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

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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

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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

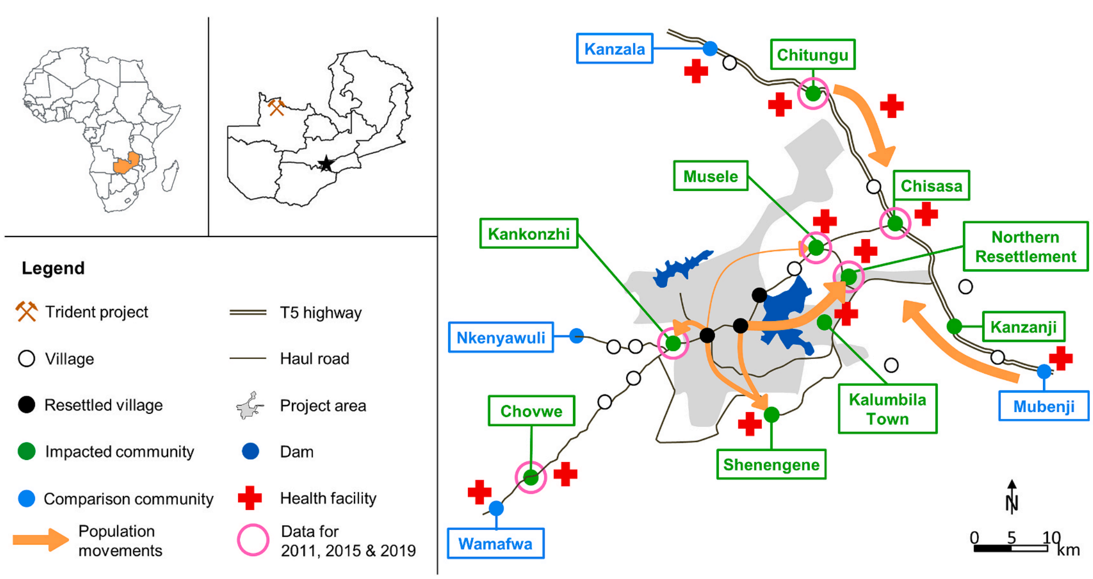

Fig. 1. Map of the study area and surveyed communities, Kalumbila district, Zambia (Knoblauch et al., 2020a).

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)	n/a	2.48 (1.11)	−0.60 (<0.001)
Chitungu	30	2.03 (1.22)			−0.45 (0.06)
Chovwe	63	1.67 (0.99)			−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)	n/a	2.48 (1.11)	n/a	2.75 (1.46)	+0.27 (<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)						+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)	n/a	2.75 (1.46)	+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)			+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.

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Declaration of competing interest

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