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ORIGINAL PAPER

The impact of Las Bambas megamine on development in Apurímac, Peru

Andoni Maiza-Larrarte[1] · **Gloria Claudio-Quiroga**[2]

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Abstract
The case of the Las Bambas megamine in the Apurímac region of Peru is particularly noteworthy, not only because it represents one of the largest mining contracts in the country's history but also because of the challenges encountered in managing the project. This article presents an interim assessment of the main socio-economic and environmental consequences, revealing a mixed balance in terms of the project's impact, within a context marked by intense conflict between local communities and the concessionaire company. Based on this evaluation, we provide several key recommendations to enhance both the assessment and management of large-scale mining projects.

Keywords Megamines · Impact · Sustainability · Las Bambas

JEL Classification R11 · Q51 · Q56

Introduction

The implementation of various public initiatives to electrify the economy and reduce polluting emissions has significantly increased the demand for minerals. This surge has driven major mining multinationals to intensify their search for new concessions. A notable feature of this trend is the establishment of new megamines in underdeveloped regions of Latin America and Africa. These areas are targeted not only due to their rich mineral resources but also because high poverty levels often result in a greater willingness to accept lower compensation for environmental and social damages.

In this context, willingness to accept (WTA) compensation for damages and willingness to pay (WTP) are two pivotal concepts widely discussed in the literature on natural resource valuation (Pearce 1992; Freeman 1994; Carson et al. 2001; Dosi 2001). However, despite extensive research on mining operations, no consensus exists on a standardized methodology for evaluating large-scale mining projects. Current approaches vary significantly, influenced not only by the specific objectives of the evaluation but also by the unique characteristics of each mine and, in particular, by constraints related to data availability and reliability.

This paper examines the case of the Las Bambas (LB) megamine in Apurímac, Peru, with the primary objective of assessing how it affects regional socio-economic development. Specifically, this intermediary assessment aims to identify and evaluate the mine's short-term direct impacts—such as revenue and employment generation, tax collection, land degradation, and pollutant emissions—while also exploring long-term trends in key health, education, and environmental indicators.

Given the limitations in the reliability and duration of available data, econometric models are not used to estimate the quantitative impacts on socio-economic indicators. Nevertheless, despite its descriptive nature, this research makes meaningful contributions to the existing literature. By adopting a holistic approach and conducting an in-depth analysis of extensive documentation, the study sheds light on critical challenges associated with managing megamines in fragile regions. Furthermore, it provides valuable recommendations for public policy initiatives to effectively address these challenges.

The paper is structured as follows: The next section reviews the literature on megamine case studies. Chapter three outlines the study's methodology and scope, while

✉ Andoni Maiza-Larrarte
joseantonio.maiza@ehu.eus

Gloria Claudio-Quiroga
g.claudio.prof@ufv.es

[1] University of the Basque Country, UPV/EHU, Bilbao, Spain

[2] Francisco de Vitoria University, Madrid, Spain

chapter four examines the main milestones in LB's development. Chapter five evaluates the mine's primary direct impacts, and chapter six analyzes trends in key socioeconomic variables. Chapter seven places LB within the broader context of Peru's mining specialization, and chapter eight highlights key challenges and provides recommendations for public policymakers. Finally, the article concludes by summarizing the main findings.

Literature research

The impact of mining activities has received renewed attention in the era of electrification. Since the introduction of the resource curse thesis (Auty 1993; Sachs and Warner 1995), many scholars have challenged this perspective, highlighting the potential contributions of extractive industries to economic development (e.g., Venables 2016; Morris et al. 2012). Additionally, an expanding body of literature has focused on examining the socioeconomic effects of mining at a regional scale (Breul and Atienza 2022; Atienza et al. 2021; Aragón and Rud 2013; Gueye et al. 2021; Söderholm and Svahn 2015; Hajkowicz et al. 2011, etc.). Noteworthy, the OECD conducted a study comparing well-being in mining regions across 50 member countries to both "OECD rural average standards" and the overall "OECD average" (OECD 2023a). The analysis identified notable strengths, such as a higher proportion of young people and significant increases in green land cover. However, it also highlighted key challenges, including lower levels of innovation, limited economic diversification, and higher greenhouse gas emissions.

Focusing on the effects of large-scale mining projects in underdeveloped regions, recent literature shows that achieving equitable benefit-sharing without compromising the well-being of local communities remains a significant challenge. In Africa, positive trends in infrastructure and socioeconomic development within nearby communities are overshadowed by significant issues, including land degradation, water pollution, social displacement, and shortcomings in mining policies and regulations (Zabré et al. 2021; Mhone et al. 2022; Essah 2021). Thus, after reviewing the broader literature on large-scale extractive investments in Africa, Muhirwa et al. (2023) concluded that their contribution to sustainable development remains low and, in some cases, has declined over time as technology advances.

Similar challenges are detected in less developed regions of Latin America. According to researchers, management strategies employed by mining companies often overlook socio-environmental dimensions (Obaya et al. 2024; Toscana-Aparicio and Uribe-Sierra 2024; Uribe-Sierra et al 2023; Kowszyk et al. 2023; Oh et al. 2023). López (2020) concluded that megamining has transformed Mexico into one of the most exploited regions in Central America, driven by a pattern of land dispossession, depletion of natural resources, and increasing land ownership concentration. In the specific case of the LB megamine, prior studies have identified several critical factors affecting sustainable development, including the limited understanding of the local culture by Chinese companies, inadequate consultation processes, weak local state institutions, and the risk of insufficient investment in non-mining activities and education (Valencia-Toledo 2024; Meléndez 2020; Saenz 2021; Torres 2019; Zavala 2023).

Over the years, the literature on socio-environmental impact assessment has explored the concepts of WTA and WTP. While early studies assumed that these values were similar (Willig 1976; Freeman 1979), later research in behavioral and environmental economics demonstrated that WTA is consistently higher than WTP, primarily due to loss aversion and the endowment effect (Thaler 1980; Knetsch and Sinden 1984; Kahneman et al. 1991, 1992). This discrepancy presents a challenge for policymakers in determining fair compensation or pricing for environmental resources, particularly since the WTA-WTP gap is more pronounced for non-market goods such as environmental resources. This is largely attributed to the lack of substitutes and strong emotional or cultural attachment to these goods (Knetsch and Sinden 1984; Hanemann et al. 1991; Shogren et al. 1994). Therefore, understanding this gap is crucial for cost–benefit analysis and policymaking, as a significantly higher WTA suggests that individuals place substantial value on existing environmental goods and are reluctant to part with them.

