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Developing models to assess the social impact of mining: An exploratory study trough necessary conditions analysis (NCA)

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ABSTRACT

The mining sector has been in the spotlight for many years because of its negative impact on society and the environment. The focus on sustainable development at the international and national levels has led to increased criticism of mining, creating issues on numerous occasions. However, the progress of many developing countries depends on the mining sector, which can provide economic benefits to local communities. This paper aims to identify the benefits that the mining sector should provide to local communities to offset its negative effects on the environment. The paper explores not only the negative environmental effects of mining but also its positive side. Using necessary condition analysis (NCA), social action, physical infrastructures, basic services, health, and education are studied from an economic development perspective to identify the necessary levels of these factors in order to achieve the environmental satisfaction of local communities. The results indicate that education, health, and basic services have a crucial impact on the local community's environmental satisfaction. This finding suggests that local communities perceive the effect of the mining sector as positive when it provides education, health, and basic services to the surrounding area.

1. Introduction

For years, international organizations, nations, and society in general have scrutinized the mining sector because of its negative effects on local communities (Grutzner and Salim, 2003), waste management, and human health (Asif and Chen, 2016), as well its considerable ecological footprint (Young, 1992; Perez and Sanchez, 2009). Akabzaa and Darimani (2001) listed some of the economic, social, environmental, and health impacts of the mining sector. Mining provides economic benefits to local communities in the form of infrastructures, foreign trade, government revenue, and direct and indirect employment. These benefits in turn help develop local communities. Nevertheless, it also has negative impacts. The concentration of mining activities in an area can lead to youth unemployment, school dropout, family disorganization, inadequate housing, drug abuse, and prostitution. Other negative social effects include mass migration and the continued growth of the population. The surroundings are also affected by the mining sector. For example, the environment, land, and vegetation quickly deteriorate, destroying biodiversity.

Given these negative effects and the increasing importance of sustainable development, the mining sector has introduced new approaches to tackle sustainability challenges. These new approaches relate to increasing investment in research and development (R&D), involving stakeholders in mining activities, creating new relationships and partnerships with other mining companies, and implementing voluntary agreements and environmental management standards to protect the environment (Sánchez, 1998; Perez and Sanchez, 2009). According to Asif and Chen (2016), the mining sector can help achieve sustainable development by implementing environmental management tools (e.g., cleaner production technologies, life cycle assessment, and multicriteria decision analysis) because these tools improve environmental performance.

Although perceptions and expectations of local communities may change over time, the perception toward the mining sector is negative (Amos, 2018). Yang and Ho (2019) found that only 20% of people living close to mining areas consider mining to be beneficial. The study's

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variables of analysis were employment opportunities, land expropriation, environmental degradation, and resettlement and land subsidence. Many studies have examined the influence of the mining sector on health (Vélez-Torres et al., 2018), the environment (Salem et al., 2018), and the economy (Yang and Ho, 2019; Karasmanaki et al., 2020). However, the mining sector also contributes to the local community in terms of social action, physical and digital infrastructures, and basic services.

This paper aims to determine which factors are necessary for the local community to feel satisfied and perceive benefits from the mining sector, despite its negative impact on the environment. The research question this study focus on is: *What the mining sector must provide to the local community to offset its negative effects on the environment?* This paper shows that it is possible to achieve high levels of environmental satisfaction when the mining sector offers other services to the local community.

Necessary condition analysis (NCA) is used to study the single necessary causes that must occur to deliver a certain outcome. In contrast, traditional methods examine the average effect of multiple predictors (Hauff et al., 2021). The conditions included in the present NCA are social action, physical infrastructures (transport), economic development, basic services, health, and education. Data on mining in Peru were collected through a face-to-face survey conducted in 2022. Basic services, health, and education have a meaningful effect on the environmental satisfaction of the local community. This finding suggests that when the mining sector provides services related to these conditions, the local community perceives that this sector has a positive impact on society. Similarly, certain levels of social action, health, and education are needed to achieve full environmental satisfaction. These findings highlight the importance of positive social, health, and education spillovers from mining to society.

This paper has four further sections. Section 2 provides a review of the literature on the links between mining and microeconomic and social impacts on the local community. The data and method are explained in Section 3. Section 4 presents the results of the NCA. Finally, the conclusions, limitations, and future lines of research are presented in Section 5.

2. Literature review

This section outlines the expected social and microeconomic effects of mining activities. The opening of new mining operations or the expansion of existing ones can produce a series of interconnected local effects across cultural, socioeconomic, and political spheres. A conceptual framework used to formulate empirical questions is presented. These questions are used as a basis for the analysis. The proposed research model is presented in Fig. 1.

