financial flow from NREPs to the public sector and to determine how funds are re-distributed to the different public sectors; (iii) to carry out cost-benefit analysis of specific health interventions that were implemented by NREPs to protect their workforce; (iv) to assess the long-term effects on selected socio-economic determinants of health in households affected by a major mining project; and (v) to assess the impact of an industrial mining project on household wealth.

Research partnership: The Health Impact Assessment for Sustainable Development (HIA4SD) project is the framework for this PhD thesis. In the same project, six other PhD students, each working on a specific but collectively complementary topic, contributed to the scientific evidence around health in resource extraction regions in different parts of sub-Saharan Africa.

Methods: For the first main paper of this PhD thesis, we conducted a scoping review in the peer-reviewed literature, searching articles published between 1998 and 2020 in PubMed and Scopus, applying the Prisma statement. Identified articles were systematically screened and characterised (i.e. project location, nature of NREP studied, production stages, type of impacts studied and economic analysis applied). For the second and third paper, data from repeated cross-sectional health surveys (2011, 2015 and 2019) that were conducted as part of the monitoring and evaluation step of a health impact assessment (HIA) of a large copper mine in Zambia were analysed by applying a health economic perspective. More specifically, we studied changes in socio-economic determinants of health between impacted and comparison communities between 2011 and 2019. Student's t-tests were used to assess the significance of the differences found. Furthermore, changes in household wealth calculated from consolidated economic indicators were compared between 2011 and 2019, and between impacted and comparison communities. A difference-in-difference linear regression model was used to compare changes over time.

Results: For the scoping review, of the 1,579 raw hits, only 13 articles describing 15 economic analyses were identified according to our inclusion and expulsion criteria. Half of the identified articles presented economic analyses conducted in the context of mining and oil/gas projects. The majority of the identified studies addressed the cost and/or benefits of environmental and/or social impacts. We found several significant effects on socio-economic determinants of health indicators in communities affected by the large copper mine in Zambia: (i) average household size was slightly reduced; (ii) the proportion of mothers who had not completed primary school increased; (iii) the ownership of economic assets increased (e.g. telephones, televisions); (iv) access to safe drinking water increased; and (v) housing structures (e.g. roofs, walls) improved. Furthermore, between 2015 and 2019, when comparing changes in impacted communities and nearby comparison communities, there was (i) an increase in the proportion of mothers who have not completed primary school in comparison communities; and (ii) greater ownership of economic assets in impacted communities compared to comparison communities in 2019. The average wealth of the communities near the mine, which was significantly lower at the outset than that of the North West Province in 2011, has exceeded the regional average in 2019. The rate of increase in average wealth has increased more rapidly in communities directly affected by the mine than in comparison communities.

Conclusion and relevance: The results of the economic impact assessments carried out in this thesis can be used as a basis for policy actions to offset the anticipated economic costs of NREP on the health system and the community. Firstly, if the negative health impacts of mines and the associated socio-economic determinants are known, they can be measured, controlled by appropriate actions and monitored over time. A case of good practice in Zambia appears to be a solution to the problem identified in this PhD thesis to be implemented. Secondly, we encourage impact assessment practitioners to make their reports and data collected publicly available whenever possible. This will reduce the problem of insufficient scientific papers on mining economic analysis and increase transparency with regards to potential impacts of NREPs and any other large infrastructure projects. Finally, the responsibility to promote better inclusion of socio-economic determinants of health, and potential health impacts at large, in impact assessment is shared among several actors, ranging from government bodies over financing institutions to extractive industry companies. In combination with multi-sectoral action for health, the results of this thesis can help to promote the inclusion of economic analysis in impact assessment practice and, hence, fully activate the potential of the resource extraction sector to support the public sector in working towards the SDGs of the 2030 Agenda.

Résumé

Contexte : Les projets d'extraction de ressources naturelles (NREP) ont le potentiel d'améliorer les déterminants socio-économiques de la santé et donc de contribuer à la réalisation des objectifs de développement durable (ODD) de l'Agenda 2030. Étant donné que la plupart des gisements de ressources naturelles sont situés dans des zones tropicales éloignées, les NREP ont un potentiel considérable de création d'emplois et d'autres opportunités de développement socio-économiques, parallèlement au renforcement des systèmes de santé locaux et à l'amélioration des infrastructures publiques. Cependant, de nombreux éléments montrent qu'au lieu d'améliorer la santé publique, les NREP ont souvent des effets négatifs sur les déterminants environnementaux, sociaux et économiques de la santé, entraînant des modifications de la charge de morbidité dans les communautés touchées. Ainsi, les difficultés économiques qui y sont liées peuvent augmenter, imposant des dépenses de santé supplémentaires. Il existe donc un risque que les NREP contrecarrent les efforts déployés par le secteur public pour œuvrer à la réalisation de l'Agenda 2030 des ODD. Du point de vue de l'économie de la santé, les ODD1 (pas de pauvreté), ODD3 (bonne santé et bien-être), ODD8 (emploi et croissance économique) et ODD10 (réduction des inégalités) sont particulièrement préoccupants. La situation est particulièrement pertinente en Afrique subsaharienne (ASS), où le sous-développement économique coexiste avec l'abondance des ressources naturelles. Pour promouvoir une collaboration efficace entre le secteur public et les entreprises de l'industrie extractive, il est nécessaire de mieux comprendre comment les systèmes de santé et les économies locales se développent dans un environnement d'extraction de ressources, y compris les intérêts économiques qui motivent chaque partie impliquée.

Objectifs : L'objectif principal de cette thèse de doctorat était de contribuer à une meilleure compréhension des impacts économiques des NREP sur les systèmes de santé dans les pays africains. Les objectifs spécifiques poursuivis étaient les suivants : (i) d'examiner systématiquement l'inclusion de l'analyse économique dans les évaluations d'impact des projets d'extraction de ressources naturelles ; (ii) d'évaluer le flux financier global des NREP vers le secteur public et de déterminer comment les fonds sont redistribués aux différents secteurs publics ; (iii) de réaliser une analyse coûts-bénéfices d'interventions sanitaires spécifiques mises en œuvre par les NREP pour protéger leur main-d'œuvre ; (iv) d'évaluer les effets à long terme sur certains déterminants socio-économiques de la santé dans les ménages affectés par un grand projet minier ; et (v) d'évaluer l'impact d'un projet minier industriel sur la richesse des ménages.

Partenariat de recherche : Le projet Health Impact Assessment for Sustainable Development (HIA4SD) constitue le cadre de cette thèse de doctorat. Dans le cadre du même projet, six autres doctorants, travaillant chacun sur un sujet spécifique mais collectivement complémentaire, ont contribué aux preuves scientifiques concernant la santé dans les régions d'extraction de ressources dans différentes parties de l'Afrique subsaharienne.

Méthodes : Pour le premier article principal de cette thèse de doctorat, nous avons effectué une revue de la littérature évaluée par les pairs, en recherchant les articles publiés entre 1998 et 2020 dans PubMed et Scopus, en appliquant la déclaration Prisma. Les articles identifiés ont fait l'objet d'un tri systématique et ont été caractérisés (c'est-à-dire la localisation du projet, la nature du NREP étudié, les étapes de production, le type d'impacts étudiés et l'analyse économique appliquée). Pour les deuxième et troisième articles, les données provenant d'enquêtes sanitaires transversales répétées (2011, 2015 et 2019) qui ont été menées dans le cadre de l'étape de suivi et d'évaluation d'une évaluation d'impact sur la santé (EIS) d'une grande mine de cuivre en Zambie ont été analysées en appliquant une perspective économique de la santé. Plus précisément, nous avons étudié les changements dans les déterminants socio-économiques de la santé entre les communautés impactées et les communautés de comparaison entre 2011 et 2019. Des tests t de Student ont été utilisés pour évaluer la signification des différences constatées. En outre, les changements dans la richesse des ménages calculés à partir d'indicateurs économiques consolidés ont été comparés entre 2011 et 2019, et entre les communautés touchées et les communautés témoins. Un modèle de régression linéaire de type "différence dans la différence" a été utilisé pour comparer les changements dans le temps.

Résultats : Pour la revue de cadrage, sur les 1 579 occurrences brutes, seuls 13 articles décrivant 15 analyses économiques ont été identifiés selon nos critères d'inclusion et d'exclusion. La moitié des articles identifiés présentaient des analyses économiques menées dans le contexte de projets miniers et pétroliers/gaziers. La majorité des études identifiées traitaient du coût et/ou des avantages des impacts environnementaux et/ou sociaux. Nous avons trouvé plusieurs effets significatifs sur les déterminants socio-économiques des indicateurs de santé dans les communautés affectées par la grande mine de cuivre en Zambie : (i) la taille moyenne des ménages a été légèrement réduite ; (ii) la proportion de mères n'ayant pas terminé l'école primaire a augmenté ; (iii) la possession d'actifs économiques a augmenté (par exemple, téléphones, télévisions) ; (iv) l'accès à l'eau potable a augmenté ; et (v) les structures des logements (par exemple, toits, murs) se sont améliorées. En outre, entre 2015 et 2019, en comparant les changements dans les communautés impactées et les communautés de comparaison proches, on a constaté (i) une augmentation de la proportion de mères n'ayant pas terminé l'école primaire dans les communautés de comparaison ; et (ii) une plus grande propriété des actifs économiques dans les communautés impactées par rapport aux communautés de comparaison en 2019. La richesse moyenne des communautés proches de la mine, qui était au départ nettement inférieure à celle de la province du Nord-Ouest en 2011, a dépassé la moyenne régionale en 2019. Le taux d'augmentation de la richesse moyenne a augmenté plus rapidement dans les communautés directement touchées par la mine que dans les communautés de comparaison.

Conclusion et pertinence : Les résultats des évaluations de l'impact économique réalisées dans le cadre de cette thèse peuvent servir de base à des actions politiques visant à compenser les coûts économiques anticipés du NREP sur le système de santé et la communauté. Tout d'abord, si les impacts négatifs des mines sur la santé et les déterminants socio-économiques associés sont connus, ils peuvent être mesurés, contrôlés par des actions appropriées et suivis dans le temps. Un cas de bonne pratique en Zambie semble être une solution au problème identifié dans cette thèse de doctorat à mettre en œuvre. Deuxièmement, nous encourageons les praticiens de l'évaluation d'impact à rendre leurs rapports et les données collectées accessibles au public dans la mesure du possible. Cela permettra de réduire le problème de l'insuffisance des articles scientifiques sur l'analyse économique minière et d'accroître la transparence en ce qui concerne les impacts potentiels des NREP et de tout autre grand projet d'infrastructure. Enfin, la responsabilité de promouvoir une meilleure prise en compte des déterminants socio-économiques de la santé, et des impacts potentiels sur la santé en général, dans l'évaluation des impacts est partagée par plusieurs acteurs, allant des organismes gouvernementaux aux entreprises de l'industrie extractive, en passant par les institutions de financement. En combinaison avec une action multisectorielle pour la santé, les résultats de cette thèse peuvent aider à promouvoir l'inclusion de l'analyse économique dans la pratique de l'évaluation d'impact, et ainsi activer pleinement le potentiel du secteur de l'extraction des ressources pour soutenir le secteur public dans la réalisation des ODD de l'Agenda 2030.

Acknowledgements

Great, very great is my joy and I will certainly miss words to express my gratitude to you my supervisors, my PhD project sponsors, my colleagues, my students, my friends, all my relatives and my family.

My dear Mirko, I will say that nothing would have been possible without you (your assistance / help). I express my gratitude through these words, which are certainly not enough. As my mentor, trainer and friend, your simplicity, your ardour and dedication to your work, your humanism and your managerial capacity crossed many borders to even reach my home in Burkina Faso. Your academic, fieldwork and social support will remain engraved in my memory. Thank you for the relaxing outings, the swimming, the common meals in public places and at home. Thank you for opening the doors of your home and socialising with yourwise and kind children, and my word of gratitude also goes to your wife for her hospitality. I imagine how deep will be my joy if I receive all of you at home in Burkina. Thank you for being a scientific and social model, without any discrimination, and for having marvellously led me to these unforgettable moments of crowning my doctoral training. I still remember the translations into English and how patiently you knew how to admit me and integrate me into an English-speaking group in which I easily found my place. Please, find in this thesis, the confirmation of the accuracy of your judgments that led you to select me among the candidates for the PhD in Burkina Faso. Barka, bark wusgo (thanks a lot).

To Prof. Jurg and his staff, a big thank to you for the dynamism of Swiss TPH, which allowed the availability of the premises, the didactic material and the essential personnel to our learning. Thank you for the simplicity of your exchanges with me, often in French; you are so kind, thank you very much.

To Prof. Serge Diagbouga, as during my Master's thesis, you believed in me and you gave me support beyond my expectations for my travel preparations, data research and the organisation of the kiff-of-meeting, data collection in Burkina Faso; you showed legendary professionalism and efficiency. Remain assured that the seed of research that you have sown in me will grow up and bear good fruit. Through you, I would like to thank the director of the IRSS for allowing this doctoral work to be carried out in his institution. May he find in these words the recognition of all his administrative support for the realization of the HIA4SD project and this thesis. May God reward you a hundredfold for your kindness.

To Dr Emile Paré, Director General of the National School of Public Health in Ouagadougou, to Mr Koné (Director of Human Resources), to Dr Siaka Compaoré (Director of Higher Education in Health Sciences), you have believed in my ambition to do this doctorate and in the contribution it will make to higher education in health system in Burkina Faso. I thank all of you heartily and assure you that you will always accompany the training of the students of the following generations.

My dear Prof. Günther, the speed with which you corrected my work and your availability for our weekly meetings made the completion of this thesis possible. I am very pleased with what I have learned in health economic with you and assure you to deepen my skills for the benefit of the HIA4SD team. Thank you for everything you did for me.

I am grateful to the funders who have made the HIA4SD project in which my PhD project is being carried out possible. These include the r4d programme, the joint funding initiative of the Swiss Agency for Development and Cooperation (SDC) and the Swiss National Science Foundation (SNSF).

To my mentors Andrea American and Astrid, I have had a great time working with you. Your efficiency and your sharing of knowledge were indispensable to complete the manuscripts for this thesis in time. Andrea, your R codes, the one to one meetings, by zoom have punctuated these learnings and the breakfast groups have brought back the smile during the difficult moments of disorientation and stress. Astrid, thank you for the welcome, the training in Zambia and your expertise in the Trident manuscripts. Your contribution was very precious to speed up my work. We still wish to continue our studies with your precious guidance, why not in Burkina Faso; you are more than welcome!

To you, dear Dominik, I still remember my first time in Switzerland, where you were waiting for me with open arms and heart at the airport in Bale/Mulhouse. It's a great thing when you step on the ground of a foreign country for the first time, with just a map in your hand and you see that people are organised for your arrival and that a certain Dominik, who speaks French, is waiting for you. Thank you for the matches you gave me tickets for, thank you for the availability to help in the students' office as well as in the university system in Basel, which I was really new to. During your stay to support the data collection in Burkina Faso, I discovered all your courage, efficiency and adaptability (terrorist attacks, eating the balls, being hungry and horribly hungry as you put it).

I thank the dynamic data collection team in Burkina Faso (Albert, Hermann, Djenaba and Maimouna) for their efficiency and the quality of the work. Yes, you have contributed to this thesis.

To the Commaires of the communes, the medeceins of the sanitary districts of Hounde, Boromo and Komgoussi, as well as the mining companies Hounde gold, Roxgold and Bissagold for hosting the data collection teams and for your time and effort. I would like you to transmit our thanks to the community for their participation in the transect walk and the various focus groups.

To all the other colleagues and members of the HIA4SD family, Herminio, Andrea Swiss, Andrea American, Anaïs, Isaac, Belinda, Fritz, Georg, Rebecca, Adithya and Junia, it was a great pleasure to meet you in the students' office, share the same accommodation and commune together. The journeys of some people were painful for the others, which shows the affection that existed in the group. This thesis certainly bears your contributions in whatever way you can, so thank you.

To my fellow doctoral students, thank you for the common meals, the hiking, the different moments of sharing in the offices during the breaks of the courses. Keep all your spirit of solidarity which is profitable to all humans on earth. I particularly thank Nina, Paco, Apolline, Louise (my office neighbour), Isaac Namango, Katrina, Laura, Louise, Marta, Mathurin, Michael, Nadja, my Burkinabe brothers Moise and Eric. I want you to know that you have added something to my doctoral training, thank you.

My dear mother Christine Mensch. Yes, I recognise all your professionalism and your humanism in welcoming us, showing us the way and facilitating our integration into the STPH. You who welcome the students with kindness and listen to them attentively to help them, you are like a mother to me. Courage in what you do and thank you very much.

To all my friends and colleagues, Francis, Alinsa, Rodrigue, Maurice, Achille, Joseph, Armel, Philippe, Valentin (known as the parent, Ivorian in Switzerland), Josiane, Judith, thank you for having supported, advised and helped me. This work is also yours. Receive all my thanks and recognition.

To my mother Kirga SIOGO, for your love and your sacrifices for all your children; may God bless and strengthen you. May God bless you and strengthen you. Find in this work, the crowning of your efforts and your prayers for my success.

To my dear and tender wife Félicité SAWADOGO; you who bore the burden of my absence and who managed our home with as much ardour as love during these formative years. This work is yours. Receive it as a symbol of gratitude for your understanding, your love and your unfailing support. This work should also be seen as a symbol of the deep love I have for you. Through this thesis, please accept my deepest gratitude and may God protect our love and make us enjoy the fruits of our efforts. Amen!

To my brothers and sisters Sanmpala, Nikiémpoko, Guédoma, Kibsiraogo, Poko, Toukoumnogo, Zindinogo, Wendwaoga, Wendnonga, M Wilfrid for their invaluable support. May God Almighty bless you.

To my darlings Hélène BANSE, Caroline COMPAORE, for your constant availability and your prayers. May this work console you, may it be a testimony of success and may it inspire you to do better; receive this work as a word of satisfaction.

To my children, Epiphane, Auguste, Aurélien, Eunice, Sylvanus, Benoît and Eleonora, you who were sometimes deprived of paternal contact during the years I spent abroad, find here all my immeasurable love.

His Majesty the NAABA KOUGRI, Tansoba of Pelga, PhD in Epidemiology, you who succeeded our father, despite the multiple solicitudes linked to your social rank, have been able to give me your support beyond my expectations. This work is the testimony of your efforts, may it galvanize you to do the same for my brothers and sisters under your care.

Hyacinthe Raogo ZABRE

Table of Contents

List of Figures

List of Tables

List of Abbreviations

AGA	AngloGold Ashanti Mining Company
BA	Benefit Analysis
CA	Cost Analysis
CBA	Cost-Benefit Analyis
CEA	Cost-Effectiveness Analysis
CMA	Cost Minimisation Analyses
CSR	Corporate Social Responsibility
CUA	Cost-Utility Analysis
DHS	Demographic and Health Survey
EA	Economic Assessment
EcIA	Economic Impact Assessment
EDH	Environmental Determinant Of Health
EIA	Environmental Impact Assessment
EITI	Extractive Industries Transparency Initiative
EPFI	Equator Principles Financial Institutions
FQML	First Quantum Minerals Limited
GDP	Gross Domestic Product
GIS	Geographic Information System
HDI	Human Development Index
HIA	Health Impact Assessment
HIA4SD	Health Impact Assessment for Sustainable Development
HIV	Human Immunodeficiency Virus
IA	Impact Assessment
IAIA	International Association for Impact Assessment
ICMM	International Council on Mining And Metals
IFC	International Finance Corporation
IPIECA	International Petroleum Industry Environmental Conservation Association
IRSS	Institue de Recherche en Science de la Santé
KII	Key Informant Interview
LMIC	Low- and Middle-Income Country
MWQ	Mean Wealth Quintile
NREP	Natural Resource Extraction Projects

ODK	Open Data Kit
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
r4d	Research for Development
SD	Standard Deviation
SDC	Swiss Agency for Development and Cooperation
SDG	Sustainable Development Goal
SEA	Strategic Environmental Assessment
SES	Socioeconomic Status
SIA	Social Impact Assessment
SIA	Social Impact Assessment
SNSF	Swiss National Science Foundation
SSA	Sub-Saharan Africa
STI	Sexually Transmitted Infection
Swiss TPH	Swiss Tropical and Public Health Institute
UN	United Nations
USD	United States Dollar
USA	United States of America
WHO	World Health Organization
WP	Work Package
ZDHS	Zambia Demographic and Health Survey

1. Introduction

1.1. Resource Extraction and Sustainable Development

1.1.1. Mining and economic development

The resource curse, also known as the "*paradox of abundance*", makes the negative link between a country's natural resource wealth and its impact on the well-being of the population [1, 2]. For example, between 1960 and 1990, the gross domestic product (GDP) per capita of mineral-rich countries increased by 1.7% against 2.5 to 3.5% for other countries [3].

Several studies explain this curse by the negative effect of the natural resource extraction projects (NREPs) on the governance of producing countries. Indeed, the abundance of oil and other minerals may act as an obstacle to the emergence of democratic institutions, according to an empirical analysis based on a sample of 113 countries between 1971 and 1997 [4]. Similarly, governance in these countries is marked by little funding for important development sectors such as education and health [5], a reduction in the competitiveness of the non-resource sectors due to high foreign exchange rates (called "Dutch disease") [6], and more frequent violent conflicts [7, 8]. More generally, the presence of multinational mining companies is linked to increased food insecurity in Africa [9]. For example, in Mali and Ghana, there was an increase in the cost of living and exposure to various diseases and loss of agricultural land [10-13]. In the health sector, the costs of uncontrolled infectious diseases can reduce the wealth of households affected by mining [10, 14]. Even worse, in Africa, health appears to be marginalised and exploited in favour of NREP interests [13].

Despite this circumstantial evidence, there is no clear causal link between an abundance of natural resources and a "curse"; on the contrary, natural resource, when properly managed, have the potential to be an economic blessing for their country [15-17]. Other studies establish the "blessings" of natural resources in certain countries in Africa under good governance conditions [18-20]. It seems that it is not the abundance of natural resources that hinders economic development but the heavy dependence on natural resources with little diversification of the rest of the economy [19]. The example of Botswana is quite illustrative: thanks to sustainable fiscal policies, solid institutions and good governance taking into account future generations, this country has been able to benefit from the natural resources, moving from one of the five poorest countries during the 1966 independence [21], to lower-middle-income in 1989, then to upper-middle-income in 1998 [21-24]. Similarly to Botswana, in Norway, Sweden, and Finland, as well as in Zambia, the presence of mines was associated with increased employment, household expenditures, lower unemployment rates and a higher average standard of living [25-27].

Whereas the resource curse has been widely discussed in the scientific literature, the health systems perspective on the link between natural resource abundance and socioeconomic development has received little attention. Given the strong correlation between economies and health systems in Africa [28] there is a strong need to better understand how an NREP contributes to local economies through its effects on population health.

1.1.2. The 2030 Agenda for Sustainable Development

In 2016, the United Nations committed itself to the 2030 Agenda for Sustainable Development, which aims to promote development in three dimensions: social, environmental and economic [29]. The economy, therefore, plays a key role in this program, as sustained economic growth and development, as well as financial stability are needed to achieve the Sustainable Development Goals (SDGs). The extraction of natural resources such as minerals, metals, oil and gas could contribute to the SDGs in two ways. First, by contributing to the financing needs of the SDGs to meet the enormous annual financing needs for achieving the SDGs, estimated at USD 5-7 trillion globally, of which 3.3-4.5 trillion are needed in developing countries [30-33]. Hence, taxes and royalties paid by natural resource extraction projects (NREPs) are essential sources of income in resource-rich low- and middle-income countries (LMICs) to work towards all SDGs [34]. Second, the creation of jobs (direct and indirect) (SDG8) and the development of the local economy in the mining areas are additional sources of local financing that hold the potential to reduce poverty (SDG1) in communities affected by resource extraction projects [35]. In addition, the improvement of social services and public infrastructures in project areas can promote health and wellbeing (SDG3), access to education (SDG4) and local industry, innovation and infrastructure (SDG9) [35, 36].

But in order to make the extractive industry an ally in working towards the achievement of the SDGs, potentials negative impacts of NREPs need to be mitigated along with the project development. This highlights the need for prospective impact assessment and public-private partnerships (SDG17) [37, 38]. This holds particularly true for remote project areas in LMICs, where the extractive industries could make a significant contribution to local, sustainable development [39-43]. Botswana and Malaysia are examples of countries where resource wealth significantly contributed to work towards the SDGs [44].

1.1.3. Africa's dependence on resource extraction projects

Poverty in Africa coexists with an abundance of natural resources estimated at over 30% of the world's mineral reserves and over 60 different metals [45]. While natural resources profits represented 1.70% of GDP globally in 2015, it represented 8.00% for sub-Saharan Africa (e.g. 6.90% in Tanzania; 13.10% in Mozambique; 17.10% in Ghana; and 21.00% in Burkina Faso) [46].

This shows, on the one hand, that the extractive sector plays an important role for the economies of resource-abundant countries in Sub-Saharan Africa. On the other hand, a dependence of many African countries on the extractive industries. In addition, these countries are also confronted with the phenomenon of "Dutch disease") (see Chapter 2) [47, 48]. Hence, it is not surprising that the presence of natural resources constitutes a curse rather than a development opportunity, according to a study of 47 countries in 2016 [49].

Even worse, NREPs could have negative effects on the governance of producing countries, constituting a major obstacle to the development of these countries. According to a study of 110 countries from 1990 to 2017, one of the solutions to natural resource dependence appears to be the development of the public sector, privatisation and the development of national tax systems, improving institutions and the political environment [48, 50-53]. Despite the continent's wealth of natural resources and potentially negative impacts, the lack of mine impact assessments is a gap that needs to be filled urgently [54-56].

1.1.4. The importance of rural development for achieving the SDGs

Poverty has a rural face because 80% of the extreme poor and 75% of the moderate poor live in rural areas [57]. This observation shows that in order to reduce poverty, emphasis should be placed on interventions targeting rural areas. Indeed, the lack of infrastructure and poor access to basic social services (school, health, roads, electricity, etc.) and media (radio, television, etc.) foster and maintain poverty in rural areas, compromising the achievement of the SDGs 1 [58].

In addition to being rural, poverty is believed to be due to factors at several levels, but especially at the household and community level [59]. Since the economy has a direct impact on all areas of life (economic, social, cultural, political and environmental), the promotion of economic development at the local level in rural areas with resource extraction activities could reduce poverty and accelerate the achievement of the SDGs, in particular SDG 1 (End poverty in all its forms everywhere) and SDG 12 (Ensure sustainable consumption and production patterns, including target 12.2: to achieve the sustainable management and efficient use of natural resources).

Given that one of the criticisms of the Millennium Development Goals (MDGs) in 2000 was that the process and targets were mainly top-down, the SDGs also promote bottom up-approaches such as partnerships between the private sector and local governments (SDG 17) [60, 61]. In this sense, the United Nations (UN) advocates ensuring that the local dimension is prioritised and successfully implemented to reach the SDGs by promoting inclusive development and effective rural development strategies [61, 62].

Promoted in the 1970s and institutionalized in some states, impact assessment (IA) has shown strong evidence of utility [63]. Indeed, IA is essential to better identify the adverse outcomes of large projects, minimizing risk while maximizing profit. Several IA strategies are developed and implemented, such as health impact assessment (HIA), Social Impact Assessment (SIA), Strategic Environmental Assessment (SEA), and Environmental Impact Assessment (EIA) [64]. Thus, the application of cost-benefit analyses in all possible impact areas of NREPs will make it possible to know to understand the mining and environment phenomenon linking to the overall economic impact on the rural communities [65].

This knowledge will then allow informed decisions by national and local governors to correct any negative effects and ensure economic development with the benefits derived from NREPS. Unfortunately, these studies are not yet sufficiently conducted, leaving uncertainty about the real impact of NREPs on reducing rural poverty towards the achievement of the 2030 SDGs.

1.2. Health Determinants, NREPs and the SDGs

Health is influenced by several factors (e.g. personal, socioeconomic, environmental) or determinants [66, 67]. Health determinants are represented in more than half of these SGDs [26]. Hence, when considering the interlinkages between the SDGs and extractive projects, it becomes obvious that NREPs hold considerable potential to promote the 2030 Agenda for sustainable development in several ways. However, health determinants could be affected (both positively and negatively) by natural resource extraction [68].

On the positive side, infrastructure developed by mines (e.g., health, education, roads, dams and drinking water sources, improved farmland, sports and recreation facilities) contribute to higher levels of education (SDG4), access to quality health services (SDG3) and drinking water (SDG6), and household income (SDG1). Also, job creation can reduce poverty (SDG1) and malnutrition (SDG2), improve housing (SDG11), improved access to clean water and sanitation [35, 36, 69-72]. An indistinguishable benefit appears to be the tax revenues and fees paid by NREPs that are essential for local and national governments to work towards all the SDGs [34].

On the negative side, first, NREPs are likely to induce immigration, putting a strain on local health systems (SDG3, SDG10 and SDG11), sanitation and water supply systems (SDG6) and food security (SDG2) [73-76]. Second, ecosystem change (environmental degradation) can be associated with altered patterns of vector-borne diseases [71, 77-79], exposure to hazardous emissions [80-82], and negative mental health effects (all SDG3) [55, 83]. Finally, NREPs often lead to societal changes, local conflicts and injustices (SDG16), problems related to equality (SDG10) and gender equity (SDG5) compromising health as defined by WHO [84-90].

While NREPs are profit-making ventures (both for the private sector and for countries), natural resources are generally non-renewable, and thus, the contributions of these mines are limited in time linked to the duration of exploitation. At the same time, their potential negative impacts (e.g. environmental degradation, soil and water pollution) may persist from one generation to the next, compromising the health of future generations [91].

Given the strong link between the economy and health, and how vital these two areas are for the SDGs, the action of NREPs on health systems and local economies could essentially contribute to the achievement of the SDG agenda. Although some good practices of NREPs have been successful in promoting local development. However, most studies were either focused on a single area of impact (e.g. environmental, social) [92, 93] or were partial (e.g. cost or benefit studies) [94, 95], making it impossible to know the real economic impacts of natural resource extraction on local communities and thus imposing cost-benefit type assessments.

1.2.1. Socioeconomic inequities

The Universal Declaration of Human and People's Rights has received equality between men [96]. Health being a right, beyond equality, equity appears to be the approach to be privileged to take into account the differences of needs of men [97, 98]. Indeed, equity is defined as “the absence of avoidable or remediable differences among groups of people, whether those groups are defined socially, economically, demographically, or geographically” [99]. Equity is closely associated with three determinants of health that define an individual’s socioeconomic status (SES): health care, environmental exposure, and health behaviour” [100, 101]. According to Dr Martin Luther King Jr in 1966, “of all the forms of inequality, injustice in health care is the most shocking and inhumane” [102]. At all these levels, the equity of providing care to all according to need is being compromised. Several observations illustrate that socioeconomic inequities exist from one individual to another, from one community to another, from one country to another or even from one continent to another [54, 56, 103, 104]. This context is under the current influence of covid-19, which exacerbates socioeconomic inequities in many contexts [105].

In the context of extractive industries, the fact that their exploitation affects the environment and health of communities differently (see Section 1.3 Mining and the economic determinants of health), without always bringing more economic resources to these impacted communities, represents a socioeconomic inequity of health (e.g. health care, environmental exposure and health behaviours) [106, 107]. It has been shown that mining increases inequalities in producing districts compared to non-producing districts [106].

However, the increase in socioeconomic and health status is not accompanied by an increase in appropriate health care provision or response. Thus, continuing to provide the same health care services regardless of mine exposure is equitable horizontally but inequitable vertically [108]. Unfortunately, due to the lack of economic evaluation of mines, it is not known to what extent mine-impacted households or communities need additional assistance than non-impacted ones. Furthermore, it is not impossible to know the extent to which actions are taken to mitigate potential impacts outweigh the losses induced by the mines. This will perpetuate inequities and compromise the reduction of inequality within and among countries (SDG 10).

Impact assessments present themselves as an opportunity on the doorstep of policy makers and development actors to quantify the socioeconomic impacts of mining before implementing appropriate remedial measures [54, 55, 81, 109, 110].

1.2.2. Burden on health systems in mining areas

Despite the potential financial support for health systems and other public services from the extractive industry in producing countries, it has been widely shown that also adverse effects on health outcomes exist at the national, local and household levels due to environmental, social, demographic, institutional and political impacts [111]. These effects, which are often unequally distributed across population groups, have the potential to ultimately increase the resources used by the health sector principally by higher treatment costs through an augmented number of cases. For example, according to a review of 52 studies, industrial extraction of natural resources have the potential to exacerbates poverty and worsens health in specific population groups [112, 113]. This is also linked to the fact that NREPs can lead to environmental destruction and pollution, which increases the incidence of more than 80% of the major diseases covered by the World Health Organization (WHO) [114]. This is the case for respiratory diseases, vector-borne diseases such as malaria, and mental health [114-116]. Second, resource extraction is often accompanied by exposure to chemicals, physical trauma to workers, and bloody conflicts [115]. Third, societal changes such as shifting populations, migration, and high population density, among others, increase the risk of the human immunodeficiency virus (HIV), addiction, traffic accidents, and mental illness [117]. Also, rapid migration often affects the availability of safe water, food, and housing, which are essential for a healthy life [49]. Fourth, agricultural, livestock and fishing activities, which are the main livelihoods in Africa, may decline due to lack of competitiveness (Dutch disease) [49], thus reducing the availability of food and leading to malnutrition [29,39]. Malnutrition, being the most important cause of morbidity and mortality in Africa, costs 11% of GDP on this continent [118].

For the local health system, the management of potential additional health problems requires resources (human, infrastructural and financial), potentially constituting a heavy economic burden. Apart from costs incurred by the health sector, these additional health problems may put financial strains on households through out-of-pocket expenditures for treatment and also through indirect expenses related to lost income due to disabilities. The absence of health insurance in countries rich in natural resources aggravates these economic consequences on households and health services [119].

In the face of this health burden, it is still unclear to what extent the revenues from NREPs offset the costs of this burden, yet whether there is a real benefit requiring cost-benefit assessments [65].

1.3. Impact Assessment

From the previous chapters, it is clear that there is a strong link between the economy and public health and health systems in Africa [94]. In this context of potential two-way impacts of NREPs on the environment, society, economy and health, systematic approaches need to be applied at the feasibility stage of any large infrastructure development in order to move from "being opportunistic to being strategic and sustainable" [55].