This research makes significant contributions to the existing body of literature. First, unlike many studies that focus on very specific aspects, it adopts a holistic approach, allowing for a comprehensive assessment of the mine's most relevant regional impacts while also considering the broader national context. Second, it offers an in-depth examination of the public procedures involved throughout the life cycle of the megamine, which is crucial for evaluating the role of public institutions. Third, the research highlights the specific challenges encountered in managing megamines, particularly when ownership changes occur. Finally, it provides recommendations for policymakers aimed at ensuring future large-scale projects are more beneficial.

Methodology and limits of the research

The methodology of this study combines case-study techniques with methods and criteria commonly used in environmental and regional development assessments. The analysis monetizes and quantifies certain direct impacts, complemented by a panel of non-monetary indicators to evaluate socioeconomic and environmental trends. The latter are essential for capturing other qualitative and multidimensional aspects of development thereby enabling a holistic approach that fully integrates inclusivity, equity and sustainability considerations (Azapagic 2004; Franks et al. 2013; Mancini and Sala 2018).

The assessment is grounded in key concepts, such as the current-use value of minerals versus the existence or legacy value of environmental resources (Krutilla 1967; Francke 1997). However, determining whether the current use of resources is justified in relation to their legacy value remains an exceptionally complex task. This complexity arises, in part, from the need to calculate the net present value of environmental resources, which depends on the choice of a discount rate—a factor directly linked to the previously mentioned WTA and WTP concepts.

To conduct this research, we collected direct indicators from the case study, as well as indirect indicators related to the wealth and socioeconomic development of Apurímac. We accessed a large number of documents: the Government of Peru has published key documents related to the project concession, and the Ministry of Energy and Mines (MINEM) periodically releases the main mining statistics. It is worth noting that Peru joined the Extractive Industries Transparency Initiative (EITI) in 2005 and was declared a Compliant Country in 2012, becoming the first country in Latin America to achieve this status.

The following section, summarizing the history of LB has been prepared after an in-depth study of the original texts of the agreement. Relevant data have been obtained from the Annual Reports, Annual Sustainability Reports, and press releases of the three companies that have owned the mine: Xstrata, GlencoreXstrata, and MMG-Las Bambas.[1] To complete the section on socioeconomic indicators, annual statistics from the National Institute of Statistics of Peru (INEI) have been used, supplemented by more reliable data from the 2017 Census of INEI. Furthermore, the information provided by EITI-Apurímac has been essential for cross-referencing the data on tax collection generated by Las Bambas.

On the other hand, we have chosen to present the economic figures in the same currency used in the original sources, so that some of them appear in United States dollars (US$) and others in Peruvian soles (S/). This approach has been preferred to present the information as faithfully as possible. However, to facilitate comparison, the estimated amount in millions of US$ has been added for the most relevant figures expressed in soles.[2]

This research is subject to important limitations. First, the study is conducted during an intermediate phase of the mine's life, a period characterized by ongoing substantial changes to its operating conditions. Second, while the analysis seeks to provide a comprehensive perspective, this broad approach inherently limits the level of detail with which individual topics are examined.[3] Third, the annual surveys on the socioeconomic conditions of Apurímac have a limited level of reliability, requiring cautious interpretation of the trends observed in these variables. Finally, since the megamine began production in 2016 and only started paying income taxes in fiscal year 2021, the available annual data series are too short to support robust econometric analyses.

Lastly, we would like to underline that both researchers are located in a distant country and have not established contact with any of the parties involved. This distance from the stakeholders can be seen as a sign of impartiality in the evaluation of a highly sensitive issue. In this regard, both authors affirm that they are independent researchers who have not received funding or any other form of support. The research is based on the analysis of data and documents, and despite its complexity, we firmly believe that the overall evaluation and key conclusions are robust and based on clear, objective criteria.

Launch and substantial modifications of the Las Bambas project

Las Bambas is a large copper development project located in the Apurímac region of Peru, which includes the Chalcobamba, Ferrobamba, Sulfobamba, and Charcas deposits. The contract was awarded to the Swiss multinational mining company Xstrata in September 2004 with a bid of 121 million dollars. Subsequently, Xstrata had up to six years to complete exploration work and decide whether to proceed with the development of the mine (Xstrata 2004; Mining Weekly 2004). Drilling programs confirmed the mine's potential: by 2007, the estimate had risen to 860 million tons with an average copper content of 0.93% (Xstrata 2008).

In May 2010, Xstrata published the first Environmental and Social Impact Study (ESIA), a document prepared by Golder Associates, an engineering and consultancy company

[1] Data have been obtained from the specific Sustainability Reports of Las Bambas (LB-SR), as well as from the Annual Reports and Sustainability Reports of the Chinese group MMG (MMG-AR and MMG-SR, respectively).

[2] The Central Reserve Bank of Peru includes the following evolution of the nominal exchange rate Banking—Purchase, average of the annual period (S/ per US$): 2,837 in 2014, 3,183 in 2015, 3,373 in 2016, 3,259 in 2017, 3,285 in 2018, 3,335 in 2019, 3,493 in 2020, 3,877 in 2021, 3,831 in 2022 and 3,742 in 2023 (Banco Central de Reservas del Perú 2023).

[3] Please refer to the bibliography cited in each section for a more comprehensive understanding of each topic.

(Golder Associates 2010). Next, the public consultation took place in July 2010, and according to Xstrata the ESIA received strong support from the local community (Xstrata 2010a). In September 2010, the contract was announced as “the largest mining contract in the history of Peru”: the investment associated with the project was expected to total US$ 4.2 billion (MINEM 2010), and Xstrata estimated an annual production of 400,000 tons of copper (Xstrata 2010a).

In February 2012, an event significantly altered the LB project: Glencore communicated its intention to acquire Xstrata (Financial Times 2012). The merger was subject to review and approval by the governments of several countries; in China, it was determined that the merger could jeopardize competition in the copper, zinc, and lead sectors. Consequently, China’s government approved the acquisition subject to several conditions, including the requirement to sell LB before June 2015[4] (Li and Wu 2013; GlencoreXstrata 2014). Thus, in April 2014, GlencoreXstrata announced the sale of LB for $5.85 billion to a Chinese state consortium led by MMG[5] (Reuters 2014; MMG 2014).

The change in ownership had a significant impact on the development conditions of the project, as LB was part of a broader initiative by Xstrata in southern Peru. When the ESIA was presented, it was assumed that Xstrata would utilize the molybdenum plant and other facilities already built in the Tintaya-Espinar area for the Xstrata-Tintaya mine (Xstrata 2010b), but after the sale, this synergy was no longer feasible.

