Evaluating the creditworthiness of a viable artisanal and small-scale mining operation

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Dates:
Received: 29 Dec. 2024
Revised: Mar. 2025
Accepted: 14 May 2025
Published: July 2025

How to cite:
Eniowo, O.D., Onifade, M., Grobler, H., Mulaba-Bafubiandi, A.F., Otuogbai, O.S. 2025. Evaluating the creditworthiness of a viable artisanal and small-scale mining operation. *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 125, no. 7, pp. 385–392

DOI ID:
https://doi.org/10.17159/2411-9717/3627/2025

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Abstract

Artisanal and small-scale miners in Nigeria struggle to attract formal financing to upgrade their operations to a more sustainable form of small-scale mining operation. Literature shows that for an investment to attract formal sources of financing; the business must be considered creditworthy by potential lenders. This means that the credit risks associated with the investment must be bearable for the potential lender. This study looks at how artisanal and small-scale miners can attract formal funding, which will help them take the leap from artisanal state to a form of sustainable small-scale mining operation. This study evaluates the creditworthiness of artisanal and small-scale mining operators using key credit risk parameters identified in the literature and through primary investigation. A quantitative study is conducted on a sample of 100 artisanal and small-scale miner establishments in Nigeria to evaluate the effect of these identified credit risk parameters on creditworthiness. It is shown in this study that being a member of a mining cooperative society, which is a form of social collateral, best improves the chances of access to formal financing for miners within the sample group. This underpins the role of social collateral, in both the formal and informal economy, and its influence in improving the creditworthiness of a typical artisanal and small-scale miner.

Keywords

funding, loans, mining, credit, formalisation, financial sustainability, investment risk, viability assessment, artisanal and small-scale mining

Introduction

Artisanal and small-scale mining (ASM) – a low tech and labour-intensive form of mineral extraction and processing – continues to grow as an occupation across developing countries (Hilson, 2016). Available data shows that more than 30 million people globally are directly employed by the ASM industry (Stocklin-Weinberg et al., 2019). A recent estimate shows that over 2 million people in Nigeria depend on ASM directly for their livelihood (Abuh, 2023), even though the occupation has been widely associated with the environmental pollution it creates, the attributed safety and health hazards, and other social concerns (Environmental Law Institute, 2014; Malone et al., 2023; Owolabi, et al., 2017). As the population of those in ASM increased exponentially over the years, some scholars have argued that the rush to the occupation is born out of the desire to tap into the attractive minerals market in order to "get-rich-quickly" (Verbrugge, 2015; 2016), while others argue that the occupation is mainly driven by poverty, which is prevalent in several communities hosting mineral resources across sub-Saharan Africa (Hilson, 2010; Siwale, Siwale, 2017). However, recent studies such as Traoré et al. (2024) and Hilson and Hu (2022) have put this debate to bed by arguing that any attempt to dismiss the "poverty-driven" nature of ASM on the account of few individuals in it who have accumulated wealth over time, is misleading because their new-found circumstances do not disprove the reason they chose to pursue work in this sector in the first place. Thus, it has been widely agreed that a primary motivation for people in this occupation is the need to seek succour owing to the prevailing rural poverty (Hilson, Hu, 2022).

It is, therefore, essential that those in this sector are supported in a way that their operations can run in an economically, socially, and environmentally sustainable manner. Specifically, considering the economic importance of the occupation, experts have agreed that a path towards formalising the operations should be pursued rather than criminalising it (Martinez et al., 2023). The drive towards formalisation has achieved notable successes across sub-Saharan Africa. In the Nigerian ASM sector

for example, there are currently 251,500 registered miners and 633 small-scale mining companies (Abuh, 2023). But this has not translated into an efficient and sustainable mining operation in the sector (Eniowo, 2024). The main reason is connected to the inability of the miners to attract formal funding that could help advance or even sustain their operations. Typically, investors in the mining industry seek funding from two probable sources – formal and informal sources (Eniowo, Meyer, 2020). While artisanal and small-scale miners usually find it easier to access informal sources owing to the simple application procedures involved, they find it difficult to gain access to formal financial sources due to their bureaucratic procedures, ill supervision, and low sustainability of the mining operations (Paschal et al., 2023). In a study by Amedu, et al. (2023) conducted in the Nasarawa state of Nigeria, it was found that up to 80% of the ASM operators in this study area fund their operations with personal savings. The study further found that the remaining 20% of these miners obtained loans from friends and family members, while not a single operator has successfully funded his operation through bank loans.