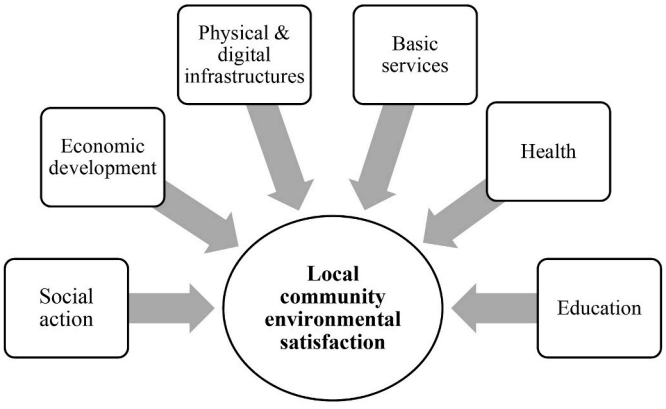

Fig. 1. Factors affecting the local community's environmental satisfaction. Source: Authors.

2.1. Local community environmental satisfaction

The mining sector is a key driver of the Latin American economy. Therefore, it is crucial for the development of Latin American communities. However, it also has an impact on the environment. The mining sector has one of the largest environmental impacts of any industry. Hence, mining companies must ensure that their actions respect the local environment and must identify and resolve any conflicts (ECLAC, 2013) to ensure that they act sustainably.

According to ECLAC (2013), on average, mining produces five times more emissions per dollar produced than other economic sectors. The impact of mining on the environment must be addressed because mining itself by definition entails a modification and reduction of the Earth's natural resources. In addition to this major impact, despite efforts to improve the socioenvironmental commitment of mining companies and policies for sustainable mining (Cisneros, 2016), there is no robust regulation on mining (Viana Ríos, 2018).

Environmental impacts include soil degradation, water, land, and air pollution, water scarcity, habitat destruction, deforestation, and deterioration of the ecosystem in general when protected areas are not respected (Hilson, 2002; Twerefou, 2009; Zárate et al., 2020). These environmental impacts lead to health problems for miners because the chemicals used in mining, poor ventilation, contaminated water, and soil degradation cause landslides, fires, and diseases (Hilson, 2002). Thus, controlling environmental impacts would also improve other aspects such as health and basic services.

The environment is a central part of sustainable development. Environmental actions are central to Sustainable Development Goals (SDGs) 6 (Clean Water and Sanitation), 7 (Affordable and Clean Energy), 12 (Responsible Consumption and Production), 13 (Climate Action), 14 (Life Below Water), and 15 (Life on Land). Many actions can be taken to achieve these SDGs, as indicated by Sonesson et al. (2016), who recommended actions by mining companies to achieve these SDGs and ensure best practices within the sector. These proposed actions include reducing the water footprint through water recycling, the use of suitable sources of water, studies of at-risk species during exploration, conservation programs, and many more.

In some Latin American countries, such as Bolivia, Chile, Ecuador, Mexico, Peru, and Venezuela, environmental policies have improved. However, it is not enough, and there are compliance problems (Hilson, 2002; Zárate et al., 2020). Hilson (2002) proposed public authority measures such as miner training and the use of expert teams to avoid environmental problems. Likewise, some mining entrepreneurs have contributed to transforming mining and changing its image (Viana Ríos, 2018) to achieve social sustainability in the local region. However, these contributions have not gone beyond CSR policies, failing to develop into actions in the region (Comisión Económica Para América Latina Y El Caribe –CEPAL-, 2015). Accordingly, there is still much progress to be made.

Everingham (2012) argued that, in relation to the impact of mining, attention has mainly been on the reduction and mitigation of environmental damage. Less is known about the management of social impacts to ensure industry sustainability. Therefore, this study focuses on identifying the necessary conditions that the mining sector must provide to local communities to offset its negative effects on the environment. The study does so by examining satisfaction with actions to prevent the pollution of rivers and fields, noise pollution, and the extinction of wildlife in the mining community.

2.2. Social action and economic development

The mining sector has contributed to development by providing minerals and metals to the manufacturing sector and the regional economy (Singh et al., 2016). Given the large number of sectors that depend on mining, the positive effects (e.g., employment creation) outweigh the negative ones (Narrei & Ataee-pour, 2021). Mining is

crucial to the survival of other economic activities that contribute to economic, environmental, and social development by improving infrastructures, increasing employment and community development, and enabling the creation of spin-offs (Singh et al., 2016). However, mining activities also generate negative environmental and social impacts, thus hindering the attainment of the SDGs set by the United Nations (UN) as part of the 2030 Agenda.

Given the debate around the positive and negative impacts of the mining sector, research on this topic is essential to improve the understanding of the current situation of mining and those directly and indirectly involved in mining. Policymakers, public administrations, and mining companies risk establishing strategies that jeopardize social sustainability. Social sustainability is the ability to engage business with the long-term objective of preserving economic, environmental, and social well-being through business in the local community (Hassini et al., 2012; Jung, 2017; Rey-Martí et al., 2021). Sustainable mining would overcome the negative impacts of mining by ensuring that it follows sustainable development principles.