An initial amendment to the ESIA was presented in July 2013, and after the mandatory report (MINEM 2013a), it was approved in August (MINEM 2013b). However, the most relevant modification to the ESIA took place in 2014. Originally, it was planned that copper would be transported via a 215 km concentrate pipeline to a molybdenum and filtering plant in Tintaya (See Fig. 1), from where it would be further transported to the Port of Matarani (Xstrata 2010c, 2013). The new ESIA amendment proposed transporting the concentrate not via a mineral pipeline, but by heavy traffic using a public highway already in use by local communities. The consultation processes and other necessary procedures for the ESIA modification were conducted during the period of transition in the ownership of LB, and, by the time it was approved, MMG had already become the owner of the project (MINEM 2014).

Nonetheless, this was not the final amendment to the ESIA. The 'Fourth Amendment of the ESIA of the Las Bambas Mining Unit' was presented in July 2023 and was still under evaluation in the early months of 2024.[6] This new proposal includes modifications to the mining components to extend the continuity of LB for an additional six years (until 2039), with an extra investment of US$1,753 million. Among other substantial changes, the project proposes expanding the Ferrobamba Pit from 408.7 to 694 hectares (a nearly 70% increase) and increasing the capacity of the Ferrobamba Waste Disposal Depot from 1,300 to 1,933 Mt. Additionally, the project proposes the use of new roads for the transit of concentrate and input trucks. In short, this request highlights that the exploitation of LB may still undergo significant changes that could substantially affect the impacts generated and the overall evaluation of the project.

Short-term direct impacts of Las Bambas

Impact on local communities’ living conditions

One of the most notable direct impacts of the launch of LB was the need to relocate the inhabitants of the Fuerabamba Community from their homes. After negotiations, it was agreed that the community would be resettled in Nueva Fuerabamba, a newly built town on nearby land that Xstrata had acquired from another community in the region (Choquenaira 2010; Huamaní, 2017). Additionally, Xstrata committed to providing various forms of compensation and ensuring services in the new town, such as electricity and garbage collection (Huamaní, 2017).

However, when MMG acquired ownership of LB, it became necessary to build new relationships with local communities, a process made difficult by cultural differences. By the end of 2014, the Chinese company reported that approximately three-quarters of the affected families had already been resettled in Nueva Fuerabamba (MMG-AR, 2014 & 2015). By the end of 2016, a total of 441 houses had been built, and 514 families—about 1,600 people in total—had been compensated (LB-SR, 2016 & 2017).

The other main short-term impact on local communities’ living conditions has been caused by heavy traffic. Because of the change in the ESIA approving the elimination of the pipeline for concentration transport, about 100–125 heavy trucks use daily communities’ ordinary roads over a distance

[4] In the EU, the European Commission determined that the merger could lead to excessive concentration in the zinc market. As a result, a condition was imposed requiring Glencore to divest from the zinc producer Nystar (European Commission 2012).

[5] MMG is a subsidiary of China Minmetals Corporation (CMC), one of China's largest state-owned enterprises engaged in the development, production and trade of metals and minerals.

[6] The detailed content can be accessed on the SENACE website: https://www.senace.gob.pe/eva/ (‘Consulta Ciudadana’ enter the ‘N° de Expediente’: M-MEIAD-00177–2023).

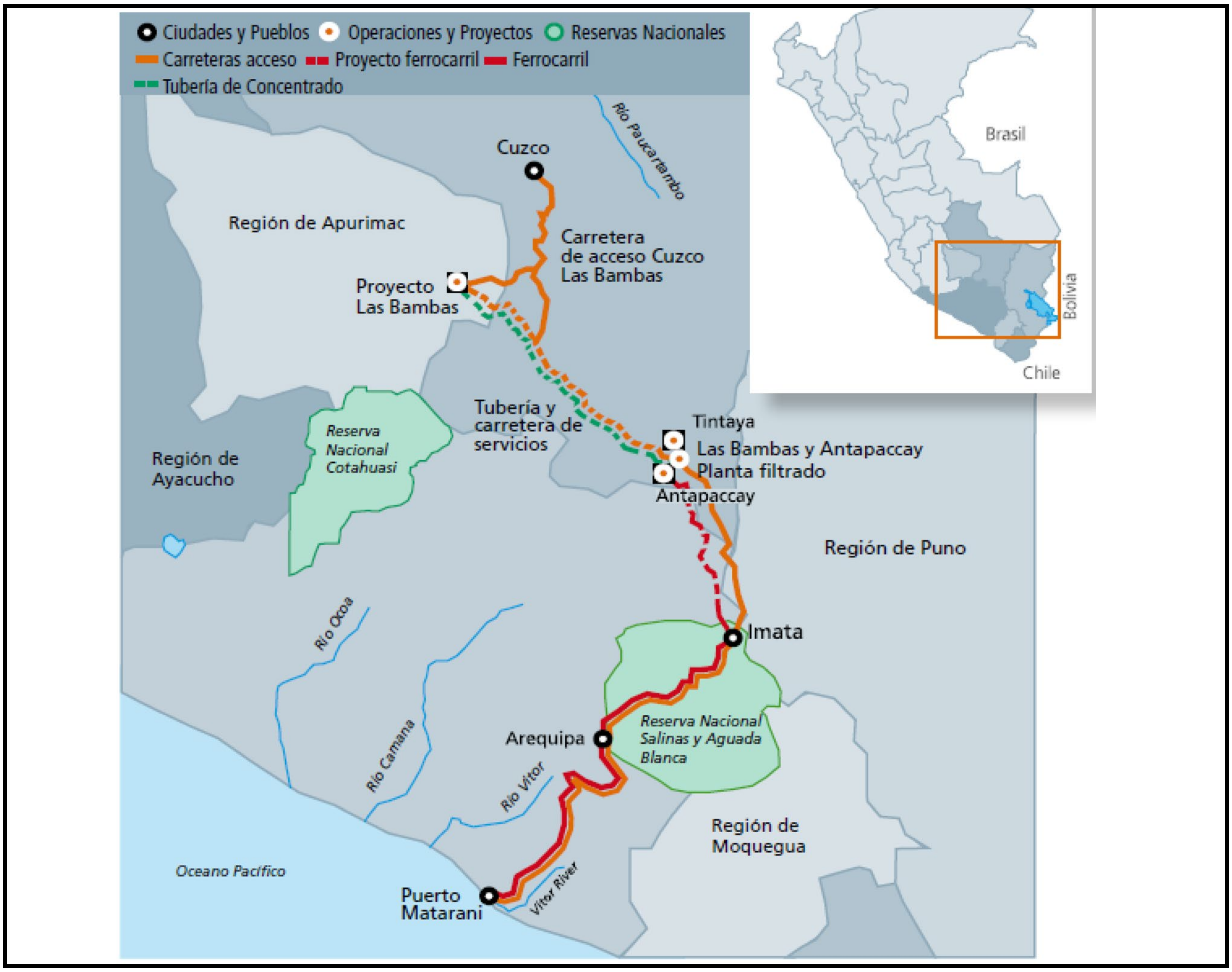

Fig. 1 Xstrata Copper mining projects in southern Peru. 2010. Source: Xstrata (2010c) Proyecto Las Bambas y Antapaccay. Sur del Perú. Octubre de 2010

of 438 km to the Pillones train station (MMG-AR 2021 & 2022).