Although accessible, informal financing has its own challenges as well. Across sub-Saharan Africa, there are reports of miners being exploited in these informal funding arrangements (Fold et al., 2014; Perks, 2016). This creates a poverty trap for the miners, reducing their capacity to engage in deep-level mechanisation to access abundant mineral deposits (Mallo, 2011; Paschal et al., 2023). Achieving meaningful improvement in this sector begins with capturing more and more miners in the formal domain through the existing formalisation drive. However, sustainable formalisation requires the acquisition of requisite permits that allows one to operate legally, have advanced equipment, access modern and affordable technical capacity, and most importantly, financial muscle to run their operations safely. All these factors are important for the sustainability of their operations. It has been established in recent literature that, the pillar to achieving sustainable formalisation includes exposing such miners to more knowledge on business development, access to credit facilities, and also commercialisation of the mineral proceeds and corporate governance (Martinez et al., 2023). Specifically, Amedu et al. (2023) opined that for banks to be disposed to ASM lending, there is need to establish risk-sharing mechanisms that mitigate ASM-related risks.

It is common knowledge that ASM establishments operate in poor and unsafe conditions that pose danger to health, safety, and the environment (Mushiri et al., 2017). However, studies concerned with ASM have shown that there are linkages between the dangerous and unsustainable practices by the miners and their inability to attract investment funds to upgrade the operations to a more sustainable form of operation (Eniowo, Meyer, 2020; Eniowo et al., 2022a; Seccatore et al., 2014). For example, scholars have argued that the absence of formal financing opportunities for mechanised operations or investment in acquisition of geological data to support the operations have pushed miners to adopt short-term mineral extraction strategies, which rely on informal arrangements with outside financiers, traders, and sometimes large-scale mining companies, just to access the global mineral market (Perks, 2016). On the one hand, such a form of capitalisation leads to the adoption of unsafe mining techniques (Mallo, 2011), and on the other hand, it results in some form of exploitation of the miners by the financiers (Fold et al., 2014) and prevents the miners from having the decision-making power to plan far into the future regarding their business (Hilson, Ackah-Baidoo, 2011; Perks, 2016). Consequently, the report of Intergovernmental Forum on Mining, Minerals, Metals, and Sustainable Development (IGF) (2018) asserts that the financiers, which the study described as 'power holders' in ASM, make the largest share of profit, while those doing the work on the ground barely make enough to survive. However, there is a scarcity of studies that develop models for enhancing the ability of ASM to attract investment capital. Rather, most studies have focused on the safety concerns and the effect of the release of harmful substances by these miners on the environment (Clement, Olaniyan, 2016; Environmental Law Institute, 2014; Mallo, 2011).

Formal lenders are usually reluctant to lend to ASM-related activities for several reasons. Some studies blame the lack of understanding of local banks on how to translate geological assets into a form of collateral with which they are familiar (Perks, 2016). Other researchers point at the inability of ASM operators to present proof of availability of ores that will assure recovery of costs and profit margins, and the lack of technical competencies, documents proving ownership, and important supporting information on the feasibility of the investment (Eniowo et al., 2022b; Marin et al., 2016; Spiegel, 2012; Van Bockstael, 2014). For these reasons, lenders consider ASM to be a high-risk investment with no guarantee of return or financial success (Marin et al., 2016). The bottom line is that beneficiaries of banks' investment capital must be creditworthy companies with financially viable operations. For ASM firms to have access to formal sources of funding, their operations must be considered viable by potential investors and lenders. Again, for an investment to be creditworthy, the credit risks associated with the investment must be acceptable to the lender. Generally, there are several variables that lenders consider before providing loans for mining operations. For ASM, a review of the literature identifies some perceived credit risks that leads to the apathy of formal lenders in the industry. They include the assurance of availability of the mineral resource, availability of collateral security for the credit facility, availability of social security for the borrower, and the ability to pay an interest rate based on the level of productivity. Others include the miners' technical and financial management competence and the proof of the existence and viability of the orebody to be mined (Amedu et al., 2023; Eniowo et al., 2022a; Reichel, 2019).