Mancini and Sala (2018) grouped the social impacts of mining into six categories: (i) economy, income, and security; (ii) employment and education; (iii) land use and territorial aspects; (iv) demographics; (v) environment, health, and safety; and (vi) human rights. Based on these categories of impacts, this paper examines social action in the mining sector through the improvement of the local community, women's empowerment, the support of mining companies in agriculture, livestock, and handicrafts, and the implementation of machinery in farming.

Mining is a key engine for economic development of the countries in which it is practiced (Gómez et al., 2021) and for the growth of the communities located around mining operations. Economic benefits obtained through mining are accounted from the tax collection and the employability entailed for local communities. Likewise, mining activity is one of the economic sectors that contributes the most to technological development and research in a country and promotes other sectors of the economy by purchasing goods and services to be able to operate such as metal-mechanics, textiles, chemicals and personal protection equipment (Narrea, 2018; Walter et al., 2021). In addition, as will be seen throughout the study, this sector also helps the development of digital and physical infrastructures, education, and basic and health resources.

2.3. Physical and digital infrastructures

Several studies (Xongo, 2013; Kuklina et al., 2021) have shown that physical infrastructures, transport accessibility, and community remoteness are crucial for assessing regional or national development. Sonesson et al. (2016) argued that physical infrastructures and information and communication technologies (ICT) contribute to sustainable development. However, in many developing countries, these infrastructures and technologies are out of the reach of most citizens. Expanding the access to physical infrastructures and ICT could improve innovation and productivity, helping create opportunities in other economic sectors, which is crucial for sustainable industrialization and diversification. This paper analyzes how mining firms improve and support road and transport networks in the local community.

The physical infrastructures, services, and facilities of a region ensure that the region itself, companies, and society can function properly (Xongo, 2013). They do so by connecting towns and boosting economic and social activity, which favors socioeconomic development and improves citizens' quality of life (Kuklina et al., 2021). Moreover, transport infrastructures contribute to economic growth and quality of life in remote areas, hence the importance of encouraging the development of these infrastructures (Berman, 2020). Therefore, the study of transport infrastructures is highly relevant for the sustainable development of mining communities in isolated areas.

In addition to physical infrastructures, digital infrastructures boost sustainable development because Internet connectivity is needed for education, health and banking services, and most jobs. Without adequate telecommunication infrastructures, isolated communities cannot participate in the emerging information economy. The positive relationship between economic development and the existence of telecommunication infrastructures has been shown to improve the economic performance of communities that use the Internet (Parker et al., 1995; Strover, 2001; Albort-Morant and Rey-Martí, 2015; Townsend et al., 2015). Public policy is concerned with addressing the spread of broadband availability and adoption in rural areas, which is slower than in other parts of the world (Stenberg et al., 2009; Genachowski, 2011). This lag is referred to as the digital divide. This situation can worsen quality of life and sustainable development (Labrianidis and Kalogeressis, 2006; Ziemba, 2018). Therefore, the digital divide has become a key type of social exclusion, highlighting the importance of working toward supporting community social sustainability. This issue is also captured in the SDGs (UN General Assembly, 2015). Remote rural communities face challenges associated with their distance from large cities. Introducing strategies, instruments, and policies that decrease the digital divide by bringing broadband to every region and household, regardless of their location or interests, can alleviate these challenges (Townsend et al., 2015). This paper also explores whether the presence of mining companies has promoted connectivity and whether such connectivity drives development.

2.4. Basic and health services

The mining sector represents an engine of growth for the local economy. It encourages private investment in human and physical capital (Bury, 2005; Tamba et al., 2007) because government revenue inflows increase (e.g., through mining canons and royalties), which drives investment in the construction and maintenance of infrastructures (Ticci, 2011). Specifically, measures have been introduced through the construction of schools, clinics, and hospitals (Sirolli, 2008). Some mining companies in Peru foster health, education, and technical training for adults. Mining donations and tax revenues are also used to finance infrastructure and facilities for communication, transportation, health, and education. These initiatives can improve human capital quality and capacity (Ticci, 2011). Sirolli (2008) argued that there is another side to the coin, noting that these initiatives sometimes only last for the duration of the mining project because there was no sense of belonging to the community, which was never consulted.

In contrast, the health risks associated with mining pose a substantial challenge to the community. Mining companies have introduced measures to prevent these risks and meet SDG 3 (Good Health and Well-being) and SDG 6 (Clean Water and Sanitation), as reported by Sonesson et al. (2016). Mining companies have shown their commitment to sustainable development by ensuring good working conditions and implementing well-developed standards and management systems for the day-to-day and long-term execution of their health and safety policies. In relation to SDG 6, mining companies, as major consumers and polluters of water, can reduce their water footprint by taking wastewater recycling measures, collecting water from suitable sources, ensuring that their operations do not pollute water supplies or displace local water users, and sharing their water monitoring, data, and expertise with local governments. The study also considers the support of the mining company in improving health services, infrastructure, and equipment in the community, as well as the quality of care provided by medical staff at the health center.