Admittedly, the company has invested over US$341 million in road improvement (MMG-AR, 2021 & Advance 2022), but the heavy truck traffic from the mine continues to significantly affect the living conditions of local communities (World Bank 2021). As a matter of fact, considering the combination of transportation distance and orographic adversity,[7] MMG evaluated LB as one of the mining projects facing the greatest geographical challenges among all its operations in Peru and Chile.

Economic contribution

The launch of LB megamine has had a notable impact in terms of economic activity. The initial years were marked by preparatory work. When Xstrata undertook the project, it anticipated an investment of US$4.1 billion, partly due to cost savings from shared infrastructure with Tintaya and Antapaccay (Xstrata 2010b). However, the actual investment was significantly higher than initially planned. Between 2013 and 2015 alone, the investment exceeded US$4.8 billion,[8] with the total estimated at around US$10 billion.

[7] Much of the route traverses a mountainous road in the Andes at an altitude of approximately 4,000 m above sea level. The Pillones train station is situated at an altitude of 4,500 m above sea level, and according to Google Maps, the travel time for the 438 km journey by car (not including the additional time for loaded trucks) is approximately 9 h. From there, the concentrate travels an additional 285 km by rail to the Port of Matarani.

[8] In 2015, MMG secured a loan of nearly US$6 billion from a Chinese financial consortium (MMG 2016, 37).

Table 1 Main production and sales figures for Las Bambas

	2016	2017	2018	2019	2020	2021	2022	2023
PRODUCTION								
Min. extracted (000 tonnes)	46,910	52,873	57,440	51,653	58,000	59,879	43,178	46,429
Min. filtered (000 tonnes)	46,503	51,498	49,444	51,283	45,184	48,477	44,043	52,872
Movement waste (000 tonnes)	–	–	115,709	128,287	137,484	135,003	116,207	122,908
SALES								
Copper (000 tonnes)	297.0	442.5	384.7	312.9	304.3	272.3	221.9	374.7
Gold (000 oz)	78.9	129.7	107.9	91.4	72.9	59.7	62.9	94.9
Silver (000 oz)	4,036.5	6,350.3	5,483.8	4,581.7	4,092.9	3,581.2	3,293.4	5,361.3
Molybdenum (tonnes)	–	1,202.0	1,990.0	1,866.0	2,609.0	4,935.0	3,156.0	4,037.0
FINANCIAL FIGURES								
Revenue (US$ Million)	1,224.2	2,936.9	2,578.6	2,013.0	1,999.8	2,965.2	2,086.8	3,417.3
EBITDA* (USD Million)	655.0	1,740.8	1,341.2	1,221.3	1,117.5	2,047.3	1,121.9	1,396.7
EBITDA Margin (%)	54	59	52	61	56	69	54	41

*EBITDA: Earnings Before Interest, Taxes, Depreciation and Amortization

Source: MMG—Annual Report. Several years. Own elaboration

Table 2 Employment in LB

	2014	2015	2016	2017	2018	2019	2020	2021	2022
Permanent	823	–	–	1,726	1,592	1,792	2,205	2,672	2,623
Temporary	17,293	–	–	6,568	7,714	3,999	4,164	2,995	4,798
Total LB	18,116	7,354	9,134	8,294	8,706	5,791	6,369	5,667	7,421
% National	96.0	–	–	99.3	99.2	98.8	99.0	98.6	94.2

Source: MMG—Sustainability Report. Several years. Own elaboration

Copper concentrate production began in December 2015 with just over 9,000 tons (MMG-AR, 2015 & 2016). In 2016, copper sales rose to 297,000 tons, and in 2017 they exceeded 400,000 tons for the first time (see Table 1). However, production declined in 2021 and 2022, falling below 300,000 tons due to protests by local communities.[9] Despite this, the significant rebound in copper prices starting in 2021 largely offset the drop in production. In 2023, with a reduction in protests, production increased to 375,000 tons, enabling LB to achieve record revenue of just over US$3.4 billion.

LB also makes a significant contribution to the region's economy through its supply chain. During the construction phase, purchases primarily consisted of machinery and services to prepare the facilities. By 2016, with the mine operating at full capacity, purchases exceeded US$1 billion, reaching US$ 1.6 billion in 2022. A detailed analysis for 2022 shows that US$64 million of this total were allocated to near-mine/district level purchases, another US$95 million to provincial-state level purchases, and US$1,468 million to national purchases.

Regarding employment, by the end of 2014 a total of 18,116 people were employed at LB, with 823 direct employees and 17,293 workers from contractor companies (see Table 2). Once construction and preparation work completed, this number decreased noticeably. However, the number of permanent workers rose again after 2019, exceeding 2,600 in both 2021 and 2022. Additionally, there has been an upward trend in the total wages paid by LB, reaching US$154 million in 2022. Another important point is that the proportion of local and national workers has remained above 90%. Specifically, with regard to employment generated in the region, in 2022, 32% of both direct and indirect local workers were from the Apurímac region[10] (LB – AR, 2022 & 2023).

Likewise, it is important to highlight the significant amount of public funds generated by mining activity, almost

[9] MMG reports a total of 367 days of road blockades between 2016 and March 2022, excluding those caused by COVID-19 health measures (MMG-AR, 2021; MMG Advance AR, 2022).

[10] The General Labor Law of Peru limits the hiring of foreign personnel to a maximum of 20%, and the total remuneration paid to foreign workers cannot exceed 30% of the company's total salary expenses.

Table 3 Public funds transferred to the Apurímac Region for mining activity

(S/ Million)	2015	2016	2017	2018	2019	2020	2021	2022
Mining Canon	0	3.2	16.5	11.7	12.6	17.1	5.9	316.5
Mining Royalties	2.0	97.6	299.0	262.4	205.2	224.3	381.9	255.6
Mining Rights	11.1	13.1	11.6	13.4	14.3	16.2	18.1	17.1
Total Transferred	13.1	113.9	327.1	287.5	232.1	257.6	405.9	589.2
Total Governm. Spendit	2,032.1	2,299.9	2,577.0	2,737.3	2.745.3	2.966.8	3.176.1	3.554.0
% Transf./Total G.P	0.6	5.0	12.7	10.5	8.5	8.7	12.8	16.6

Sources: EITI Apurimac. Fourth Regional Transparency Study. MINEM (2023) Anuario Minero 2022. Own elaboration

entirely through LB operations (see Table 3). These funds are distributed to the regions as Mining Canon, Mining Royalties, and Mining Rights.[11] The revenue collected as royalties increased substantially starting in 2016 thanks to LB, ranging between 205 and 382 million soles during the 2016–2022 period. Regarding the mining canon, Apurímac received 316.5 million soles in 2022, as LB began generating income taxes starting in fiscal year 2021 (EITI 2023).