The existing conventional method for evaluating the viability of a typical mining operation involves a careful geological exploration research, detailed analysis, review, and modelling of technical data on the indicated resources, and proving such resources to be a viable reserve (Seccatore et al., 2014). This process is usually complex, lengthy, and expensive. Most conditions demanded by formal lenders can only be met by large-scale mining (LSM) operators. In practice, it is only when these outlined processes have been completed that a bankable feasibility study report that is pleasing to a formal lender can be produced (Rupprecht, 2004). Owing to previous failed attempts at accessing formal financing, ASM operators know that they cannot easily attract funds from formal sources of funding. Apathy in formal finance for ASM operations therefore exists on both sides of the divide, that is, amongst both formal lenders and ASM operators (Eniowo et al., 2022b). Quantification of credit risk involves assigning measurable and comparable numbers to the likelihood of default risk to loans (Ross, 2020). In literature, the variables required for analysing credit risks can broadly be classified into financial and nonfinancial variables. Most studies on credit risk prediction focus on the use of financial variables. In such models, default risks are computed based on the available data from the credit history and credit report of the loan applicant. However, for small companies, studies have shown that

non-financial variables particularly play key roles in influencing default risk. For example, Kanapickiene and Spicas (2019) observed that non-financial variables, such as indicators of litigation and behaviours in social networks, critically affect the default risks of small companies. In ASM, the adoption of non-financial variables for the prediction of credit risks could even be more important, owing to the rudimentary nature of the occupation where proper documentation of productivity is sometimes non-existent. Also, the unavailability of external rating agencies that can provide credit ratings for small companies in some developing countries creates a bottleneck in the use of credit reports for credit risk predictions for such operations. Thus, it is essential that a simplified method be developed to estimate the viability of ASM operations – a method that is void of the encumbrances seen in banks' due diligence for larger mining companies. The scarcity of such, in the existing literature, necessitates this study. This paper therefore evaluates the creditworthiness for a viable small-scale mining operation using identified credit risk variables. Before going deep into this discussion, it is important to look briefly at the policy directions for the Nigerian ASM sector – the study area for this research.

Policy directions of the Nigerian ASM sector

The artisanal and smalls-scale mining (ASM) sector is considered a peculiar sector for the economic development of Nigeria. Mining of metals in Nigeria has a long history dating back to the 19th century, several decades before the promulgation of the Nigeria Minerals Act of 1946 (Mallo, 2011). Prior to the political independence of Nigeria in 1960, Nigeria was a major producer of metals, supplying more that 10% of the global output of tin concentrate (FELL, 1939). In the 1960s, the mining sector accounted for approximately four to five percent of the nation's GDP (PWC, 2023). After Nigeria had gained its independence from Britain in 1960, many factors contributed to the collapse of her large-scale mining industry. They include the indigenisation decree of 1973, a decline in global metal prices (including tin) in the 1980s, the Nigerian crude oil boom in the 1970s, and subsequent overdependence on the oil sector. Others include the depletion of alluvial reserves, the Nigerian civil war (1966–1970), and ineffective state control (Oramah et al., 2015; World Bank, 2012). In effect, ASM now dominates the country's solid mineral sector, representing up to 95% of the industry (Oramah et al., 2015). Consequently, the contribution of this sector to the economy of Nigeria has since dropped significantly, representing a meagre 0.17% of the GDP in the years 2018 to 2022 (PWC, 2023). However, in recent years, officials of the Nigerian government have identified this sector as the potential alternative for the needed diversification of the country's economy, away from its dependence on petroleum sector. The current elected government, which was inaugurated in May 2023 released a policy framework to support the country's sustainable and inclusive economic growth. This is in furtherance to the Economic Recovery Growth Plan (ERGP) developed by the immediate past government.