2.5. Education

Mancini and Sala (2018) cited education as one of the biggest social impacts of mining. In mining areas, the literature focuses on the so-called resources curse, which refers to the negative relationship between the presence of natural resources and low public investment in education (Oyarzo and Paredes, 2021). This theory is based on the notion that in areas that are rich in natural resources, such as mining

areas, there are high economic benefits, which creates a false sense of security and economic stability (Polterovich et al., 2010). This situation discourages investment in public goods such as education because of a lack of visible short-term returns (Gylfason, 2001; Shao and Yang, 2014; Oyarzo and Paredes, 2021).

Moreover, mining requires a labor force with a low educational level. This requirement also decreases the desire to study because mining offers a source of income for families (Oyarzo and Paredes, 2021). Primary school enrollment rates in mineral-rich economies are below the world average. This situation highlights the importance of monitoring primary and secondary school enrollment rates in emerging mining regions (Sonesson et al., 2016). Typically, labor markets with a mining presence consist mainly of a small proportion of highly skilled workers such as engineers and a majority of medium-skilled workers in operating roles (Gylfason, 2001). Thus, in mining areas, investment in education is pushed down the agenda and interferes with the development prospects of local communities, thus limiting economic development. However, this situation can change. Investing in the standard of living of local communities and investing in education, health, and environmental standards of local communities would help attract investment, thus sustaining communities after mine closures and achieving future sustainability.

Although mining companies are not required by law to develop projects for social inclusion, they can support the community in terms of infrastructure, health, and education (Young et al., 2007; Miranda, 2015; Widana, 2021). Communities appreciate the work of mining companies, basically because the government does not reach these remote areas. The mining companies are the ones that oversee this social response, but the onus cannot fall on them (Miranda, 2015). Miranda (2015) studied the case of Peru, where the state requires mining companies to pay taxes, royalties, and validity rights, voluntary contributions, and employment funds. Part of the proceeds are transferred to local and regional governments to finance public investment projects or are used to create funds (such as the employment fund or the voluntary contribution) to finance development projects and social support in miners' areas of influence. However, mining companies neither execute nor are responsible for these projects. Since 2003, the mining companies have volunteered to carry out projects aimed at sustainable development in the regions where they operate. Between 2007 and 2011, 26.1 million people benefited from local development, education, self-employment, infrastructure, nutrition, health, and other projects, with investment totaling more than 460 million dollars.

Even though major efforts have been made to facilitate access to education around the world, there is still much to be done. In fact, quality education is one of the SDGs. Sonesson et al. (2016) discussed how mining can contribute to this goal through technical, vocational, and educational training programs for the current and future mining workforce. This study considers the satisfaction of the local community with the support of mining companies in literacy programs and infrastructure investment in education within the community.

3. Method and data

3.1. Data and contextualization of the mining sector in Peru

This study is based on a face-to-face regional-level survey conducted in Peru in 2022. The items of the survey questionnaire appear in Table A1 in Appendix I. The responses to these items provide insights into the effects of mining on the local society. These items relate to six areas: social action, physical infrastructures, economic development, basic services, health, and education. Respondents indicated their level of satisfaction in these six areas on a Likert scale ranging from 1 to 5. The sample size was 244, based on 11,089 community members of the Apurimac-Cusco mining corridor in Peru. Stratified random sampling was employed. Individuals were divided into subgroups or communities based on community characteristics. The communities belong to Cotabambas and Grau, provinces of the Apurimac region, and Chumbivilcas province from the Cusco region. The research unit is made up of the members of the family household. However, people under 12 years of age and living on the property for less than one year were not considered in the sample. Some communities were considered to be of direct influence, while others indirect influence, differentiating the communities around the location of the mine and the road where the mineral is transported to the seaport.

Mining positively affects economic development in Peru. Its economic model is based on the massive export of raw materials (e.g., gold, copper, silver, zinc, lead, and tin). In 2020, Peru was the world's second largest exporter of copper. It was also the second largest exporter of gold in Latin America and the 12th largest worldwide (INEI, 2020). Most of the demand for minerals mined in Peru comes from the United States, China, Switzerland, Japan, Canada, and the European Union. Peru has entered into several bilateral agreements (e.g., Free Trade Agreements or FTAs) with the United States, Canada, China, Singapore, South Korea, and Mexico. These bilateral agreements provide Peru with better economic opportunities for investment in these markets.

Peru has a total area of 128 million hectares. Of this area, 13,455,080 ha (10.51%) were allocated to mining in 2008 (MINEM, 2008), and 4,104,576 ha (3.21%) were allocated to mining between January 2020 and October 2022 (MINEM, 2022). Fig. 2 shows the regions with mining concessions. Most are located in the highlands (mountainous regions) and along the coast of Peru. Crucially, the conditions of small-scale mining and large and medium-sized mining companies differ considerably. Therefore, the characteristics of the local region and environment are important. They should be considered when analyzing the situation of the mining sector in each area in order to design policies to boost the positive effect of mining on society and the environment.