As a result, the total amount of public funds reached 589 million soles in 2022, approximately US$154 million, representing 16.6% of public spending in the region. Furthermore, these contributions become even more significant for local governments, financing 43.8% of their budget in 2022 through the mining canon and royalties (EITI 2023). Additionally, it must noted that, like all mining companies, LB contributes to Peru's tax revenue through various other taxes.[12] Therefore, LB reports that its total annual tax payments have ranged from approximately US$250 to $325 million in recent years, once labor taxes and withholdings included.

Environmental impact

MMG has been a member of the International Council on Mining and Metals (ICMM) for more than 10 years, and the company states that its management adheres to the principles of the ISO 14001:2016 and ISO 31000:2009 standards. Nevertheless, the environmental impacts of a mine the size of LB remain significant. For instance, during the construction phase in 2014, large volumes of hazardous waste were generated, including over 133,000 tonnes of hydrocarbon-contaminated soil and 8,400 tonnes of oils (LB – SR 2014 & 2015). Although recent data show a decrease in waste volumes, the figures are still substantial, with approximately 150–180 million metric tonnes of tailings and waste, and just over 2,000 tonnes of hazardous waste annually (see Table 4).

On the other hand, water usage is a particularly critical issue in Apurímac, as a significant portion of the population faces challenges in accessing drinking water. Data shows that during the 2021–2022 fiscal years, LB consumed between 80,000 and 100,000 million liters of water, of which approximately 3,000 million liters were fresh water. This means that fresh water accounted for around 4% of total water consumption (LB-SR 2021 & 2022; MMG-SR 2022 & 2023). Additionally, LB emits between 600,000 and 730,000 tons of CO2-equivalent gases annually into the atmosphere, along with air measurements in the range of 12,000–25,000 particles per cubic meter of other harmful substances, such as nitrogen oxides and PM10.

A final crucial indicator of the short-term environmental impact of LB megamine is the area of land impacted, as it directly affects the biodiversity of both fauna and flora. According to the 2020 Sustainability Report, the total area disturbed reached 3,389 hectares, which accounts for 50% of the 7,800 hectares of the concession (LB-SR 2020). Of this, 101 hectares had been rehabilitated, representing 3% of the total affected land.[13]

Finally, it should be noted that the company reports an annual investment of around US$4 million in environmental management. Specifically, in 2022, this figure rose to US$3.8 million, with more than half allocated to waste

[11] In Peru, the Mining Canon consists of 50% of the Income Tax collected by the State (Law No. 27506). The canon is distributed as follows: 75% to the municipalities within the region, 20% to the regional government, and 5% to the region's public university. In the case of the Las Bambas Mining Royalties, the provisions outlined in the contract between Proinversión and Xstrata apply, stipulating a rate of 3% of the annual net income from mineral sales. As a result, Law No. 29788 on Mining Royalties in Peru does not apply. Mining Rights, on the other hand, refer to an annual fee that concession holders must pay to maintain their rights (Derechos de Vigencia Minera).

[12] Mining holders are also subject to the Special Mining Tax, the Special Mining Levy, contributions to the Complementary Mining, Metallurgical, and Steel Retirement Fund, and the Mine Closure Guarantee.

[13] There is some inconsistency in this information, as the 2022 Sustainability Report states a significantly lower accumulated disturbed area of 2,422 hectares (MMG-SR, 2022).

Table 4 Evidence of direct environmental impact of Las Bambas*

	2015	2016	2017	2018	2019	2020	2021	2022
Mining waste (Million Tonnes)								
Mineralized: Non-Acid Forming Waste Rock Mined	6.1	99.7	110.8	115.7	128.3	137.5	135.0	116.2
Mineralized: Tailings generated	3.1	46.5	50.0	48.3	50.3	44.5	47.5	43.3
Total	9.2	146.2	160.8	164.0	178.6	182.0	182.5	159.5
Hazardous waste (Tonnes)								
Recycled/reused/treated/combusted oil	278	401	708	1,665	1,162	937	701	807
Other hazardous waste disposed of in an off-site landfill	526	622	662	1,228	1,040	690	1,375	1,215
Total	804	1,023	1,370	2,893	2,202	1,627	2,076	2,022
Total water withdrawal by source (Mega Liters)								
Borefields	825	3,039	0	662	1,788	2,679	2,653	1,729
Entrained in ore and tailings consolidation	0	0	1,545	1,287	2,085	1,566	2,608	1,759
Precipitation and runoff	8,386	5,463	8,739	6,672	9,271	10,139	15,301	13,717
Rivers and creeks	830	2,962	16,809	4,950	1,819	3,842	7,896	7,270
Total	10,041	11,464	27,093	13,571	14,963	18,226	28,458	24,475
Gas emission								
Total greenhouse gases (tonnes CO_2-eq)	184,140	574,910	651,179	631,756	730,372	738,025	665,912	623,053
Other emissions (NOx, PM10 and others)	n.a	n.a	19,428	23,214	12,352	25,380	n.a	n.a

n.a.: not available

* This data is reported following the guidelines established by the Global Reporting Initiative (GRI), specifically the standards related to waste generation (GRI 306–3), waste diversion (GRI 306–4), and waste disposal (GRI 306–5)

Source: Las Bambas—Sustainability Report. Various exercises

management and a significant portion dedicated to environmental and biodiversity monitoring (MMG – SR 2022 & 2023). Considering that LB's turnover exceeded US$2 billion in 2022, this means that the company allocates just under 0.2% of its revenue to environmental investment.

Analysis of socio-economic trends

Wealth, economic diversification and employment

The Apurímac region had just over 430,000 inhabitants in 2021, accounting for approximately 1.3% of Peru's total population. Traditionally, the region ranked among the lowest in various indicators measuring wealth, health, and education. However, recent data shows significant improvement. Specifically, the region's Gross Domestic Product (GDP) at constant prices in 2022 is 140% higher than in 2015 (See Table 5). This highlights an important outcome: the increase in the value of regional production, largely driven by LB. GDP per capita in the region is now approaching, and in some years even exceeding, the national average, while the percentage of the population with one or more unsatisfied basic needs has decreased.

On the other hand, the rapid growth of mining activities also has negative consequences on the region's economic structure, primarily increasing dependence on extractive industries. Mining now accounts for about 55–60% of the region's GDP, compared to less than 10% nationally, highlighting the need for economic diversification to achieve long-term sustainable development.