1.3.1. Health impact assessment

One such approach to minimise potential negative impacts of NREPs is health impact assessment (HIA), which was recently defined as "a process which systematically judges the potential, and sometimes unintended, effects of a project, program, plan, policy, or strategy on the health of a population and the distribution of those effects within the population. HIA generates evidence for appropriate actions to avoid or mitigate health risks and promote health opportunities. HIA guides the establishment of a framework for monitoring and evaluating changes in health as part of performance management and sustainable development" [120]. HIA allows to assess and anticipate the impacts of policies, plans and projects in various areas of life on health [121, 122]. Hence, HIA provides decision-makers with tangible information that is essential for determining appropriate strategies for prevention, control and promotion of health throughout the project cycle [123]. Given the critical role of HIA in achieving the health-related SDGs, this strategy is increasingly being adopted as a legal requirement in developed countries [124]. In contrast, not a single African government has rigorously institutionalised HIA in their legal frameworks regulating impact assessment [56].

In addition to weak institutionalisation of HIA in most countries [110], HIA quantification of impacts in HIA is often insufficient. Indeed, Veerman et al. showed that, in 2005, out of 115 HIAs only 14% quantified health impacts [125]. This is unfortunate since the quantification of health impacts would allow the application of economic analysis to, for example, compare costs and benefits of a health intervention proposed for impact mitigation in a mining area. When taking into account how influential economic data can be in decision-making processes, this points to a missed opportunity (section 1.1.6.Economic considerations in HIA).

1.3.2. Economic considerations in HIA

The potential economic burden of NREPs on health clashes with the financial benefits to national and local socioeconomic systems. In fact, economic and financial considerations are almost absent from EIAs and HIAs [56, 126]. Despite this, financial impact assessments bear the potential to guide the optimisation of NREPs' profitability and positive spillovers to populations by assessing potential gains from improved health and availability of its workers. For example, a study of the AngloGold Ashanti Mining Company (AGA) in Ghana in 2006 found that the implementation of an internal health service, including malaria case management, helped to reduce costs from USD 55,000 to USD 510 from 2006 to 2008, resulting in an annual saving of USD 54,490 [127]. Finally, financial impact assessment is essential to evaluate and promote fundamental economic sustainability concepts such as long-term distributive effects, the polluter-pays principle [128], the precautionary principle [129], and non-renewable resources [111].

The absence of economic considerations in IA, despite their importance and the evidence of economic impacts of NREPs on health, deprives policymakers and development actors of key information for strategic health and mining choices to drive the health sector towards the SDGs. To fill this gap, impact assessments, in addition to needing to be conducted, must also include economic analyses in the health sector [53-56, 130].

1.3.3. Identified research gaps

Extractive resources are an important part of the economies of producing countries, but the economy, in turn, is fundamental to health. In addition, just as NREPs support health with their revenues, due to their direct impacts on health or indirect impacts on its determinants (e.g. environmental, socioeconomic), these same NREPs constitute an economic burden for it (health). Therefore, the lack of information on the economic impacts of NREPs on health is a serious gap to be filled in the context of the SDGs 2030. It is therefore imperative to know to what extent these impact assessments are carried out and to what extent economic analyses are included.

Especially in sub-Saharan Africa, NREPs provide financial support to the health sector. But the extent, nature and distribution of this funding remain largely unknown. The lack of public information from these companies masks their contribution to health and is a potential source of unexplored health funding [56, 126]. Hence there is a need to evaluate financial flows (benefits) for the health system from NREPs.

On the other hand, NREPs cause health expenditures related to the management of the diseases they impact [115, 116]. The costs of these health expenditures are typically unknown and therefore not taken into account in policy discussions. Thus, in the face of the above-mentioned "benefits", an assessment of NREP costs is necessary for a global analysis of their impacts on public health.

Leading by example, peer learning and sharing of best practices are often strategies used to get newcomers to adopt methods and practices that might otherwise appear sceptical and to change more easily [131, 132]. In the field of mining, conducting impact assessments with the active involvement of the mine itself is consistent with these visions. Socioeconomic health impact assessments should be carried out on these "model" mines and made into a case study for other mines and other countries [133].

The potential economic interest of the NREPs in the implementation of health measures for its workers [127], which could engage these projects in the investment in local health, is not highlighted in the producing countries and requires case study analysis.

In summary, there is a lack of knowledge about the extent to which NREPs impose a financial burden on health systems [56, 126]. At the same time, economic considerations constitute a key part of policy decisions to promote sustainable health development. This lack of information makes it difficult, if not impossible, to integrate the economic impacts of NREPs on health into evidence-based debates. In addition, best practice examples or case studies are often not known to mine impact assessment stakeholders in policy dialogues. This gap in the evidence highlights the need for economic assessments of NREPs alongside HIA of NREPs in producing countries.

The aim of this study is to evaluate and critically discuss the economic benefit and costs imposed by NREPs on the health system and the population in Burkina Faso, Ghana, Mozambique and Tanzania, and in Zambia for the case study.

1.4. Aim and Objectives of the PhD Project

The primary objective of this PhD project was to assess the associations between resource extraction projects and the socioeconomic determinants of health in sub-Saharan Africa. More specifically, based on identified research gaps, five distinct objectives were initially pursued in this PhD project:

- Objective 1: To systematically review the inclusion of economic analysis in impact studies of natural resource extraction projects

- Objective 2: To assess the overall financial flow from NREPs to the public sector and to determine how funds are re-distributed to the different public sectors, with emphasis on the health sector
- Objective 3: To evaluate the costs of illnesses that were identified as being attributable to the presence of NREPs
- Objective 4: To carry out cost-benefit analyses of specific health interventions that were implemented by NREPs to protect their workforce

But due to the many difficulties faced in accessing financial data from extractive industry projects in the project countries (this aspect is further discussed in chapter 10.3) and challenges faced with data quality for calculating illnesses attributable to NREPs (this was a research objective that was pursued by another PhD candidate on the same project), objectives 2, 3 and 4 had to be abandoned. Fortunately, the opportunity came up to collect primary health and economic data in the context of the HIA of a large copper mine in Zambia (see Chapter 3 & 4), which allowed adding two alternative research objectives:

- Objective 5: To assess long-term effects on selected socioeconomic determinants of health in households affected by a large mining project
- Objective 6: To evaluate the impact of a large mining project on household wealth

1.5. Overall Methodology

1.5.1. Framing research project

This PhD thesis is embedded within a large research project entitled: " Health impact assessment for engaging natural resource extraction projects in sustainable producer region" (short title: Health Impact Assessment for Sustainable Development (HIA4SD)). The HIA4SD Project is a 6-year multi-country project financed by the Swiss Program for Research on Global Issues for Development (r4d Programme; www.r4d.ch), which is a joint funding initiative of the Swiss National Science Foundation (SNSF) and the Swiss Agency for Development and Cooperation (SDC) [134, 135]. The overarching goal of the HIA4SD Project is to induce a policy dialogue at the national and international level on whether or not current regulatory approaches to impact assessment of natural resource extraction projects in Africa promote sustainable development in four African countries, namely Burkina Faso, Ghana, Mozambique, Tanzania [135]. Figure 1-1 shows the location of the selected mining in the four countries.

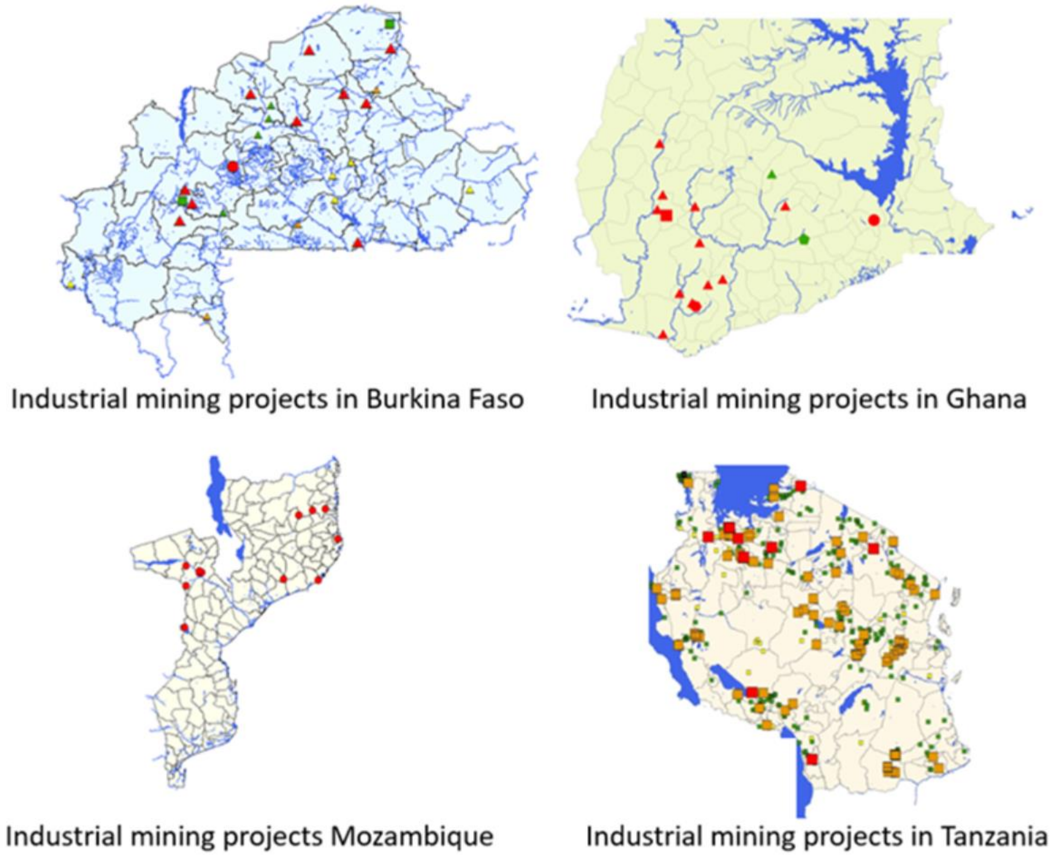

Figure 1-1: Location of ongoing large industrial mining projects in the four project countries

Table 1-1: PhD student and PI in the HIA4SD Project

Partner Institute	Name (role)	PhD Students (and topic)
Switzerland Swiss Tropical and PublicHealth Institute	PD Dr. Mirko Winkler (PI, overall project coordinator)	Andrea Leuenberger (Social determinants of health) and Dominik Dietler (Environmental determinants of health)
Burkina Faso Institut de Recherches enSciences de la Santé	Prof. Serge Diagbouga (Co-PI)	R Hyacinthe Zabré (Health economics)
Ghana University of Health andAllied Sciences	Prof. Fred Binka (Co-PI)	Belinda Nimako (Health systems)
Mozambique Centro de Investigação emSaúde de Manhiça	Dr. Eusebio Macete(Co-PI)	Herminio Cossa (Childhood and maternal health)
Tanzania Ifakara Health Institute	Dr. Fredros Okumu (Co-PI)	Isaac Lyatuu (Morbidity and mortality)

In total, six PhD candidates pursued their research in the frame of the HIA4SD project, each focusing on different, complementary topics (see Table 1-1). In addition to allowing each candidate to better understand the various research themes covered by HIA4SD Project, this approach was conducive for the triangulation of results. An important implication of the mixed-methods research approach pursued was that the six PhD students worked closely together for the data collection in the different countries, as well as for the interpretation of the research findings. Consequently, there are several publications to which the current PhD project contributed (see Table 1-2), in addition to the three main papers of this PhD thesis.

1.5.2. The Trident project in Zambia

The Trident Copper Project, located in the Kalumbila District of the North West Province of Zambia, is a large-scale mining project operated by First Quantum Minerals Limited (FQML) [136, 137]. The feasibility studies of the Trident Copper Project (2009-2011) comprised a comprehensive HIA. As an outcome of the HIA, the project implemented several health and socioeconomic interventions targeting, for example, the prevention of sexually transmitted diseases, improvement of drinking water sources, girls' empowerment and the strengthening of health infrastructure in communities directly impacted by the mine [138].

The monitoring and evaluation components of the HIA included repeated cross-sectional health surveys every four years (2011, 2015 and 2019). For the last survey round in 2019, the PhD candidate actively contributed to the development of the survey tools and implementation of the survey in Solwezi district, Zambia. The cross-sectional surveys used a comprehensive approach to health by covering a broad range of socioeconomic, behavioural and health indicators [139]. Household-level socioeconomic indicators, such as ownership of assets, cooking fuel, housing materials and drinking water infrastructure, were comparable to data generated in Zambia's Demographic and Health Surveys (DHS) [140]. In addition, both households impacted by the Trident project and households in comparison communities were sampled.

The wealth of data generated in the context of the Trident project made it possible to study the socioeconomic impacts of the mine development over time, representing an excellent opportunity for this PhD project investigating the associations between mining projects and socioeconomic health determinants in sub-Saharan Africa.

1.6. Outputs of the PhD Thesis

Table 1-2: List of publications on which PhD candidate has been either the leading author or co-author

Title	Authors	Country	Year	Outlet	Role	Status
Scoping review of the inclusion of economic analysis in impact studies of natural resource extraction projects (chapter 4 of this thesis)	**Hyacinthe R. Zabré,** Dominik Dietler, Serge P. Diagbouga, Mirko S. Winkler		2021	Impact Assessment and Project Appraisal	First author	Published
Changes in socioeconomic determinants of health in a copper mine development area, northwestern Zambia (chapter 5 of this thesis)	**Hyacinthe R. Zabré**, Astrid M. Knoblaucha, Serge P. Diagbouga, Günther Fink, Milka Owuord, Kennedy Nduna, Marcus Chisanga, Gertrude Musunka, Mark J. Divall, Mirko S. Winkler, Andrea Farnhama	Zambia	2021	The Extractive Industries and Society	First author	Published
Changes in household wealth in communities living in proximity to a large-scale copper mine in Zambia (chapter 6 of this thesis)	**Hyacinthe R. Zabré,** Andrea Farnhama, Serge P. Diagbouga, Günther Fink, Mark J. Divall, Mirko S. Winkler, Astrid M. Knoblauch	Zambia	2021	Resources Policy	First author	Published
Investigating health impacts of natural resource extraction projects in Burkina Faso, Ghana, Mozambique, and Tanzania: Protocol for a mixed-methods study	Andrea Farnham, Hermínio Cossa, Dominik Dietler, Rebecca Engebretsen, Andrea Leuenberger, Isaac Lyatuu, Belinda Nimako, **Hyacinthe R Zabré,** Fritz Brugger, Mirko S Winkler	Burkina Faso, Ghana, Mozambique, Tanzania	2020	JMIR Research Protocols	Co-author	Published
Community health impacts of the Trident Copper mine Project in Northwestern Zambia: Results from Repeated Cross-Sectional Surveys	Astrid M Knoblauch, Colleen Archer, Andrea Farnham, **Hyacinthe R Zabré,** Milka Owuor, , Kennedy Nduna, Marcus Chisanga, Leonard Zulu, Gertrude Musunka, Jürg Utzinger, Mark J. Divall, Günther Fink and Mirko S. Winkler	Zambia	2020	International Journal of Environmental Research and Public Health	Co-author	Published
“It is like we are living in a different world”: Health equity in communities surrounding industrial mining sites in Burkina Faso, Mozambique and Tanzania	Andrea Leuenberger, Olga Cambaco, **Hyacinthe R Zabré,** Isaac Lyatuu, Sonja Merten and Mirko S. Winkler	Burkina Faso	2020	International Journal of Environmental Research and Public Health	Co-author	Published
Exploring the impact of mining on health and health service delivery: Perceptions of key informants involved in three different gold mining communities in Burkina Faso	Gianna Himmelsbach, Mirko S. Winkler, **Hyacinthe R Zabré**	Burkina Faso	2021	Master’s thesis	Advisor	Draft

1.7. References

1. Busse M, Gröning SJPC: The resource curse revisited: governance and natural resources. 2013, 154(1):1-20.
2. Nwonwu FOC: The paradox of natural resource abundance and widespread underdevelopment in Africa. *International Journal of African Renaissance Studies - Multi-, Inter- and Transdisciplinarity* 2016, 11(2):52-69.
3. Meijia PX, Castel V: Could Oil Shine like Diamonds? How Botswana Avoided the Resource Curse and its Implications for a New Libya. In.: Banque africaine de developpement; 2012: 16.
4. Ali MSB, Krammer S: Economic Development in the Middle East and North Africa: Springer; 2016.
5. Cockx L, Francken N: Extending the concept of the resource curse: Natural resources and public spending on health. *Ecol Econ* 2014, 108:136-149.
6. Brahmbhatt M, Canuto O, Vostroknutova E: Dealing with Dutch disease,Washington, DC. In: *The world Bank.* World; 2010: 7.
7. Hellendorff B: Ressources naturelles, conflits et construction de la paix en Afrique de l'Ouest: GRIP Brussels; 2012.
8. Busse M, Gröning S: The resource curse revisited: governance and natural resources. *Public Choice* 2013, 154(1):1-20.
9. Wegenast T, Beck J: Mining, rural livelihoods and food security: A disaggregated analysis of sub-Saharan Africa. *World Development* 2020, 130:104921.
10. Viliani F, Edelstein M, Buckley E, Llamas A, Dar OJTEI, Society: Mining and emerging infectious diseases: Results of the Infectious Disease Risk Assessment and Management (IDRAM) initiative pilot. *Extr Ind Soc* 2017, 4(2):251-259.
11. Chuhan-Pole P, Dabalen AL, Land BC, Sanoh A, Smith G, Tolonen AK, Aragaon F, Andersson CME, Hall OD, Kotsadam KA: Socioeconomic impact of mining on local communities in Africa. In. Washington, DC: The World Bank; 2015.
12. Korah PI, Nunbogu AM, Cobbinah PB, Akanbang BAA: Analysis of livelihood issues in resettlement mining communities in Ghana. *Resour Policy* 2019, 63:101431.
13. Schrecker T, Birn A-E, Aguilera M: How extractive industries affect health: Political economy underpinnings and pathways. *Health & Place* 2018, 52:135-147.
14. Tonts M, Plummer P, Lawrie M: Socio-economic wellbeing in Australian mining towns: A comparative analysis. *J Rural Stud* 2012, 28(3):288-301.

15. Gerelmaa L, Kotani K: Further investigation of natural resources and economic growth: Do natural resources depress economic growth? *Resources Policy* 2016, 50:312-321.
16. Sterck O: Natural resources and the spread of HIV/AIDS: curse or blessing? *Social Science & Medicine* 2016, 150:271-278.
17. Canuto O, Cavallari M: Natural Capital and the Resource curse. 2012.
18. Brosio G, Singh RJ: Revenue Sharing of Natural Resources in Africa: Reflections from a Review of International Practices. 2014.
19. Brunnschweiler CN, Bulte EH: The resource curse revisited and revised: A tale of paradoxes and red herrings. *Journal of environmental economics and management* 2008, 55(3):248-264.
20. Fenske J, Zurimendi I: Oil and ethnic inequality in Nigeria. *Journal of Economic Growth* 2017, 22(4):397-420.
21. Mogalakwe M, Nyamnjoh F: Botswana at 50: democratic deficit, elite corruption and poverty in the midst of plenty. *Journal of Contemporary African Studies* 2017, 35(1):1-14.
22. Meija P, Castel V: Could oil shine like diamonds? How Botswana avoided the resource curse and its implications for a new Libya. In.: AfDB Chief Economist Comples, Tunis, Tunisia: The African Development Bank; 2012.
23. Sarraf M, Jiwanji M: Beating the resource curse: the case of Botswana. 2001.
24. Lewin M: Botswana’s success: Good governance, good policies, and good luck. *Yes Africa Can* 2011, 81.
25. Frederiksen A, Kadenic MD: Mining the North: Local impacts. *Labour Econ* 2020, 63:101790.
26. Loayza N, Teran AMY, Rigolini J: Poverty, inequality, and the local natural resource curse. In.: World Bank, Washington, DC; 2013.
27. Lippert A: Spill-overs of a resource boom: Evidence from Zambian copper mines. In., vol. 131: Oxford centre for the analysis of resource rich economies, University of Oxford; 2014.
28. Moatti J-P, Ventelou B: Économie de la santé dans les pays en développement des paradigmes en mutation. 2009, 60(2):241-256.
29. United Nations GAOWG: TST ISSUES BRIEFS - A compendium of issues briefs prepared by the United Nations inter-agency technical support team for the United

Nations General Assembly Open Working Group on Sustainable Development Goals. In. Rio; 2014.

30. United Nations: World investment report 2014, investing in the SDGs: an action plan. In., vol. 2019. New York and Geneva: United Nations; 2014.
31. World Development Indicators [https://datacatalog.worldbank.org/dataset/gdp-ranking]
32. GDP (current US$) | Data [https://data.worldbank.org/indicator/NY.GDP.MKTP.CD]
33. Horn P, Grugel J: The SDGs in middle-income countries: Setting or serving domestic development agendas? Evidence from Ecuador. *World Development* 2018, 109:73-84.
34. Otto J, Andrews CB, Cawood F, Doggett M, Guj P, Stermole F, Stermole J, Tilton J: Mining royalties : a global study of their impact on investors, government, and civil society (English): Washington, DC : World Bank Group.; 2006.
35. von der Goltz J, Barnwal P: The Local Wealth and Health Effects of Mining in Developing Countries. In.; 2014.
36. Langston JD, Lubis MI, Sayer JA, Margules C, Boedhihartono AK, Dirks PHGM: Comparative development benefits from small and large scale mines in North Sulawesi, Indonesia. *Extr Ind Soc* 2015, 2(3):434-444.
37. World Bank: The growing role of minerals and metals for a low carbon future. Washington D.C.: World Bank Group; 2017.
38. UNDP IFCI, IPIECA: Mapping the oil and gas industry to the SDGs: An Atlas. In.: IFC, IPIECA, UNDP; 2017.
39. Mawdsley E: From billions to trillions: financing the SDGs in a world 'beyond aid'. *Dialogues Hum Geogr* 2018, 8(2):191-195.
40. Scheyvens R, Banks G, Hughes E: The private sector and the SDGs: The need to move beyond 'business as usual'. *J Sustain Dev* 2016, 24(6):371-382.
41. Stafford-Smith M, Griggs D, Gaffney O, Ullah F, Reyers B, Kanie N, Stigson B, Shrivastava P, Leach M, O'Connell D: Integration: the key to implementing the Sustainable Development Goals. *Sustain Sci* 2017, 12(6):911-919.
42. Aust V, Morais AI, Pinto I: How does foreign direct investment contribute to Sustainable Development Goals? Evidence from African countries. *J Clean Prod* 2020, 245:118823.

43. Ike M, Donovan JD, Topple C, Masli EK: The process of selecting and prioritising corporate sustainability issues: Insights for achieving the Sustainable Development Goals. *J Clean Prod* 2019, 236:117661.
44. Venables AJ: Using Natural Resources for Development: Why Has It Proven So Difficult? *Journal of Economic Perspectives* 2016, 30(1):161-184.
45. United Nations: Minerals and Africa's development: the international study group report on Africa's mineral regimes. In. Addis Ababa: Economic Commission for Africa; 2011.
46. Group WB: Total des bénéfices tirés des ressources naturelles (% du PIB). In.; 2015.
47. Mulwa R M, J.: Natural resource curse in Africa: Dutch Disease and institutional explanations. In. Edited by Washington DCIFPRII, vol. 2019; 2016.
48. Muhamad GM, Heshmati A, Khayyat NT: How to reduce the degree of dependency on natural resources? *Resources Policy* 2021, 72:102047.
49. Mulwa R M, J.: Natural resource curse in Africa: Dutch Disease and institutional explanations. In., vol. 2019; 2016.
50. Asiedu E: Foreign Direct Investment in Africa: The Role of Natural Resources, Market Size, Government Policy, Institutions and Political Instability. *The World Economy* 2006, 29(1):63-77.
51. Petrou S, Gray A: Economic evaluation using decision analytical modelling: design, conduct, analysis, and reporting. *BMJ* 2011, 342:d1766.
52. Adamiak G: Methods for the economic evaluation of health care programmes. *J Epidemiol Community Health* 2006, 60(9):822-823.
53. Wonderling D: Introduction to health economics, second edn. London: McGraw-Hill Education (UK); 2011.
54. Erlanger TE, Krieger GR, Singer BH, Utzinger J: The 6/94 gap in health impact assessment. *Environ Impact Assess Rev* 2008, 28(4):349-358.
55. Winkler MS, Adongo PB, Binka F, Brugger F, Diagbouga S, Macete E, Munguambe K, Okumu F: Health impact assessment for promoting sustainable development: the HIA4SD project. *Impact Assess Proj Apprais* 2020, 38(3):225-232.
56. Winkler MS, Krieger GR, Divall MJ, Cissé G, Wielga M, Singer BH, Tanner M, Utzinger J: Untapped potential of health impact assessment. *Bull World Health Organ* 2013, 91:298-305.

57. Castaneda R, Doan D, Newhouse DL, Nguyen M, Uematsu H, Azevedo JP: Who are the poor in the developing world? *World Bank Policy Research Working Paper* 2016(7844).

58. Oyeyemi B: ACHIEVING THE SUSTAINABLE DEVELOPMENT GOALS (SDGs) THROUGH ROAD SAFETY MANAGEMENT IN NIGERIA.

59. Jiang Y, Huang C, Yin D, Liang C, Wang Y: Constructing HLM to examine multi-level poverty-contributing factors of farmer households: Why and how? *Plos one* 2020, 15(1):e0228032.

60. ElMassah S, Mohieldin M: Digital transformation and localizing the Sustainable Development Goals (SDGs). *Ecological Economics* 2020, 169:106490.

61. Utting P: Achieving the sustainable development goals through social and solidarity economy: Incremental versus transformative change.

62. World investment report 2014, investing in the SDGs: an Action Plan [https://unctad.org/en/PublicationsLibrary/wir2014_en.pdf]

63. Assessment SI: Guidelines and principles for social impact assessment. *Environmental impact assessment review* 1995, 15(1):11-43.

64. Keshkamat SS: The Road Less Travelled: Scale in the Assessment and Planning of Highways: ITC, University of Twente; 2011.

65. Rai R, Singh TN: Cost benefit analysis and its environmental impact in mining. *Journal of Industrial Pollution Control* 2004, 20:17-24.

66. WHO: Social Determinants of Health. In.; 2021.

67. Diomidous M, Magdalinou A: Health and Health Determinants. *Stud Health Technol Inform* 2020, 274:3-9.

68. WHO: Constitution. In.; 2021.

69. Bradley J, Rehman AM, Schwabe C, Vargas D, Monti F, Ela C, Riloha M, Kleinschmidt I: Reduced prevalence of malaria infection in children living in houses with window screening or closed eaves on Bioko Island, Equatorial Guinea. *PLoS One* 2013, 8(11):e80626.

70. Carter RC, Danert K: The private sector and water and sanitation services—policy and poverty issues. *J Int Dev* 2003, 15(8):1067-1072.

71. Knoblauch AM, Hodges MH, Bah MS, Kamara HI, Kargbo A, Paye J, Turay H, Nyorkor ED, Divall MJ, Zhang Y *et al*: Changing patterns of health in communities

impacted by a bioenergy project in northern Sierra Leone. *International journal of environmental research and public health* 2014, 11(12):12997-13016.

72. Morrison-Saunders A, Retief F: Walking the sustainability assessment talk — Progressing the practice of environmental impact assessment (EIA). *Environ Impact Assess Rev* 2012, 36:34-41.
73. Hilson G: An overview of land use conflicts in mining communities. *Land Use Policy* 2002, 19(1):65-73.
74. Westwood E, Orenstein M: Does resource development increase community sexually transmitted infections? An environmental scan. *The Extractive Industries and Society* 2016, 3(1):240-248.
75. Campbell C: Migrancy, masculine identities and AIDS: the psychosocial context of HIV transmission on the South African gold mines. *Social science & medicine* 1997, 45(2):273-281.
76. Mek AK, Kelly-Hanku A, Eves R, Thomas V: Resource Extraction, Gender and the Sexual Economy in Hela Province, Papua New Guinea:“Everything has Changed”. *Sexuality & Culture* 2021:1-19.
77. Kleinschmidt I, Schwabe C, Benavente L, Torrez M, Ridl FC, Segura JL, Ehmer P, Nchama GN, hygiene: Marked increase in child survival after four years of intensive malaria control. *Am J Trop Med Hyg* 2009, 80(6):882-888.
78. Steinmann P, Keiser J, Bos R, Tanner M, Utzinger J: Schistosomiasis and water resources development: systematic review, meta-analysis, and estimates of people at risk. *Lancet Infect Dis* 2006, 6(7):411-425.
79. Afrane YA, Zhou G, Lawson BW, Githeko AK, Yan G: Effects of microclimatic changes caused by deforestation on the survivorship and reproductive fitness of Anopheles gambiae in western Kenya highlands. *Am J Trop Med Hyg* 2006, 74(5):772-778.
80. Gibb H, O'Leary KG: Mercury exposure and health impacts among individuals in the artisanal and small-scale gold mining community: a comprehensive review. *Environ Health Perspect* 2014, 122(7):667-672.
81. Dietler D, Lewinski R, Azevedo S, Engebretsen R, Brugger F, Utzinger J, Winkler MS: Inclusion of Health in Impact Assessment: A Review of Current Practice in Sub-Saharan Africa. *Int J Environ Res Public Health* 2020, 17(11):4155.

82. Molina-Villalba I, Lacasaña M, Rodríguez-Barranco M, Hernández AF, Gonzalez-Alzaga B, Aguilar-Garduño C, Gil F: Biomonitoring of arsenic, cadmium, lead, manganese and mercury in urine and hair of children living near mining and industrial areas. *Chemosphere* 2015, 124:83-91.
83. Farnham A, Cossa H, Dietler D, Engebretsen R, Leuenberger A, Lyatuu I, Nimako B, Zabre HR, Brugger F, Winkler MS: Investigating health impacts of natural resource extraction projects in Burkina Faso, Ghana, Mozambique, and Tanzania: Protocol for a mixed methods study. *JMIR Research Protocols* 2020, 9(4):e17138.
84. Bhattacharyya S, Mamo N: Natural Resources and Conflict in Africa: What Do the Data Show? *Economic Development and Cultural Change* 2021, 69(3):903-950.
85. Watts MJ: RIGHTEOUS OIL? HUMAN RIGHTS, THE OIL COMPLEX, AND CORPORATE SOCIAL RESPONSIBILITY. *Annual Review of Environment and Resources* 2005, 30(1):373-407.
86. Netalieva I, Wesseler J, Heijman W: Health costs caused by oil extraction air emissions and the benefits from abatement: the case of Kazakhstan. *Energy Policy* 2005, 33(9):1169-1177.
87. Franks DM, Brereton D, Moran CJ: Managing the cumulative impacts of coal mining on regional communities and environments in Australia. *Impact Assess Proj Apprais* 2010, 28(4):299-312.
88. Damigos D, Kaliampakos D: The "battle of gold" under the light of green economics: A case study from Greece. *Environ Geol* 2006, 50(2):202-218.
89. Damigos D: An overview of environmental valuation methods for the mining industry. *J Clean Prod* 2006, 14(3):234-247.
90. Considine TJ, Considine NB, Watson R: Economic and environmental impacts of fracking: A case study of the marcellus shale. *Environ Resour Econ* 2016, 9(3–4):209-244.
91. Amoah P, Eweje G: Impact mitigation or ecological restoration? Examining the environmental sustainability practices of multinational mining companies. *Business Strategy and the Environment* 2021, 30(1):551-565.
92. Alp E, Yetis U: Application of the contingent valuation method in a developing country: a case study of the Yusufeli dam in northeast Turkey. *Water Sci Technol* 2010, 62(1):99-105.

93. Tajziehchi S, Monavari SM, Karbassi AR, Shariat SM, Khorasani N: Quantification of social impacts of large hydropower dams- a case study of alborz dam in mazandaran province, northern Iran. *INT J ENVIRON RES* 2013:377-382.
94. Moran MD, Taylor NT, Mullins TF, Sardar SS, McClung MR: Land-use and ecosystem services costs of unconventional US oil and gas development. *Front Ecol Environ* 2017, 15(5):237-242.
95. Fanaian S, Graas S, Jiang Y, van der Zaag P: An ecological economic assessment of flow regimes in a hydropower dominated river basin: The case of the lower Zambezi River, Mozambique. *Sci Total Environ* 2015, 505.
96. Nations U: Universal Declaration of Human Rights | United Nations. In.: United Nations; 2021.
97. Braveman P: Health disparities and health equity: concepts and measurement. *Annu Rev Public Health* 2006, 27:167-194.
98. Sen A, Ahmed S, Peter F: Why health equity. In: :. edn.: Oxford University Press; 2004: 21-33.
99. WHO: WHO | Equity. In.: World Health Organization; 2011.
100. Adler NE, Newman K: Socioeconomic disparities in health: pathways and policies. *Health Aff (Millwood)* 2021, 21(2):60–76.
101. WHO | Equity. In.: World Health Organization; 2011.
102. "Of all the forms of inequality, injustice in health care is the most shocking and inhumane." | WA Patient Safety. In.; 2021.
103. Swain S, Aggarwal D, Kumar S: Addressing health inequity through strategic planning and management. *Indian Journal of Public Health* 2020, 64(4):417-420.
104. Leuenberger A, Farnham A, Azevedo S, Cossa H, Dietler D, Nimako B, Adongo PB, Merten S, Utzinger J, Winkler MS: Health impact assessment and health equity in sub-Saharan Africa: A scoping review. *Environmental Impact Assessment Review* 2019, 79:106288.
105. Johnson-Mann C, Hassan M, Johnson S: COVID-19 pandemic highlights racial health inequities. *The Lancet Diabetes & Endocrinology* 2020, 8(8):663-664.
106. Loayza N, Rigolini J: The Local Impact of Mining on Poverty and Inequality: Evidence from the Commodity Boom in Peru. *World Development* 2016, 84:219-234.
107. Lewis J, Hoover J, MacKenzie D: Mining and Environmental Health Disparities in Native American Communities. *Curr Environ Health Rep* 2017, 4(2):130-141.