One of the mines that makes a substantial contribution to the Peruvian economy is Las Bambas. Las Bambas is the fourth largest national copper producer. It is a large-scale mining company and one of the best ranked (top 5) according to Bambas report (Bambas, 2022). This company, together with its mine, accounts for around 1% of Peru's GDP and generates around 6400 direct and indirect jobs. Las Bambas is located at more than 4000 m above sea level. It lies between the Peruvian provinces of Cotabambas and Grau, in the Apurimac region (Bambas, 2022). Fig. 2 shows the location of the Las Bambas mine in red.

However, Peru has the second most mining conflicts of any country, with 46 cases (MCM, 2022). Las Bambas mine has constant conflicts with local communities. These conflicts affect the running of the mine. Therefore, new proposals are required to diagnose, evaluate, and recommend solutions that contribute to the sustainable development of mining and change society's perception of this sector.

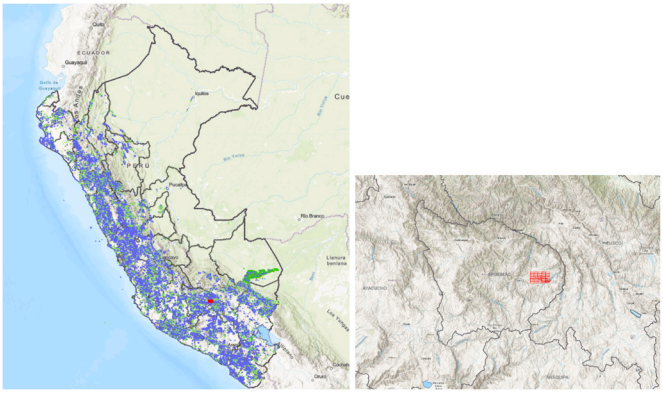

Fig. 2. Concession of mining areas in Peru.
Source: INGEMMET (2022).

3.2. Method

To determine which conditions are necessary to explain the local environmental community's satisfaction with the mining sector despite its negative environmental impact, necessary condition analysis (NCA) was used. A necessary condition constrains the occurrence of an outcome. In other words, its absence also implies the absence of the outcome (Hauff et al., 2021). However, other factors may also be needed for the outcome to occur. Hence, even if a condition is necessary, it may not be sufficient to lead to the outcome (Dul, 2016b). NCA indicates the minimum degree of conditions needed to achieve a specific outcome level. In this case, the aim is to determine the degree of conditions (social action, physical infrastructures, economic development, basic services, health, and education) that can explain different levels of community satisfaction with the environmental performance of the mining sector.

NCA relies on XY scatter plots to examine empty areas in the upper-left corner. These empty areas reflect the existence of a necessary condition. To analyze the necessity level of these conditions, a ceiling line between the empty area and the area with observations is drawn (Dul, 2016b). The two approaches recommended to draw the ceiling line are ceiling envelopment with free disposal hull (CE-FDH) for discrete conditions (Dul, 2016a) and ceiling regression with free disposal hull (CR-FDH) for continuous conditions (www.erim.nl). The OLS regression line is drawn through the upper left borders of the linear function of the CE-FDH. The two measures to determine the validity in NCA are accuracy and effect size. Accuracy expresses the percentage of cases above the ceiling lines (Dul, 2016b). The effect size *d* is the ratio between the ceiling area and the total observation area (Linder et al., 2022). The effect size of necessary conditions can be small ($0 < d < 0.1$), medium ($0.1 = d < 0.3$), large ($0.3 = d < 0.5$), or very large ($d \geq 0.5$), depending on the value of *d* (Dul, 2016b). The effect size should exceed 0.1 to be considered practically and theoretically meaningful (Ding, 2022).

4. Results

As explained earlier, NCA determines the necessary conditions for an outcome to occur. This study aimed to identify the levels of social action, physical infrastructures, economic development, basic services, health, and education that the mining sector must provide to the local community to offset its negative impact on the environment. In other words, the study explored whether the mining sector can elicit high levels of environmental satisfaction among citizens by offering the local community other services. To obtain the parameters for the six aspects required for the NCA, the Likert scale values from the survey were averaged, according to the responses for each aspect. This value indicated respondents' average rating regarding levels of social action, physical infrastructures, economic development, basic services, health, and education provided by the mining sector. The values were thus transformed for the NCA. Fig. 3 shows the ceiling lines for environmental satisfaction and other conditions, which are used to identify necessary conditions. The ceiling lines represent the borders between the areas with and without observations (Hauff et al., 2021). A condition is present whenever the scatter plot has an empty space in the upper-left corner.