Employment indicators in the region show a slight upward trend. Around 8,500–9,000 people are directly employed in mining activities (compared to about 230,000 nationwide), representing roughly 3% of total regional employment. The employment rate is high, around 98%, and monthly income from work has been rising, reaching just over 1,100 soles in 2021—narrowing the gap with the national average of just over 1,300 soles. Nevertheless, approximately 60% of the active workforce is classified as underemployed and about 85–90% of employment in the region is informal,[14] significantly exceeding the national average of 70–75%. Besides, mining's contribution to regional employment is much lower than its contribution to GDP.

[14] The active workforce is classified as underemployed when hours and income are insufficient to meet basic needs. Informal employment refers to any type of work arrangement that falls outside the scope of national labor laws, social protection systems, and employment-related benefits.

Table 5 Indicators of wealth and employment in Apurímac

	2014	2015	2016	2017	2018	2019	2020	2021	2022
Gross Domestic Product in millions of soles (2007 constant prices) (a)									
	2.44	2.63	6.34	7.72	7.13	7.17	6.45	6.59	6.29
Gross Domestic Product per capita in soles (2007 constant prices) (a)									
	–	–	–	18,173	16,688	16,692	14,946	15,313	14,274
Extraction of oil, gas, minerals and related services (% GDP at constant 2007 prices) (a)									
	4.7	10.4	60.9	67.4	62.8	61.9	61.2	58.3	54.8
Population with one or more unsatisfied basic needs (%) (b)									
	18.2	13.9	18.0	15.5	11.7	11.3	13.9	10.7	–
Poor households with at least one member beneficiary of food programs (% households) (b)									
	51.6	63.0	68.0	65.0	62.2	62.1	68.0	60.4	63.0
Economically active population (thousands of people) (b)									
	258	267	262	263	267	273	264	293	–
Employment rate of the economically active population (%) (b)									
	98.0	98.8	98.1	98.2	98.1	97.7	98.0	97.5	–
Rate of underemployed population of the economically active population (%) (b)									
	65.8	65.2	65.6	65.5	62.5	56.8	67.6	60.4	–
Average monthly income for work (soles) (b)									
	841.6	925.6	889.4	900.8	936.9	1,123.8	1,004.5	1,104.8	–
Direct employment in mining (people) (c)									
	–	16,783	10,426	11,374	11,143	9,736	7,347	8,770	8,578

Source: a) INEI. National Directorate of National Accounts

b) INEI (2022). Apurímac. Compendio Estadístico 2021

c) MINEM. Mining Statistics and Mining Statistical Yearbooks

Table 6 Healthcare, health, and living conditions indicators in Apurímac

	2014	2015	2016	2017	2018	2019	2020	2021
Rate of chronic malnutrition in children under 5 years of age (%)								
	27.3	22.3	20.0	20.9	20.1	16.1	17.5	19.4
Prevalence of anemia in girls and boys from 6 to 59 months of age (%)								
	40.2	43.3	39.7	42.6	39.4	38.0	38.1	38.4
Population with access to improved sanitation services (%)								
	45.1	48.7	52.9	54.7	58.9	64.4	62.5	68.0
Households without free residual chlorine in water for human consumption (%) (b)								
	82.7	79.1	80.0	79.2	76.8	65.4	69.7	69.9
Number of hospital beds								
	825	846	947	1,048	1,049	1,023	1,140	1,130
Number of inhabitants per doctor								
	1,047	971	925	894	883	875	881	–

Source: INEI (2022). Apurímac. Compendio Estadístico 2021

Health, living conditions and education

Data from the 2017 Census provide a clear picture of the region's challenges: approximately 75% of households relied primarily on firewood for cooking, nearly 45% accessed water from springs, wells, or neighboring houses, and around 50% lacked access to sanitation services connected to the public sewage network in their homes or buildings. Admittedly, more recent data show a downward trend in malnutrition and anemia rates among children, though these remain very high and still exceed the national average[15] (See Table 6).

The proportion of the population with access to improved sanitation services and the number of hospital beds have

[15] The data obtained from annual INEI surveys are less reliable than the data gathered from Censuses.

Table 7 Education and educational level indicators in Apurímac

	2014	2015	2016	2017	2018	2019	2020	2021	2022
Illiteracy rate of the population aged 15 and over (%)									
	17.1	13.8	16.3	15.2	14.0	12.6	13.5	11.5	10.9
Education level of the population aged 15 and over – Secondary and higher (%)									
	59.0	63.9	63.3	62.9	61.8	67.0	68.1	66.3	67.7
Net school enrollment rate for primary education of the population aged 6 to 11 (%)									
	93.4	88.4	94.4	92.4	96.4	97.3	89.8	93.5	94.7
Population aged 6 to 11 years attending primary education at the grade level corresponding to their age (%)									
	59.0	56.3	49.1	61.7	59.3	60.1	56.3	62.8	61.4
Population aged 12 to 16 years attending secondary education at the grade corresponding to their age (%)									
	45.7	47.3	46.5	51.0	50.9	53.8	57.1	63.1	61.3
Average number of years of study achieved by the population aged 15 and over									
	9.1	9.4	9.2	9.2	9.1	9.7	9.7	9.6	9.7

Source: INEI (2023). Perú: Indicadores de Educación según departamento, 2012-2022

Table 8 Environmental quality indicators in Apurímac

	2014	2015	2016	2017	2018	2019	2020	2021	2022
Area of degraded land (thousands of hectares) (a)									
	–	10,3	12,9	15,7	14,5	14,6	15,2	14,3	n.d
Reforested area (thousands of hectares) (b)									
	0,6	0,0	0,0	0,0	0,1	0,4	0,5	0,3	n.d
Mining environmental liabilities (number) (c)									
	149	149	149	n.d	149	137	111	111	101
Environmental complaints registered due to mining activity (number) (d)									
	n.d	n.d	n.d	n.d	13	15	15	33	43

Source: a) Geoservidor (2023) Estadística de Areas Degradadas

b) INEI (2022). Apurímac. Compendio Estadístico 2021

c) MINEM (2023) Anuario Minero 2022

d) Organismo de Evaluación y Fiscalización Ambiental. 2023

increased. A concerning statistic, however, is that only 25.2% of the urban population and a small 1.9% of the rural population in the Apurímac region have access to water that is free from fecal and chemical contamination (Gobierno Regional de Apurímac 2022). Moreover, despite improvements, around 70% of households still have access to drinking water that lacks any level of chlorine.