108. Pettinger T: Horizontal and Vertical Equity Definition - Economics Help. In.; 2021.
109. Impact Assessment [https://www.iaia.org/wiki-details.php?ID=4]
110. Winkler MS, Furu P, Viliani F, Cave B, Divall M, Ramesh G, Harris-Roxas B, Knoblauch AM: Current Global Health Impact Assessment Practice. *Int J Environ Res Public Health* 2020, 17(9):2988.
111. Informatique CA: ECOMET - Espace environnement - Les ressources énergétiques non renouvelables. In.; 2021.
112. Kim D-H, Lin S-C: Human capital and natural resource dependence. *Structural Change and Economic Dynamics* 2017, 40:92-102.
113. Gamu J, Le Billon P, Spiegel S: Extractive industries and poverty: A review of recent findings and linkage mechanisms. *Extr Ind Soc* 2015, 2(1):162-176.
114. Prüss-Üstün A, Corvalán CF, World Health O: Preventing disease through healthy environments : towards an estimate of the environmental burden of disease / Prüss-Üstün A, Corvalán C. In. Geneva: World Health Organization; 2006.
115. Bassou A: Africa’s natural resources and geopolitical realities. 2017.
116. Remoundou K, Koundouri P: Environmental effects on public health: an economic perspective. *International journal of environmental research and public health* 2009, 6(8):2160-2178.
117. Shandro J, Koehoorn M, Scoble M, Ostry A, Gibson N, Veiga M: Mental Health, Cardiovascular Disease and Declining Economies in British Columbia Mining Communities. *Minerals* 2011, 1(1):30-48.
118. Brief AP: NUTRITION andthe Post-2015 Sustainable Development Goals.
119. Kruk ME, Goldmann E, Galea S: Borrowing and selling to pay for health care in low- and middle-income countries. *Health Affairs* 2009, 28(4):1056-1066.
120. Winkler MS, Viliani, F., Knoblauch, A.M., Cave, B., Divall, M., Ramesh, G., Harris-Roxas, B. and Furu, P.: Health Impact Assessment International Best Practice Principles. Special Publication Series No. 5. Fargo, USA: International Association for Impact Assessment. 2021.
121. Kemm J, Parry J: What is HIA? Introduction and overview: Health impact assessment. Oxford, Oxford University Press; 2004.
122. Dannenberg AL: Peer reviewed: Effectiveness of health impact assessments: A synthesis of data from five impact evaluation reports. *Preventing chronic disease* 2016, 13.

123. Krieger G: Introduction to Health Impact Assessment. *International Finance Corporation, World Bank Group, Washington, DC* 2009.
124. Health W-U, Environment Linkages I: Health environment : managing the linkages for sustainable development : a toolkit for decision-makers : synthesis report. In. Geneva: World Health Organization; 2008.
125. Veerman JL, Barendregt JJ, Mackenbach JP: Quantitative health impact assessment: current practice and future directions. *Journal of Epidemiology and Community Health* 2005, 59(5):361.
126. Fehr R, Viliani F, Nowacki J, Martuzzi M: Health in Impact Assessments. Copenhagen: WHO Regional Office for Europe; 2014.
127. Center. ANR: African Development Bank AGA Malaria and Public-Private Partnerships in Ghana's Health Sector to Obtain Value from Extractives Projects: A Case Study.
128. What is the polluter pays principle? In.; 2020.
129. Quiggin J: The precautionary principle in environmental policy and the theory of choice under uncertainty. In.; 2005.
130. Rudmik L, Drummond M: Health economic evaluation: Important principles and methodology, vol. 123. The Laryngoscope: John Wiley & Sons, Ltd; 2013.
131. Saetova L, Uulu ZY, Kisunko G: Applying Community of Practice Peer-to-Peer Learning Approach in Rural Kyrgyzstan. *World Bank, Washington, DC* 2018.
132. CFI: Leading By Example - 6 Methods & Strategies of Leadership. In.; 2021.
133. McMahon G: The World Bank's Evolutionary Approach to Mining Sector Reform. *World Bank, Washington, DC* 2010.
134. Leuenberger A, Farnham A, Azevedo S, Cossa H, Dietler D, Nimako B, Adongo PB, Merten S, Utzinger J, Winkler MS: Health impact assessment and health equity in sub-Saharan Africa: A scoping review. *Environ Impact Assess Rev* 2019, 79:11.
135. Winkler MS, Adongo PB, Binka F, Brugger F, Diagbouga S, Macete E, Munguambe K, Okumu F: Health impact assessment for promoting sustainable development: The HIA4SD project. *Impact Assess Proj Apprais* 2020, 38(3):225-232.
136. FQML: Development Projects: Trident. In., vol. 2015; 2015.
137. First Quantum Minerals Limited (FQML) [https://www.first-quantum.com/English/our-operations/development-projects/enterprise/reserves-and-resources/default.aspx]

138. Knoblauch AM, Divall MJ, Owuor M, Nduna K, Ng'uni H, Musunka G, Pascall A, Utzinger J, Winkler MS: Experience and lessons from health impact assessment guiding prevention and control of HIV/AIDS in a copper mine Project, northwestern Zambia. *Infect Dis Poverty* 2017, 6(1):114.

139. Winkler MS, F. Viliani, A.M. Knoblauch, B. Cave, M.J. Divall, G. Ramesh, B. Harris-Roxas, and P. Furu.: Health impact assessment international best practice principles. *Impact Assess Proj Apprais* 2020, Special Publication Series No. 5

140. Rutstein S, Johnson K: The DHS Wealth Index. DHS Comparative Reports No. 6. Calverton, Maryland;. In.; 2004.

2. Paper 1 – Scoping Review of the Inclusion of Economic Analysis in Impact Studies of Natural Resource Extraction Projects

This article was published in

Impact Assessment and Policy Appraisal https://doi.org/10.1080/14615517.2021.1910182

IMPACT ASSESSMENT AND PROJECT APPRAISAL
https://doi.org/10.1080/14615517.2021.1910182

IAIA International Association for Impact Assessment
Taylor & Francis Taylor & Francis Group

ARTICLE

OPEN ACCESS Check for updates

Scoping review of the inclusion of economic analysis in impact studies of natural resource extraction projects

Hyacinthe R. Zabré[a,b,c], Dominik Dietler[b,c], Serge P. Diagbouga[a] and Mirko S. Winkler[b,c]

[a]Research Institute of Health Sciences, Ouagadougou, Burkina Faso; [b]Department of Epidemiology and Public Health, Swiss Tropical and Public Health Institute, Basel, Switzerland; [c]University of Basel, Basel, Switzerland

ABSTRACT

The extraction of natural resources, such as minerals, oil, and gas, can have profound economic effects. The application of economic analysis methods in impact studies of resource extraction projects holds potential to inform decision-making in order to optimise gains and minimise negative externalities. This paper aims to identify and characterise peer-reviewed publications that report on economic studies implemented as part of impact assessments of resource extraction projects. We conducted a systematic scoping review in PubMed and Scopus of articles published between 1998 and 2020. Out of 1,579 raw hits, we identified 13 articles describing 15 economic analyses of resource extraction projects. Half of the identified papers presented economic analyses conducted in the context of mining and oil/gas projects. The majority of the identified studies dealt with the cost and/or benefits of environmental and/or social impacts. Only one study investigated economic aspects associated with potential health impacts. Given the small number of papers identified, economic analysis of impacts associated with natural resource extraction projects seems to be a small field of published research. Yet the inclusion of economic analysis in impact assessment of resource extraction projects holds promise to better harness benefits for local communities and governments while minimising negative externalities.

ARTICLE HISTORY
Received 17 November 2020
Accepted 24 March 2021

KEYWORDS
Economic analysis; extractive industry; impact assessment; resource extraction; scoping review

Background

To achieve the Sustainable Development Goals (SDGs) of the Agenda 2030, it is estimated that US$ 5–7 trillion are needed annually, which corresponds to approximately a third of the gross domestic product (GDP) of the United States of America (US$ 21 trillion in 2019) (United Nations 2014; World investment report 2014; World Bank 2020a; World Bank 2020b). In the same report, investment needs in developing countries alone were estimated at US$ 3.3–4.5 trillion per year, corresponding to several times the annual GDP of sub-Saharan Africa (US$ 1.75 trillion in 2019) (United Nations. 2014). Hence, a significant contribution is expected from the private sector to jointly strive towards the SDGs, particularly in low- and middle-income countries (LMICs) (Scheyvens et al. 2016; Stafford-Smith et al. 2017; Mawdsley 2018; Ike et al. 2019; Aust et al. 2020).

The abundance of natural resources in many LMICs is an opportunity for the private sector to be an essential player in promoting economic growth and societal development (IPIECA 2017; World Bank 2017). Particularly in Africa, which is endowed with over 30% of the world's global mineral reserves and over 60 different metals (United Nations 2011), the mining industry might play an even more important role in a low carbon future (Slavova and Bankova 2017; Sturman et al. 2020). Indeed, renewable energy sources, such as wind, solar, and hydrogen, are significantly more material-intensive than current traditional fossil fuel-based energy supply systems, resulting in a rapidly increasing demand for relevant metals (Arrobas et al. 2017; Valero et al. 2018; Giurco et al. 2019).

Extractive industries and the SDGs

Tax revenues and royalties paid by the extractive industries are essential for local and national governments to work towards all SDGs (Otto et al. 2006). The resulting increased government revenue can be used to promote investments in schools, health facilities, and other public infrastructures, ultimately leading to improved health and well-being (SDG3), better education (SDG4), and access to clean drinking water and sanitation (SDG6) (Carter and Danert 2003; Morrison-Saunders and Retief 2012; Knoblauch et al. 2014). The creation of employment and income can reduce poverty (SDG1) along with improving housing conditions (SDG11) and health insurance coverage (SDG3) (Bradley et al. 2013; Langston et al. 2015; Von Der Goltz and Barnwal 2019). Hence, the development and operation of natural resource extraction projects

CONTACT Mirko S. Winkler mirko.winkler@swisstph.ch Swiss Tropical and Public Health Institute, P.O. Box, CH-4002, Basel, Switzerland

(NREPs) come with many opportunities for sustainable development, which holds particularly true in LMICs (Horn and Grugel 2018).

Despite these opportunities, there is also evidence that extractive industries can trigger negative socio-economic effects at the local and national levels; thus opposing progress towards the SDGs (Papyrakis 2017; Sachs et al. 2019). Indeed, the resource curse – also known as the '*paradox of abundance*' – draws a negative link between a country's natural resource wealth and its impact on economic development (Mehlum et al. 2006). Several studies have explained this curse through the negative effects of the extractive sector on the governance of producing countries (Busse and Gröning 2013; James 2015; Hong 2018). Governance in many LMICs with a strong extractive sector is marked by (i) inadequate funding for important development sectors such as education and health (Calain 2008; Cockx and Francken 2014), (ii) a reduction in the competitiveness of the non-resource sectors (e.g. manufacturing sector or agriculture) due to high foreign exchange rates (called 'Dutch disease') (Brahmbhatt et al. 2010), and (iii) an increased frequency of violent conflicts (Ross 2004). Indeed, at the national level, a study found that from 1960 to 1990, the increase in GDP of mineral-rich countries was lower (1.7%) than that of other countries (2.5–3.5%) (Meijia and Castel 2012). At the local level, environmental, social, and public health challenges induced by NREPs have direct and indirect costs for communities. For example, NREPs can potentially exacerbate poverty in marginalised population groups (SDG1 and SDG10) (Winkler et al. 2012; Carney and Gushulak 2016). Another important concern is the overburdening of local health systems through project-induced immigration and alterations in local disease patterns (SDG3) (Winkler et al. 2012; Schrecker et al. 2018).

The potential of economic analyses

Economic analyses are applicable to all domains of sustainable development (e.g. economy, environment, and society) and to all sectors of development (e.g. construction, agriculture, industry). To estimate changes in employment and levels of business activity that may result from a proposed project, economic impact assessment (EcIA) can be applied as part of the feasibility studies (Rushton et al. 1999; International Association for Impact Assessment 2021a). Within EcIA, or as a standalone process, different types of economic analyses can be carried out (Hitch 2014). For example, cost-benefit analysis (CBA) can be used to estimate the net public benefits of a project by comparing the total benefits (e.g. jobs created, tax revenues) with the cost of the same project (e.g. cost of economic, social, or environmental impacts) (Briggs and O'Brien 2001; Abelson 2015). Cost-effectiveness analysis (CEA) can be applied to compare the relative cost of one or several courses of action (e.g. financing of revenue-generating activities by the mining project *versus* professional training of the members of the households displaced by a mining project) and the resulting outcomes (e.g. the economic well-being of displaced households) (Drummond et al. 2015). Cost minimisation analyses (CMA) aim to select the cheapest method by comparing the cost of two or more interventions with the same results (Rudmik and Drummond 2013). Finally, cost-utility analysis (CUA) compares the incremental cost of a program/intervention (e.g. knee arthroplasty in the treatment of osteoarthritis) to incremental costs of quantitative and qualitative aspects of the consequences (e.g. cost of quality-adjusted life years) (Gui et al. 2019). An economic analysis is full or complete if it compares both the cost and the consequences (effectiveness or benefits) of two or more interventions, as is done in CBA. Otherwise, the analysis is partial, for instance, if only costs are analysed (Drummond et al. 2015; Ciani and Federici 2020). The different types of economic analyses can be done through prospective studies (referred to as 'assessments' in this paper) or as retrospective studies ('evaluations') (International Association for Impact Assessment 2021b). In the present study, we apply the term 'economic studies' to encompass both assessments and evaluations.

Economic analysis in impact studies of NREPs

Impact assessments (IA) are a structured process for considering the implications of proposed actions for people and their environment at the planning stage (International Association for Impact Assessment 2021b). IA can be applied at all levels of decision-making, ranging from policies to specific projects. Hence, through the inclusion of economic analysis in prospective impact assessments of NREPs, economic considerations can be incorporated into the decision-making process, thus promoting profitable projects with minimal negative financial externalities (Adamiak 2006; Petrou and Gray 2011; Wonderling 2011). In addition, economic analysis can support the selection of corporate social responsibility (CSR) interventions and, at the same time, promote public-private partnerships for jointly working towards the 2030 Agenda for Sustainable Development (Araja 2012; Jomo et al. 2016; Winkler et al. 2020a). Hence, the application of economic analysis in impact assessments and evaluations (referred to as 'impact studies') holds the potential to create a more sustainable extractive sector.

The objective of this paper is to identify economic analysis methods and scientific case studies that can support our on-going research efforts studying impacts of NREPs in sub-Saharan Africa (Farnham et al. 2020; Winkler et al. 2020a). For this purpose, we conducted a scoping literature review to systematically identify and characterise peer-reviewed publications that report on economic studies that apply a community-perspective and have been implemented as part of impact studies of NREPs globally. The research was guided by the following research questions: In the context of which types of NREPs have economic analysis methods been applied in the frame of impact assessments or evaluations, as reported in the peer reviewed literature? What types of impacts (environmental, social, economic, or health) were considered in the economic analyses identified? What are the types of economic analyses that were applied?

Methods

The methodology of our scoping literature review was inspired by a recent paper by Leuenberger et al. (2019) who carried out a scoping review on the topic of health impact assessment and health equity in sub-Saharan Africa. The search for articles was conducted in accordance with the principles outlined in the 'Preferred Reporting Items for Systematic Reviews and Meta-Analyses' (PRISMA) statement (Moher et al. 2009). The search targeted peer-reviewed articles only. Grey literature was excluded as the objective of the scoping review is to identify economic analysis methods that can be applied in scientific research. Methods and case studies that have been published in the peer-reviewed journals were scrutinised by experts in the field and can therefore be considered robust. In addition, journal search and indexing databases, such as PubMed and Scopus, provide the possibility to conduct systematic literature searches using elaborated search strings. This cannot be done for grey literature searches.

Search strategy

The search terminology consisted of three components: (i) NREPs, specified by a wide range of natural resources (e.g. gold, aluminum, coal, gas, oil) and other NREP-related terminologies such as mining, industry, and exploration; (ii) different types of impact studies (e.g. economic impact analysis, environmental impact assessment, health impact evaluation); and (iii) different types of economic analyses (e.g. CBA, CEA). The full search terminology is available in Appendix I and Appendix II. The search terms were applied in PubMed and Scopus. The search was restricted to records published between 1 January 1998 and 30 September 2020. No geographical restriction was applied.

Table 1. Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
• Peer-reviewed original research article or systematic review • Focusing on an extractive industry projects • Presents an economic or financial study • Oriented towards public economic perspective • Impacts on the society, environment or health are assessed or evaluated • Written in English or French • Abstract available	• Study not reporting original data • Paper not presenting details of methodology and results • No full text available

Paper selection and characterisation

All identified publications were screened for the inclusion and exclusion criteria listed in Table 1. English and French original peer-reviewed research articles and systematic reviews were included if they complied with the inclusion criteria: (i) paper investigated environmental, social, or health impacts of NREPs, and (ii) determined the financial and/or economic costs and/or benefits of NREPs from a community-perspective. Articles that (i) were not based on original data, (ii) did not present full details of the methodology applied and the results obtained, or (iii) did not have an abstract or full text available within the access rights of the University of Basel were excluded from further analysis.

In a three-step process, two independent researchers (HZ and DD) performed the screening of the papers. In the first step, titles and abstracts were screened to assess the inclusion criteria. The exclusion criteria were applied to the full-texts of the retained publications in a second step. Discrepancies were discussed among the two independent reviewers and, if needed, with a third author until consensus was reached on which papers to include in the final sample. Zotero Version 5.0.34 (George Mason University, Fairfax, Virginia, USA) was used for extracting and managing the records. In the final step, articles selected for the full-text analysis were read in detail and previously specified characteristics (i.e. project location, nature of NREP studied, production stages, type of impacts studied and economic analysis applied) were extracted and entered into an Excel spreadsheet for subsequent descriptive interpretation (Microsoft Excel 2010, Microsoft Corp.; Redmond, WA, USA).

Data analysis

The articles selected for the full-text analysis were grouped in an Excel sheet and selected characteristics (e.g. project location, nature of NREP studied, production stages, type of impacts studied, and economic analysis applied) were recorded. In the full-text screening, we also determined whether a single paper presented one or several economic studies.

Results

Peer-reviewed literature

In total, 1,579 articles were found in PubMed and Scopus. After removing 47 duplicates, 1,532 articles were included for the title and abstract screening. Of those, 1,459 articles did not meet the inclusion criteria and were excluded at this step (Figure 1).

Thus, 73 articles were included for full-text screening (rough description of papers available in Appendix III and Appendix IV). After the full-text screening, 13 papers remained for the final analysis. As one of the articles presented three case studies (Damigos 2006), the final dataset of the scoping review consisted of 13 papers reporting on economic studies that were carried out in the context of 15 NREPs. An overview of the articles is provided in Table 2.

Characterisation of studies identified

Out of the 15 economic studies identified, seven presented on economic analyses in the context of mining (n = 4) and oil/gas projects (n = 3) (see Figure 2) (Netalieva et al. 2005; Damigos 2006; Damigos and Kaliampakos 2006; Franks et al. 2010; Considine et al. 2016). The majority of included papers (n = 7) reported on economic studies in the context of water resource projects (Morimoto and Hope 2004; Hjerpe and Kim 2007; Alp and Yetis 2010; Mirumachi and Torriti 2012; Tajziehchi et al. 2013, 2014; Fanaian et al. 2015). One economic study was carried out in the context of a biofuel project (Miranda and Hale 2001).

The economic studies were carried out at different stages of the project development cycle of the NREPs: pre-production (n = 2); production (n = 9); and post-production (n = 4). The included papers were published between 2001 and 2017. As illustrated in Figure 2, most of the 15 economic studies had a focus on Asian countries (n = 6), whereas others were conducted in America (n = 4), Europe (n = 4) and Africa (n = 1).

Types of impacts studied

The characterisation of the economic studies in terms of the impact domains studied (i.e. environment, social, or health) revealed that eight of the economic analyses considered more than one impact domain (see Table 2). Among those studies, most (n = 6) dealt with both environmental and social impacts. The remaining two considered environmental, social, and economic impacts (n = 1) and socio-economic impacts (n = 1). All other studies (n = 7) focused on a single impact domain: environment (n = 3), social (n = 2), ecological (n = 1), and health (n = 1).

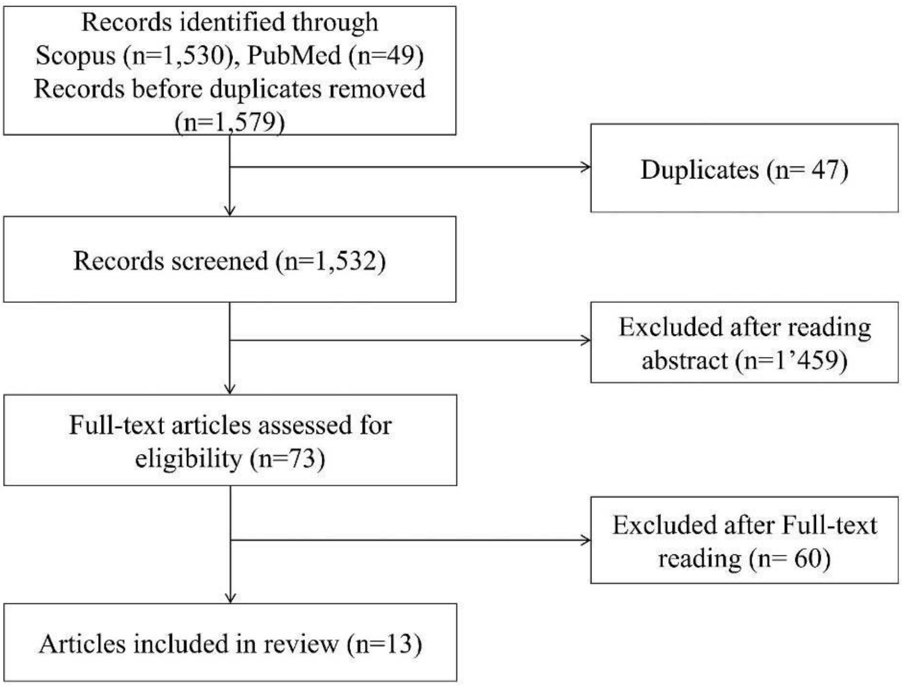

Figure 1. PRISMA flowchart illustrating the article selection process.

Table 2. Appraisal of included articles and studied projects.

References Country	Project characteristics Types of NREP	Name of NREP	Production stage	Type of impact	Type of Analysis
Moran et al. 2017 United States of America	Oil/gas	Not available[a]	Production	Environment-social	CA
Considine et al. 2016 United States of America	Oil/gas	Marcellus Shale of Pennsylvania	Production	Environment	CBA
Fanaian et al. 2015 Mozambique	Water resource	Zambezi river	Production	Ecological	BA
Tajziehchi et al. 2014 Iran	Water resource	Alborz Dam in northern Iran	Production	Social	CBA
Tajziehchi et al. 2013 Iran	Water resource	Alborz Hydropower Plant	Pre-production	Social	CA
Mirumachi and Torriti 2012 Laos	Water resource	Theun 2 hydropower project	Production	Environment-social	CBA
Alp and Yetis 2010 Turkey	Water resource	Yusufeli dam & Hydroelectric power plant	Production	Environment	CA
Hjerpe and Kim 2007 United States of America	Water resource	The Grand Canyo	Production	Socio-economic	CBA
Damigos and Kaliampakos 2006 Greece	Mining	Perama gold project	Post-production	Environment-social	CBA
	Mining	Eagle Mine	Post-production	Environment	CA
Damigos 2006 United States of America	Mining	P. Viaropoulos quarry	Post-production	Environment-social	BA
	Mining	Perama gold mine project	Post-production	Environment-social	CBA
Netalieva et al. 2005 Kazakhstan	Oil/gas	Astana & Atyrau town oil industries	Production	Health	CBA
Morimoto and Hope 2004 China	Water resource	The Three Gorges project	Pre-production	Environment-social-economic	CBA
Miranda and Hale 2001 Sweden	Biofuel	Not available[2]	Production	Environment-social	CA

[a]Unconventional oil and gas development regions; [2]Energy production; CBA: cost-benefit analyis, BA: Benefit analysis, CA: Cost analysis

Types of economic analyses applied

Three main types of economic analysis were applied in the 15 included studies: CBA (n = 8); cost analysis (n = 5); and benefit analysis (n = 2). Hence, seven of the economic analyses identified were incomplete analyses (five cost analyses and two benefit analyses). The eight CBAs were used in socio-environmental impact studies of water resources (n = 4), mining (n = 2), oil/gas (n = 2) developments. The five cost analyses were applied in socio-environmental impact studies of water resources (n = 2), mining (n = 1), oil/gas (n = 1), and biofuel (n = 1) projects. The two benefit analyses were embedded in socio-environmental impact studies of a water resource development (n = 1) and a mining project (n = 1).

Discussion

This scoping review reveals that few papers exist in the peer-reviewed literature presenting on economic analyses that were included in impact studies of extractive industry projects. The thirteen papers identified in our review were mainly oriented towards environmental or social impacts, with only one study investigating economic aspects associated with potential health impacts. In terms of geographical representation, we identified a similar number of papers focussing on projects in the global north (North America and Europe) and the global south (Asia and Africa). Most economic studies identified were conducted in the context of water resource developments and mining projects.

Our paper aligns with previous papers that made an attempt to characterise impact studies in the context of large infrastructure projects. For example, a systematic review of scientific papers investigating the health and economic outcomes of mining on surrounding communities in LMICs found no more than 12 relevant articles (Mactaggart et al. 2018). Hodbod and Tomei could only identify 17 peer-reviewed papers studying the social and economic impacts of biofuel projects (Hodbod and Tomei 2013). A more substantial number of papers (n = 52) were identified in a systematic review on the inclusion of poverty considerations in impact studies of resource extraction projects (Gamu et al. 2015). Overall, the limited number of peer-reviewed papers presenting economic analyses that were included in impact studies of extractive industry projects shows that this is not a very active field of published research. This is unfortunate when considering the important role economic analysis could play in impact assessment of extractive projects (Scheyvens et al. 2016; Stafford-Smith et al. 2017; Mawdsley 2018; Ike et al. 2019; Aust et al. 2020). However, it is important to note that the number of publications in the peer-reviewed literature only partly reflects the number of economic analyses done in impact studies of extractive industry projects. Many of the completed EcIA are presented in reports ('grey literature') that are, in the best case, found on websites of organisations and companies. But as neither grey

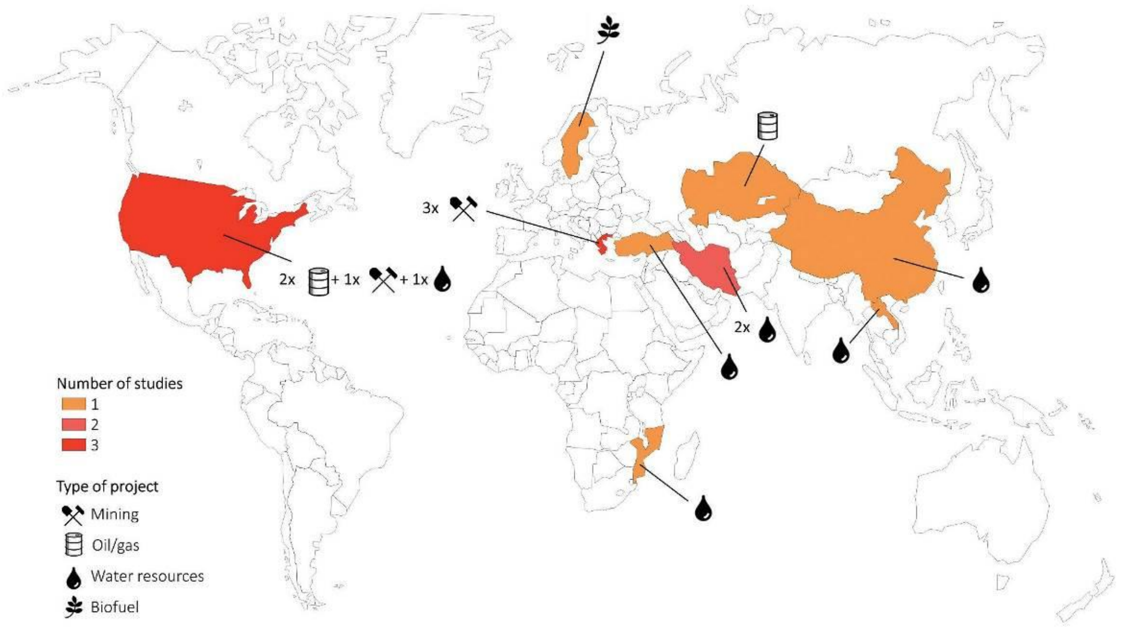

Figure 2. Geographical location of economic studies included and types of NREPs investigated.

literature nor websites were included in the present scoping review, we cannot make any judgment about EcIA practice in different world regions.

None of the studies included in our scoping review presented an economic analysis that was conducted in the framework of a prospective impact assessment on the African continent. This finding is not unexpected given previous papers that have identified weaknesses in impact assessment research and practice in Africa (Erlanger et al. 2008; Winkler et al. 2013). At the same time, it is a relevant finding, as it contrasts with the booming extractive industries sectors in many African countries (Grégoire 2011). If negative externalities associated with NREPs are to be prevented at the local and national level, strong impact assessment practice is required (Joyce et al. 2018). Therefore, governments and project financing institutions should make an effort to strengthen the application of impact assessments of NREPs on the African continent, placing emphasis on inter-disciplinary approaches that include economic analysis components. Importantly, this needs to be coupled with capacity building efforts, as the paucity of technical expertise and capacity has been identified as an important barrier to impact assessment practice (Winkler et al. 2020b).

Despite the multilateral impacts of NREPs, many studies have focused on one type of impact only, with environmental and social impacts being considered most frequently. This finding is consistent with other studies that have found that impact assessment and evaluation studies of NREPs have mainly focused on environmental impacts (Rafael Fernandes De Mesquita et al. 2017; Dietler et al. 2020). This is concerning as the multiplicity and diversity of effects triggered by the development and operation of NREPs have been well documented (Downey et al. 2010; Franks et al. 2010; Papyrakis et al. 2017; Mancini and Sala 2018; Buse et al. 2019). However, based on our findings we cannot determine whether the limited number of studies focused on health or socio-economic impacts identified in our scoping review is due to a lack of appropriate methodologies, capabilities or interest.

According to the types of economic analyses identified, almost half of the fifteen studies can be considered partial since they only considered costs or benefits (Drummond et al. 2015; Ciani and Federici 2020). This is in line with the findings of a systematic review of Ayuk et al. (2013), concluding that CBAs are insufficiently integrated into impact assessments of mining projects in sub-Saharan Africa. This is unfortunate, as the challenge in measuring the contribution of the mining sector to society lies mainly in the estimation of added economic value, which requires a complete CBA (Mancini and Sala 2018). Overall, there is a paucity of scientific papers presenting on both economic gains and losses of NREPs. This deprives policy-makers of the information needed to adjust the financial and economic contributions of NREPs to match the costs of their negative externalities. In addition, there is a lack of evidence to inform appropriate strategies to minimise negative impacts of NREPs on local and national economies. In order to overcome these shortcomings, impact assessment practice of extractive projects could attempt to learn from other fields of impact assessment application how to more proactively incorporate economic analysis in the impact assessment process. For example, in transport planning economic considerations have been systematically integrated in strategic environmental assessment (Fischer 2006).

Limitations

The research presented comes with several limitations. First, our research strategy only targeted published scientific articles. Consequently, unpublished studies or grey literature such as EcIA reports of NREPs are not included in our scoping review, inducing a publication bias towards the peer-reviewed literature. Thus, the research presented refrains from making any appraisal of EcIA practice. Second, our scoping may have missed some relevant articles. For example, our research was done in Scopus and PubMed, while other studies may be published in other databases that we did not include. However, these databases included all major economic or environmental journals in which EcIA reports or economic analyses are commonly published. Third, since impact assessments are commonly conducted for large-scale infrastructure projects, our scoping review was oriented towards the industrial extraction of natural resources, excluding artisanal and small-scale mining. Finally, the search string of our scoping review was only in English and the papers included were restricted to English and French. Hence, we might have missed relevant papers presented in other languages.

Conclusion

This scoping review shows that economic analysis of impacts associated with the development and operation of natural resource extraction projects is a relatively small field of published research. Hence, compared to other impact assessment domains, such as environmental, social or health impact assessment, research capacity in EcIA of extractive industry projects seems limited. This is unfortunate since the inclusion of economic analysis in impact assessment of resource extraction projects is needed to incorporate economic considerations in the decision-making process for promoting sustainable projects with minimal negative financial externalities. The EcIA community should make an effort to publish their findings and methodologies of economic analyses in the context of natural resource extraction projects. This will not only increase transparency on economic risks and benefits associated with the development of extractive industry projects, but also promote EcIA research and practice.

Acknowledgments

We are grateful to our colleagues Dr. Andrea Leuenberger, Dr. Belinda Nimako, and Hermínio Cossa for their inputs and assistance in developing the search strategy of the scoping review. Many thanks to Dr. Andrea Farnham for the English proofreading.

Disclosure statement

The authors declare that they have no conflict of interest.

Funding

This work is part of the r4d programme (www.r4d.ch), which is a joint funding initiative by the Swiss Agency for Development and Cooperatoin (SDC) and the Swiss National Science Foundation (SNSF) [grant number 169461].

ORCID

Dominik Dietler http://orcid.org/0000-0001-9629-125X
Mirko S. Winkler http://orcid.org/0000-0001-7387-3863

References

Abelson P. 2015. Cost-benefit evaluation of mining projects. Aust Econ Rev. 48(4):442–452. doi:10.1111/1467-8462.12132.

Adamiak G. 2006. Methods for the economic evaluation of health care programmes. J Epidemiol Community Health. 60(9):822–823. eng.

Alp E, Yetis U. 2010. Application of the contingent valuation method in a developing country: a case study of the Yusufeli dam in northeast Turkey. Water Sci Technol. 62 (1):99–105. eng.. doi:10.2166/wst.2010.272.

Araja D. 2012. Economic evaluation as a decision-making tool in health care. Les Ulis: EDP Sciences.

Arrobas DLP, Hund KL, Mccormick MS, Ningthoujam J, Drexhage JR. 2017. The growing role of minerals and metals for a low carbon future. Washington D.C.: World Bank Group.

Aust V, Morais AI, Pinto I. 2020. How does foreign direct investment contribute to Sustainable Development Goals? Evidence from African countries. J Clean Prod. 245:118823. doi:10.1016/j.jclepro.2019.118823.

Ayuk E, William F, Kouame E. 2013. Application of quantitative methods in natural resource management. In: Peter V, Ek S, editors. IGI Global. Pennsylvania; p. 40.