The effect sizes following CE-FDH (e.g., Ding, 2022; Eggers et al., 2022; Linder et al., 2022) are 0.013, 0, and 0 for social action, physical infrastructures, and economic development, respectively (see Table 1). These effect sizes are small or non-significant (below the 0.1 threshold). Hence, social action, physical infrastructures such as transport, and economic development are not necessary to offset the negative environmental impacts of mining. Therefore, even if mining companies provided local communities with social action, transport, and economic development, citizens would remain unsatisfied and would continue to have a negative perception of the mining sector. These findings are corroborated by Fig. 3, which has no empty space for the conditions of social action, physical infrastructures, and economic development. In contrast, the conditions of basic services, health, and education are meaningful necessary conditions because they have an effect size that is greater than or equal to 0.1 (0.1, 0.319, and 0.297, respectively). Basic services and education would have a medium effect on the community's perceived environmental impact of the mining sector because the effect size is lower than 0.3. Health has a large effect for this same outcome. Therefore, when the mining sector provides new basic services and higher levels of health care and education to the local community, the local community feels that the mining sector's negative impacts on the environment are offset. The local government gains greater revenue from mining (Akabzaa and Darimani, 2001) and can thus invest in other areas such as health and education (Sirolli, 2008). Otherwise, the

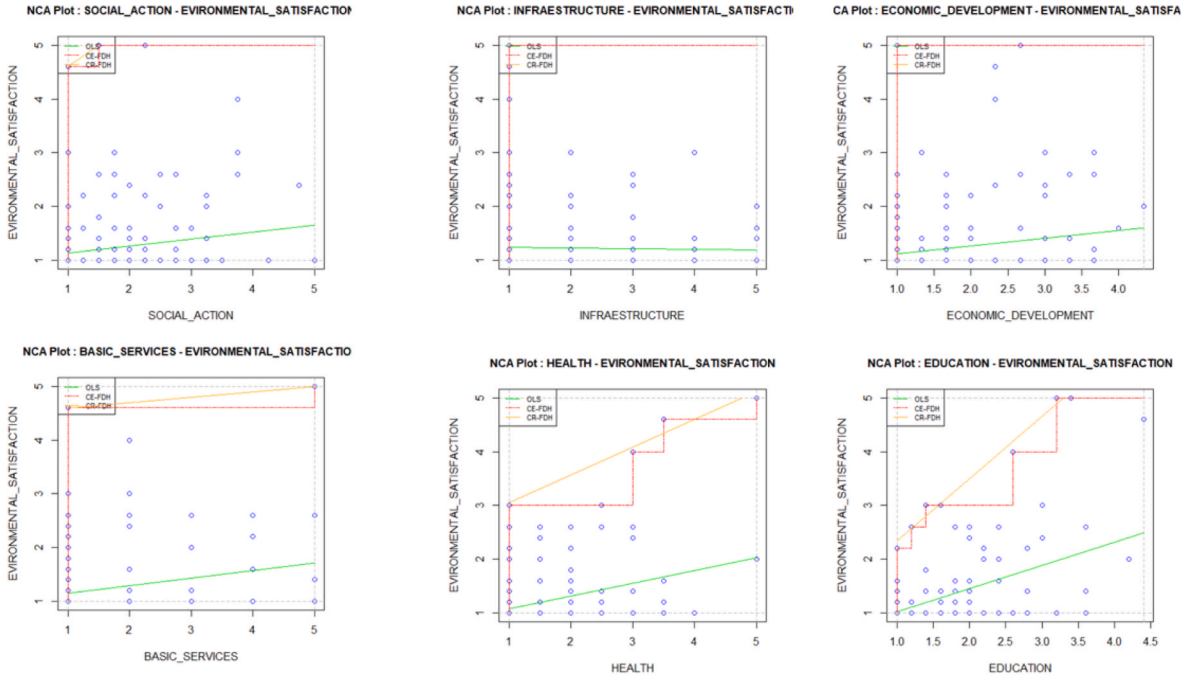

Fig. 3. Ceiling lines for environmental satisfaction and other conditions.

Table 1
Effect size of conditions according to each ceiling line.

	Social action	Physical infrastructures	Economic development	Basic services	Health	Education
CE FDH	0.013	0.000	0.000	0.100	0.316	0.298
CR FDH	0.006	0.000	0.000	0.050	0.229	0.224
p-value	0.478	1.000	1.000	0.010*	0.000*	0.000*

Note: CE-FDH = ceiling envelopment with free disposal hull; CR-FDH = ceiling regression with free disposal hull; (p-value <.05).

government may be unable to provide these services to the local community.

The bottleneck tables make the interpretation of the NCA results easier when multiple necessary conditions may explain the same outcome (see Table 2). The bottleneck table represents the ceiling line of one or more necessary conditions. It shows the necessary conditions required to achieve a specific level of the outcome (Hauff et al., 2021). The outcome levels are expressed in terms of the percentage of observed values. The values 0 and 100 are the minimum and maximum observed values, respectively. Conditions are expressed in terms of actual values (Dul, 2016b). For a level of the outcome of 30%, there is no minimum value of any necessary condition for environmental satisfaction. However, for a level of 40% or 50% of the outcome, a minimum of education level of 6.7 or 16.8 is required. For a levels of 60%, 70%, 80%, or 90% of environmental satisfaction, certain values of health and education are simultaneously needed. For 60% of the outcome, health and education must have values that are greater than 16.8 and 26.9, respectively. For 70%, the values must be at least 36.2 and 37. For 80%, the values must be at least 55.5 and 47.1. For 90%, the values must be at least 74.0 and 57.2. Finally, to achieve full environmental satisfaction (100%) by the local community, the minimum required values for social action, health, and education are 12.5, 94.3, and 67.4, respectively.