In terms of education, Apurímac has historically been one of the regions with the lowest educational levels. In 1981, the illiteracy rate was strikingly high at 52.3%. However, significant progress has been made since then. In recent years, the rate has decreased notably, from 17.1% in 2014 to 10.9% in 2022 (See Table 7). Furthermore, school enrollment has risen, and academic delays have diminished, resulting in an increasing number of students attending grade levels appropriate for their age. As a result of this progress, by 2022, approximately two-thirds of Apurímac's population aged 15 and older had attained secondary or higher education.

Environment

Regional environmental indicators show a concerning deterioration. The area of classified degraded land has increased by approximately 4,000 hectares in recent years (See Table 8), a figure that closely aligns with the 'disturbed land' data provided by LB, which was discussed in the previous section. Additionally, the number of mining-related environmental liabilities[16] rose from 43 in 2006 to 149 in 2011. However, since then, a downward trend has been observed due to remediation efforts, with 101 liabilities recorded in 2022. The total volume of authorized wastewater discharges from mining activities between 2017 and 2021 amounted to 52,560 m^3, or roughly 10% of the total discharges authorized

[16] Mining environmental liabilities refer to facilities, remnants, or waste deposits from abandoned or inactive mining operations that pose a permanent risk to both human health and the ecosystem.

during that period (INEI 2022). Lastly, recent years have seen an increase in environmental complaints related to mining activity in Apurímac, a trend likely linked to heightened social conflict during that period.

Las Bambas in the context of the mining specialization of the Peruvian economy

Apurímac's mining specialization is embedded within the broader context of Peru's substantial commitment to mining development. The LB concession is located within the southern copper belt of Peru, which is one of the country's most significant mining regions. Between 1996 and 2018, investments in the Peruvian mining sector totaled US$ 65.3 billion, with 85% of this investment concentrated in the period between 2009 and 2018 (MINEM 2019). Despite its large scale, data indicate that Las Bambas ranks as the third or fourth largest copper-producing mine in the country, contributing between 10.4% and 18.6% of Peru's total copper production (See Table 9).

Mining activities contribute approximately 8% of Peru's GDP (MINEM 2023), and around 20–25% of the Peruvian population depends on the mining industry for employment (Cooper 2021). This mining specialization has driven substantial economic growth in the country over the last two decades, resulting in a reduction in poverty levels (OECD 2023b). However, this strategy carries significant economic risks. Peru has become highly dependent on resources whose prices are known for their volatility, largely influenced by the demand for raw materials from a single country, China.

Table 9 Ranking of top 5 copper producing companies in Peru

(tonnes)	2016	2017	2018	2019	2020	2021	2022
TOTAL	2,352,960	2,440,181	2,416,881	2,437,925	2,153,952	2,329,886	2,445,110
% LB / TOTAL	14.0	18.6	15.9	15.7	14.5	12.5	10.4
Comp. Min. Antamina	443,625	439,248	459,539	459,513	396,247	460,652	467,905
Soc. Min. Cerro Verde	522,134	501,815	494,284	473,980	387,928	418,596	459,109
South. Perú Copper Corp	312,859	306,153	330,837	414,394	423,798	398,362	341,898
LAS BAMBAS	329,368	452,950	385,308	382,524	312,776	290,106	254,838
Chinalco Mining Peru	168,376	194,704	208,298	190,014	202,771	235,691	244,712

Source: MINEM (2023) Anuario Minero 2022

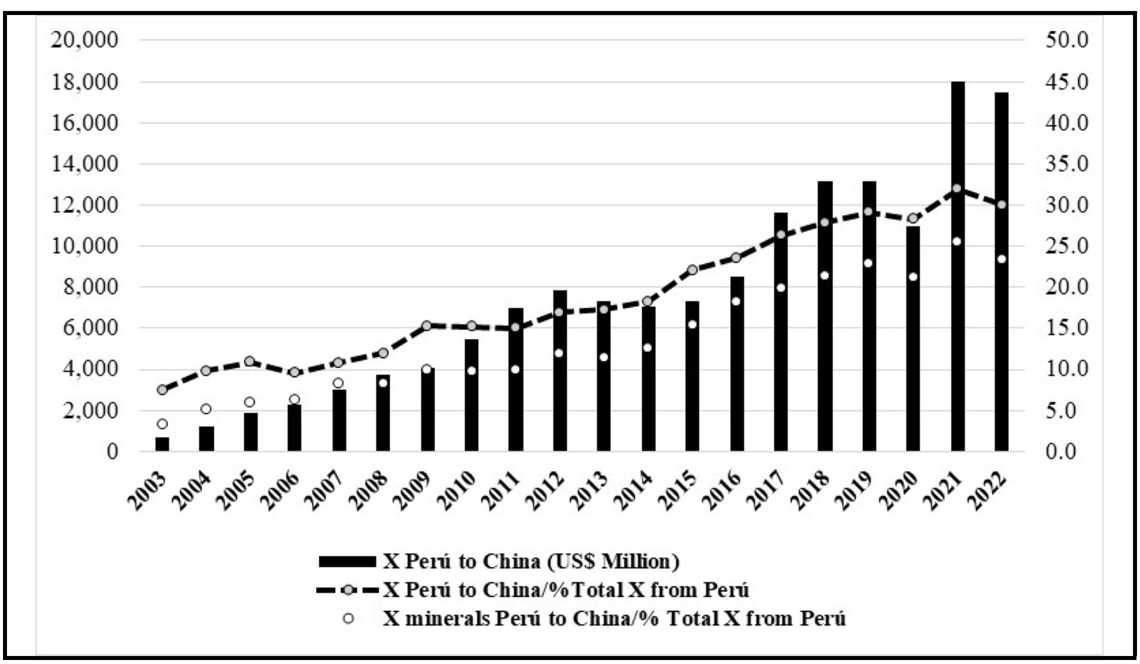

Fig. 2 Concentration of Peru's exports to China. Source: ITC Trademap 2024

Trade data reflect a shift toward what some authors have described as the 'reprimarization of the economy' (Bernal-Meza 2020). In recent years, China has been the destination for just over 30% of Peruvian exports, with more than three-quarters of these exports falling under HS Code 26, 'Ores, slag, and ash' (See Fig. 2). Additionally, Chinese investments have become a significant component of total foreign investment in Peru's mining sector, amounting to nearly US$15 billion between 2009 and 2020 (MINEM 2020). This high level of specialization means that the Apurímac region might well face difficulties in receiving support from the central government in the event of a mining crisis, as such a crisis would likely affect large parts of the country.

Apart from the economic risks associated with this strategy, there are other critical factors to consider, particularly the environmental damage. Mining activities have, among other consequences, led to a significant increase in the area of degraded land and a rise in mining-related environmental liabilities. Between 2001 and 2021, the loss of Amazonian humid forest reached 2.6 million hectares, reducing the total area from just over 70 million hectares in 2001 (Geobosque 2022). Furthermore, it is important to note that the significant challenges in transporting concentrate are not unique to LB. In fact, the lack of adequate infrastructure for transporting minerals is a widespread issue that hampers the development of many mining projects throughout Peru (World Bank 2021).