Bradley J, Rehman AM, Schwabe C, Vargas D, Monti F, Ela C, Riloha M, Kleinschmidt I. 2013. Reduced prevalence of malaria infection in children living in houses with window screening or closed eaves on Bioko Island, Equatorial Guinea. PLoS One. 8(11):e80626. doi:10.1371/journal.pone.0080626.

Brahmbhatt M, Canuto O, Vostroknutova E. 2010. Dealing with Dutch disease. Washington D.C.: The World Bank.

Briggs AH, O'Brien BJ. 2001. The death of cost-minimisation analysis? Health Econ. 10(2):179–184. doi:10.1002/hec.584.

Buse CG, Sax M, Nowak N, Jackson J, Fresco T, Fyfe T, Halseth G. 2019. Locating community impacts of unconventional natural gas across the supply chain: a scoping review. Extr Ind Soc. 6(2):620–629. doi: 10.1016/j.exis.2019.03.002.

Busse M, Gröning S. 2013. The resource curse revisited: governance and natural resources. Public Choice. 154(1):1–20. doi:10.1007/s11127-011-9804-0.

Calain P. 2008. Oil for health in sub-Saharan Africa: health systems in a 'resource curse' environment. Globalization Health. 4(1):10. doi:10.1186/1744-8603-4-10.

Carney JG, Gushulak BD. 2016. A review of research on health outcomes for workers, home and host communities of population mobility associated with extractive industries. J Immigr Minor Health. 18(3):673–686. doi:10.1007/s10903-015-0328-4.

Carter RC, Danert K. 2003. The private sector and water and sanitation services—policy and poverty issues. J Int Dev. 15(8):1067–1072. doi:10.1002/jid.1051.

Ciani O, Federici C. 2020. Introduction to economic evaluation and health technology assessment. In: Clinical Engineering Handbook. Cambridge, Massachusetts: Academic Press. p. 789–794.

Cockx L, Francken N. 2014. Extending the concept of the resource curse: natural resources and public spending on health. Ecol Econ. 108:136–149. doi:10.1016/j.ecolecon.2014.10.013.

Considine TJ, Considine NB, Watson R. 2016. Economic and environmental impacts of fracking: a case study of the marcellus shale. Environ Resour Econ. 9(3–4):209–244.

Damigos D. 2006. An overview of environmental valuation methods for the mining industry. J Clean Prod. 14 (3):234–247.

Damigos D, Kaliampakos D. 2006. The "battle of gold" under the light of green economics: a case study from Greece. Environ Geol. 50(2):202–218. doi:10.1007/s00254-006-0201-9.

De Mesquita RF, Xavier A, Klein B, Frn M. 2017. Mining and the sustainable development goals: a systematic literature review. GREE. 2:29–34.

Dietler D, Lewinski R, Azevedo S, Engebretsen R, Brugger F, Utzinger J, Winkler MS. 2020. Inclusion of Health in Impact Assessment: a Review of Current Practice in Sub-Saharan Africa. Int J Environ Res Public Health. 17(11):4155. doi:10.3390/ijerph17114155.

Downey L, Bonds E, Clark K. 2010. Natural Resource Extraction, Armed Violence, and Environmental Degradation. Organ Environ. 23(4):417–445. doi:10.1177/1086026610385903.

Drummond MF, Sculpher MJ, Claxton K, Stoddart GL, Torrance GW. 2015. Methods for the economic evaluation of health care programmes. Oxford: Oxford University Press.

Erlanger TE, Krieger GR, Singer BH, Utzinger J. 2008. The 6/94 gap in health impact assessment. Environ Impact Assess Rev. 28(4):349–358. doi:10.1016/j.eiar.2007.07.003.

Fanaian S, Graas S, Jiang Y, Van Der Zaag P. 2015. An ecological economic assessment of flow regimes in a hydropower dominated river basin: the case of the lower Zambezi River, Mozambique. Sci Total Environ. 505:464–473. doi:10.1016/j.scitotenv.2014.10.033.

Farnham A, Cossa H, Dietler D, Engebretsen R, Leuenberger A, Lyatuu I, Nimako B, Zabre HR, Brugger F, Winkler MS. 2020. Investigating health impacts of natural resource extraction projects in Burkina Faso, Ghana, Mozambique, and Tanzania: protocol for a mixed methods study. JMIR Res Protoc. 9(4):e17138. doi:10.2196/17138.

Fischer TB. 2006. Strategic environmental assessment and transport planning: towards a generic framework for evaluating practice and developing guidance. Impact Assess Proj Apprais. 24(3):183–197. doi:10.3152/147154606781765183.

Franks DM, Brereton D, Moran CJ. 2010. Managing the cumulative impacts of coal mining on regional communities and environments in Australia. Impact Assess Proj Apprais. 28(4):299–312. doi:10.3152/146155110X12838715793129.

Gamu J, Le Billon P, Spiegel S. 2015. Extractive industries and poverty: a review of recent findings and linkage mechanisms. Extr Ind Soc. 2(1):162–176.

Giurco D, Dominish E, Florin N, Watari T, McLellan B. 2019. Requirements for minerals and metals for 100% renewable scenarios. Achieving the Paris Climate Agreement Goals. Berlin: Springer; p. 437–457.

Grégoire E. 2011. Niger: a State Rich in Uranium. Hérodote. 142(3):206–225. doi:10.3917/her.142.0206.

Gui Q, Zhang X, Liu L, Zhao F, Cheng W, Zhang Y. 2019. Cost-utility analysis of total knee arthroplasty for osteoarthritis in a regional medical center in China. J Health Econ. 9(1):15.

Hitch M. 2014. A real options approach to implementing corporate social responsibility policies at different stages of the mining process. Corp Gov. 14(1):45–57. doi:10.1108/CG-07-2012-0060.

Hjerpe EE, Kim YS. 2007. Regional economic impacts of Grand Canyon river runners. J Environ Manage. 85(1):137–149. doi:10.1016/j.jenvman.2006.08.012.

Hodbod J, Tomei J. 2013. Demystifying the social impacts of biofuels at local levels: where is the evidence? Geogr Compass. 7(7):478–488. doi:10.1111/gec3.12051.

Hong JY. 2018. How Natural Resources Affect Authoritarian Leaders' Provision of Public Services: evidence from China. J Politics. 80(1):178–194. doi:10.1086/694199.

Horn P, Grugel J. 2018. The SDGs in middle-income countries: setting or serving domestic development agendas? Evidence from Ecuador. World Dev. 109:73–84. doi:10.1016/j.worlddev.2018.04.005.

Ike M, Donovan JD, Topple C, Masli EK. 2019. The process of selecting and prioritising corporate sustainability issues: insights for achieving the Sustainable Development Goals. J Clean Prod. 236:117661. doi:10.1016/j.jclepro.2019.117661.

International Association for Impact Assessment. 2021a. Economic and Fiscal Assessment. https://www.iaia.org/wiki-details.php?ID=11.

International Association for Impact Assessment. 2021b. Impact assessment. International Association for Impact Assessment; [accessed]. https://www.iaia.org/wiki-details.php?ID=4.

IPIECA, UNDP, IFC. 2017. Mapping the oil and gas industry to the SDGs: an Atlas. IFC, IPIECA, UNDP. London, Geneva and Washington, D.C.

James A. 2015. The resource curse: a statistical mirage? J Dev Econ. 114:55–63. doi:10.1016/j.jdeveco.2014.10.006.

Jomo KS, Chowdhury A, Sharma K, Platz D 2016. Public-Private Partnerships and the 2030 Agenda for Sustainable Development.

Joyce S, Sairinen R, Vanclay F. 2018. Using social impact assessment to achieve better outcomes for communities and mining companies. Mining and Sustainable Development. London: Routledge; p. 65–86.

Knoblauch AM, Hodges MH, Bah MS, Kamara HI, Kargbo A, Paye J, Turay H, Nyorkor ED, Divall MJ, Zhang Y, et al. 2014. Changing patterns of health in communities impacted by a bioenergy project in northern Sierra Leone. Int J Environ Res Pub He. 11(12):12997–13016. doi:10.3390/ijerph111212997

Langston JD, Lubis MI, Sayer JA, Margules C, Boedhihartono AK, Dirks PHGM. 2015. Comparative development benefits from small and large scale mines in North Sulawesi, Indonesia. Extr Ind Soc. 2(3):434–444.

Leuenberger A, Farnham A, Azevedo S, Cossa H, Dietler D, Nimako B, Adongo PB, Merten S, Utzinger J, Winkler MS.

2019. Health impact assessment and health equity in sub-Saharan Africa: a scoping review. Environ Impact Assess Rev. 79:11. doi:10.1016/j.eiar.2019.106288.

Mactaggart F, McDermott L, Tynan A, Whittaker M. 2018. Exploring the broader health and well-being outcomes of mining communities in low- and middle-income countries: a systematic review. Glob Public Health. 13 (7):899–913. doi:10.1080/17441692.2016.1240821.

Mancini L, Sala S. 2018. Social impact assessment in the mining sector: review and comparison of indicators frameworks. Resources Policy. 57:98–111. doi:10.1016/j.resourpol.2018.02.002.

Mawdsley E. 2018. From billions to trillions: financing the SDGs in a world 'beyond aid'. Dialogues Hum Geogr. 8 (2):191–195. doi:10.1177/2043820618780789.

Mehlum H, Moene K, Torvik R. 2006. Institutions and the resource curse. Econ J. 116(508):1–20. doi:10.1111/j.1468-0297.2006.01045.x.

Meijia PX, Castel V. 2012. Could oil shine like diamonds? How botswana avoided the resource curse and its implications for a New Libya. Abidjan: Banque Africaine de Developpement.

Miranda ML, Hale B. 2001. Protecting the forest from the trees: the social costs of energy production in Sweden. Energy J. 26 (9):869–889. doi:10.1016/S0360-5442(01)00037-8.

Mirumachi N, Torriti J. 2012. The use of public participation and economic appraisal for public involvement in large-scale hydropower projects: case study of the Nam Theun 2 Hydropower Project. Energy Policy. 47:125–132. doi:10.1016/j.enpol.2012.04.034.

Moher D, Liberati A, Tetzlaff J, Altman DG. 2009. Preferred reporting items for systematic reviews and meta-nalyses: the PRISMA Statement. Ann Intern Med. 151(4):264–269. the PG. doi:10.7326/0003-4819-151-4-200908180-00135.

Moran MD, Taylor NT, Mullins TF, Sardar SS, McClung MR. 2017. Land-use and ecosystem services costs of unconventional US oil and gas development. Front Ecol Environ. 15 (5):237–242. doi:10.1002/fee.1492.

Morimoto R, Hope C. 2004. Applying a cost-benefit analysis model to the Three Gorges project in China. Impact Assess Proj Apprais. 22(3):205–220. doi:10.3152/147154604781765888.

Morrison-Saunders A, Retief F. 2012. Walking the sustainability assessment talk — progressing the practice of environmental impact assessment (EIA). Environ Impact Assess Rev. 36:34–41. doi:10.1016/j.eiar.2012.04.001.

Netalieva I, Wesseler J, Heijman W. 2005. Health costs caused by oil extraction air emissions and the benefits from abatement: the case of Kazakhstan. Energy Policy. 33 (9):1169–1177. doi:10.1016/j.enpol.2003.11.014.

Otto J, Andrews CB, Cawood F, Doggett M, Guj P, Stermole F, Stermole J, Tilton J. 2006. Mining royalties: a global study of their impact on investors, government, and civil society. Washington D.C.: The World Bank.

Papyrakis E. 2017. The resource curse - What have we learned from two decades of intensive research: introduction to the special issue. J Dev Stud. 53(2):175–185. doi:10.1080/00220388.2016.1160070.

Papyrakis E, Rieger M, Gilberthorpe E. 2017. Corruption and the Extractive Industries Transparency Initiative. J Dev Stud. 53(2):295–309. doi:10.1080/00220388.2016.1160065.

Petrou S, Gray A. 2011. Economic evaluation using decision analytical modelling: design, conduct, analysis, and reporting. BMJ. 342:d1766. doi:10.1136/bmj.d1766.

Ross ML. 2004. What Do We Know about Natural Resources and Civil War? J Peace Res. 41(3):337–356. doi:10.1177/0022343304043773.

Rudmik L, Drummond M. 2013. Health economic evaluation: important principles and methodology. Vol. 123, The Laryngoscope; 6. The Laryngoscope: John Wiley & Sons, Ltd.

Rushton J, Thornton PK, Otte MJ. 1999. Methods of economic impact assessment. Rev Sci Tech. 18(2):315–342. doi:10.20506/rst.18.2.1172.

Sachs J, McCord G, Nicolas M, Smith T, Fajans V, Turner LSS. 2019. SDG costing & financing for low-income developing countries. United nations.

Scheyvens R, Banks G, Hughes E. 2016. The private sector and the SDGs: the need to move beyond 'business as usual'. J Sustain Dev. 24(6):371–382. doi:10.1002/sd.1623.

Schrecker T, Birn A-E AM. 2018. How extractive industries affect health: political economy underpinnings and pathways. Health Place. 52:135–147. doi:10.1016/j.healthplace.2018.05.005.

Slavova I, Bankova Y. 2017. The role of clusters for sustainable development: socially responsible practices, limitations and challenges. In: Case study of a Bulgarian industrial cluster. London: International Institute of Social and Economic Sciences; p. 199-225.

Stafford-Smith M, Griggs D, Gaffney O, Ullah F, Reyers B, Kanie N, Stigson B, Shrivastava P, Leach M, O'Connell D. 2017. Integration: the key to implementing the Sustainable Development Goals. Sustain Sci. 12(6):911–919.

Sturman K, Toledano P, Akayuli CF, Gondwe M. 2020. African Mining and the SDGs: from Vision to Reality. In: Africa and the Sustainable Development Goals. Springer. p. 59–69.

Tajziehchi S, Monavari SM, Karbassi AR, Shariat SM, Khorasani N. 2013. Quantification of social impacts of large hydropower dams: a case study of Alborz Dam in Mazandaran province, northern Iran. Int J Environ Res. 7 (2):377–382.

Tajziehchi S, Monavari SM, Karbassi AR, Shariat SM, Khorasani N, Narimisa P. 2014. A critical look at social impact evaluation of dam construction by revised SIMPACTS software: a case study of Alborz Dam in northern Iran. Int J Environ Res. 8(2):329–334.

United Nations. 2011. Minerals and Africa's development: the international study group report on Africa's mineral regimes. Addis Ababa: Economic Commission for Africa.

United Nations. 2014. World investment report 2014: Investing in the SDGs: an action plan. New York and Geneva: United Nations.

Valero A, Valero A, Calvo G, Ortego A, Ascaso S, Palacios J-LJE. 2018. Global material requirements for the energy transitionan exergy flow analysis of decarbonisation pathways.. Energy 159:1175–1184. doi:10.1016/j.energy.2018.06.149.

Von Der Goltz J, Barnwal P. 2019. Mines: the local wealth and health effects of mineral mining in developing countries. J Dev Econ. 139:1–16. doi:10.1016/j.jdeveco.2018.05.005.

Winkler MS, Adongo PB, Binka F, Brugger F, Diagbouga S, Macete E, Munguambe K, Okumu F. 2020a. Health impact assessment for promoting sustainable development: the HIA4SD project. Impact Assess Proj Apprais. 38(3):225–232. doi:10.1080/14615517.2019.1694783.

Winkler MS, Furu P, Viliani F, Cave B, Divall M, Ramesh G, Harris-Roxas B, Knoblauch AM. 2020b. Current Global Health Impact Assessment Practice. Int J Environ Res Public Health. 17(9):2988. doi:10.3390/ijerph17092988.

Winkler MS, Krieger GR, Divall MJ, Cissé G, Wielga M, Singer BH, Tanner M, Utzinger J. 2013. Untapped potential of health impact assessment. Bull World Health Organ. 91 (4):298–305. doi:10.2471/BLT.12.112318.

Winkler MS, Krieger GR, Divall MJ, Singer BH, Utzinger J. 2012. Health impact assessment of industrial development projects: a spatio-temporal visualisation. Geospat Health. 6(2):299–301. doi:10.4081/gh.2012.148.

Wonderling D. 2011. Guinness L, Wiseman V, editors. Introduction to health economics. second ed. London: McGraw-Hill Education (UK).

World Bank.2017. The growing role of minerals and metals for a low carbon future. Washington D.C.: World Bank Group.

World Bank.2020a. GDP (current US$) | data. [updated 2020 Nov 02; accessed]. https://data.worldbank.org/indicator/NY.GDP.MKTP.CD.

World Bank TW. 2020b. World Development Indicators. [updated 2020 Nov 02; accessed]. https://datacatalog.worldbank.org/dataset/gdp-ranking.

Appendix I: Search terms and results in Scopus

Set	Search term and strategy	Hits (01.01.1998–- 30.09.2020)
#1 NREPs	TITLE-ABS-KEY ((exploration OR exploitation OR extractive OR extraction OR mine OR mines OR mining OR industry OR industries OR factory OR factories OR plantation OR production OR dam OR drilling) AND (asbestos OR carbon OR coal OR diamond OR diamonds OR fluorite OR gas OR 'natural gas' OR metal OR metals OR salt OR aluminum OR alumina OR bauxite OR cobalt OR copper OR chrome OR chromium OR gold OR iron OR 'iron ore' OR lead OR manganese OR nickel OR phosphate OR phosphor OR palladium OR platinum OR potassium OR silver OR steel OR sulphate OR sulphur OR tin OR titanium OR tungsten OR uranium OR vermiculite OR zinc OR zirconium OR hydrocarbon OR oil OR petrol OR gas OR hydroelectric OR hydropower OR biofuel OR biofuels OR timber OR electricity OR electricities OR cement) OR ('extractive industry' OR 'extractive industries' OR 'mining development' OR 'mining industry' OR 'mining industries' OR 'resource curse' OR 'resource extraction' OR 'power plant' OR 'power plants'))	**2'131'194**
#2 Economic/ finance	TITLE-ABS-KEY ("economic impact analysis" OR 'economic evaluation*' OR 'economic assessment' OR 'financial evaluation*' OR 'financial assessment' OR 'cost-effectiveness analysis' OR 'cost minimization analysis*' OR ' cost-utility analysis' OR 'cost-benefit analysis')	**308'797**
#3 Impact assessments/ evaluation	TITLE-ABS-KEY ('economic impact assessment*'OR eia OR 'environmental impact' OR 'environmental impacts' OR 'environmental impact assessment' OR hia OR 'health impact' OR 'health impacts' OR 'health impact assessment' OR sia OR 'social impact' OR 'social impacts' OR 'social impact assessment' OR esia OR eshia OR 'integrated impact' OR 'integrated impacts' OR 'integrated impact assessment')	**262'290**
#1AND #2 AND #3	**NREPs AND Economic/finance AND Impact assessments**	**1'530**

Appendix II: Search terms and results in PubMed

Set	Search term and strategy	Hits (30.09.2020)
#1 NREPs	(exploration[tiab] OR exploitation[tiab] OR extractive[tiab] OR extraction[tiab] OR mine[tiab] OR mines[tiab] OR mining[tiab] OR industry[tiab] OR industries[tiab] OR factory[tiab] OR factories[tiab] OR plantation[tiab] OR production[tiab] OR dam[tiab] OR drilling[tiab]) AND (asbestos[tiab] OR carbon[tiab] OR coal[tiab] OR diamond[tiab] OR diamonds[tiab] OR fluorite[tiab] OR gas[tiab] OR 'natural gas'[tiab] OR metal[tiab] OR metals[tiab] OR salt[tiab] OR aluminum[tiab] OR alumina[tiab] OR bauxite[tiab] OR cobalt[tiab] OR copper[tiab] OR chrome[tiab] OR chromium[tiab] OR gold[tiab] OR iron[tiab] OR 'iron ore'[tiab] OR lead[tiab] OR manganese[tiab] OR nickel[tiab] OR phosphate[tiab] OR phosphor[tiab] OR palladium[tiab] OR platinum[tiab] OR potassium[tiab] OR silver[tiab] OR steel[tiab] OR sulphate[tiab] OR sulphur[tiab] OR tin[tiab] OR titanium[tiab] OR tungsten[tiab] OR uranium[tiab] OR vermiculite[tiab] OR zinc[tiab] OR zirconium[tiab] OR hydrocarbon[tiab] OR oil[tiab] OR petrol[tiab] OR gas [tiab] OR hydroelectric[tiab] OR hydropower[tiab] OR biofuel[tiab] OR biofuels[tiab] OR timber[tiab] OR electricity[tiab] OR electricities[tiab] OR cement[tiab] OR 'natural resources'[tiab]) OR ('extractive industry' [tiab] OR 'extractive industries'[tiab] OR 'mining development'[tiab] OR 'mining industry'[tiab] OR 'mining industries'[tiab] OR 'resource curse'[tiab] OR 'resource extraction'[tiab] OR 'Extraction and Processing Industry'[tiab])	**249'517**
#2 Economic/ finance	('economic impact analysis' [tiab] OR 'economic evaluation*' [tiab] OR 'economic assessment' [tiab] OR 'financial evaluation*'[tiab] OR 'financial assessment'[tiab] OR 'cost-effectiveness analysis'[tiab] OR 'cost minimization analysis*'[tiab] OR 'cost-utility analysis'[tiab] OR 'cost-benefit analysis'[tiab])	**25'473**
#3 Impact assessments/ evaluations	('economic impact assessment'[tiab] OR eia [tiab] OR 'environmental impact'[tiab] OR 'environmental impacts'[tiab] OR hia[tiab] OR 'health impact'[tiab] OR 'health impacts'[tiab] OR 'health impact assessment'[tiab] OR sia[tiab] OR 'social impact'[tiab] OR 'social impacts'[tiab] OR 'social impact assessment'[tiab] OR esia[tiab] OR eshia[tiab] OR 'integrated impact'[tiab] OR 'integrated impacts'[tiab])	**33'473**
#1AND #2 AND #3	**NREPs AND Economic/finance AND Impact assessments**	**49**

Appendix III: Articles excluded after the full text screening with exclusion reason

Final exclusion reasons
Title

No full text available
- Economic assessment of market and non-market damages of oil spills
- The environmental impact of auriferous mining excavation from the perspective of the cost-benefit analysis
  - Assessment of the socio-economic impacts of quarrying and processing of limestone at Obajana, Nigeria

Study not concerning NREPs
- Marginal cost pricing for coal fired electricity in coastal cities of China: The case of Mawan electricity plant in Shenzhen City, China
- Manufacturing variability drives significant environmental and economic impact: The case of carbon fiber reinforced polymer composites in the aerospace industry
- Net Social Impact of Illegal Unconventional Onshore Tin Mining in South Bangka, Bangka Island
- Economic, environmental, and job impacts of increased efficiency in existing coal-fired power plants
- Cost benefit analysis for solar water heating systems
- Avança Brasil: Environmental and social consequences of Brazil's planned infrastructure in Amazonia
- A decision-aid framework to provide guidance for the enhanced use of best available techniques in industry
- Environmental costs of mercury pollution
- Estimating human health impacts and costs due to Iranian fossil fuel power plant emissions through the impact pathway approach
- Optimal Ozone Control with Inclusion of Spatiotemporal Marginal Damages and Electricity Demand
- Analysis of the environmental impact of a biomass plant for the production of bioenergy
- Environmental and socioeconomic impacts of utilising waste for biochar in rural areas in Indonesia–a systems perspective
  - Applying cost analyses to drive policy that protects children: Mercury as a case study

Conference paper
- Conceptual design and economic evaluation on OTEC power plants in japan

Not focusing in public economic perspective or not a economic/financial study
- Economic and environmental impact evaluation of various biomass feedstock for bioethanol production and correlations to lignocellulosic composition
- Sustainability analysis of bioethanol promotion in Thailand using a cost-benefit approach
- Environmental and socio-economic assessment of cork waste gasification: Life cycle and cost analysis
- Assessment of the environmental impact and economic benefits of the adoption of cleaner production in a Brazilian metal finishing industry
- Natural gas as a transitional solution for railway powering systems: Environmental and economic assessment of a fuel cell based powering system
- Biodiesel production from Nannochloropsis gaditana using supercritical CO2 for lipid extraction and immobilised lipase transesterification: Economic and environmental impact assessments
- Economic and environmental evaluation of aluminium recycling based on a belgian case study
- Economic and environmental impact evaluation of various biomass feedstock for bioethanol production and correlations to lignocellulosic composition
- Realising the values of natural capital for inclusive, sustainable development: Informing China's new ecological development strategy
- Modeling the costs and benefits of dam construction from a multidisciplinary perspective
- Considerations of Project Scale and Sustainability of Modern Bioenergy Systems in Uganda
- Bioshale FP6 European project: Exploiting black shale ores using biotechnologies?
- Bioenergy project appraisal in sub-Saharan Africa: Sustainability barriers and opportunities in Zambia
- Brazil's Samuel Dam: Lessons for hydroelectric development policy and the environment in Amazonia
- Political benefits as barriers to assessment of environmental costs in Brazil's Amazonian development planning: The example of the Jatapu Dam in Roraima
- Demystifying the social impacts of biofuels at local levels: Where is the evidence?
- Review of risks to communities from shale energy development
- The benefits of a Brazilian agro-industrial symbiosis system and the strategies to make it happen
- Hydropower royalties: A comparative analysis of major producing countries (China, Brazil, Canada and the United States)
- Holistic environmental assessment and offshore oil field exploration and production
- Valuing the environmental impacts of electricity production: A critical review of some 'first-generation' studies
- An integrated assessment of energy conversion processes by means of thermodynamic, economic and environmental parameters

Theoretical study
- The cost of unconventional gas extraction: A hedonic analysis
- The economic, social and environmental impact of shale gas exploitation in Romania: A cost-benefit analysis
- A CBA model of a hydro project in Sri Lanka
- Public acceptance of surface mining projects and the determination of the marginal environmental cost
- Promoting biofuels use in Spain: A cost-benefit analysis
- The social cost of dredging: The Bahia Blanca Estuary case

Paper does not present a full economic evaluation/assessment, including a detailed methodology and original results
- Proximate analysis of Lakhra coal power plant and its health and environmental impact
- The determination of reclamation parameters and cost analysis in mining sites
- Mining in the Arctic environment – A review from ecological, socioeconomic and legal perspectives

Not written in English
- Benchmarking – Austrian Waste Management: Are the objectives of waste management achieved?
- The external cost of coal power chain in China
- Energy evaluation for ecological impacts of small hydropower in China

Appendix IV: main results of the included studies

Author, (year) Country, continent	NREP Name	Mean economic objectives	Mean data sources	Type of impact - Impact on what	Economic analysis - What is measured	Main economic results
Moran et al. 2017 America	Oil and gas	To measure land-use Estimate ecosystem services costs in eight oil and gas regions in the US from 2004 until 2015	Previously study and public land survey system	**Environmental** -Land-use by well -Ecosystem services *Social impact -Habitat change	**Cost analysis** -Ecosystem services cost calculations using a linear function with sensitivity analysis -Habitat comparison using satellite images with the situation of oil wells	- From 2004 to 2015, more than 200,000 hectares of land were developed or modified - By 2015, annual ecosystem services costs were estimated at US$ 272 million in 2015 and US$ 1.4 billion in total - By 2040, this cost will be between US$ 9.4 billion to US $ 31.9 billion.
Considine et al. 2016 Pennsylvania, America Marcellus shale is beneficial for public perspective: - Well economic benefits are about US$ 23 million fits -	Marcellus Shale of	Pennsylvania	To conduct a cost-benefit analysis of developing natural gas from the Marcellus shale formation in Pennsylvania Environmental damage costs about US$ 360,000 - Net benefits is between (US $13,896.6 – US $30,539.6)	Existing data	**Environmental** -Environmental violations, air, land, and water	**Cost-benefit analysis** -Cost of environmental damage and air pollution -The benefit is a total of direct and indirect cost, including impacts
Fanaian et al. 2015 Mozambique, Africa	Zambezi river	To demonstrate the value of alternative flow regimes in a river	Published studies	**Ecological-economic** -River flow impact on public economy	**Benefit analysis** - Ecosystem goods e.g. Prawn and freshwater fisheries, tourism, hydropower, irrigated agriculture	- Ecosystem goods value for US$ 283 million of which 55% (or US$ 154 million) for hydropower -6 flow regime scenarios (pre-dam flows, Post-dam flows, December high flow, February medium high flow, January and February high flow, February high flow) were given respectively US$ 222, 285, 263, 294, 313 and 259 million for 2010
Tajziehchi et al. 2014 Ira, Asia	Alborz Dam in northern Iran	To examine whether the SIMPACTS software model output complies with the existing realities or not	SIMPACTS software modified by programming a new cost-benefit model	**Social** -Hydropower dam with all anthropogenic activities in the basin of the Alborz Dam	**Cost-benefit analysis** -Costs of power generation, irrigation and drainage, aquatics, drinking water -Benefits from electricity sales, elimination of pollutants, increased cultivated area, aquaculture practice, prevention of flood	Alborz Dam is beneficial for public perspective: -Total costs estimated to US$ 32,182,945 -Total revenues estimated to US$ 61,152,127 -The benefit over cost ratio of 1.90
Tajziehchi et al. 2013 Iran, Asia	Alborz Hydropower Plant	To calculate the real cost of generating electricity imposed on communities and environment	IMPACT software	**Social** -Population -Economic activities	**Cost analysis** - Resettlement cost, loss of land, agricultural and livestock production -Economic losses: increased disease incidents, air pollution	- Socioeconomic cost is US$ 4.8 million/year - Need to take into account benefits in the IMPACT software

(Continued)

(Continued).

Author, (year) Country, continent	NREP Name	Mean economic objectives	Mean data sources	Type of impact - Impact on what	Economic analysis - What is measured	Main economic results
Mirumachi and Torriti 2012 Laos, Asia	Theun 2 Hydropower Project	To examine the role of the Asian	Development Bank (ADB) in facilitating public involvement to gain public acceptance	Secondary data: (wCD, 2000), (MAFF, 1999))	**Environmental-social** -Environmental ecosystem costs -Human resettlement	**Cost-benefit analysis** - Indirect costs: resettlement, fisheries losses, watershed sedimentation -Benefit: power generation, agricultural irrigation, water supply, flood control
-Asian Development Bank was only partially involved in facilitating public participation -			Environmental and social impacts were treated as market values only -Discount rates were set discretionarily			
Alp and Yetis 2010 Turkeum, Asia	Yusufeli dam and	hydroelectric power plant	To estimate the cost of environmental damage caused by Yusufeli dam and hydroelcetric power plant	Population of 04 villages	**Environmental** -Local environmental damage due to dam	**Cost analysis** - Willingness to pay (WTP) value - No market value estimation with cost analysis
- WTP is US$ 761 per person						
Hjerpe and Kim 2007, America	Grand Canyon river	To determine the regional economic impacts, and to examine the attributes of these economic impacts in terms of regional multipliers, leakage, and types of jobs created.	The Grand Canyon region of northern Arizona	**Socioeconomic** -Recreation and tourism -Job creation	**Cost-benefit analysis** - Cost: regional commercial rafting expenditures - Benefit: regional expenditure of rafting	• Indirect and induced total expenditures: US$21,100,000 • Potential total postive impacts: US$23,415,000
Damigos and Kaliampakos (2006)Greece, Europe	Perama gold project	To assess the mining investment, namely "Perama gold project", for the extraction of a gold and silver	Mining firms	**Environmental-Social** - Social Net - Present Value (SNPV) and Social Internal Rate of Return	**Cost-benefit analysis** -Benefits: salaries, imported tariffs, taxes paid, benefits to the community -Cost: environmental impact by 03 scenarios (A = simultaneous approach, B = major accident, C = additive approach)	Total benefits (e.g: to communities 498,644€ during the construction period and 523,000€ per annum; employees 206,150€ per annum, training 300,000€, imported tariffs 249,332€) surpass the total costs for all the 3 scenarios Cost: 1,400,000–4,900,000€ per annum for the neighboring communities.

(*Continued*)

(Continued).