First, as indicated by the effect size values, these results suggest that the condition with the largest effect on the community's environmental satisfaction is education. Hence, education is the necessary condition with the greatest power to explain the outcome. Second, certain levels of the health condition are also necessary for the local community to have an environmental satisfaction of 50%. Finally, for full satisfaction that offsets the negative environmental effects of mining, mining companies must provide specific levels of social action, health, and education. The local community would perceive the mining sector as valuable to its economic and social future only if these levels are met. If mining companies do not contribute through social action, health, and education, the local community would be concerned about the negative environmental effects of the mining sector on the environment. Therefore, as an actor in the economic, social, and environmental decision-making processes, the local community would oppose mining activities and create barriers that hinder mining development in different regions.

After conducting the NCA and identifying the necessity level for each condition, the relationship between variables could explain the degree to which they jointly contribute to environmental satisfaction. Table 3 presents the Pearson's correlation coefficient (and associated significance) between the variables considered in the research model. All correlations are positive, indicating that the variables tend to move in the same direction. Moreover, many of the correlations between the variables are strongly significant (most with a *p*-value of .001).

5. Conclusions

The mining sector has existed since the dawn of human society. Through the extraction of valuable materials, the mining sector has contributed to the development of civilizations. Mining involves other activities that contribute to the economic, environmental, and social development of the local environment. However, mining also has negative environmental and social impacts on local communities. These impacts can potentially harm people's quality of life and jeopardize the social sustainability of future generations. Furthermore, traditional mining does not comply with the UN SDGs set out in the 2030 Agenda. Therefore, the mining industry faces major challenges in terms of sustainability. Research is essential to understand current mining activity and the people it affects in order to establish strategies that do not harm the local region or the people who inhabit it. Only then can the mining sector move toward a sustainable future.

However, the economies of many countries depend on the mining sector. In Latin America, this sector makes a major contribution to GDP (Viana Ríos, 2018). For example, this study focuses on Peru, where the mining sector plays a crucial role in supporting the development of remote areas. Mining can thus help in integrating these areas with the rest of the country. Given the role of mining, the Peruvian government has introduced policies to achieve social inclusion and more equitable wealth distribution. To ensure that mining is responsible and sustainable, environmental management and other instruments are required. These measures should target the achievement of sustainable development, building on in-depth analysis of the mining sector (Miranda, 2015). Despite the positive effects of mining on the economy and development, different groups that are affected by the mining sector have joined together to raise visibility of environmental problems and defend the local community's rights (Viana Ríos, 2018).

This paper reveals the necessary factors for the local community to feel satisfied and perceive that mining is beneficial, despite its negative environmental effects. The results show that the conditions of basic services, health, and education have a necessary and significant effect on the environmental satisfaction of the local community. This finding suggests that when the mining sector provides services in these areas,

Table 2
Bottleneck table for necessary conditions for environmental satisfaction.

Y (environmental satisfaction)	Social action	Physical infrastructures	Economic development	Basic services	Health	Education
0	NN	NN	NN	NN	NN	NN
10	NN	NN	NN	NN	NN	NN
20	NN	NN	NN	NN	NN	NN
30	NN	NN	NN	NN	NN	NN
40	NN	NN	NN	NN	NN	6.7
50	NN	NN	NN	NN	NN	16.8
60	NN	NN	NN	NN	16.8	26.9
70	NN	NN	NN	NN	36.2	37.0
80	NN	NN	NN	NN	55.5	47.1
90	NN	NN	NN	NN	74.9	57.2
100	12.5	NN	NN	NA	94.3	67.4

Note: Y = outcome, NN = not necessary.

Table 3
Pearson's correlation coefficients between the research model variables.

Variable		Economic develop.	Social action	Physical infras.	Environ. satis.	Basic services	Health	Educ.
Economic develop.	PPC	–						
	p-value	–						
Social action	PPC	0.168**	–					
	p-value	0.008	–					
Physical infras.	PPC	0.293***	0.143*	–				
	p-value	<.001	0.026	–				
Environ. Satisf.	PPC	0.142*	0.114	−0.011	–			
	p-value	0.027	0.076	0.860	–			
Basic services	PPC	0.234***	0.203**	0.177**	0.085	–		
	p-value	<.001	0.001	0.006	0.185	–		
Health	PPC	0.429***	0.160*	0.303***	0.161*	0.410***	–	
	p-value	<.001	0.012	<.001	0.012	<.001	–	
Educ.	PPC	0.434***	0.251***	0.264 ***	0.366***	0.431***	0.387***	–
	p-value	<.001	<.001	<.001	<.001	<.001	<.001	–

Note: PPC = Pearson correlation coefficient or Pearson's r. *p < .05, **p < .01, ***p < .001.

the local community perceives that this sector has a positive impact on society. Similarly, certain minimum levels of social action, health, and education are needed to achieve full environmental satisfaction. These results highlight the importance of ensuring that mining has positive social, health, and educational effects on the local society. However, these factors may not be sufficient (Dul, 2016a).