Discussion of key challenges and public policy recommendations

The case of Las Bambas highlights the extreme complexity involved in managing such megaprojects in underdeveloped regions, driven by factors such as the large number of stakeholders and the difficulty in assessing the accuracy of the estimates provided. While mining projects generally include a period for information dissemination and consultation with local communities, it seems doubtful that this is sufficient for communities—often composed of individuals with a basic level of education—to fully comprehend the highly technical and extensive documentation. This challenge is further compounded by the frequent modifications of the Environmental Impact Studies (ESIAs).[17] Additionally, the complexity is heightened by changes in ownership of the concessions and the uncertainty surrounding how new owners will uphold the commitments made by previous stakeholders.

Given these challenges, we recommend the creation of a qualified, international advisory body to provide expert opinions on large mining projects and offer guidance to affected communities in fragile regions. Additionally, there is a need for regional governments and public administrations to strengthen their administrative procedures. In the case of Peru, efforts have been made to enhance these practices, including the establishment of organizations such as the National Environmental Certification Service for Sustainable Investments (SENACE).[18] Recent regulations have been positively evaluated in the World Bank's Mining Sector Diagnosis (World Bank 2021). However, this same report highlights a gap between legislation and its enforcement, noting instances of corruption and maladministration (World Bank 2021; Cooper 2021).

Secondly, this analysis has demonstrated that the LB megamine is having significant socio-environmental impacts. The issue lies in the insufficient standardization of accounting frameworks and assessment methodologies, which makes it very difficult to determine whether the current use of resources is paying off. Notably, this problem is identified in the fourth amendment of the Las Bambas Environmental Impact Study (ESIA-d). The document presents cost and benefit estimates that seem disproportionately low given the scale of the planned expansion, while also acknowledging significant limitations in the study. More precisely, it states that "…vulnerable populations tend to have a lower willingness to pay than urban areas…" and that "…the estimates obtained are also questionable due to the premises considered for the economic valuation of a good, resource, or ecosystem service…" (Las Bambas – Fourth Amendment of ESIA-d, pp. 7–5 and 7–6). Moreover, from a conceptual perspective, it is important to highlight that the assessment refers to WTP rather than WTA, even though the literature has proven that WTP is typically significantly lower than WTA in the case of environmental resources.

Therefore, we align with the IEA in recognizing that one of the most pressing issues is the urgent need for increased scrutiny of environmental and social performance (IEA 2022). We strongly recommend the standardization of international accounting frameworks, as such standards would allow policymakers in regions with weak local institutions to rely on them to compel mining companies to take the necessary corrective measures. Additionally, we propose standardizing the use of the WTA concept in cost–benefit analysis to ensure a fair valuation of losses resulting from the exploitation of irreplaceable local resources.

[17] For instance, Las Bambas' Fourth Amendment ESIA documentation spans thousands of pages, including maps and technical documents.

[18] Created in 2012 as an organization under the Ministry of the Environment, its specific task is to evaluate and approve detailed Environmental Impact Studies for large investment projects (Government of Peru, Law No. 29968).

Finally, another important concern is that there are no regulations in place for regions to save during years of high mineral prices, nor is there an effective system for evaluating the resources transferred to the regions through the mining canon. These factors likely have a significant impact, preventing the income generated by LB from delivering the expected levels of well-being to the population of Apurímac. This fact aligns well with broader trends observed in mining activities across Peru as a whole (Cooper 2021), evidencing the need for stronger public policy initiatives to ensure that the current use of minerals is justified considering the legacy value of environmental resources.

Conclusions

In this paper, we present a comprehensive intermediate assessment of the LB megamine. On the positive side, we find that LB's operations contribute approximately 50–55% of the region's GDP. Besides, revenue generated through the mining canon and other taxes accounts for about 15–20% of the region's public spending. This increase in economic resources has likely played a significant role in reducing poverty and improving health and education outcomes, although progress has been relatively slow, with notable deficiencies in critical areas such as access to drinking water and wastewater treatment.

On the downside, LB's direct contribution to employment is relatively small compared to its impact on GDP, generating only about 2–3% of total employment. The high levels of underemployment and informal employment suggest that poor working conditions remain prevalent for most inhabitants. As is the case with many megamines, only a small number of workers with specialized skills have secured formal, high-paying jobs, potentially exacerbating regional inequality in the long term. Additionally, LB's activities have led to negative environmental impacts, including the expansion of degraded areas, increased environmental liabilities, water consumption and contamination, and the generation of mining waste and hazardous materials. Furthermore, the heavy traffic associated with concentrate transportation has resulted in significant conflicts with local communities.

The analysis also reveals that the region's heavy reliance on mining is further compounded by the country's intense mining specialization and its dependence on China's mineral consumption. Mineral transportation remains a significant challenge nationwide, necessitating urgent measures to improve infrastructure and mitigate its environmental and social impacts. Long-term sustainability concerns include health risks from mining pollution and the insufficient development of other economic sectors that could provide more stable employment opportunities for vulnerable populations.

It is crucial to ensure that revenues from mining taxes are efficiently allocated to strengthen public services. Policies should prioritize local economic diversification, skills training, and equitable revenue distribution to foster broader and more sustainable regional benefits. In addition to strengthening linkages with local suppliers, encouraging LB to increase its investment in environmental management through public–private partnership could help establish a strong framework for developing training centers and supporting new small businesses in this sector. This approach would generate positive socio-economic and environmental impacts.

Given the increasing prevalence of mining projects in impoverished regions worldwide, we propose the establishment of a new international advisory body to guide and inform local communities. Our research also highlights the need for a standardized methodology to evaluate the socio-economic impacts of large-scale projects. Specifically, more in-depth studies are required to develop internationally recognized benchmarks for the concepts of Willingness to Accept (WTA) and Willingness to Pay (WTP). These benchmarks would be essential in determining whether the compensation provided by such megaprojects adequately addresses the damage and loss of natural resources experienced by local communities.

Overall, our results align well with recent studies on large mining projects in underdeveloped regions (Obaya et al. 2024; Valencia-Toledo et al. 2024; Cooper 2021; IEA 2022). In the short term, direct impacts include a substantial positive economic contribution alongside some concerning negative socio-environmental consequences. However, considering that substantial modifications continue to take place in the megamine and the relevant methodological and temporal limitations of this analysis, further research is needed to precisely quantify the outcomes of the LB megamine and to identify the public initiatives that should be adopted to mitigate the associated damages.

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Declarations

Competing interests The authors declare no competing interests.

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