Author, (year) Country, continent	**NREP Name**	**Mean economic objectives**	**Mean data sources**	**Type of impact** - Impact on what	**Economic analysis** - What is measured	**Main economic results**
Damigos 2006 Colorado, America	Eagle Mine	To estimate the damages caused by the mine	Eagle County survey	**Environmental** -Contingent valuation - Hedonic property	**Cost-benefit analysis** -Fishing, hiking, camping, drinking water, passive use service flows, and the aesthetic quality of the river -Willingness to pay (WTP)	Cost: US$ 26,163 (linear model) to US$ 24,400 (semi-log model) WTP: median between US$ 4.16- US $16.01
	P. Viaropoulos quarry	To estimate the economic value that could potentially be derived from the reclamation of the quarry site	200 households interviews, Fuzzy Delphi Method	**Environmental-Social** - Quarry site rehabilitation - Apartment pricing	**Cost-benefit analysis** -Willingness to pay (WTP) by scenario (1: reforestation, 2: backfilling, 3: partial backfilling) -Apartment price	-WTP: 56% could pay, 820 apartments within -WTP by scenario: 3 = €58.20; 2 = €49.47; 1 = €30.75 –820 apartments would attract a premium of between €17,700,000 and €35,500,000 - Price by apartment €31,200
	Perama gold mine project	To estimate the cost of the	environmental impacts of the project	Databases EVRI (Environmental Valuation Reference Inventory_)	**Environmental** • Landscape, intrusion, biodiversity, water, air pollution, noise	**Cost-benefit analysis** - Cost: environmental impact by 03 scenarios (A = simultaneous approach, B = major accident, C = additive approach)
By scenario/ annum: -A: Neighbouring					area = €1,320,000 Broader	area = €9,000,000–13,000,000 -B: Neighbouring area = €1,400,000-€4,900,000 Broader area €9,000,000-€12,000,000 -C: Neighbouring area = €4,000,000 to 182,500,000; Broader area €9,000,000 and 13,000,000
Netalieva et al. 2005 Kazakhstan, Asia	Atyrauskaya and Akmolinska procinces oil industries	To estimate the health benefits that can result from reducing air pollution	–497 interviews -Levels of pollution (hydro-meteorological forecast service)	**Heath** - Excess case of disease - Working days and incomes losses	**Cost-benefit analysis** - Benefit: decrease in health costs from reduced air pollution - Cost: income losses due to respiratory diseases	Benefits: about US$ million 0.46 per year Cost: least US$ million 5.1 per year
Morimoto and Hope 2004 China, Asia	The	ThreeGorges project (TGP)	To bring the major economic, environmental and social impacts	-World Bank - TGP staff	**Environmental-Social- Economic** - Mean present value - Cumulative net present value	**Cost benefit analysis** - Benefit: economic grow, power generation, clean power - Cost: construction, lost archeological sites, resettlement
Mean present value Benefit: US $ billion 138 Cost: US $ billion 89.3						
Miranda and Hale 2001 Sweden, Europe	Sweden	To estimate production and	environmental costs for various forest residue, coal, oil and natural gas energy production systems	Center for Business and Policy Studies in Stockholm	**Full social cost analysis** - Production cost, producers pay - Environmental (air and water pollution)	**Cost analysis** - Production cost: forest residue, fossil fuel - Environmental cost: residue removal, forest residue combustion, ash disposal

(*Continued*)

3. Paper 2 – Changes in Socioeconomic Determinants of Health in a Copper Mine development Area in Northwestern Zambia

This article was published in

The Extractive Industries and Society https://doi.org/10.1016/j.exis.2021.100985

The Extractive Industries and Society 8 (2021) 100985

Contents lists available at ScienceDirect

The Extractive Industries and Society

journal homepage: www.elsevier.com/locate/exis

Original article

Changes in socioeconomic determinants of health in a copper mine development area, northwestern Zambia

Hyacinthe R. Zabré [a,b,c], Astrid M. Knoblauch [a,b,*], Serge P. Diagbouga [c], Günther Fink [a,b], Milka Owuor [d], Kennedy Nduna [e], Marcus Chisanga [f], Gertrude Musunka [f], Mark J. Divall [d], Mirko S. Winkler [a,b], Andrea Farnham [a,b]

[a] Swiss Tropical and Public Health Institute, Basel, Switzerland
[b] University of Basel, Basel, Switzerland
[c] Research Institute of Health Sciences, Ouagadougou, Burkina Faso
[d] Shape Consulting, St Peter Port, Guernsey
[e] Nvumabaranda Public Health Services, Ndola, Zambia
[f] First Quantum Minerals Limited, Lusaka, Zambia

ARTICLE INFO

Keywords:
Determinants of health
Health impact assessment
Mining
Socioeconomic
Zambia

ABSTRACT

In 2011, an industrial copper mine was developed in northwestern Zambia. A health impact assessment was conducted to anticipate and address potential health impacts. To monitor these impacts, three community-based surveys were conducted in the area (2011, 2015 and 2019). We analysed these data to determine how household socioeconomic indicators – considered determinants of health – have changed in the area over time. In mine-impacted communities, between 2011 (pre-construction) and 2019, significant changes were observed for: (i) average household size (-0.6 members); (ii) proportion of mothers that have not completed primary school (+20.4%); (iii) ownership of economic assets (e.g. phones +29.3%; televisions +15.6%); (iv) access to safe drinking water (+27.4%); and (v) improved housing structures (e.g. finished roof +58.6%). When comparing changes between 2015 and 2019 in impacted communities to nearby comparison communities, there was (i) an increased proportion of mothers that had not completed primary school in comparison communities vs. no change in impacted communities; and (ii) increased ownership of economic assets in impacted vs. comparison communities in 2019. This study found generally positive changes in the socioeconomic development of impacted compared to comparison communities, with the most pronounced improvements in the early phases of mine development.

Abbreviations

FQML	First Quantum Minerals Limited
HIA	Health Impact Assessment
ODK	Open Data Kit
SD	Standard Deviation
ZDHS	Zambia Demographic and Health Survey

1. Introduction

Natural resource extraction projects constitute a major economic sector in many sub-Saharan African countries, with new mines often creating a large number of jobs and resulting in large-scale investments in the local infrastructure. Zambia has a long history of copper mining, and is the second largest copper producer in Africa (Meller and Simpasa, 2011; Sikamo et al., 2016; World Bank Group, 2015). As in many resource-rich low-income countries, Zambia's economy is heavily dependent on natural resource extraction, which is responsible for 12% of the country's gross domestic product and accounts for more than 80% of the country's exports (World Bank Group 2020).

Large-scale industrial copper mines can have positive economic effects on surrounding local communities, as previous studies show. For example, increased employment rates were observed in municipalities in Norway, Sweden and Finland (Frederiksen and Kadenic, 2020) and better average standards of living were observed in Peruvian mining districts as compared to other districts (Loayza et al., 2013). In Zambia,

* Corresponding author.
E-mail address: astrid.knoblauch@swisstph.ch (A.M. Knoblauch).

https://doi.org/10.1016/j.exis.2021.100985
Received 27 April 2021; Received in revised form 20 August 2021; Accepted 20 August 2021
Available online 13 September 2021

it was estimated that a 10% increase in copper production resulted in a 2% increase in household expenditure and a 3% decrease in the overall unemployment rate between 1996 and 2010 (Lippert, 2014). In contrast, neutral or detrimental impacts of mining on the economy of local communities have also been observed. For example, in Mali, poverty reduction in mining communities was no different than that of non-mining communities (Chuhan-Pole et al., 2017). More generally, the presence of multinational mining companies has been linked to increased food insecurity in Africa (Wegenast and Beck, 2020) and decreases in the wealth of mining-affected households due to costs caused by a surge in uncontrolled infectious diseases (Viliani et al., 2017).

The Trident Copper Project (hereafter referred to as "the Project") operated by First Quantum Minerals Limited (FQML) is a greenfield copper project located in Kalumbila district, North-Western province of Zambia. The Project conducted its feasibility studies between 2009 and 2011 and moved into the construction phase in 2012. As part of the feasibility studies, a health impact assessment (HIA) was conducted in 2010/2011, using a comprehensive approach to health, i.e. considering the physical, socioeconomic, behavioural and biological determinants of health (Winkler et al., 2021). Potential health impacts were systematically anticipated and addressed by the HIA with the ultimate objective of protecting and promoting public health in surrounding communities (Knoblauch et al., 2020). The impact monitoring program defined by the HIA recommended that the Project conduct repeated cross-sectional health surveys every 4 years. The health surveys measured selected health outcomes and determinants of health. These included socioeconomic indicators at the household level to assess socioeconomic status in a nationally comparable way, such as possession of assets, cooking fuel, housing material and drinking water infrastructure (Rutstein and Johnson, 2004).

Findings of the monitoring of selected health indicators are presented elsewhere (Knoblauch et al., 2020). Here, we present the findings of the selected socioeconomic indicators and their changes over time in both, communities affected by the Project and comparison communities. We describe (i) the overall changes in the indicators in six communities impacted by the Project in an eight-year time period between the Project start (2011) and the Project operational phase (2019) and (ii) how trends in the indicators differ in local communities impacted by the Project vs. comparison communities.

2. Methods

2.1. Study area, design and sampling

The Project is located in Kalumbila district, North-Western province of Zambia (Fig. 1). Three cross-sectional surveys were conducted. Following a baseline survey in 2011, two follow-up surveys were conducted in 2015 and 2019, all during the same season (June/July), in communities impacted by the Project as well as comparison communities. Six impacted communities were sampled in all three surveys, namely: Northern Resettlement (previously Wanyinwa), Musele, Chisasa, Kankonzhi, Chovwe and Chitungu. For another six communities, data was only available for 2015 and 2019 (i.e. Kalumbila Town, Shenengene, Kanzanji, Wamafwa, Kanzala, Mubenji) (Table 1) (Knoblauch et al., 2017).

For the 13 communities ever surveyed, nine communities were considered "impacted" because they were affected by the Project development. This could be due to changes intrinsically caused by the mining Project, such as infrastructure investments or community resettlements. For example, Kalumbila Town was developed by the Project to accommodate workers and their families as well as to provide services to these communities, while Shenengene developed as a host site for communities that were physically resettled. In addition, they could be affected due to health and socioeconomic interventions initiated by the Project. These included, for example, programs to prevent sexually transmitted diseases, improvement of drinking water sources, girls' empowerment programs, health infrastructure development,

Table 1
Study populations, Kalumbila district, Zambia (2011, 2015, 2019).

Community	Number of households		
	2011	2015	2019
Impacted communities			
Kalumbila Town	n/s	29	31
Wanyinwa/Northern Resettlement	35	34	30
Shenengene	n/s	32	31
Musele	29	67	65
Chisasa	62	65	66
Kankonzhi	39	30	32
Chovwe	63	32	32
Kanzanji	n/s	32	32
Chitungu	30	33	32
Total impacted communities	**258**	**354**	**351**
Comparison communities			
Nkenyawuli	29	32	31
Wamafwa	n/s	33	32
Kanzala	n/s	30	63
Mubenji	n/s	33	32
Total comparison communities	**29**	**128**	**158**

n/s, not sampled
Adapted from Knoblauch et al. (Knoblauch et al., 2020).

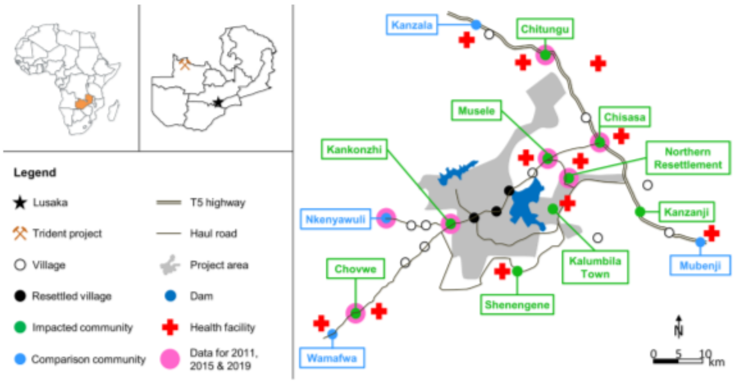

Fig. 1. Map of the study area and surveyed communities, Kalumbila district, Zambia (Adapted from Knoblauch et al. (Knoblauch et al., 2020)).

education, and conservation farming amongst other programs in the communities around the Project (Knoblauch et al., 2017). Another four communities were considered "comparison" because they did not benefit directly from the Project through e.g. Project-initiated health or community development interventions or infrastructure investments (Knoblauch et al., 2017; Knoblauch et al., 2018; Knoblauch, Divall et al., 2017; Knoblauch et al., 2020; Winkler et al., 2012). After the initial assessment, systematic monitoring through periodic surveys was used to assess long-term changes in the area. Moreover, in addition to assessing long-term changes in villages impacted by the mine's activities, systematic monitoring of nearby comparison communities over time was also conducted. Comparison communities were selected because they were similar to impacted communities except for the presence of mine interventions. This was increasing the robustness of our study by providing a comparison point of background changes over time in nearby villages not impacted by the mine (Ferragina, 2021; Krzywinski and Altman, 2014).

Within the selected communities, random sampling was used to select a quota of 25 to 35 households per community (Winkler et al., 2012). In order to increase representativeness, the sample size was doubled in communities with larger population sizes (i.e. Chisasa, Musele and Kanzala) (Knoblauch et al., 2020). Within the selected communities, the household inclusion criteria was the presence of a mother aged 15-49 years with a child under 5 years of age.

2.2. Questionnaire data collection

Data collection at household level included (i) administering a questionnaire to household members aged ≥15 years; (ii) measuring biomedical indicators in children under 5 years of age and women aged 15-49 years; (iii) testing for intestinal parasites and schistosomiasis in school children aged 9-14 years; and (iv) environmental sampling (e.g. water quality). Here, we present data only from the questionnaire and hence, do not introduce the other data collection methods that are described elsewhere (Knoblauch et al., 2020). The household questionnaire included a list of standardized socioeconomic variables used by the ZDHS to calculate a nationally comparable wealth index. These indicators were related to household members, mothers' age and education level, possession of selected household assets (e.g. bank account, bicycle, phone, radio and television), characteristics of the household floor, walls and roof, energy sources for food preparation and main sources of water for drinking. Standard categories for housing structures, drinking water and cooking sources were used in accordance with the ZDHS (ZSA et al., 2019). Data were collected with Open Data Kit (ODK) software on tablets.

2.3. Data analysis

In a first analysis, to determine how the socioeconomic indicators have evolved across impacted communities since baseline, we conducted a cross-sectional analysis to determine overall household socioeconomic change from the pre-project (2011) phase to the operational phase (2019). Importantly, only those impacted communities for which data were available for all three survey rounds were analysed over the entire study period to ensure comparability (n=6). Changes in proportions or mean values between 2011 and 2019 were calculated and tested for significance (t-test or chi-square test).

In a second analysis, the impact of the Project on local communities was measured by comparing the indicators in the impacted (n=9) vs. the comparison (n=4) communities and the change between 2015 and 2019. This comparative analysis was conducted only for the 2015 and 2019 survey rounds because 2011 data included only one comparison community (i.e. Nkenyawuli) (Knoblauch et al., 2020). The changes from 2015 to 2019 were calculated for both the impacted vs. the comparison communities, similar to the first analysis. Then, the difference between impacted and comparison was calculated by subtracting the impacted mean (or proportion) value from the comparison mean value. t-tests and chi-square tests were used to test whether the change in means or proportion, respectively, was significant.

All analyses were done with R software version 3.4.3 (The R Foundation; Vienna, Austria).

2.4. Ethical considerations

The health survey study protocols were approved by the ethics review board of the Center for Tropical Disease Research, Ndola, Zambia (TRC/ERC/04/07/2011, TRC/C4/07/2015, TRC/C4/01/2019). Data were collected after signing informed consent by the heads of households and women participating in this study. For illiterate people, the consent was translated into the local language, read and explained before fingerprinting.

3. Results

3.1. Study population

Table 1 summarizes the number of households interviewed in each survey round and community. For the 2011-2019 trend analysis, data from 258 households in 2011 were compared with data from 257 households in 2019. For the 2015-2019 difference-in-differences analysis, households from nine impacted communities (354 in 2015 and 351 in 2019, respectively) were compared with households from four comparison communities (128 in 2015 and 158 in 2019, respectively).

3.2. Changes in socioeconomic indicators

Changes in key socioeconomic indicators in all six impacted communities followed between 2011 (baseline) and 2019 (8-year follow-up) are summarized in Table 2 and Fig. 2. Average household size decreased from 4.4 persons (±2.4 standard deviations (SD)) in 2011 to 3.8 (±2.3 SD) persons in 2019 (p-value=0.007). The age of participating mothers was similar in both rounds, with marginal increases in the proportion of the 24-28 year old strata of women (+7.8%, p-value=0.06).

The proportion of mothers that did not complete primary education increased from 34.3% to 54.7% (p-value<0.001). There was a corresponding decrease in the proportion of women who completed primary (-11.0%, p-value=0.020) or secondary school (-9.4%, p-value=0.006).

Ownership of bank accounts increased by +9.5% (p-value<0.001), ownership of phones increased from 34.9% to 64.2% (p-value<0.001) and ownership of televisions increased from 11.2% to 26.8% (p-value<0.001). Bicycle ownership decreased by 12.6% (p-value=0.020), from 53.4% to 40.9%.

The type of cooking fuel used changed significantly. The share of households using wood declined from 93.6% to 63.4% (p-value<0.001), while the share of households using charcoal increased from 6.4% to 35.0% (p-value<0.001).

The use of finished materials as opposed to rudimentary materials for the housing structures increased significantly for floors (+15.6%, p-value<0.001), roofs (+58.8%, p-value<0.001) and walls (+47.8%, p-value<0.001). The proportion of household having access to an improved water sources increased from 61.9% to 89.3% (+27.4%, p-value <0.001).

3.3. Changes in socioeconomic indicators between impacted vs. comparison communities

Table 3 shows separate trends for impacted (n=9) and comparison communities (n=4) for the 2015-2019 period. Age of participating mothers increased slightly in impacted communities, where the proportion of 15-23 year olds decreased from 33.9% to 27.6% (p-value=0.08) and that of 24-28 year olds increased by +6.7% from 23.2% to 29.9% (p-value=0.05). In the comparison communities, the proportion

Table 2
Changes in the socioeconomic indicators in the six impacted communities between 2011 (before Project start) and 2019 (Project operational phase)

Indicator	2011 (258 HH)	2019 (257 HH)	Mean Change 2019-2011	p-value comparing 2011 vs. 2019
Household members; mean (±SD)				
Children under 5 years	1.9 (±1.0)	1.8 (±0.9)	-0.1	0.270
Total household size	4.4 (±2.4)	3.8 (±2.3)	-0.6	0.007
Mother's age (years); n (%)				
15-23	70 (27.1)	70 (27.2)	+0.1%	1.000
24-28	60 (23.3)	80 (31.1)	+7.8%	0.060
29-33	57 (22.1)	41 (16.0)	-6.1%	0.100
34-49	58 (22.5)	65 (25.3)	+2.8%	0.590
Missing	13 (5.0)	1 (0.4)	-4.6%	n/a
Educational attainment of mothers; n (%)*				
Not completed primary	70 (34.3)	140 (54.7)	+20.4%	<0.001
Completed primary	95 (46.6)	91 (35.5)	-11.0%	0.020
Completed secondary or higher	39 (19.1)	25 (9.8)	-9.4%	0.006
Household asset possession; n (%)				
Bank account	18 (7.2)	43 (16.7)	+9.5%	0.001
Bicycle	133 (53.4)	105 (40.9)	-12.6%	0.020
Phone	87 (34.9)	165 (64.2)	+29.3%	<0.001
Radio	97 (39.0)	95 (37.0)	-2.0%	0.950
TV	28 (11.2)	69 (26.8)	+15.6%	<0.001
Cooking fuel; n (%)				
Charcoal	16 (6.4)	90 (35.0)	+28.6%	<0.001
Electricity	0 (0.0)	0 (0.0)	+0.0%	1
Gas	0 (0.0)	4 (1.6)	+1.6%	1.130
Wood	233 (93.6)	163 (63.4)	-30.2%	<0.001
Main material of the floor; n (%)				
Finished	26 (10.5)	67 (26.1)	+15.6%	<0.001
Rudimentary	222 (98.5)	190 (73.9)	-15.6%	<0.001
Main material of the roof; n (%)				
Finished	92 (37.9)	246 (95.7)	+58.8%	<0.001
Rudimentary	157 (63.1)	11 (4.3)	-58.8%	<0.001
Main material of the walls; n (%)				
Finished	66 (26.5)	191 (74.3)	+47.8%	<0.001
Rudimentary	183 (73.5)	66 (25.7)	-47.8%	<0.001
Main source of drinking water; n (%)[a]				
Safe/improved sources[b]	169 (61.9)	241 (89.3)	+27.4%	<0.001
Unsafe/unimproved sources[b]	104 (38.1)	29 (10.7)	-27.4%	<0.001

HH, household; n/a: not applicable; SD, standard deviation.
*Mother's missing data on educational attainment were omitted from the denominator.
[a] Multiple drinking water sources possible per household.
[b] Improved sources of drinking water include piped water, public taps, standpipes, tube wells, boreholes, protected dug wells and springs, rainwater, water delivered via a tanker truck or a cart with a small tank and bottled water. Unimproved water sources include unprotected dug wells, unprotected springs and surface water.

of 15-23 year olds increased from 31.2% to 35.4% (p-value=0.61) and thus, a marked difference between the impacted communities and the comparison communities was therefore recorded for the 15-23 year olds (10.5% difference).

In impacted communities, maternal education levels remained relatively constant, while in comparison communities the proportion of mothers with incomplete primary education increased significantly from 54.7% to 68.4% (+13.7%, p-value=0.02) and the proportion of those who have completed primary dropped from 40.6% to 24.7% (-15.9%, p-value=0.005). Overall, basic educational attainment improved slightly in the impacted communities and worsened in the comparison communities.

In 2015, household possession of economic assets was generally higher in impacted communities than in comparison with regard to bank accounts (34.6% vs. 8.6%), phones (77.3% vs. 62.5%), cars (7.4% vs. 3.1%), motorcycles (6.5% vs. 6.3%), radios (48.4% vs. 35.9%) and televisions (36.3% vs. 10.2%). In 2019, the ownership rates were still higher in impacted vs. comparison communities with regard to bank accounts (23.6% vs. 8.9%), phones (68.4% vs. 61.3%), cars (7.9% vs. 3.1%), radios (39.9% vs. 25.9%) and televisions (31.9% vs. 15.8%). In contrast, bicycle and motorcycle ownership in the comparison communities surpassed that of those impacted communities in 2019 (42.4% vs. 39.3% and 8.2% vs. 5.9%, respectively). Importantly, when comparing asset holdings, there were almost universal decreases in both community groups between 2015 and 2019. Decreases were significant in the impacted communities with regard to bank accounts (-11.0%, p-value=0.002), phones (-8.9%, p-value=0.01) and radios (-8.5%, p-value=0.03). In the comparison communities, bicycle ownership decreased from 56.3% to 42.4% (-13.9%, p-value=0.03).

Overall, the biggest differences in the change between 2015 and 2019 in impacted and comparison communities were in the proportion of mothers in the youngest 15-23 year age group (-10.5%), the proportion of mothers that did not complete primary school (-20.6%), possession of bank accounts (-11.0%), bicycles (+12.7%) and TVs (-10.0%), use of charcoal as a cooking fuel (+10.4%) and the use of safe or improved water sources (-19.1%).

Fig. 3 shows the differences in changes in socio-economic indicators between the impacted and comparison communities.

4. Discussion

Using data from three consecutive cross-sectional surveys spaced four years apart (2011, 2015 and 2019), we analysed the changes in selected socioeconomic indicators considered determinants of health in households living near a large-scale copper mining Project in Zambia. Six communities impacted by the Project saw improvements in the selected socioeconomic indicators from the pre-Project implementation phase in 2011 to the Project operational phase in 2019, driven especially by increases in asset ownership such as bank accounts, phones and televisions, use of charcoal instead of wood as cooking fuel and

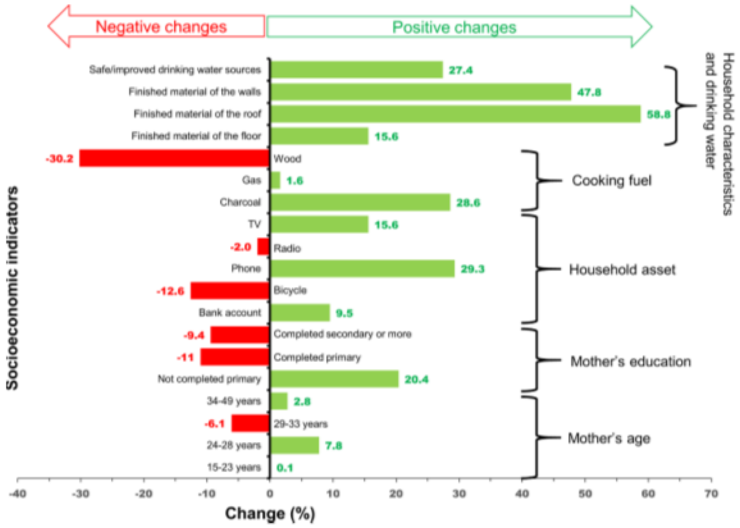

Fig. 2. Changes in the socioeconomic indicators in the six impacted communities between 2011 (before Project start) and 2019 (Project operational phase).

significant improvements in housing and drinking water infrastructure (Dietler et al., 2021b; 2021a). An important exception to this overall positive trend is the educational attainment of mothers, with a decrease in the proportion of mothers who completed primary school. In both 2015 and 2019, educational attainment of mothers, ownership of most assets (especially bank accounts, radios and televisions), use of charcoal as a cooking fuel and having finished floors and using improved water sources were all better for communities that had been impacted by the Project than comparison communities. This overall improvement in socioeconomic status in the study communities driven especially by communities directly impacted by the Project suggests that the impact of the Project on the local economy was predominantely positive. These various positive changes in the impacted communities could be linked to the in-migration induced by the mine, which typically attracts young, healthy people capable of generating household income.

While overall socioeconomic status was higher for most indicators in impacted than in comparison communities in both 2015 and 2019, asset ownership, housing quality and drinking water infrastructure declined slightly or remained the same in impacted communities between 2015 and 2019. This counterintuitive finding suggests that the main gains in the socioeconomic indicators measured in the impacted communities occurred in the Project construction phase, prior to 2015. This finding has important implications for the mechanisms by which mining projects affect local economies.

4.1. Changes in the possession of economic assets of households

The significant changes in the possession of assets revealed by our study between 2011 and 2019 are different from those of the ZDHS between 2013/14 and 2018 in rural areas (bank accounts: +9.5% vs. +0.3%, televisions: +15.6% vs. -1.3%, phones: +29.3% vs. +11.7%, bicycles: -12.6% vs. -5.9%) (CSO et al. 2014; ZSA et al. 2019). Thus, possession of these economic assets was higher in the study area, except for bicycles, suggesting that these changes were not simply improvements in Zambia as a whole and instead improvements driven by the presence of the mining Project. Interestingly, in 2015, ownership of economic assets was higher in the impacted communities than in the comparison communities. Despite a decrease of the possession of assets in impacted communities between 2015 and 2019, ownership levels in impacted communities remained higher in 2019 than in comparison communities. This could potentially reflect a positive impact of the mining Project on the possession of household assets. This aligns with numerous studies that found an increase in the economic level of poor households and employment and higher possession of economic assets in the vicinity of mines (Benshaul-Tolonen et al., 2019; Chuhan-Pole et al., 2017; Lippert, 2014).

The decrease in possession of household assets within the impacted communities between 2015 and 2019 is surprising and may reflect either changing demographics around the Project due to increasing in-migration of poorer residents, or that the positive changes in socioeconomic indicators diminish over time (Chuhan-Pole et al., 2017; Frederiksen and Kadenic, 2020; Gamu et al., 2015; Habiyaremye, 2020; James, 2015; Papyrakis, 2017; Srinivasan and Nuthalapati, 2020; Yang and Ho, 2019). Indeed, Nguyen et al. (Nguyen et al., 2017) found that impacts of mining at the local level are nuanced for the local community in an analysis of data from 63 provinces in Vietnam from 2009 to 2014. To better analyse the complexities of how mines impact on the economies of local communities over time, longitudinal studies such as cohort studies would be useful.

4.2. Changes in mother's education

The educational level of mothers in 2019 in the study were similar to those of the 2018 ZDHS in North-Western province ('not completed primary': 49.0% vs. 62.5%; 'primary completed': 31.8% vs. 27.5%; 'completed secondary or more': 8.7% vs. 9.8%) (ZSA et al., 2019). For those six impacted communities observed at baseline in 2011, educational levels have deteriorated, with 18.6% more women having 'not completed primary' education. However, between 2015 and 2019, trends toward better educational levels were observed in the impacted communities while comparison communities saw a decrease in educational attainment in mothers. Several dynamics could have contributed to these changes in the impacted communities: (i) in-migration of families with lower educational attainment since the baseline; (ii) a better educated population of mothers in the impacted communities added to the sample in 2015; and (iii) the more highly educated women employed

Table 3
Changes in the socioeconomic indicators between 2015 and 2019 in communities impacted by the mining Project and comparison communities.

Indicator	Impacted communities 2015 (354 HH)	Impacted communities 2019 (351 HH)	Change [A]	p-value	Comparison communities 2015 (128 HH)	Comparison communities 2019 (158 HH)	Change [B]	p-value	Difference in changes [A] - [B]
Household members; mean (SD)									
Children under 5 years	1.9 (0.9)	1.8 (0.9)	-0.1	0.31	1.9 (0.9)	1.8 (0.9)	-0.1	0.55	0.0
Total household size	3.7 (1.9)	3.8 (2.2)	+0.1	0.69	3.8 (1.6)	3.8 (2.2)	0.0	0.83	+0.1
Mother age (years); n (%)									
15-23	120 (33.9)	97 (27.6)	-6.3%	0.08	40 (31.2)	56 (35.4)	+4.2%	0.61	-10.5%
24-28	82 (23.2)	105 (29.9)	+6.7%	0.05	28 (21.9)	31 (19.6)	-2.3%	0.75	+9.0%
29-33	82 (23.2)	57 (16.2)	-7.0%	0.03	30 (23.4)	22 (13.9)	-9.5%	0.05	+2.5%
34-49	68 (19.2)	87 (24.8)	+5.6%	0.09	28 (21.9)	44 (27.8)	+5.9%	0.31	-0.3%
Missing	2 (0.5)	5 (1.4)	+0.9%	n/a	2 (1.6)	5 (3.2)	+1.6%	n/a	-0.7%
Educational attainment of mothers; n (%)									
Not completed primary	198 (55.9)	172 (49.0)	-6.9%	0.08	70 (54.7)	108 (68.4)	+13.7%	0.02	-20.6%
Completed primary school	112 (31.6)	121 (34.5)	+2.9%	0.47	52 (40.6)	39 (24.7)	-15.9%	0.005	+18.8%
Completed secondary school or more	42 (11.9)	53 (15.1)	+3.2%	0.25	4 (3.1)	6 (3.8)	+0.7%	1	+2.5%
Missing	2 (0.6)	5 (1.4)	+0.8%	n/a	2 (1.6)	5 (3.2)	+1.6%	n/a	-0.8%
Household asset possession; n (%)									
Bank account	122 (34.6)	83 (23.6)	-11.0%	0.002	11 (8.6)	14 (8.9)	+0.3%	1	-11.3%
Bicycle	143 (40.5)	138 (39.3)	-1.2%	0.83	72 (56.3)	67 (42.4)	-13.9%	0.03	+12.7%
Car	26 (7.4)	88 (7.9)	+0.5%	0.90	4 (3.1)	5 (3.1)	+0.0%	1	+0.5%
Motorcycle	23 (6.5)	21 (5.9)	-0.6%	0.86	8 (6.3)	13 (8.2)	+1.9%	0.75	-2.5%
Phone	273 (77.3)	240 (68.4)	-8.9%	0.01	20 (62.5)	19 (61.3)	-1.2%	0.48	-7.7%
Radio	171 (48.4)	140 (39.9)	-8.5%	0.03	46 (35.9)	41 (25.9)	-10.0%	0.09	+1.5%
TV	128 (36.3)	112 (31.9)	-4.4%	0.27	13 (10.2)	25 (15.8)	+5.6%	0.22	-10.0%
Cooking fuel; n (%)									
Charcoal	81 (22.9)	110 (31.3)	+8.4%	0.01	14 (10.9)	14 (8.9)	-2.0%	0.70	+10.4%
Electricity	28 (7.9)	22 (6.3)	-1.6%	0.48	0 (0.0)	1 (0.6)	+0.6%	1	-2.2%
Gas	0 (0.0)	4 (1.1)	+1.1%	0.13	0 (0.0)	0 (0.0)	0.0%	n/a	+1.1%
Wood	244 (69.1)	215 (61.3)	-7.8%	0.04	114 (89.1)	143 (90.5)	+1.4%	0.84	-9.2%
Main material of the floor; n (%)									
Finished	100 (28.3)	130 (37.0)	+8.7%	0.02	5 (3.9)	18 (11.4)	+7.5%	0.04	+1.2%
Rudimentary	253 (71.7)	221(63.0)	-8.7%	0.02	123 (96.1)	140 (88.6)	-7.5%	0.04	-1.2%
Main material of the roof; n (%)									
Finished	328 (92.9)	340 (96.9)	+4.0%	0.02	117 (91.4)	141 (89.2)	-2.2%	0.68	+6.2%
Rudimentary	25 (7.1)	11 (3.1)	-4.0%	0.03	11 (8.6)	17 (10.8)	+2.2%	0.68	-6.2%
Main material of the walls; n (%)									
Finished	282 (80.1)	273 (77.8)	-2.3%	0.60	97 (75.8)	109 (69.0)	-6.8%	0.25	+4.5%
Rudimentary	70 (19.9)	78 (22.2)	+2.3%	0.48	31 (24.2)	49 (31.0)	+6.8%	0.25	-4.5%
Main source of drinking water; n (%) [a]									
Safe/improved	363 (96.8)	312 (85.0)	-11.8%	0.001	92 (69.7)	124 (77.0)	+7.3%	0.20	-19.1%
Unsafe/unimproved	12 (3.2)	55 (15.0)	+11.8%	<0.001	40 (30.3)	37 (23.0)	-7.3%	0.20	+19.1%

HH, household; n/a: not applicable; SD, standard deviation.
[a] Multiple drinking water sources per household possible.

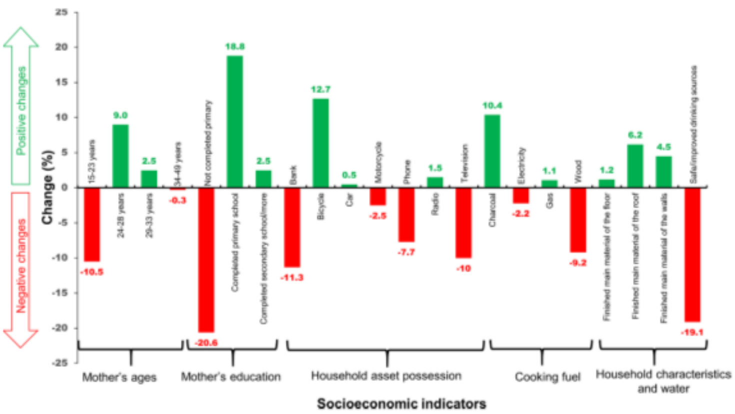

Fig. 3. Differences of changes in socioeconomic indicators between 2015 and 2019 in communities impacted by the mining Project and comparison communities.

by the mining Project were not at home during daytime data collection in 2015 and 2019. With regard to in-migration, it is known that communities such as Kalumbila Town, Shenengene or Northern Resettlement have experienced a high influx of labour-seeking, skilled and semi-skilled in-migrants (CSO et al., 2014; Knoblauch et al., 2017; Knoblauch et al., 2020; ZSA et al. 2019). It may also be possible that in-migration of families with lower educational attainment affected the comparison communities, even if they were not directly impacted by the Project. A more in-depth analysis of the migration background of the respondents would shed light on these changes and the potential impact migration had on the observed levels of maternal education.

4.3. Implications for health impact assessment practice

The current study provides a rare example of continued monitoring of socioeconomic indicators with particular relevance to health in the context of a large-scale greenfield mining project. The findings generated through the periodic collection of data, covering the phases of exploration, construction and operation, were readily incorporated in the health management plan of the Trident Project. Hence, our study underscores the value HIA can add for performance management and auditing of management plans by establishing a framework to monitor and evaluate changes in health early in the project development (Winkler et al., 2021). This was further enhanced through the evaluation of the trends over time in both impacted communities (intervention) and comparison communities, which allowed the disentanglement of Project-related impacts from broader socioeconomic changes in the Project region. In addition to representing an HIA best practice example, the study contributes to the evidence-base on potential impacts of large infrastructure projects being developed and implemented in similar contexts. Indeed, evaluation of impacts is a key aspect of HIA from a management and learning perspective (Quigley and Taylor, 2003), but also for justifying the continued promotion of HIA globally (Winkler et al., 2020).