These results do not pertain to social action, physical infrastructure (e.g., transport), and economic development. Accordingly, these conditions are not considered necessary to offset the negative environmental impacts of the mining sector. Even if mining provides local communities with social action, transport, and economic development, these communities would still be dissatisfied and have a negative perception of mining. Basic services and education would have a medium effect on the community's environmental perception of the mining sector. When the mining sector provides new basic services and higher levels of health care and education to the local community, the community considers that it offsets its negative impacts on the environment.

Globally and nationally, mining policy appears more and more in the local media and non-governmental organizations. Citizens, governments, banks, investors, and insurance companies increasingly distance themselves from this sector, which at times seems careless and indifferent to the present and future biophysical and socioeconomic well-being of local communities. Mining companies must now align their interests with those of the communities where they operate. The long-term sustainability and viability of both the mining industry and local communities warrant close attention. To ensure the well-being and health of these communities, reducing the environmental effects of mining and improving environmental performance are not enough. Therefore, gaining in-depth knowledge of sustainability in the context of mining is crucial.

Communications, education, decision-making cooperation, and diversification are relevant for long-term community sustainability. A sustainable mining community can achieve a net benefit from mining activities that lasts long after mine closures. In practice, such sustainability would mean that the community adheres to the three fundamental requirements for sustainable societies outlined by George Francis (2006): ecological sustainability, economic vitality, and social equity. As an ideal, sustainability fits well with the common desire to achieve decent levels of health and well-being in a pleasant environment, with strong community networks and a range of opportunities for work and fulfillment. Mining companies face the challenge of engaging in equitable collaboration and cooperation with the local community to ensuring long-term sustainability and well-being and avoid social dislocation and environmental degradation.

This study is not without limitations. First, the analysis focused on only one geographical area in Peru. Therefore, the study only considered the characteristics of Peru. Mining areas in other countries or regions were omitted. Their inclusion could potentially lead to different conclusions, depending on their national contexts and circumstances. Second, respondents consisted only of local residents. Other mining sector stakeholders such as mining companies and the government were not surveyed. Given these limitations, future research could apply the same analysis approach in other countries. The importance of the necessary factors to achieve local community satisfaction despite the negative environmental effects of mining could then be compared across countries. Other mining sector stakeholders could be invited to participate in the survey to gain a broader overview of the local community's perception of and satisfaction with the mining sector.

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Declaration of competing interest

The authors declare no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resourpol.2023.103704.

Appendix I. Survey of the economic impact of the Apurimac-Cusco mining corridor (2022)

Table A1
Apurimac-Cusco mining corridor questionnaire items on the six areas of analysis

AREA OF INTEREST	QUESTIONNAIRE ITEMS
Local community environmental satisfaction	Rate your satisfaction regarding actions against the contamination of rivers and/or lagoons in your community by mining companies
	Rate your satisfaction regarding actions against the contamination of pastures and crops with particles (Dust) by mining companies
	Rate your satisfaction regarding actions against noise pollution by mining companies.
	Rate your satisfaction regarding actions against the extinction of fauna and flora generated by mining companies in your community
	Rate your satisfaction with the support of mining companies in caring for water for agricultural activities in your community
Social action	Rate your satisfaction with the work of the committee and advisors that fight against mining companies in achieving goals to help your community.
	Rate your satisfaction with mining companies' support of women's social organizations in your community, such as mothers' clubs.
	Rate your satisfaction with mining companies' support of neighborhood councils for the security of your community.
	Rate your satisfaction with mining companies' support of youth social organizations in your community, such as youth clubs.
Physical infrastructures	Rate your satisfaction with mining companies' support in providing transportation services to your community.
Economic development	Rate your satisfaction with the job opportunities that mining companies offers your community.
	Regarding your main economic activity, rate your satisfaction with the support provided by mining companies.
	Rate your satisfaction with the economic incentives that mining companies provides your community.
Basic services	Rate your satisfaction with the support of mining companies in improving or maintaining basic services (water, drains, and electricity).
Health	Rate your satisfaction with the support of mining companies in improving health services in your community.
	Rate your satisfaction with the support of mining companies in improving or maintaining medical infrastructure and equipment.
Education	Rate your satisfaction with the support of mining companies for literacy programs in your community.
	Rate your satisfaction with the support of mining companies in infrastructure for education in your community and/or district.
	Rate your satisfaction with the support of mining companies for technical training in agriculture, livestock handicrafts, and/or other areas in your community.
	Rate your satisfaction with the support of mining companies in offering scholarships for higher education for young people in your community.
	Rate your satisfaction with the support of mining companies in the training of kindergarten, primary, and secondary school teachers.

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