Longitudinal household cohort studies in mining communities would aid in establishing causality and patterns in changes in determinants of health and health outcomes, but would require substantial financial commitment which might well be beyond the capacities of the proponent and the country. Similarly, another research-driven approach would be to establish a Health and Demographic Surveillance System (HDSS) with a specific focus on understanding the influence of large-scale mines on their surrounding communities (Ali Källestål et al., 2020; Sié, 2021).

Based on the experiences and outputs of the HIA in the Trident Project area presented here and elsewhere, we recommend that other private sector companies use the same or similar methodology for assessing and monitoring impacts of their operations. By promoting health and facilitating data collection in close collaboration with health authorities and research institutions, a win-win-win situation can be created. First, health benefits in communities can be promoted and negative health risks minimised, building healthier communities that can strive for better development. Second, improved monitoring and research will provide governments with tangible evidence for better health policies and prevent downstream health costs caused by the negative health impacts of such a project. Third, a healthier workforce results in higher productivity, benefiting the project (Better data, 2020; Winkler et al., 2020).

4.3.1. Limitations of the study

Our study has several limitations. First, only a selection of indicators was collected in the three surveys, potentially omitting other important socioeconomic indicators. For example, no information on employment was collected in 2011 and thus, this factor was not included in this analysis. Second, several comparison communities were only added to the 2015 sample, thus limiting the comparison between the impacted and the comparison communities to the period between 2015 and 2019 (Knoblauch et al., 2017). Third, it is possible that socioeconomic changes occurred in local communities prior to 2011, meaning that the full extent of socioeconomic changes due to the Project may not have been captured. Similarly, the small sample of comparison communities for the pre-Project baseline makes it difficult to establish whether communities impacted by the mine were already socioeconomically different prior to Project development.

5. Conclusion

Our analysis showed generally higher socioeconomic indicators in the communities impacted by the mining Project compared to the comparison communities and an overall positive trend in socioeconomic status in the study area from before the Project opened until the operational phase. A similar picture is found for the health outcome indicators collected during the same surveys, with impacted communities generally having better health outcomes than comparison communities.

However, the stagnation or slight declines in socioeconomic status between 2015 and 2019 raise concerns about the long-term sustainability of these positive socioeconomic impacts on mining communities, as well as the role that in-migration and changing demographics may have played in these changes. Care is indicated in order to avoid development inequalities and inequities between mine-impacted and non-impacted communities but also between households within the mine-affected communities (Leuenberger et al., 2020). Despite the Project's efforts to support local communities, in the absence of broad policy support from the government, inequalities between those who benefit and those who do not may emerge. Private-public collaboration and shared responsibilities, which are organised around periodic monitoring of key performance indicators at the level of determinants of health and health outcomes, have the potential to promote public health and equal socioeconomic development in the context of large infrastructure project developments.

Funding

First Quantum Minerals Limited funded the health impact assessment and supported data collection for the 2011, 2015 and 2019 surveys. RHZ's involvement in the study and the development of the manuscript was funded through the HIA4SD Project of the r4d programme (www.r4d.ch), which is a joint funding initiative by the Swiss Agency for Development and Cooperation (SDC) and the Swiss National Science Foundation (SNSF) [grant number 169461].

Author contributions

Conceptualization, M.J.D., M.S.W.; methodology, H.R.Z., A.M.K., A. F., M.O., M.J.D., M.S.W.; formal analysis, H.R.Z., A.M.K., A.F., M.O.,; writing—original draft preparation, H.R.Z., A.M.K., A.F., M.S.W.; writing review and editing, K.N., M.C., L.Z., G.M., J.U., M.J.D., M.O., S. P.D., G.F., A.F.; supervision, H.R.Z., A.M.K., M.O., K.N., M.C., M.S.W. All authors have read and agreed to the published version of the manuscript.

Declaration of Competing Interest

FQML funded the health impact assessment and supported data collection for the 2011, 2015 and 2019 surveys. A.M.K., M.O., M.J.D. and M.S.W. have supported the Trident Project as independent public health and occupational health specialists. G.M. was previously employed by FQML. M.C. is currently employed by FQML. The corresponding author had full access to all the data of all surveys. FQML had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript and in the decision to publish the results.

Acknowledgments

We thank the Kalumbila District Health Management team for the constructive collaboration. In addition, we acknowledge the traditional authorities and communities in the study area for their support, engagement and participation. Particular thanks go to the Trident Project health promotion team for their support prior, during and after the surveys.

References

Sié, Ali (2021).Burkina Faso - Observatoire de santé et de population de Nouna (1992 - en cours) - Aperçu.

Benshaul-Tolonen, A., Chuhan-Pole, P., Dabalen, A., Kotsadam, A.S., Sanoh, A., 2019. The local socioeconomic effects of gold mining: evidence from Ghana. Extr. Ind. Soc. 6, 1234–1255. https://doi.org/10.1016/j.exis.2019.07.008.

Chuhan-Pole, P., Dabalen, A.L., Land, B.C., 2017. Mining in Africa: Are local communities better off? AFD, World Bank Group, Washington D.C.

CSO, MOH, ICF International, 2014. Zambia Demographic and Health Survey 2013-2014. Central Statistics Office, Ministry of Health. ICF International, Lusaka.

Dietler, D., Farnham, A., Loss, G., Fink, G., and Winkler, M. S. (2021a). Impact of mining projects on water and sanitation infrastructures and associated health outcomes in children: a multi-country analysis of Demographic and Health Surveys (DHS) in sub-Saharan Africa. *Int. J. Hyg. Environ. Health.* https://doi.org/10.1186/s12992-021-00723.

Dietler, D., Loss, G., Farnham, A., de Hoogh, K., Fink, G., Utzinger, J., Winkler, M.S., 2021b. Housing conditions and respiratory health in children in mining communities: an analysis of data from 27 countries in sub-Saharan Africa. Environ. Impact Assess. Rev. 89, 106591 https://doi.org/10.1016/j.eiar.2021.106591.

EITI. Better data, better debate. (2020). Available at: https://eiti.org/blog/better-data-better-debate.

Ferragina, E. (2021). Principles and Practice of Comparative Research.

Frederiksen, A., Kadenic, M.D., 2020. Mining the north: local impacts. Labour Econ. 63, 101790 https://doi.org/10.1016/j.labeco.2019.101790.

Gamu, J., Le Billon, P., Spiegel, S., 2015. Extractive industries and poverty: a review of recent findings and linkage mechanisms. Extr. Ind. Soc. 2 (1), 162–176. https://doi.org/10.1016/j.exis.2014.11.001.

Habiyaremye, A., 2020. Natural resource abundance: A hidden drag on Africa's development? The Palgrave Handbook of African Political Economy. Springer, pp. 699–723.

James, A., 2015. The resource curse: a statistical mirage? J. Dev Econ. 114, 55–63. https://doi.org/10.1016/j.jdeveco.2014.10.006.

Källestål, C., Blandón, E.Z., Peña, R., Peréz, W., Contreras, M., Persson, L.-Å., Sysoev, O., Selling, K.E., 2020. Assessing the multiple dimensions of poverty. Data mining approaches to the 2004-14 Health and Demographic Surveillance System in Cuatro Santos, Nicaragua. Front. Public Health 7, 409. https://doi.org/10.3389/fpubh.2019.00409.

Knoblauch, A.M., Divall, M.J., Owuor, M., Archer, C., Nduna, K., Ng'uni, H., Musunka, G., Pascall, A., Utzinger, J., Winkler, M.S., 2017. Monitoring of selected health indicators in children living in a copper mine development area in northwestern Zambia. Int. J. Environ. Res. Public Health 14 (3633). https://doi.org/10.3390/ijerph14030315.

Knoblauch, A.M., Divall, M.J., Owuor, M., Musunka, G., Pascall, A., Nduna, K., Ng'uni, H., Utzinger, J., Winkler, M.S., 2018. Selected indicators and determinants of women's health in the vicinity of a copper mine development in northwestern Zambia. BMC Woman's Health 18 (1), 62. https://doi.org/10.1186/s12905-018-0547-7.

Knoblauch, A.M., Divall, M.J., Owuor, M., Nduna, K., Ng'uni, H., Musunka, Pascall, A., Utzinger, J., Winkler, M.S., 2017. Experience and lessons from health impact assessment guiding prevention and control of HIV/AIDS in a copper mine project, northwestern Zambia. Infect. Dis. Poverty 6 (1), 114. https://doi.org/10.1186/s40249-017-0320-4.

Knoblauch, A.M., Farnham, A., Zabré, H.R., Owuor, M., Archer, C., Nduna, K., Chisanga, M., Zulu, L., Musunka, G., Utzinger, J., Divall, M.J., Fink, G., Winkler, M. S., 2020. Community health impacts of the Trident copper mine project in northwestern Zambia: results from repeated cross-sectional surveys. Int. J. Environ. Res. Public Health 17 (10), 3633. https://doi.org/10.3390/ijerph17103633.

Krzywinski, M., Altman, N., 2014. Comparing samples—part I - Nature Methods. Nat. Methods 11, 215–216. https://doi.org/10.1038/nmeth.2858.

Leuenberger, A., Cambaco, O., Zabré, H.R., Lyatuu, I., Merten, S., Winkler, M.S., 2020. "It is like we are living in a different world": health equity in communities surrounding industrial mining sites in Burkina Faso. Frontiers in Public Health. Submitted for publication.

Lippert, A., 2014. Spill-overs of a resource boom: Evidence from Zambian copper mines. University of Oxford, Oxford.

Loayza, N., Teran, A.M.Y., Rigolini, J., 2013. Poverty, Inequality, and the Local Natural Resource Curse. World Bank Group, Washington D.C.

Meller, P., Simpasa, A., 2011. Role of copper in the Chilean and Zambian economies: main economic and policy issues. Global Development Network. New Delhi.

Nguyen, N.B., Boruff, B., Tonts, M., 2017. Mining, development and well-being in Vietnam: a comparative analysis. Extr. Ind. Soc. 4 (3), 564–575. https://doi.org/10.1016/j.exis.2017.05.009.

Papyrakis, E., 2017. The resource curse - what have we learned from two decades of intensive research: introduction to the special issue. J. Dev. Stud. 53 (2), 175–185. https://doi.org/10.1080/00220388.2016.1160070.

Quigley, R.J., Taylor, L.C., 2003. Evaluation as a key part of health impact assessment: the English experience. Bull. World Health Organ. 81 (6). https://apps.who.int/iris/handle/10665/268952.

Rutstein, S.O., Johnson, K., 2004. The DHS Wealth Index. ORC Macro, Calverton.

Sikamo, J., Mwanza, A., Mweemba, C., 2016. Copper mining in Zambia - history and future. J. S. Afr. Inst. Min. Metall. 116, 491–496. https://doi.org/10.17159/2411-9717/2016/v116n6a1.

Srinivasan, J., Nuthalapati, C., 2020. Development-induced displacement risks and coping with resettlement. J. Rural Dev. 39, 1–18.

Viliani, F., Edelstein, M., Buckley, E., Llamas, A., Dar, O., 2017. Mining and emerging infectious diseases: results of the infectious disease risk assessment and management (IDRAM) initiative pilot. Extr. Ind. Soc. 4 (2), 251–259. https://doi.org/10.1016/j.exis.2016.08.009.

Wegenast, T., Beck, J., 2020. Mining, rural livelihoods and food security: a disaggregated analysis of sub-Saharan Africa. World Development 130, 104921. https://doi.org/10.1016/j.worlddev.2020.104921.

Winkler, M.S., Adongo, P.B., Binka, F., Brugger, F., Diagbouga, S., Macete, E., Munguambe, K., Okumu, F., 2020. Health impact assessment for promoting sustainable development: the HIA4SD project. Impact. Assess Proj Apprais 38 (3), 225–232. https://doi.org/10.1080/14615517.2019.1694783.

Winkler, M.S., Divall, M.J., Krieger, G.R., Schmidlin, S., Magassouba, M.L., Knoblauch, A.M., Singer, B.H., Utzinger, J., 2012. Assessing health impacts in complex eco-epidemiological settings in the humid tropics: modular baseline health surveys. Environ. Impact Assess. Rev. 33 (1), 15–22. https://doi.org/10.1016/j.eiar.2011.10.003.

Winkler, M.S., Furu, P., Viliani, F., Cave, B., Divall, M., Ramesh, G., Harris-Roxas, B., Knoblauch, A.M., 2020. Current global health impact assessment practice. Int. J. Environ. Res. Public Health 17 (9). https://doi.org/10.3390/ijerph17092988.

Winkler, M.S., Viliani, F., Knoblauch, A.M., Cave, B., Divall, M.J., Ramesh, G., Harris-Roxas, B., Furu, P., 2021. Health impact assessment international best practice principles. Impact Assess Proj Apprais. Special Publication Series No. 5.

World Bank Group, 2015. Zambia economic brief, June 2015, Issue 5. World Bank Group, Washington D.C.

World Bank Group, 2020. How can Zambia Benefit More from Mining? World Bank Group, Washington D.C.

Yang, X., Ho, P., 2019. Is mining harmful or beneficial? A survey of local community perspectives in China. Extr. Ind. Soc. 6 (2), 584–592. https://doi.org/10.1016/j.exis.2019.02.006.

ZSA, MOH, ICF, 2019. Zambia Demographic and Health Survey 2018. Zambia Statistics Agency, Ministry of Health, and ICF, Lusaka.

4. Paper 3 – Changes in Household Wealth in Communities Living in Proximity to a Large-Scale Copper Mine in Zambia

This article was published in

Resources Policy https://doi.org/10.1016/j.resourpol.2021.102395

Resources Policy 74 (2021) 102395

Contents lists available at ScienceDirect

Resources Policy

journal homepage: www.elsevier.com/locate/resourpol

Changes in household wealth in communities living in proximity to a large-scale copper mine in Zambia

Hyacinthe R. Zabré [a,b,c], Andrea Farnham [a,b], Serge P. Diagbouga [c], Günther Fink [a,b], Mark J. Divall [d], Mirko S. Winkler [a,b], Astrid M. Knoblauch [a,b,*]

[a] Swiss Tropical and Public Health Institute, Basel, Switzerland
[b] University of Basel, Basel, Switzerland
[c] Research Institute of Health Sciences, Ouagadougou, Burkina Faso
[d] Shape Consulting, St Peter Port, Guernsey

ARTICLE INFO

Keywords:
Health impact assessment
Mining
Wealth index
Socio-economic
Zambia

ABSTRACT

Large-scale mining can alter the living conditions of surrounding communities in positive and negative ways. A health impact assessment conducted in the context of a newly developed large-scale copper mine in rural Zambia gave us the opportunity to measure changes in health determinants over time. We conducted periodic household surveys at baseline in 2011, during the construction phase in 2015 and during the operational phase in 2019. Data collected included economic indicators that were based on the standardized list of household assets used in the Zambia Demographic and Health Survey, which we subsequently converted into a wealth score using principal component analysis. We compared mean wealth scores in six communities directly impacted by the mine with comparison communities, as well as the rest of the North-Western province of Zambia. A difference-in-differences linear regression model was used to compare changes over time. Mean wealth of the communities near the mine was significantly lower at baseline than that of the North-Western province (−0.54 points; p-value<0.001) in 2011, but surpassed the regional average in 2019 (+1.07 points; p-value <0.001). Mean wealth increased more rapidly in communities directly impacted by mine than in the comparison communities (+0.30 points, p-value <0.001). These results suggest a positive impact on living conditions in communities living near this copper mine. Our findings underscore the potential of the mining sector to contribute to economic development in Zambia.

1. Introduction

The Trident Project (hereafter ‘project’) is an industrial copper mine located in northwestern Zambia, developed by First Quantum Minerals Limited (FQML) since 2011 (FQML, 2021). Given the large scale of the copper mine, drastic changes were expected to affect the environment and socio-economic determinants of the population of this previously rural, under-developed area. Aside from a broad range of environmental, demographic, social and economic impacts such a project might cause, health was of particular concern, both as a risk for the project itself due to the potential loss of workers and work force productivity (ANRC and AFDB, 2016), but also because of the projects’ potential impact on the local health system and a range of health determinants (Viliani et al., 2017).

In order to anticipate health risks as well as identify opportunities to promote health in the local communities, the Trident project committed to a health impact assessment (HIA) in 2010/2011, prior to project commencement (Divall et al., 2010). As part of the HIA, a detailed baseline assessment of a large set of determinants of health and health outcomes was conducted. These included socio-cultural, environmental and economic factors, the physical environment (e.g. housing quality, access to safe drinking water), institutional factors (e.g. health system capacities) as well as individual characteristics (e.g. gender, dietary practices) (Winkler et al., 2021). Repeated cross-sectional household surveys were conducted to monitor changes in health and associated determinants over the course of the project. The first survey was

* Corresponding author. Swiss Tropical and Public Health Institute, P.O. Box, CH-4002, Basel, Switzerland.
E-mail addresses: raogohyacinthe.zabre@swisstph.ch (H.R. Zabré), andrea.farnham@swisstph.ch (A. Farnham), diagbouga.serge@gmail.com (S.P. Diagbouga), guenther.fink@swisstph.ch (G. Fink), mdivall@shapeconsulting.org (M.J. Divall), mirko.winkler@unibas.ch (M.S. Winkler), astrid.knoblauch@swisstph.ch (A.M. Knoblauch).

https://doi.org/10.1016/j.resourpol.2021.102395
Received 28 May 2021; Received in revised form 28 September 2021; Accepted 29 September 2021

implemented in 2011, before project onset, followed by two repetitions in 2015, at the end of the construction phase, and in 2019, during the operational phase. Data were collected in local communities through quantitative and qualitative methods (e.g. biomedical sampling, environmental sampling, household questionnaire interviews, key informant interviews, health facility assessments).

In order to assess households' overall socio-economic status, we computed a wealth index based on household ownership of assets (e.g. phones, televisions or cars) and housing characteristics such as the source of drinking water, toilet facilities and housing materials (ZSA et al., 2019). Using this score, every household's wealth was ranked in a standardized way and compared to the wealth of other households in the country. Therefore, this score is a valuable socio-economic comparison indicator, which enables the measurement of differences between households and the evolution over time.

In the present article, we use the data collected as part of the monitoring step of the HIA to assess the impact of the mining operations on the wealth of households located near the mining project. We compare changes in wealth in communities impacted by the mining project to average changes at the province-level (North-Western province) and average changes in comparison communities not directly impacted by the mining project.

2. Methods

2.1. Study area

The project is located in Kalumbila district, North-Western province of Zambia (Fig. 1). Six communities (marked with a pink circle) were surveyed in all three survey rounds (Knoblauch et al., 2017a, 2018, 2020b). Of those, five communities were considered 'impacted' by the mine, whilst one was selected as a 'comparison'. In 2015, four communities were added to the sample in order to (i) include new settlements and (ii) increase the comparison population, resulting in a total of 13 communities (9 impacted and 4 comparison communities).

Impacted communities were defined as affected by the project development in ways such as location within the concession area, project-required resettlement, infrastructure investments, health interventions or experience of project-induced in-migration due to job or opportunity seekers (Winkler et al., 2012). Comparison communities were defined as (i) located outside the mining concession, (ii) not or minimally impacted by the mine through any of the elements described above, and (iii) as close to the impacted communities as possible in order to increase socio-demographic and topographic similarity (Knoblauch et al., 2017b).

2.2. Data sources

Two data sources were used: (i) Data from the three cross-sectional surveys where random sampling was applied until a quota of 25–35 or 50–80 households per community were reached, depending on community size (Knoblauch et al., 2017a, 2018, 2020b; Zabré et al., 2021); and (ii) data from the DHS that were conducted around the same years as the cross-sectional surveys, i.e. in 2007 and 2018, where comparisons were made especially with the North-Western province of Zambia (CSO et al., 2009; ZSA et al., 2019).

2.3. Data analysis

As reported in Knoblauch et al. (2020), the wealth index was calculated from a set of indicators on asset ownership (e.g., radio, television, bicycle, telephone and bank account) and housing characteristics (e.g., number of household members per sleeping room, source of drinking water, floor, roof and wall materials); this process is the same as that detailed in the handbook for the Demographic Health Survey (DHS) (Filmer and Pritchett, 2001; Knoblauch et al., 2020a). From the above indicators, the first principal component of a principal component analysis (PCA) was used to create a unidimensional asset score (Rutstein and Johnson, 2004). Based on the wealth rank, the whole population was divided into five equally large groups, thus creating the five wealth quintiles (1–5). The mean wealth quintile (MWQ) was calculated per community and/or per year. The PCA was conducted using data from the three surveys conducted in the study area and on the raw data from the 2007 and 2018 DHS to ensure comparability of our data at the national level and over the study period, meaning that the raw DHS data was normalized together with the study data for the entire time period (CSO et al., 2009; ZSA et al., 2019). In other words, if a household fell into the bottom 20% of wealth in Zambia per their wealth rank after being normalized relative to all households in 2007, 2011, 2015 and 2018, that household was assigned a value of one. We report here the mean wealth quintiles (MWQ) for each community and group per the corresponding analysis.

Five distinct analyses were performed (see Table 1), with the overall aim of determining when and where significant differences in mean

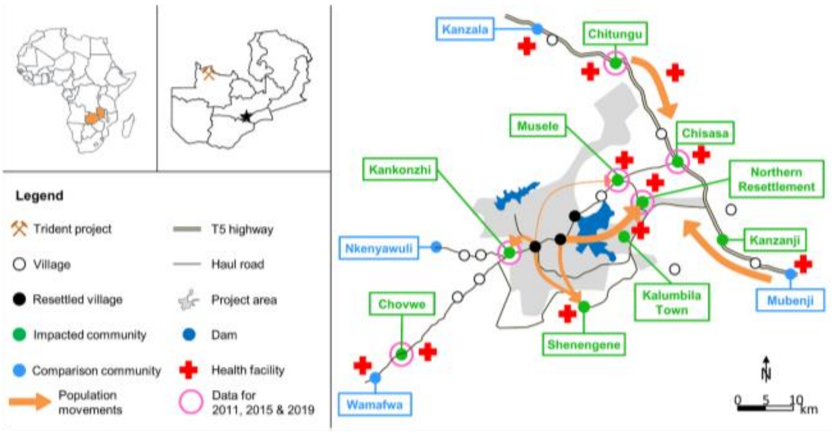

Fig. 1. Map of the study area and surveyed communities, Kalumbila district, Zambia (Knoblauch et al., 2020a).

Table 1
Data sets used, available sample sizes and analyses performed.

Analysis/Details and goals	Before project onset ('baseline')		End of project construction phase	Project operational phase	
	DHS 2007	Health survey 2011	Health survey 2015	DHS 2018	Health survey 2019
Analysis 1	726	254	–	–	–
Details and goal	Comparing six communities in study area (2011) vs. North-Western province (2007) in order to assess if the wealth status is similar at baseline.				
Analysis 2	726	254	–	1010	257
Details and goal	Difference-in-differences analysis comparing six communities in the study area in 2011 vs. the same six communities in 2019 in order to assess whether the MWQ in the study area is changing at a different rate than that of the North-Western province (2007–2018).				
Analysis 3	–	–	–	1010	257
Details and goal	Comparing the MWQ in the study area in 2019 vs. North-Western province in 2018 in order to assess if the study area has a higher MWQ score than the province.				
Analysis 4	–	–	Impacted: 354 Comparison: 128	–	Impacted: 351 Comparison: 158
Details and goal	Comparing nine impacted communities with four comparison communities to determine if impacted communities experience a greater increase in MWQ than comparison between 2015 and 2019.				
Analysis 5	726	254	–	1010	257
Details and goal	Assessing the significance of difference of the MWQ change in the study area (2011–2019) compared with North-Western province (2007–2018).				

wealth emerged in the study area. Differences or changes in MWQ were calculated by subtraction. For all calculated differences, T-tests were used to assess whether the change in means was significant. Difference-in-differences models using linear regression were performed for comparing changes over time in one area (study area vs. North-Western province) or group (impacted vs. comparison communities) to another area or group (Frederiksen and Kadenic, 2020; Fredriksson and de Oliveira, 2019). The difference-in-differences models were adjusted for age of the female respondent and education of the female respondent to control for whether changing demographics of the study population could be confounding these associations.

Statistical analyses were performed using R version 3.4.3 (The R Foundation; Vienna, Austria).

2.4. Ethical considerations

The health surveys received ethical approval from the Ethics Committee of the Tropical Disease Research Centre, Ndola, Zambia (TRC/ERC/July 04, 2011, TRC/C4/07/2015, TRC/C4/01/2019). In addition, the signing of informed consent by the heads of households and women participating in this study always preceded data collection. Where necessary, the consent was taken by fingerprinting for illiterate persons.

3. Results

The number of households surveyed per community in each health survey is summarized in Table 2. The sample size of the 2011 survey was slightly smaller as only one comparison village was included.

Table 3 compares average wealth of the communities surveyed in 2011 to that of North-Western province in 2007. On average, households in the province had a higher wealth than the study communities around the project. This difference was significant ($p < 0.05$) for 4 out of 6 communities (Chisasa, Chovwe, Kankonzhi, Musele).

Table 4 illustrates the changes in mean wealth over the entire study period in the six communities around the project (2011–2019) and the North-Western province (2007–2018). All impacted communities experienced improvements in wealth between 2011 and 2019. The smallest change was recorded in Wanyinwa/Northern Resettlement with +0.52 points (p-value = 0.03) and the largest in Chisasa with +1.71 (p-value<0.001). In comparison, mean wealth in North-Western province improved by only 0.28 points (p-value<0.001) between 2007 and 2018. The simple difference-in-differences model implies an additional improvement of 1.07 wealth points ($p < 0.001$) for impacted communities relative to the province. This did not change after adjusting by age and education of female respondent (mean difference: 1.08 MWQ points, $p < 0.001$), suggesting that this difference is not due solely to

Table 2
Number of study households, Kalumbila district, Zambia (2011, 2015, 2019).

Communities		Number of households		
Impacted communities		2011	2015	2019
Data collected in 3 surveys (2011, 2015, 2019)	Chisasa	58	65	66
	Chitungu	30	33	32
	Chovwe	63	32	32
	Kankonzhi	39	30	32
	Musele	29	67	65
	Wanyinwa/Northern Resettlement	35	34	30
Total impacted (2011, 2015 and 2019)		**254**	**261**	**257**
Data collected in 2 surveys (2015, 2019)	Kalumbila Town	n/s	29	31
	Kanzanji	n/s	32	32
	Shenengene	n/s	32	31
Total impacted (2015 and 2019)		**n/s**	**93**	**94**
Total impacted		**254**	**354**	**351**
Comparison communities				
Data collected in 3 surveys (2011, 2015, 2019)	Nkenyawuli	29	32	31
Data collected in 2 surveys (2015, 2019)	Kanzala	n/s	30	63
	Mubenji	n/s	33	32
	Wamafwa	n/s	33	32
Total comparison		**29**	**128**	**158**

n/s = not sampled.

Table 3
Mean wealth index at baseline, study area vs. North-Western province.

Communities	2011 survey		2007 DHS		Difference
	HH	MWQ *(A)* (SD)	HH	MWQ *(B)* (SD)	*(A)-(B)*; (p-value)
Chisasa	58	1.88 (1.01)			−0.60 (<0.001)
Chitungu	30	2.03 (1.22)			−0.45 (0.06)
Chovwe	63	1.67 (0.99)	n/a	2.48 (1.11)	−0.81 (<0.001)
Kankonzhi	39	1.85 (0.96)			−0.63 (<0.001)
Musele	29	1.72 (1.03)			−0.76 (<0.001)
Wanyinwa/Northern Resettlement	35	2.71 (1.27)			+0.23 (0.29)
Overall	**254**	**1.94 (1.10)**	**726**	**2.48 (1.11)**	**- 0.54 (<0.001)**

HH = Households; MWQ = Mean Wealth Quintile; SD= Standard Deviation.

Table 4
Difference-in-differences analysis of the changes of the mean wealth quintile (MWQ) in the study area (2011–2019) vs. North Western province (2007–2018).

	2011 survey		2019 survey		Change (2019–2011)	DHS 2007		DHS 2018		Change (2018–2007)	Difference of changes
	HH	MWQ (SD) *(A)*	HH	MWQ (SD) *(B)*	*(B)-(A)*; (p-value)	HH	MWQ (SD) *(C)*	HH	MWQ (SD) *(D)*	*(D)-(C)*; (p-value)	
Chisasa	58	1.88 (1.01)	66	3.59 (0.82)	+1.71 (<0.001)						+1.44
Chitungu	30	2.03 (1.22)	32	2.75 (0.98)	+0.72 (0.01)						+0.45
Chovwe	63	1.67 (0.99)	32	2.97 (0.54)	+1.30 (<0.001)						+1.03
Kankonzhi	39	1.85 (0.96)	32	3.41 (0.76)	+1.56 (<0.001)	n/a	2.48 (1.11)	n/a	2.75 (1.46)	+0.27 (<0.001)	+1.29
Musele	29	1.72 (1.03)	65	3.35 (0.84)	+1.63 (<0.001)						+1.36
Wanyinwa/ NR	35	2.71 (1.27)	30	3.23 (0.50)	+0.52 (0.03)						+0.25
Overall	**254**	**1.94 (1.10)**	**257**	**3.28 (0.82)**	**+1.35 (<0.001)**	**726**	**2.48 (1.11)**	**1010**	**2.75 (1.46)**	**+0.27 (<0.001)**	**+1.07**

HH = Households; MWQ = Mean Wealth Quintile; NR = Northern Resettlement; SD = Standard Deviation.

Table 5
Comparison of mean wealth in the study area 2019 vs. North-Western province 2018.

Communities	2019 survey		2018 DHS		Difference
	HH	MWQ (SD) *(A)*	HH	MWQ (SD) *(B)*	*(A)-(B)*; (p-value)
Chisasa	66	3.59 (0.82)			+0.84 (<0.001)
Chitungu	32	2.75 (0.98)			0.00 (0.976)
Chovwe	32	2.97 (0.54)			+0.22 (<0.05)
Kalumbila Town	31	4.97 (0.18)			+2.22 (<0.001)
Kankonzhi	32	3.41 (0.76)			+0.66 (<0.001)
Kanzala	63	2.76 (0.86)			+0.01 (0.956)
Kanzanji	32	3.16 (0.81)	n/a	2.75 (1.46)	+0.41 (0.011)
Mubenji	32	3.09 (0.73)			+0.34 (0.018)
Musele	65	3.35 (0.84)			+0.6 (<0.001)
Nkenyawuli	31	2.97 (0.71)			+0.22 (0.124)
Wanyinwa/NR	30	3.23 (0.50)			+0.48 (<0.001)
Shenengene	31	3.87 (0.43)			+1.12 (<0.001)
Wamafwa	32	2.63 (0.75)			−0.12 (0.359)
Overall	**509**	**3.28 (0.92)**	**1010**	**2.75 (1.46)**	**+0.54 (<0.001)**

HH = Households; MWQ = Mean wealth quintile; NR = Northern Resettlement; SD = Standard Deviation.

Table 6
Changes in mean wealth over time in impacted vs. comparison communities.

Communities	2011 survey		2015 survey		2019 survey		2011, 2015 and 2019
	HH	MWQ (SD)	HH	MWQ (SD)	HH	MWQ (SD)	Mean (SD/p-value)
Impacted	260	1.97 (1.13)	355	3.56 (0.80)	362	3.43 (0.89)	3.11 (1.14)
Comparison	31	1.54 (0.64)	130	3.01 (0.49)	160	2.87 (0.75)	2.81 (0.75)
Difference (p-value)		+0.43 (<0.001)		+0.55 (<0.001)		+0.56 (<0.001)	+0.30 (<0.001)

HH = Households; MWQ = Mean Wealth Quintile; SD = Standard Deviation.

changing demographics in the area.

Table 5 compares mean wealth of the communities studied to that of the North-Western province at the end of the study period in 2019, eight years after project development began. Apart from Chitungu, which had the same MWQ level as the province (2.75), the other five communities had a MWQ significantly higher than that of the region ranging from +0.22 points (p-value = 0.05) for Chovwe to +0.84 points (<0.001) in Chisasa. When pooled together, the communities studied had an overall MWQ significantly higher than that of the province (+0.54, p-value<0.001) in 2019.

Table 6 compares changes in wealth between 2011 and 2019 in impacted communities to changes in the comparison communities. Relative to comparison communities, the impacted communities experienced an additional 0.30 points increase in wealth (p-value<0.001). The MWQ in the impacted communities increased from 1.97 (2011) to 3.56 (2015) to 3.43 (2019). In comparison communities, the MWQ increased from 3.01 in 2015 to 2.87 in 2019. Thus, this level was higher in the impacted communities than comparison communities by +0.55 points (p-value <0.001) in 2015 and +0.56 points (p-value <0.001) in 2019, respectively (Table 6).

4. Discussion

In this paper, we measured changes in the household wealth in areas surrounding a large-scale mining project in North-Western province in Zambia from 2011, before the project was constructed, up until 2019, when the project was in its operational phase. Although there are few studies assessing the economic impacts on local communities living in the vicinity of mining projects, our findings are discussed in the light of some previous studies.

The comparison of households impacted by the project and comparison households not affected by the project revealed that at baseline (2011) households in the six surveyed communities located in the study area had a significantly lower mean wealth than the households in the North-Western province (−0.54 points; p-value<0.001). Given that the mining project is located in a previously underdeveloped, rural area, it was not surprising to observe a generally low wealth index at household level before the project was developed. In comparison, the DHS in North-Western province may have included potentially wealthier urban clusters such as Solwezi town, which could partly explain this difference.

Eight years into mine development, households both in the studied mining area and the North-Western province significantly increased in wealth index. However, communities in the study area had an accelerated increase in wealth, surpassing that of the overall province by 2019 (+1.07 points; p-value<0.001). These results suggest a positive effect of the Trident project on the economic status of the households that are in the area of influence. As shown in Zabré et al., 2021, the positive changes were most pronounced in the first years (i.e. the construction phase) of project development. Apart from the intrinsic economic impact the mine has on the local host communities through, e.g. employment opportunities or improvement of the local infrastructure, including roads that can facilitate trade (De Haas and Poelhekke, 2019), the in-migration of highly skilled and wealthier populations could also have influenced this result. A separate analysis of in-migration to the Trident project area showed that migrants tended to be younger, more highly educated, and had more wealth and assets as compared to the local population; these benefits extended to disease prevention, with migration status appearing to be particularly protective against malaria in children <5 years (Farnham et al., 2021).

Similar results were found elsewhere. In Peru, comparing the periods before and after the 2007 mining boom and taking into account differences between districts and provinces, mining districts were found with larger average consumption per capita and lower poverty rates than districts that did not have mining activities but were otherwise similar (Loayza and Rigolini, 2016). The same study also found that inequalities within mining districts were higher than within non-mining districts. We had a comparable finding: the communities impacted by the Trident project had significantly higher wealth index than the comparison communities located in the same district, eight years after project onset (0.30 points difference; <0.001). While this difference suggests a positive impact of the mine on poverty reduction, especially in communities in proximity to the mine, it is noteworthy that also comparison communities markedly improved their wealth level, which was slightly higher than the provincial average by 2019. Thus, even though the comparison communities were not affected by e.g. resettlement or mine-initiated interventions, they were likely to have experienced spillover effects of the project development such as improvement of access roads or in-migration. A country-wide difference-in-differences analysis by Lippert (2014) also found that positive spillovers from mining in Zambia extended to the rural hinterlands of mining areas as well as along transportation routes (Lippert, 2014). In an analysis covering copper, gold and diamond mining activities in sub-Saharan Africa from 1997 to 2015, an increase in local wealth was found (Wegenast et al., 2020). In Zambia specifically, a 10% increase in copper production at the district level was associated with a 2% increase in real household expenditure (Lippert, 2014).

In contrast to these positive impacts on surrounding communities, some studies point to rather negative economic consequences of mining (Brahmbhatt et al., 2010; Calain, 2008; Cockx and Francken, 2014; Hosein, 2021; Mehlum et al., 2006; Ross, 2004). Indeed, natural resource extraction has also been found to further impoverish surrounding communities in some settings (Al Rawashdeh et al., 2016; Chuhan-Pole et al., 2015; Gamu et al., 2015; Mwitwa et al., 2012). In Jordan, mining appears to largely have failed to benefit local communities based on the measurement of selected socioeconomic indicators (e.g. poverty) pre- and post-mine development (Al Rawashdeh et al., 2016). Furthermore, a review of 52 empirical studies conducted worldwide showed that industrial mining was more frequently associated with the exacerbation of poverty (Gamu et al., 2015).

Interestingly, the trends and differences found in wealth largely correspond with the findings on health outcomes and other health determinants in this mining area. Indeed, several studies showed that health improved overall, also in the larger province, but impacted communities were often found with better indicators, thus also indicating the potential interplay between health and economic development (Knoblauch et al., 2017a, 2018, 2020b).

Given Zambia's wealth in copper, our results demonstrate that there is an opportunity for the country to leverage the benefits of copper industries to develop the local economies if potential negative impacts are actively addressed and mitigated (Sikamo et al., 2016; World Bank Group, 2020). HIA provides a powerful approach to systematically judge the potential, and sometimes unintended, effects of mining projects and generate evidence for appropriate actions to avoid risks and promote opportunities (Senécal et al., 1999; Vanclay, 2003; Winkler et al., 2021). While environmental impact assessments are largely institutionalized in sub-Saharan Africa, regulatory frameworks for HIA are still weak in most countries (Winkler et al., 2013, 2020). The HIA applied for the current project has demonstrated that it is feasible to prospectively and proactively manage potential negative effects on health and its determinants. In this process, data monitoring and evaluation plays a crucial role to generate the evidence required for the adjustment of management plans based on undesirable outcomes observed along with substantiating positive developments. HIA is thus a powerful tool that governments and projects should further promote to prevent adverse effects on health determinants in the context of any large-scale infrastructure developments (Leuenberger et al., 2021; Thondoo and Gupta, 2020).

4.1. Limitations

While the comparability between the study data and the DHS data is useful to put the results into perspective and into context, three methodological considerations are noteworthy: (i) there are time lapses between the survey years (e.g. 2007 vs. 2011, 2018 vs. 2019); (ii) fewer households were surveyed in the study than in the DHS although the geographic concentration and thus the representativeness is accordingly higher; and (iii) the exact locations of the clusters surveyed in the DHS in North-Western province are unknown but may have included potentially wealthier urban centres such as Solwezi town. In addition, the inclusion of only one comparison community with 31 households in 2011 limits the ability to make comparisons between the impacted communities and unaffected local communities over the early opening phase of the mine, when most changes in wealth appear to have occurred; however, the inclusion of the DHS data from North-Western province suggests that overall, the mining area did increase in wealth at a faster rate than the region as a whole.

5. Conclusions

The results presented here suggest positive economic changes in household wealth due to a large-scale mining development in Zambia. The Trident project is unique in its prospective use of HIA over time to evaluate and mitigate risks to local populations in sub-Saharan Africa, providing valuable new evidence that this strategy can promote equitable development of the local area and distribution of positive economic impacts of the mine and other health determinants.

Author contributions

Conceptualization: M.J.D., M.S.W.; Methodology: H.R.Z., A.M.K., A.F., M.J.D., M.S.W.; Formal analysis: H.R.Z., A.M.K., A.F.; Writing – original draft: H.R.Z., A.M.K., A.F., M.S.W.; Writing – review & editing: S.P.D., M.J.D., G.F. All authors have read and agreed to the published version of the manuscript.

Funding

The health impact assessment, including the data collection for the 2011, 2015 and 2019 surveys was funded by First Quantum Minerals Limited. RHZ's involvement in the study and the development of the manuscript was funded through the HIA4SD Project of the r4d programme [grant number 169461], which is a joint funding initiative by the Swiss National Science Foundation (SNSF) and the Swiss Agency for Development and Cooperation (SDC).

Declaration of competing interest

FQML was the funder of the health impact assessment and supported data collection for the 2011, 2015 and 2019 surveys. Authors A.M.K., M.J.D. and M.S.W. supported the Trident Project as independent experts and consultants. The corresponding author had full access to all the data of all surveys. FQML had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

Acknowledgments

Our gratitude is extended to the Kalumbila District Health Management team for the collaboration on the health surveys. We would like to acknowledge the administrative and traditional authorities as well as the communities in the study area for their support, engagement and participation. Particular thanks go to the Trident Project health promotion team, as well as specifically Gertrude Musunka, Milka Owuor, Kennedy Nduna and Marcus Chisanga for their support prior, during and after the surveys.

References

Al Rawashdeh, R., Campbell, G., Titi, A., 2016. The socio-economic impacts of mining on local communities: the case of Jordan. Extr Ind Soc 3, 494–507.

ANRC, AFDB, 2016. AGA Malaria and Public-Private Partnerships in Ghana's Health Sector to Obtain Value from Extractives Projects - a Case Study. African Natural Resources Center, African Development Bank, Abidjan.

Brahmbhatt, M., Canuto, O., Vostroknutova, E., 2010. Dealing with Dutch Disease. World, Washington, DC.

Calain, P., 2008. Oil for health in sub-saharan Africa: health systems in a 'resource curse' environment. Glob. Health 4, 10.

Chuhan-Pole, P., Dabalen, A.L., Land, B.C., Sanoh, A., Smith, G., Tolonen, A.K., et al., 2015. Socioeconomic Impact of Mining on Local Communities in Africa. The World Bank, Washington, DC.

Cockx, L., Francken, N., 2014. Extending the concept of the resource curse: natural resources and public spending on health. Ecol. Econ. 108, 136–149.

CSO, MOH, TDRC, 2009. University of Zambia, ICF International. Zambia Demographic and Health Survey 2007. Central Statistical Office Zambia, Ministry of Health Zambia, Tropical Diseases Research Centre Zambia, University of Zambia, and Macro International, Claverton.

De Haas, R., Poelhekke, S., 2019. Mining matters: natural resource extraction and firm-level constraints. J. Int. Econ. 117, 109–124.

Divall, M.J., Barnes, D., Knoblauch, A.M., 2010. First Quantum Minerals Limited: Health Impact Assessment Scoping Study Trident Project. NewFields LLC, Denver.

Farnham, A., Winkler, M.S., Zabré, H.R., Divall, M.J., Fink, G., Knoblauch, A.M., 2021. Spatial Mobility Induced by a Large Copper Mining Project in Zambia and Changes in Health and Socioeconomic Indicators in Nearby Communities.

Filmer, D., Pritchett, L.H., 2001. Estimating wealth effects without expenditure data–or tears: an application to educational enrollments in states of India. Demography 38, 115–132.

FQML, May 2021. Our operations: sentinel. https://www.first-quantum.com/English/our-operations/default.aspx.

Frederiksen, A., Kadenic, M.D., 2020. Mining the north: local impacts. Lab. Econ. 63, 101790.

Fredriksson, A., de Oliveira, G.M., 2019. Impact evaluation using difference-in-differences. RAUSP Management Journal 54, 519–532.

Gamu, J., Le Billon, P., Spiegel, S., 2015. Extractive industries and poverty: a review of recent findings and linkage mechanisms. Extr Ind Soc. 2, 162–176.

Hosein, R., 2021. Resource Curse and the Dutch Disease. Oil and Gas in Trinidad and Tobago. Cham. Palgrave Macmillan, Switzerland, pp. 87–114.

Knoblauch, A., Farnham, A., Zabré, H.R., Owuor, M., Archer, C., Nduna, K., et al., 2020a. Community health impacts of the trident copper mine project in northwestern Zambia: results from repeated cross-sectional surveys. Int. J. Environ. Res. Publ. Health 17, 3633.

Knoblauch, A.M., Divall, M.J., Owuor, M., Archer, C., Nduna, K., Ng'uni, H., et al., 2017a. Monitoring of selected health indicators in children living in a copper mine development area in northwestern Zambia. Int. J. Environ. Res. Publ. Health 14.

Knoblauch, A.M., Divall, M.J., Owuor, M., Archer, C., Nduna, K., Ng'uni, H., et al., 2017b. Monitoring of selected health indicators in children living in a copper mine development area in northwestern Zambia. Int. J. Environ. Res. Publ. Health 14, 315.

Knoblauch, A.M., Divall, M.J., Owuor, M., Musunka, G., Pascall, A., Nduna, K., et al., 2018. Selected indicators and determinants of women's health in the vicinity of a copper mine development in northwestern Zambia. BMC Wom. Health 18, 62.

Knoblauch, A.M., Farnham, A., Zabré, H.R., Owuor, M., Archer, C., Nduna, K., et al., 2020b. Community health impacts of the Trident copper mine project in northwestern Zambia: results from repeated cross-sectional surveys. Int. J. Environ. Res. Publ. Health 17, 3633.

Leuenberger, A., Cambaco, O., Zabré, H.R., Lyatuu, I., Merten, S., Winkler, M.S., 2021. "It is like we are living in a different world": health equity in communities surrounding industrial mining sites in Burkina Faso. IJERPH. Submitted for publication.

Lippert, A., 2014. Spill-overs of a resource boom: evidence from Zambian copper mines. In: Oxford Centre for the Analysis of Resource Rich Economies. University of Oxford.

Loayza, N., Rigolini, J., 2016. The local impact of mining on poverty and inequality: evidence from the commodity boom in Peru. World Dev. 84, 219–234.

Mehlum, H., Moene, K., Torvik, R., 2006. Institutions and the resource curse. Econ. J. 116, 1–20.

Mwitwa, J., German, L., Muimba-Kankolongo, A., Puntodewo, A., 2012. Governance and sustainability challenges in landscapes shaped by mining: mining-forestry linkages and impacts in the Copper Belt of Zambia and the DR Congo. For. Pol. Econ. 25, 19–30.

Ross, M.L., 2004. What do we know about natural resources and civil war? J. Peace Res. 41, 337–356.

Rutstein, S., Johnson, K., 2004. The DHS Wealth Index.

Senecal P, Goldsmith B, Conover S, Sadler B, Brown K, IAIA'97 Workshop Participants, et al. Principles of environmental impact assessment best practice. 1999. Fargo: IAIA International, Institute of Environmental Assessment.

Sikamo, J., Mwanza, A., Mweemba, C., 2016. Copper mining in Zambia - history and future. J S Afri Min Metal 116, 491–496.
Thondoo, M., Gupta, J., 2020. Health impact assessment legislation in developing countries: a path to sustainable development? Rev Eur Comp Int Environ 11.
Vanclay, F., 2003. International principles for social impact assessment. Impact Assess. Proj. Apprais. 21.
Viliani, F., Edelstein, M., Buckley, E., Llamas, A., Dar, O., 2017. Mining and emerging infectious diseases: results of the infectious disease risk assessment and management (IDRAM) initiative pilot. Extr Ind Soc 4, 251–259.
Wegenast, T., Khanna, A.A., Schneider, G., 2020. The micro-foundations of the resource curse: mineral ownership and local economic well-being in Sub-Saharan Africa. Int. Stud. Q. 64, 530–543.
Winkler, M.S., Adongo, P.B., Binka, F., Brugger, F., Diagbouga, S., Macete, E., et al., 2020. Health impact assessment for promoting sustainable development: the HIA4SD project. Impact Assess. Proj. Apprais. 38, 225–232.
Winkler, M.S., Divall, M.J., Krieger, G.R., Schmidlin, S., Magassouba, M.L., Knoblauch, A.M., et al., 2012. Assessing health impacts in complex eco-epidemiological settings in the humid tropics: modular baseline health surveys. Environ. Impact Assess. Rev. 33, 15–22.
Winkler, M.S., Krieger, G.R., Divall, M.J., Cissé, G., Wielga, M., Singer, B.H., et al., 2013. Untapped potential of health impact assessment. Bull. World Health Organ. 91, 298–305.
Winkler, M.S., Viliani, F., Knoblauch, A.M., Cave, B., Divall, M.J., Ramesh, G., et al., 2021. Health Impact Assessment International Best Practice Principles. International Association for Impact Assessment, Fargo.
World Bank Group, 2020. How Can Zambia Benefit More from Mining? Washington D.C.
Zabré, H.R., Knoblauch, A.M., Diagbouga, S.P., Fink, G., Owuor, M., Nduna, K., et al., 2021. Changes in Socioeconomic Determinants of Health in a Copper Mine Development Area, Northwestern Zambia. The Extractive Industries and Society, p. 100985.
ZSA, MOH, ICF, 2019. Zambia Demographic and Health Survey 2018. Zambia Statistics Agency, Ministry of Health, and ICF, Lusaka.

5. Discussion

The objective of this dissertation is to assess the impact of mining projects in Africa on the socio-economic determinants of health in those affected communities. The main results of the thesis, which consist of three papers prepared for the international peer-reviewed literature (all papers are published), are the focus of this PhD thesis. The first paper presents an exploratory literature review to identify and characterise peer-reviewed publications reporting on economic studies implemented as part of impact assessments of resource extraction projects (Chapter 2); the second and third papers present the impacts of the Trident copper mine in Kalumbila, Zambia on socio-economic determinants (Chapter 3) and household wealth levels in surrounding communities (Chapter 4), respectively.

The discussion on the results in these manuscripts includes several aspects. By systematically reflecting on the observed positive and negative impacts on socio-economic determinants of health, the question is answered whether the Trident copper mine can be considered as a health impact assessment (HIA) best practice example (see Section 5.1). Next, the potential of mining projects to promote SDGs is discussed against the given importance of natural resource extraction projects (NREPs) to local and national economies (Section 5.2). Section 5.3 presents the challenges we faced when trying to accessing financial data from mining companies. This includes a comparison between the four countries of the Health impact assessment for promoting sustainable development (HIA4SD) project (Burkina Faso, Ghana, Mozambique and Tanzania), as well as Zambia. For systematically reflecting on how socio-economic determinants of health are taken into account in current impact assessment practice, the roles of key actors (e.g. national and local governments, mining companies and lending institutions) are examined and recommendations for strengthening the role of health in impact assessment are made (Section 5.4). Section 5.5 presents the overall conclusions of the thesis and a summary of key recommendations elaborated in the frame of the discussion chapter. Needs for future research identified in the frame of this PhD thesis are featured in the final Section 5.6.

The three main papers of this PhD thesis contribute to the value chain promoted by the Swiss Tropical and Public Health Institute (Swiss TPH), namely: innovation, validation and application.

Table 5-1 summarises the contribution of the different studies of the PhD project to the main activities of the Swiss TPH. In the case of this PhD thesis, innovation corresponds to the introduction of new approaches, tools and methods. Validation corresponds to practical application/experimentation or implementation and use of these tools and methods.

In the application stage, validated tools and methods resulting from this PhD thesis are suitable for impact assessment practitioners, researchers and mine managers for the systematic assessments and evaluation of impacts on socio-economic determinants of health resulting from the natural resource extraction projects (NREPs) and any other large infrastructure projects.

Table 5-1: Contributions of the different manuscripts developed under this PhD project to the core activities of Swiss TPH: innovation, validation and application

Chapter	Innovation	Validation	Application
Paper 1: Scoping review of the inclusion of economic analysis in impact studies of natural resource extraction projects	- First study to investigate the magnitude of application of economic analyses in impact assessment of NREP	- Application of Scoping review to economic analysis in impact studies of natural resource extraction projects	- The results will motivate the impact assessment community to more proactively incorporate economic analysis in impact assessment and associated studies
Paper 2: Monitoring of selected socio-economic indicators in households living in a copper mine development area in northwestern Zambia	- Innovative approaches to evaluate long term effects of a mining project on socio-economic determinants of health	- Application of socio-economic analysis in a specific mining context in Zambia	- The results will facilitate the socio-economic analysis of mining impacts based on the HIA data - Findings will make a valuable contribution to the policy dialogue facilitated by the HIA4SD project in four African countries
Paper 3: Changes in household wealth in communities living in proximity to a large-scale copper mine in Zambia	- Use of Standardized Indicators to examine wealth index from HIA data comparable to DHS data	- Application of the wealth index in the HIA of the Trident copper project in Zambia	

5.1. Is the Trident Copper Mine an HIA Best Practice Example?

For any planned large mining projects that is at the stage of feasibility studies, it is recommended to conduct a health impact assessment, or a strong health component within other forms of impact assessments [1]. This will allow to systematically identify pre-existing health challenges and needs to ultimately define a set of mitigation and health promotion measures that should be implemented along with the project development [2]. Thus, through well-targeted actions on the problems identified, such as health education programmes and provision of access to safe drinking water infrastructures,the communities are empowered maintain their level of health or even improve it despite the presence of the mine [3, 4]. Importantly, such mitigation and health promotion plans should pay special attention to vulnerable and marginalised population groups such as children, adolescent girls and women [5]. The subsequent chapters focus on the case of the Trident copper mining project (hereafter refered to as “Trident project”) in Kalumbila, Zambia. More specifically, the results of the repeated cross-sectional surveys conducted in the vicinity of the Trident project are discussed in light of external scientific literature. A conclusion is drawn on the potential of the Trident project case study to serve as a HIA best practice example.

5.1.1. Positives impacts observed

My results show that from 2011 to 2019, a reduction in average household size (-0.6 members, p-value=0.007), and an increase in ownership of economic assets (e.g., phones +29.3% points, p-value<0.001; televisions +15. 6%, p-value<0.001), access to safe water sources (+27.4% points%, p-value<0.001), and improved housing structures (e.g., finished roof +58.6% points, p-value<0.001) in the study area. In addition, socio-economic indicators were higher in affected communities than in comparison communities in 2019 (telephone ownership 68.4% vs 61.3%, television ownership 31.9% vs 15.8%, finished floor 37.0% vs 11.4%), and more changes in mothers who completed elementary school (+18.8%) and completed high school or higher (+2.5%). In the third study, we found that the mean wealth quintile (MWQ) of the near-mine communities, which was significantly lower at baseline than that of the Northwest Province (-0.54 points; p-value<0.001) in 2011, became higher than that of the surrounding province (+1.07 points; p-value <0.001) by the end of the study period (2019). Within the study communities, the MWQ increased at a significantly higher rate in impacted communities than in comparison communities (+0.30 points, p-value <0.001).

These positive results on socio-economic determinants of health (income) are in line with the positive changes in health outcomes in the same study area found by Knoblauch et al. [3, 4, 6]. For example, in impacted sites, the percentage of mothers delivering in a health facility and the percentage of women who recognize that HIV cannot be transmitted through witchcraft or other supernatural means increased significantly compared to comparison communities [4]. At the child level, only in impacted communities was stunting significantly lower in 2015 [3].

Also studies from other mining settings have found similar results for socio-economic changes in health in mine-impacted communities. Thus, a multi-country study (Norway, Finland, Peru and Sweden) found that large-scale industrial mines can have positive economic effects on the surrounding local communities [7]. More specifically, an increase in employment was found associated to the opening of copper mines in 1,035 municipalities in Norway, Sweden and Finland between 1995 and 2012. In Zambia, copper production improves the standard of living of households. Indeed, in the vicinity of the mines a 10% increase in copper production at district level is associated with a 2% increase in real household expenditure [8]. Furthermore, a study in Peru observed that mining (including copper) districts have a better average standard of living than comparable non-mining districts [9]. Despite the similarity of my results, the studies identified did not clearly report the interventions implemented by the mining companiesand it seems that these mines did not commission an HIA as part of the feasibility studies. Hence, while it does not seem exceptional that mining projects result in positive effects on socio-economic determinants of health in communities where they are implemented. On the other hand, the Trident project might be an exception from a methodological perspective as it was very systematic in setting an impact monitoring and evaluation programme as informed by the HIA.

5.1.2. Negatives impacts observed

In contrast to my studies, several studies point to negative effects of mining on health in general and socio-economic determinants in particular. For example, the costs caused by uncontrolled infectious diseases, high food prices, elevated water and electricity bills, the management of illnesses and loss of farm land, can decrease the wealth of the mining-affected households [10-13]. In addition to these negative impacts, mines often cause health inequities that affect women, children and the poorest population segments [9, 14, 15].

Like these studies, my second study initially showed an increase of the proportion of mothers that have not completed primary school (+20.4 % points, p-value<0.001) from 2011 to 2019. This reflects a decrease in the level of education of mothers in the Trident project area in Kalumbila. However, only when stratifying the population by Trident project's impact we find a decrease in the proportion of mothers who have not completed primary school (-20.6%) in favour of those who had completed primary school and more (+21.4%). This suggests an overall increase in the level of education of mothers.

This experience of the Trident project suggests that mining interventions (if any) should be taken into account in the analysis of potential impacts; given the possibility that the status of impacted or non-impacted communities may be biased and hide the actual impacts on impacted vs. non-impacted communities. To remedy this, the World Bank is drawing the attention of the governments of producing countries to the potential negative socio-economic effects of mining, and advocating transparency and good governance [16].

The overview of the impacts of natural resource extraction projects as experienced in some countries and for some mines suggests that in terms of negative impacts on socio-economic determinants of health, there appears to be less in the context of the Trident Project compared to the evidence provided by other studies.

5.1.3. The Trident project: an HIA best practice example

Based on the reflections presented above, we can conclude that the Trident project in Kalumbila, Zambia, is an HIA best practice example as it followed a very systematic methodological approach for impact mitigation and monitoring, which resulted in comparatively fewer negative impacts on socio-economic determinants of health, along with promoting positive effects. This can be considered a success that was made possible because of the private-public partnership established between the Trident project and Swiss TPH since 2010 [17]. This allowed the Trident project to have external expertise in HIA and the mitigation and monitoring of health effects (e.g., malaria, helminthic infections, HIV/AIDS and STI control) [18]. In addition, in contrast to the difficulty in accessing data concentrated in most of the selected mines in the four HIA4SD Project countries, the Trident project provided full access to health data from their own health facility, as well as financial and administrative data. On the basis of this collaboration, several studies were carried out in 2020 (Community health impacts of the Trident project in Northwestern Zambia: Results from Repeated Cross-Sectional Surveys), 2018 (Selected indicators and determinants of women's health in the vicinity of a copper mine development in northwestern Zambia) and 2017 (Experience and lessons from health impact assessment guiding prevention and control of HIV/AIDS in a copper mine Project, northwestern Zambia, and Monitoring of selected health indicators in children living in a copper mine development area in northwestern Zambia) [3, 4, 6, 19]. Transparency and the right to publish the data collected can be considered very important framework conditions for the success of such a private-public partnership between a mining company and a research institute. It is to be hoped that many other mining projects will follow this HIA best practice example as it can ultimately result in a win-win-win situation for the local community, public services (e.g. health system) an the company itself.

5.1.4. Potential of HIA to be a source for economic analysis

The implementation of mining projects in the HIAs also provides opportunities for economic evaluations. Indeed, since HIAs seek to identify health challenges and need or determinants of health in order to propose and monitor their evolution. We could then estimate the costs to society of the impacts found [20, 21]. For example, excess cases of a mine-related disease could benefit from cost of illness analysis for society, but also for the health care system [22-24]. Similarly, the costs of environmental impacts can also be estimated [25-32].

In sum, the estimated costs of the various impacts could then be compared to the expected financial contributions in order to clearly identify the opportunities for gain. It seems appropriate to reconsider the HIAs already conducted and to include economic analyses of the impacts found.

5.2. Potential Of Mining Projects to Promote SDGs 1, 3, 17

As the HIA4SD project aims to contribute to the SDGs through the promotion of HIAs, it seems relevant to identify the place of my studies (as part of HIA4SD) in the mechanism by which natural resource extraction affects the SDGs. Indeed, these mechanisms will be very useful in policy dialogue processes or in the communication phase. To this end, the following chapters reflect on the potential impacts of NREPs on selected SDGs based on the results of my study.

5.2.1. SDG 1: End poverty in all its forms everywhere

The achievement of SDG1, on which most of the SDGs, including SDG 3 “Ensure healthy lives and promote well-being for all at all ages”, depend could be significantly accelerated by the positive effects of NREPs at the local and national levels. Since poverty is predominantly rural and female-focused [33, 34], the employment of local labour, women’s empowerment, and direct and indirect employment for women are important mechanisms to reduce poverty at the rural level, as advocated by the World Bank in the Philippines [35]. For example, the interventions of the Trident project, such as the empowerment of girls, fit very well with this vision of the World Bank [36]. Thus, these direct NREP actions on SDG 1 could increase household incomes directly or indirectly by reducing impacts that absorb household resources (e.g., costs of mine-related illnesses, including road accidents (SDG3), and elevated cost of living) or by ensuring the continuity of other rural development sectors (e.g., agriculture, livestock and fisheries) [37]. In this sense, the World Bank wrote "growth in the agricultural sector is two to four times more effective in raising the incomes of the poorest than other sectors" [38].

At the regional and national level, NREP revenues can be used to invest in state industries (e.g., modernisation of the agricultur and fisheries sectorsmodernisation, renewable energy development) to increase gross domestic product per capita, while reducing the dependence on producer states that would cause the resource curse [39, 40]. The evidence is that many countries have been able to take advantage of NREPs and reduce poverty levels [41-43], but under certain conditions such as good governance, good policies, dcentralization and good services [44]. For example, in mining communities with low corruption and a relatively high capacity to collect revenue, positive spillover benefits compared to other communities [45].

5.2.2. SDG 3: Ensure healthy lives and promote well-being for all at all ages

SDG3 is a prerequisite for all 16 SDGs as they all depend healthy populations while also contributing to health indirectly [46]. In this sense, the arrival of natural resource extraction projects should *a priori* improve the health status of local communities in several ways.

First, the baseline health status of affected communities and the local health system must be maintained. This requires a thorough initial assessment of likely significant health impacts, which is then followed by appropriate interventions and regular monitoring in case of project implementation [1]. In most mining contexts, migration, increased staffing, investments in health infrastructure (e.g. health facility, referral hospitals) and traffic management are essential to reduce the pressure imposed by the influx of populations and additional cases of disease [47, 48]. In the case of the Trident project, the affordable housing Layout, town clinic at Kalumbila, frontier affordable school, frontier affordable school, aerodrome, screening and prevention of certain diseases (e.g. malaria, STI/HIV) were important features for preventing potential negative effects associated with the construction- and operation-related activities of the mine [3, 4, 19, 49, 50]. However, these investments and actions must imperatively follow national health policies in order to avoid having two parallel health systems in the same area, meaning collaboration and partenership. This absolutely requires a partnership between the NREPs and local and national leaders. Hence, the establishment of public-private partnerships between health systems and extractive industry projects – as promoted by SDG 17 – are an essential mechanism for ensuring healthy lives and promote well-being for all at all ages (SDG3) in regions where natural resources are extracted.

5.2.3. SDG 17: Partnerships for the goals

SDGs 1 and 3 above cannot be achieved without parallel action on SDG 17. This also applies to the promotion of sustainable resource extraction projects, as illustrated in the previous chapter. Indeed, if NREPs are convinced that the partnership will benefit them, they will fully embrace it. Cost-benefit studies of health interventions for the mine may well convince them. It is in this perspective that the health of the population must be considered as a whole, including the health of NREPS workers, without which no production is possible. Moreover, with the intermingling of the general population and the mine workers, one cannot really separate the health of one from that of the other. There is a strong need for a partnership between the public health services and their counterparts at the mine, and upstream, the extractive industry projects and the country's health system. This partnership could take the form of the development of national, regional and annual health policies and action plans, in which NREPs could participate and even contribute to their funding. This funding as well as the distribution and use of mining resources (e.g. royalties) to local and regional communities should be made known to NREPs in a transparent way. In this way, local Extractive Industries Transparency Initiative (EITI) can truly cease to be just another structure but an interface structure between NREPs, leaders and the community [51].

Swiss TPH et les autorités sanitaires locales peut être considérée comme un excellent exemple de partenariat privé-public pour la promotion de la santé (SDG3).

5.2.4. Comparison, conclusion, recommendations

Reflection on the potential impacts of NREPs on SDGs 1, 3 and 17 suggests that positive impacts are possible under certain conditions, including good governance, motivation and commitment of NREP stakeholders, partners such as the World Bank, IFC and even the host communities of these NREPs [52-54]. To have a truly sustainable impact on SDGs 1, 3, and 17, we recommend that NREPs leverage a win-win tripartite partnership with local communities, relevant authorities and independent impact assessors. Such a partnership should be grounded in mutual trust and transparency, which includes the sharing of data and study results with other NREPs, local and national authorities and the research community. By knowing that the case of the Trident project is the exception rather than the rule, it is further recommended to strengthen regulatory requirements for NREPs to systematically identify, monitor and mitigate potential significant health impacts.

5.3. The Challenge of Accessing Financial Data

One goals of this PhD was to evaluate and critically discuss the economic benefits and costs imposed by NREPs on the health system and impacted population groups in Burkina Faso, Ghana, Mozambique and Tanzania. This included to assess the overall financial and other flows from NREP to the public sector and determine how it is re-distributed to the different public sectors, with emphasis on the health sector (Table 5-2). But unfortunately the initial objectives 2-4 failed because of the many diffiulties faced in accessing financial data from mining companies.In what follows, the difficulties in collecting financial data in the frame of this PhD thesis are summaries and potential solutions to the problems encountered are identified.

5.3.1. Planned data collection activities

It was planned to collect financial data at the local and national level in all four HIA4SD Project countries. For this purpose, a semi-structured interview guide was developed for conducting key informant interview (KII) at the central and local level. At the level of each mine, the collection covered three parts: donation/contribution from the mine to the mayor’s office (tax, in-kind, cash) and to the health district (in-kind and cash transfer). Then, at the level of each town hall, the collection covered three parts: the annual budget of the town hall, the financial contribution received by the town hall from the mine and the financial contribution of the town hall to the health district. Finally, at the level of each health district, the data were collected in three parts: Donation from NREP to health district (in kind and cash), donation from town hall (in-kind and cash), health district financial data (annual budget including annual expenditures).

Table 5-2: Overview of failed research objectives, methods and data sources

Objectives	Methods	Data sources
Objective 2: To assess the overall financial and other flows from NREP to the public sector and determine how it is re-distributed to the different public sectors, with emphasis on the health sector	**Benefit analysis:** Summarising/estimation of contributions to health systems from NREPs (financial tracking)	Key informant interviews (KII) at the central and local level; and national, district and NREPs financial reports, contracts, management registers
Objective 3: To evaluate the costs of diseases for health outcomes that were identified as being attributable to the presence of NREPs at health system and population level	**Cost analysis:** Estimation of costs for diseases attributable to NREPs on health systems and households.	Costs incurred by households will be obtained through patient exit interviews. Health system costs will be extracted onsite (interviews with clinical staff) and from published information. Number of excess cases attributable to the presence of NREPs will be obtained from the thesis on health impacts in work package (WP) 3
Objective 4: To carry out cost-benefit analysis of specific health interventions those were implemented by NREPs to protect their workforce	**Cost-benefit analysis:** Comparison of costs and benefits of prior health interventions implemented by NREPs	NREP financial, insurance and health reports, workforce registers, time sheets, absences

At the central level, KIIs were carried out at the following institutions: (i) ministry of health; (ii) representatives of NREPs; and (iii) ministry of finances. At the local level, KIIs were target (i) health authorities/coordinators in NREP areas; (ii) management of NREP; and (iii) local authorities. In the course of these interviews, access to all sorts of financial reports and documentation was requested. While it is was notfully clear what financial data was available and accessible in the different project countries, the targeted spatial resolution was set at the national level for taxes and at district level for NREP specific contributions at the local level. Data was supposed to be collected for the last 10 years (2008-2017) or at least since the beginning of the NREPs. A combination of collection grid, interviews with data managers, and review of accounting documents was applied. Data collection was done by a combination of the six PhDs in the HIA4SD project and local study assistants hired for around 3 months.

5.3.2. Challenges faced when implementing the planned research

In Burkina Faso

The data collection tools were sent out as planned in the methodology two weeks before the interviewers arrived in the field. Then, the mayor's office, the health district and the mine were contacted by telephone one week or on the first day of the interviewers' arrival at each of the three study sites in the health districts of Houndé and Kongoussi with, respectively, the gold mines of Houndé (Houndé Gold), Bagassi (Roxgold) and Bissa (Bissa Gold).

In general, the KIIs were easy to conduct in the health districts, more difficult at the town hall and mine levels. At the health district level, financial contributions from the mines and/or the mayor's office were available but were not complete according to managers. At the level of the town halls, it was often the same report from the mine that was given to us and it was difficult to find all the interventions from the mine because some donations were made directly to the district or to the communities without going through the town hall. At the mine level (especially in Bagassi), all contributions to the communities are documented and made available to us. Some of these contributions were verified at the Boromo district (e.g. generator), at the health facility of Bagassi (e.g. solar panel), in the community (e.g. training of young people in electricity and mechanics, whose graduation we attended).

In summary, despite the approval of their managers at the central level, the local interlocutors were very reserved at the local level. Some preferred to fill out our questionnaires (which were interview guides) on their own and return them to us later. But this return was never made. Out of the nine tools, three were completes, four were incomplete and two were missing information (at the mine level) as shown in the Table 5-3.

Comparison/lessons learned across four countries

In the three others counties namely Ghana, Mozambique and Tanzania, very similar experiences were made as in Burkina Faso.

Table 5-3 summarises the data collected and their characteristics for the four countries. It can be seen that the respondents (mines, town hall, and health district) had difficulty filling out the Excel tools during the entire field collection period (more than 3 months). In Burkina Faso, for example, the reasons were administrative, inability to find the appropriate supports (the traces), and lack of time. In Bagassi, all of their financial reports (Table 5-3) on commune and health funding, including the films, were given to us. In sum, it was easier to give the available reports than to extract the requested data and fill in the forseen data collection tools.

Table 5-3: Overall assessment of data collection in the four HIA4SD countries by study site

Countries	Study sites	Mine	Town hall	Health district
Burkina Faso	Houndé	NR	Partial (report)	Partial (report)
	Bagassi	Full (report)	NR	Partial (report)
	Kongoussi	Full*	Full *	Partial (report)
Ghana	Asutifi	NR	NR	NR
	Tarwa	NR	NR	NR
Mozambique	Larde	NR	Full	NR
	Moatize	NR	NR	Partial
	Moma	NR	Partial	Full
	Montepuez	Partial (report)	NR	NR
Tanzania	Geita	Partial (report)[1]	Partial (report)	NR
	Buzwagi	NR	Partial (report)	Partial (report)
	Bulyanhulu	NR	NR	NR

*NR= Not Received; * Disturbed by terrorist attacks*

The main difficulties in the four project countries can be summarised as follows:

- Unavailability of respondents in the mines;
- The inexistence of some of the data requested;
- Lack of a local coordination structure that brings together key stakeholders such as the mines, local government and the health district;
- Lack of transparency from the mines or fear of sharing sensitive data (money), including willingness to provide the financial data;
- Insufficient archiving of financial data at the health district level, including data quality issues.

5.3.3. Recommendations derived from the lessons learned

The experiences and lessons learnt in the implementation of the studies can be useful for the collection methods to better overcome potential difficulties, or for the shortcomings to be identified and corrected for future studies. Thus, in relation to the different reasons for not obtaining data, we make recommendations to the three entities where data should be collected (health district, town hall, mining).

<u>Recommendation for the mining level</u>

The main problems were the availability of data and staff in combination with the fear of sharing financial data. Given the inability to obtain primary data at some mines, the last resort would be secondary data through mine reports, EITI, and mine data sites such as those of the World Bank [55, 56]. However, these databases are often updated with varying degrees of timeliness and not all of the indicators requested in my research were necessarily included.

This may require secondary data collection to be complemented by specific primary data for indicators not included. Triangulation with data collected at the town hall and health district levels could ensure data quality. Another issue was the lack of staff time at the mines. As a solution, investigators could spend more time in the mines collecting data. Indeed, collecting data from all PhDs at the same time may not have allowed for greater attention to financial data despite the specificity of the mines and the sensitivity of these data. In the long term, an ultimate and sustainable solution would be to introduce the collection of the missing indicators into routine mining and EITI and CSR reporting. In addition to the above, activating local EITIs, producing mine collaboration journals, and even initiating the promotion of good practices (celebrating model mines) could further motivate mines. A sustainable and effective solution would be a collaboration/partnership for HIAs with national and/or international research institutes, as is the case with Trident project in Zambia.

Recommendation for the hall

The main problem encountered was data archiving and management. Despite the willingness of most town hall officials, financial data was difficult to find and the physical implementation of the mines difficult to quantify the costs (unavailability of implementation costs). Indeed, the teams of the town hall are changing (according to the deadlines of the mandates) the data are lost from one team to the next. In addition, the level of technical expertise in data management is often limited at the local level. One scenario would be to first collect the data at the mine level and then return to verify the accuracy in the town halls (but without creating a conflict between the two structures). In this scenario, it will also be necessary to go to the community and verify the accuracy of the achievements as in the transect walk [57, 58]. Part of the contribution received at the town hall, such as royalties, can be collected at the central level by the ministries in charge of the town halls.

Recommendation for the health districts

As with the town halls, the main problem here is the archiving of data. However, the health districts are generally better equipped with high-level administrative and management personnel. It is therefore difficult to understand why data from the mines and town halls are not archived in a timely manner. One scenario would be to collect data from all the health centers covered by the commune to which the mine belongs. This would make it possible to track achievements and contributions not capitalised in the health district. Again, the data from the mine should serve as a benchmark for comparison. Another scenario would be to collect secondary data such as annual action plans (where all financial inputs are normally included), and then secondarily, conduct KIIs to extract (or complete) the study indicators. This experience in the four countries of the HIA4SD project has shown us the difficulties of collecting financial data, especially from the mines. Therefore, the analysis in the discussion opens up other opportunities such as secondary and primary data collection, and especially a partnership between mines and research institutions. This could facilitate the collection of data on the contribution of mining at the local level, and set a new course for future studies on the financial impacts of mining on health.

5.4. Role of Key Actors in Promoting HIA Practice

In view of the insufficient inclusion of the socio-economic determinants of health in impact assessments noted in my scoping review, it seems relevant to reflect on how the practice of HIA can be further promoted. To this end, the following chapter presents reflections on the role that the identified key actors should play in promoting the practice of HIA.

5.4.1. Role of academic institutions

The vocation of knowledge givers is intimately linked to the role of research in an academic institution [59]. Academic institutions are essentialfor providing training that can feed communities of impact assessment practice such as the International Association for Impact Assessment (IAIA) [60]. In addition, research institutions have a responsibility in providing educational resources (e.g., training materials, guidance documents) to integrate health in impact assessments and existing course offerings [61]. This is the case of the Swiss TPHwhere the Department of Epidemiology and Public Health deals with HIA research and capacity building [62]. Moreover, through research the benefits of impact assessments can be demonstrated, which is important for convincing stakeholders such as governments, private sector projects and financing institutions about the importance of further strengthening HIA practice [63]. In this sense, the HIA conducted in partnership with the Trident project can serve as a best practice example [17, 36].

- *Key roles identified: Development of educational resources, offering of trainings, research*

5.4.2. Role of extractive industry companies

Private sector companies themselves have an key role in impact assessment as an actor of change (introduction of new projects) in the communities where they operate. This is particularly true for HIA, or health within other forms of impact assessment, which is generally not well regulated at the national level, especially on the African continent [18]. In the absence of national legislation it is imperative that mining companies apply the rules and standards set by international organisatoins such as the International Finance Corporation (IFC), the International Council on Mining and Metals (ICMM) and the International Petroleum Industry Environmental Conservation Association (IPIECA) [64-66]. This should actually be in their own interest as it will promote a healthier workforce (increased productivity) and also healthier host communities (essential for collaboration and conflict prevention) [67]. Given these benefits, companies should become more active in incorporating health expertise among their staff, who are capable of collaborating with research institutions and governments to ensure high quality HIA and implementation of health interventions in partnership with the local health system and other actors. Again, the example of the Trident project appears illustrative as the health interventions implemented resulted in overall positive impacts on socio-economic determinants and shown in Chapter 3 and Chapter 4 of this PhD thesis. In addition, companies should commit to improve access to data and transparency (see Section 5.3) [68].

- *Key roles identified: compliance with national and international impact assessment regulatory frameworks, engaging health expertise (HIA specialist and internally), partnering with local institutions for implementation of interventions, impact monitoring, data sharing*

5.4.3. Role of lending institutions

The World Bank and the banks that have subscribed to the Equator Principle, including the IFC, are potential partners respectively for the development of producer countries, and lenders for the mines [38, 69].

First, the World Bank, which advocates natural resource extraction as a means of reducing poverty, and lends to countries for development initiatives and large public works (e.g. roads, hydropower, ports, private sector projects), has a definite power to impose the use of HIA for planned resource extraction projects [70, 71]. Thus, the World Bank as a major partner in economic development could on the one hand impose HIA as a condition for mitigating the health impacts of mining, on the other hand it could also promote research by funding governmental HIA initiatives in the mining context. For example, a project such as HIA4SD, because of its focus on SDGs and mining producing countries, could be government-led and funded by the World Bank for the benefit of each country [72]. In addition, the impact studies on economic determinants that we have already conducted in Zambia could easily be sponsored for replication at the HIA already conducted in other countries/ or mines.

Secondly, banks, including IFC, have signed up to the Equator Principles. As a reminder, the Equator Principles (EPs) are a set of ten principles that signatory financial institutions must respect in order to, among other things, manage risks and identify, assess and manage the environmental and social risks of projects [73]. As the environmental and social risks of mining are health endpoints, the importance of the EPs for this area is clear. Therefore, banks adhering to these principles, in addition to financing the private sector such as mining, should also work to reduce the health risks that HIAs identify. In addition, the IFC may condition its support to companies on the inclusion of IA in the company's assessment.

Together, the World Bank and IFC could formally institute the inclusion of IA and in particular socio-economic determinants in the terms of operating contracts and evaluation/performance criteria of these mining companies, and fund IA research.

- *Key roles identified: Incentivising governments, introducing IA into loan conditions, funding research.*

5.4.4. Role of national and local governments

One of the average objectives of any government is to ensure the health of its citizens and their economic development, and this gives them many roles in promoting assessed impacts.

Regulating HIA or the rigorous inclusion of health in other forms of AI is an appropriate role for governments given the sovereignty of states and their regalian role to protect for the population. According to the United Nations ‘’ The right of peoples and nations to permanent sovereignty over their natural wealth and resources must be exercised in the interest of their national development and of the well-being of the people of the State concerned’’ [74].

To do this, national governments need to reform laws and regulations such as mining codes to incorporate AR, while attracting mining investors [75, 76]. These legislative reforms would be more acceptable to the mines if they are consistent with those of the lending institutions (section 10.4.3 above). Furthermore, it is also the responsibility of the state to review the quality of the impact assessment reports in order to correct potential errors and to ensure the relevance of the results for sound decision-making based on valid scientific evidence. This is crucial for the effectiveness of the measures that will be taken on the basis of these results [77].

Partnering with NREPs to mitigate health impacts (e.g. local health systems) is useful to identify impacts through AI, and to plan actions to monitor and correct them as done in Kalumbila, Zambia every 4 years (section 10.1.1). For example, in view of the results obtained by the HIA4SD project, governments could then appropriate the results of my studies, the experience of the Trident project and the wider HIA4SD project to extend these studies and make better use of them to inform their mining policies. This logically leads to a partnership with the main mines for the study of impacts in each country. Once mitigation measures have been agreed, the role of governments is also to enforce the implementation of mitigation measures. This is especially important for mines where corruption and misrepresentation are common [78, 79]. In this context, mitigation actions (e.g. drinking water supply vs. pollution of water sources, fight against malaria, STI/HIV) must be audited, externally controlled and capitalised. This makes it possible to ensure the effectiveness of the actions, their quality and their effects on the targeted problems. Also, it is important to involve local communities as victims of the impacts and beneficiaries of the interventions in these follow-ups for more accountability of governments and for transparency.

After the first impact assessments, governments still need to review the impact monitoring data, to ensure the quality of the studies and to be able to establish trends, project long-term trends, plan and implement effective and sustainable remedial actions.

At the local level, governments should ensure strict enforcement, alert the national level, and work with local NREPs, local structures such as EITI, and encourage local community participation in IA.

- *Key roles identified: Regulating HIA or rigorous inclusion of health in other forms of IA, Reviewing quality of impact assessment reports, Partnering with NREPs for health impact mitigation (e.g. local health systems), Enforcing implementation of mitigation measures, Reviewing impact monitoring data.*

5.5. General Conclusion and Recommendations for HIA Practice

My thesis work provided multiple analytical results as part of the HIA4SD project focusing on the topic of health economics. Thus, my results show among others:

Firstly, a low level of economic analysis in published community impact assessments of mines, incomplete economic analyses (e.g. either only benefit or cost analyses), and a focus on the environmental and social domains with little interest in the health domain. Secondly, the presence of a copper mine in Zambia is associated with positive changes such as a higher level of childbearing, the possession of certain economic goods (e.g. television, ...), access to healthy water sources and better quality housing (e.g. walls, floor, roof). Finally, communities impacted by the copper mine in Zambia (e.g. receiving health, education, infrastructure interventions) whose wealth level was low at the start of the studies in 2011, have grown rapidly and have outgrown the non-impacted community and the region, reflecting a positive impact of the Trident project on household wealth levels. Furthermore, the Trident project has carried out multiple community interventions, which can justify the positive impacts on both the socio-economic determinants of health and household wealth in the impacted communities, appears to be a best practice case.

In the light of the above findings and the objectives of the HIA4SD project, recommendations have been made to the various stakeholders in HIAs and the governments of producing countries:

Despite the importance of the economic analyses that mines must underpin in their business of operation, there is a glaring lack of economic analysis in mine impact assessments, particularly those relating to health. Increasing the practice of economic impact assessment involves several actors. Governments should reform their regulations to require periodic assessments of mining projects and the monitoring of these impacts. In addition, governments should invest in conducting these studies, as well as ensuring that all impacts assessed can benefit from economic analysis. As well as governments, mining projects (which must comply with government regulations and lending institution standards), research institutions (which must implement impact assessments and increase knowledge of possible approaches), equatorial banks and extractive industry lenders (which must include impact assessments in their lending standards and conditions) all have key roles to play in carrying out these assessments. The inclusion of economic analyses should therefore be clearly recognised and included in the standards and contracts between these different actors. However, given the scientific capacity of the research institutions, they could work fully to publish the results found.

Our results also found positive impacts of the Trident project on the socio-economic determinants of health in the impacted communities. In contrast to some projects where economic impacts are generally negative, even leading to the term 'commodity curse', and given the promotion of impact assessments by the Trident project, it was considered a best practice case. Indeed, this best practice case is further justified by the interventions to mitigate potential negative impacts and the promotion of impact assessments by the Trident project compared to the difficulties of collecting financial data in the HIA4SD countries. All this leads us to recommend to the mining projects in the four HIA4SD countries (Burkina Faso, Ghana, Mozambique and Tanzania), the well contextualised duplication of Trident's best practice to ensure positive health and economic impacts on the populations as in Kalumbila, Zambia. Research institutions such as those already involved in the HIA4SD project (IRSS in Burkina Faso), as well as the governments of these countries, are the key authors to be included in this approach. This best practice case should then be included in the packaging of the other results to be transformed into appropriate messages for policy dialogue so that each actor can play its role and mine action IA effectiveness under HIA4SD leadership.

Finally, impact assessment reports are difficult to obtain and monitoring data is rarely published. Public disclosure and even scientific publication of the process and findings of impact assessment reports should therefore be encouraged by regulatory bodies (e.g. governments, lending institutions). This could not only increase the accountability of the mining sector for potential negative impacts, but also increase the visibility of their positive contributions to the 2030 Agenda for Sustainable Development. Furthermore, mining revenues and their distribution to communities and health services could be known in order to avoid inequalities in the sharing of development goods, recognise the importance of mining contributions and ensure equitable development based on informed policy choices with relevant IA data. Furthermore, in these IAs, very importantly, cost-benefit analysis of mines from a social and private perspective should be prioritised, so that companies, as well as the population, can situate themselves on their potential gains from their health actions, and thus help in decision making [22].

Given the close link between the economy and health, it is clear that in order to "Ensure healthy lives and promote well-being for all at all ages" (SDG3), it is necessary to "End poverty in all its forms everywhere" (SDG1).

5.6. Outlook and Possibilities for Future Research

In the second phase of the HIA4SD project, the results of my thesis, together with those of the HIA4SD team as a whole, should be used to formulate policy dialogues to induce the promotion of impact assessments in resource-rich countries in Sub-Saharan Africa.

In particular, my thesis found that the lack of inclusion of economic analyses in mine impact assessments, as well as the lack of inclusion of economic analyses in mine impact assessments, will contribute to increasing the knowledge of the scientific community and users of published information (including international agencies, mines and policy makers) on the current state of inclusion of economic analyses in impact assessments on the one hand, and the evolution of impacts on the socio-economic determinants of health on the other.

In the same continuity of the promotion of HIA, we will be involved in the training of HIA students, but also in research. Thus, the unfulfilled objectives (2, 3 and 4) can be achieved after the PhD by taking advantage of the lessons learned and by having the results of the impacted diseases of another colleague (this objective has been moved to the second phase of the project).

Firstly, it will be necessary to complete the objectives not achieved in phase 2 of HIA4SD, which are:

- To assess the overall financial and other flows from NREPs to the public sector and determine how the funds are redistributed to the different public sectors, with a focus on the health sector;
- Assess the costs of diseases or health outcomes that have been identified as being attributable to the presence of NREPs at the health system and population level.

Then, it would be appropriate to look for the benefits of mining by supplementing health actions through the conduct of a cost-benefit analysis of specific health interventions implemented by NREPs to protect their personnel. This requires a cost-benefit analysis of the mining operation before the relevant authorities grant new mining contracts [80].

Finally, the impacts on the distribution of potential epidemic diseases, as well as the quantification of the costs of other impacts found by the HIA4SD project (e.g. environmental, water and sanitation) are other relevant research topics that could complement our already completed studies.

5.7. References

1. Winkler MS, Viliani, F., Knoblauch, A.M., Cave, B., Divall, M., Ramesh, G., Harris-Roxas, B. and Furu, P.: 2021. Health Impact Assessment International Best Practice Principles. Special Publication Series No. 5. Fargo, USA: International Association for Impact Assessment.
2. Winkler MS et al: 2012. Assessing health impacts in complex eco-epidemiological settings in the humid tropics: modular baseline health surveys. Environ Impact Assess Rev, 33(1).15-22. https://doi.org/10.1016/j.eiar.2011.10.003
3. Knoblauch AM et al: 2017. Monitoring of selected health indicators in children living in a copper mine development area in northwestern Zambia. Int J Environ Res Public Health, 14(3).315. https://doi.org/10.3390/ijerph14030315
4. Knoblauch AM et al: 2018. Selected indicators and determinants of women's health in the vicinity of a copper mine development in northwestern Zambia. BMC women's health, 18(1).62. https://doi.org/10.1186/s12905-018-0547-7
5. Leuenberger A et al: 2019. Health impact assessment and health equity in sub-Saharan Africa: A scoping review. Environ Impact Assess Rev, 79.11. 10.1016/j.eiar.2019.106288
6. Knoblauch A et al: 2020. Community health impacts of the Trident Copper mine Project in Northwestern Zambia: Results from Repeated Cross-Sectional Surveys. Int J Environ Res Public Health, 17(10).3633. https://doi.org/10.3390/ijerph17103633
7. Frederiksen A, Kadenic MD: 2020. Mining the north: local impacts. Labour Econ, 63.101790. https://doi.org/10.1016/j.labeco.2019.101790
8. Lippert A, 2014. Spill-overs of a resource boom: evidence from Zambian copper mines, Available at: https://ideas.repec.org/p/oxf/oxcrwp/131.html (Accessed on September 17, 2020)
9. Loayza N et al, 2013. Poverty, inequality, and the local natural resource curse, Available at: https://openknowledge.worldbank.org/handle/10986/13169 (Accessed on September 11, 2020)
10. Viliani F et al: 2017. Mining and emerging infectious diseases: Results of the Infectious Disease Risk Assessment and Management (IDRAM) initiative pilot. Extr Ind Soc 4(2).251-259. https://doi.org/10.1016/j.exis.2016.08.009

11. Korah PI et al: 2019. Analysis of livelihood issues in resettlement mining communities in Ghana. Resour Policy, 63.101431. https://doi.org/10.1016/j.resourpol.2019.101431
12. Schrecker T et al: 2018. How extractive industries affect health: Political economy underpinnings and pathways. Health & Place, 52.135-147. https://doi.org/10.1016/j.healthplace.2018.05.005
13. Wegenast T, Beck J: 2020. Mining, rural livelihoods and food security: A disaggregated analysis of sub-Saharan Africa. World Development, 130.104921. https://doi.org/10.1016/j.worlddev.2020.104921
14. Pearce A et al: 2020. Reducing inequities in health across the life-course: early years, childhood and adolescence.
15. Adamson R: 2017. Vulnerabilities of Women in Extractive Industries. ANTYAJAA: Indian Journal of Women and Social Change, 2(1).24-31. 10.1177/2455632717714134
16. Group WB: Mining: Sector Results Profile. In.; 2021.
17. KQML, 2019. Kalumbila Minerals Limited: Trident Project, Health Impact Assessment Follow-Up Health Survey 2019, Available at: https://www.first-quantum.com/English/search-results/default.aspx?SearchTerm=Health+Impact+Assessment+Follow-Up+Health+Survey+2019 (Accessed on Novemver 17, 2020)
18. Winkler MS et al: 2013. Untapped potential of health impact assessment. Bull World Health Organ, 91.298-305.
19. Knoblauch AM et al: 2017. Experience and lessons from health impact assessment guiding prevention and control of HIV/AIDS in a copper mine Project, northwestern Zambia. Infect Dis Poverty, 6(1).114. https://doi.org/10.1186/s40249-017-0320-4
20. Winkler MS, F. Viliani, A.M. Knoblauch, B. Cave, M.J. Divall, G. Ramesh, B. Harris-Roxas, and P. Furu.: 2020. Health impact assessment international best practice principles. Impact Assess Proj Apprais, Special Publication Series No. 5
21. Dietler D et al: 2020. Inclusion of Health in Impact Assessment: A Review of Current Practice in Sub-Saharan Africa. International journal of environmental research and public health, 17(11).4155.
22. Almansa C, Martinez-Paz JM: 2011. What weight should be assigned to future environmental impacts? A probabilistic cost benefit analysis using recent advances on discounting. Sci Total Environ, 409(7).1305-1314. 10.1016/j.scitotenv.2010.12.004

23. Rai R, Singh TN: 2004. Cost benefit analysis and its environmental impact in mining. Journal of Industrial Pollution Control, 20.17-24.
24. Rudmik L, Drummond M: Health economic evaluation: Important principles and methodology, vol. 123. The Laryngoscope: John Wiley & Sons, Ltd; 2013.
25. Joseph C et al: 2020. Assessing the public interest in environmental assessment: lessons from cost-benefit analysis of an energy megaproject. Impact Assessment and Project Appraisal, 38(5).397-411. 10.1080/14615517.2020.1780371
26. de Oliveira Neto GC et al: 2020. Assessment of the environmental impact and economic benefits of the adoption of cleaner production in a Brazilian metal finishing industry.
27. Nicholls C et al: 2019. What is the value of the environment?
28. Nalule VR: Mining and the law in Africa: Exploring the social and environmental impacts; 2019.
29. Jatoi WB et al: 2019. Proximate analysis of Lakhra coal power plant and its health and environmental impact.
30. Danh V: Economic Analysis Methods for Natural Resource and Environmental Policies. In., edn.; 2019: 3-9.
31. Porgo M, Gokyay O: 2017. Environmental impacts of gold mining in Essakane site of Burkina Faso. Human and Ecological Risk Assessment: An International Journal, 23(3).641-654. 10.1080/10807039.2016.1263930
32. Kurochkina I et al: 2017. The analysis method perfomance indicators of environmental costs.
33. Agarwal B: 1989. Rural Women, Poverty and Natural Resources: Sustenance, Sustainability and Struggle for Change. Economic and Political Weekly, 24(43).WS46–WS65.
34. Muryani, Esquivias MA: 2020. Factors influencing the gender gap in poverty: the Indonesian case. World Review of Entrepreneurship, Management and Sustainable Development
35. Reducing Poverty in Rural Areas. In.; 2021.
36. FQML, 2015. Development Projects: Trident., Available at: https://www.first-quantum.com/Our-Business/Development-Projects/Trident/default.aspx (Accessed on August 3, 2020)
37. Iimi A et al: New Rural Access Index. In.; 2016.
38. Group WB: Overview. In.; 2021.

39. Taylor I: 2016. Dependency redux: why Africa is not rising. Review of African Political Economy, 43(147).8-25. 10.1080/03056244.2015.1084911
40. Mulwa R, Mariara J: 2016. Natural resource curse in Africa: Dutch disease and institutional explanations. Report prepared for the International Food Policy Research Institute Washington, United States
41. Sarraf M, Jiwanji M: 2001. Beating the resource curse: the case of Botswana.
42. Lewin M: 2011. Botswana's success: Good governance, good policies, and good luck. Yes Africa Can, 81
43. Mogalakwe M, Nyamnjoh F: 2017. Botswana at 50: democratic deficit, elite corruption and poverty in the midst of plenty. Journal of Contemporary African Studies, 35(1).1-14. 10.1080/02589001.2017.1286636
44. Overview. In.; 2021.
45. Konte M, Vincent RC: 2021. Mining and quality of public services: The role of local governance and decentralization. World Development, 14010.1016/j.worlddev.2020.105350
46. Who WHO: 2020. Sustainable Development Goals. World Health Organization: WHO
47. Owen JR, Kemp D: 2017. Social management capability, human migration and the global mining industry. Resources Policy, 53.259-266. https://doi.org/10.1016/j.resourpol.2017.06.017
48. Awedoba AK, Hahn HP: 2014. Wealth, Consumption and Migration in a West African Society. New Lifestyles and New Social Obligations among the Kasena, Northern Ghana. Anthropos, 109(1).45-56. 10.5771/0257-9774-2014-1-45
49. Knoblauch AM et al: 2020. Community Health Impacts of the Trident Copper Mine Project in Northwestern Zambia: Results from Repeated Cross-Sectional Surveys. 17(10).3633.
50. minerals Fq: First Quantum Minerals Ltd. - 2020 Annual Report. In.; 2021.
51. Extractive Industries Transparency Initiative. In.; 2021.
52. Gerelmaa L, Kotani K: 2016. Further investigation of natural resources and economic growth: Do natural resources depress economic growth? Resources Policy, 50.312-321. 10.1016/j.resourpol.2016.10.004
53. Sterck O: 2016. Natural resources and the spread of HIV/AIDS: curse or blessing? Social Science & Medicine, 150.271-278.
54. Canuto O, Cavallari M: 2012. Natural Capital and the Resource curse.

55. WHO: Indicators | Data. In.; 2021.
56. EITI: Extractive Industries Transparency Initiative. In.; 2021.
57. Leuenberger A et al: 2020. "It is like we are living in a different world": Health equity in communities surrounding industrial mining sites in Burkina Faso, Mozambique and Tanzania Frontiers in Public Health – Environmental Health Section,
58. Keller S: Transect Walk | SSWM - Find tools for sustainable sanitation and water management! In.; 2021.
59. Online F: 2017. Role of research in an academic institution is significant, here's why. Financial Express
60. IAPA: IAIA The leading global network on impact assessment. In.; 2021.
61. Kamenetzky A, Hinrichs-Krapels S: 2020. How do organisations implement research impact assessment (RIA) principles and good practice? A narrative review and exploratory study of four international research funding and administrative organisations. Health Research Policy and Systems, 18(1).6. 10.1186/s12961-019-0515-1
62. Http://www. cs2. ch CA-S-: Swiss TPH | Taking Science to Impact. In.; 2021.
63. Morrison-Saunders A et al: 2015. Demonstrating the benefits of impact assessment for proponents. Impact Assessment and Project Appraisal, 33(2).108-115. 10.1080/14615517.2014.981049
64. Winkler MS et al: 2020. Current Global Health Impact Assessment Practice. Int J Environ Res Public Health, 17(9).2988.
65. ICMM: ICMM Guidance - ICMM Guidance. In.; 2021.
66. IPIECA: The global oil and gas industry association for advancing environmental and social performance. In.; 2021.
67. Group WB: Better Health in Mines and Mining Communities: A Shared Responsibility. In.; 2021.
68. Better data, better debate. In.; 2020.
69. Burlea AS, Popa O: World Bank (Sep Article on IFC Policy Social Env Sustainability). In: *Encyclopedia of Corporate Social Responsibility.* edn. Edited by Idowu SO, Capaldi N, Zu L, Gupta AD. Berlin, Heidelberg: Springer Berlin Heidelberg; 2013: 2727-2735.
70. About the World Bank. In.; 2021.
71. About IFC. In.; 2021.

72. Winkler MS et al: 2020. Health impact assessment for promoting sustainable development: the HIA4SD project. Impact Assess Proj Apprais, 38(3).225-232. 10.1080/14615517.2019.1694783
73. Baumast A: Equator Principles. In: *Encyclopedia of Corporate Social Responsibility*. edn. Edited by Idowu SO, Capaldi N, Zu L, Gupta AD. Berlin, Heidelberg: Springer Berlin Heidelberg; 2013: 1045-1051.
74. UN: OHCHR | Permanent sovereignty over natural resources. In.; 2021.
75. Jara JJ et al: 2020. Attracting mining investments: the relationship between natural endowments and public policies. Mineral Economics, 33(1).231-243. 10.1007/s13563-020-00230-7
76. Investopedia: How Does Government Regulation Impact the Metals and Mining Sector? In.; 2021.
77. Urquhart R et al: 2019. The role of scientific evidence in decisions to adopt complex innovations in cancer care settings: a multiple case study in Nova Scotia, Canada. Implementation Science, 14(1).14. 10.1186/s13012-019-0859-5
78. Williams A, Dupuy K: 2017. Deciding over nature: Corruption and environmental impact assessments. Environmental Impact Assessment Review, 65.118-124. https://doi.org/10.1016/j.eiar.2017.05.002
79. Konte M, Vincent RC: 2021. Mining and quality of public services: The role of local governance and decentralization. World Development, 140.105350. https://doi.org/10.1016/j.worlddev.2020.105350
80. Obiri S et al: 2016. Assessing the Environmental and Socio-Economic Impacts of Artisanal Gold Mining on the Livelihoods of Communities in the Tarkwa Nsuaem Municipality in Ghana. International Journal of Environmental Research and Public Health, 13(2).160.

6. Curriculum Vitae

Personal details

Name: Raogo Hyacinthe ZABRE

Date of birth: 24 February 1974

Nationality: Burkinabe

Address: Ouagadougou, Burkina Faso

Phone: +226 62 66 66 51/ 78 08 87 70

E-Mail: raogohyacinthe.zabre@unibas.ch

raogohyacinthe.zabre@swisstph.ch

Education

9/2017 – 05/2021	**PhD candidate in Epidemiology** at the Swiss Tropical and Public Health Institute. Thesis title: "Associations between mining projects and socio-economic determinants of health in sub-Saharan Africa".
09/2014-06/2016	**Master in Public Health, Society and Development** (SPSD), SESSTIM, UMR 912 Medical School Aix-Marseille, France.
10/2010-12/2012:	**Diploma of Health in Epidemiology** (Master1, BAC+4), National School of Public Health, 02 Po Box 7002 Ouaga 02, Ouagadougou, Burkina Faso.
10/2010-12/2012:	**Diploma of Health in Epidemiology** (Master1, BAC+4), National School of Public Health, 02 Po Box 7002 Ouaga 02, Ouagadougou, Burkina Faso.
10/2008-09/2010	**Master in Project Management and Local Development**, African Institute of Professionalization in Management, Bobo-Dioulasso, Burkina Faso.
09/1995-07/1998	**Diploma of State Nurse**, National School of Public Health, 02 Po Box 7002 Ouaga 02, Ouagadougou Burkina Faso.

Selected work experience

02/2015-9/2017	**Permanent teacher and Coordinator of Health Students in Epidemiology**, Ministry of Health, Burkina Faso.
09/2014-08/2015	**Data manager in Performance-Based on Financement (FBR)**, technical service FBR, Burkina Faso.
03/2013-02/2015	**Data Manager, responsable of Epidemiologic Surveillance**, Health District of Sapouy, Ministry of Health, Burkina Faso.
11/2006-09/2010	**Health Responsible of Tuberculosis** Diagnostic and Treatment center (CDT) in the health district, Houndé, Burkina Faso.
10/2000-11/2006	**Responsible of the Health and social Promotion center,** district of Houndé, Ministry of Health, Burkina Faso.
11/1998-10/2000	**Nurse** in Medical Center with Hounde Surgical Antenna in the health district of Houndé, Ministry of Health, Burkina Faso.

Language skills

French	Native speaker
English	A2, 2017

Software skills

STATA, IBM SPSS, Microsoft Office (Word, Excel, Outlook, PowerPoint, Access), Nvivo, SatScan, Philcarto, Phildigit, R3.4.0 software, EpiInfo7, Health Mapper, CSPro

List of Publications

Zabré HR, Dietler D., Diagbouga S.P., Winkler MS. Scoping review of the inclusion of economic analysis in impact studies of natural resource extraction projects. Impact Assessment and Project Appraisal. 2021:1-16.

Farnham A, Cossa H, Dietler D, Engebretsen R, Leuenberger A, Lyatuu I, Nimako, B.; **Zabre, H.R.;** Brugger, F.; Winkler, M.S.; Investigating health impacts of natural resource extraction projects in Burkina Faso, Ghana, Mozambique, and Tanzania: Protocol for a mixed methods study. JMIR Research Protocols 2020; 9(4):e17138.

Knoblauch A.; Farnham A.; **Zabré H.R.;** Owuor M, Archer C, Nduna K.; Chisanga, Marcus Zulu, L.; Musunka, G.; Utzinger, J.; Community health impacts of the Trident Copper mine Project in Northwestern Zambia: Results from Repeated Cross-Sectional Surveys. Int J Environ Res Public Health. 2020; 17(10):3633.

Zabré H.R.; Knoblauch A.; Diagbouga S.P, Fink G.; Owuord M.; Nduna K.; Chisanga M.; Musunka G.; Divall M.J.; Winkler S.M, Farnhama A.; Changes in socioeconomic determinants of health in a copper mine development area, northwestern Zambia. The Extractive Industries and Society. 8 (2021) 100985.

Zabré H.R.; Farnhama A.; Diagbouga S.P, Fink G.; Divall M.J.;Winkler S.M, Knoblauch A.(2021) Changes in household wealth in communities living in proximity to a large-scale copper mine in Zambia. Resources Policy 74 (2021) 102395.

Leuenberger A.; Cambaco O.; **Zabré H.R.;** Lyatuu I.; Merten S.; and Winkler S.M.; "It is like we are living in a different world": Health equity in communities surrounding industrial mining sites in Burkina Faso, Mozambique and Tanzania (2021); Int. J. Environ. Res. Public Health2021,18, 11015.

Gianna Himmelsbach G.; Winkler S.M; **Zabré H.R.** (2021) Community health impacts of the Trident Copper mine Project in Northwestern Zambia: Results from Repeated Cross-Sectional Surveys (Master's thesis)