Furthermore, in this new framework, unlocking the potential of the mining sector was identified as a major deliverable. The roadmap to unlocking the potential of this sector involves repositioning it to attract large international mining players. It also involves implementing a framework to formalise and legitimise informal ASM activities. It is noteworthy that previous governments had also identified the potential of the country's ASM subsector. Specifically, the policy direction of the immediate past government focused on upgrading and upscaling the existing ASM industry. Based on this policy direction, the then Ministry

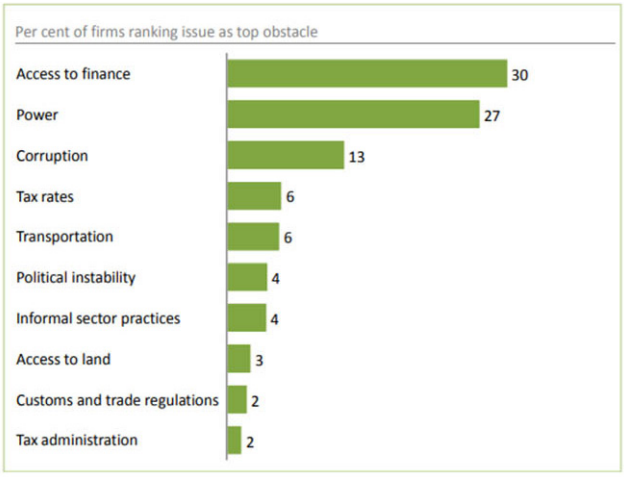

Figure 1—Firms ranking obstacles to business in Nigeria (Source: World Bank, 2014; Salati, 2024)

of Solid Minerals projected, albeit ambitiously, an increase in the GDP contribution of the mining sector from less than USD1 billion in 2016 to USD25 billion in 2026 (Akintola, 2016). The potential of the solid mineral sector is even further energised by the recent discovery of significant deposits of high-grade lithium in various parts of Nigeria, establishing the country as one of the nations that is rich in lithium resources worldwide (Amans et al., 2023). In its review of mining sector performance from 2017 – 2020 in line with its Economic Recovery Growth Plan (ERGP), the previous government stated that it had increased the number of registered mining cooperatives from 600 to 1,495. It had provided a total of 500 members of these cooperatives with extension services. It had also trained more than 1,000 of them on safer mining practices and occupational hygiene through the safer mining pilot project (Federal Government of Nigeria, 2021). Officials of the government recognised that to optimise the contribution of ASM to Nigeria's economic development, the issue of insufficient funding must be tackled (see Figure 1). In this regard, the Minister pinpointed insufficient funding and lack of access to capital as major factors militating against ASM operations. To combat this challenge, the Ministry of Mines and Steel Development (MMSD), in collaboration with the Nigerian Bank of Industry (BOI), launched a N5 billion (then approximately USD14 million) fund in support of ASM miners in the country. The government ministry under that administration also secured other funding interventions. Some of these funds include a USD100 million fund secured from the mining sector component of the Natural Resources Development Fund sponsored by the Nigeria Federal Government and USD150 million from the World Bank for the Mineral Sector Support for Economic Diversification (MinDiver) programme (Mohammad, 2017). How these various interventions impacted the output of ASM operations is the question that remains unanswered in academic and professional discussions centred on the Nigerian ASM industry.

However, available data have shown that the contribution of the mining sector (excluding petroleum and natural gas) to the country's economy is still minimal after seven years since the government launched the intervention by the BOI in 2017. The current contribution of the sector to the nation's nominal GDP is still in the neighbourhood of USD1.5 billion, translating to less than 1% of the economy (National Bureau of Statistics, 2023). Mining activities are capital-intensive in nature, and as such, capital plays an important role in providing the needed external financing for

mining operations. A cursory look at the disbursement of the BOI loan scheme indicates that there has been a low level of access by ASM miners. At a workshop with miners in December 2020, more than three years after the scheme kicked off, the government minister expressed displeasure over low access by miners to the loan scheme: by the end of September 2020, only 138 completed applications totalling N14.59 billion (approximately USD19.45 million) had been received and were at various stages of processing. In this same period, only 13 loan applications totalling N1.08 billion (approximately USD1.44 million) were approved under the scheme. Moreover, the rate of disbursement is also low when compared with the total applications. The reason ascribed to this by the government ministry is that applicants have largely failed to meet the necessary but stringent requirements of the BOI who handled the disbursement. This adds credence to the existing argument in literature that the stringent conditions attached to formal loans usually force artisanal and small-scale miners to opt for informal loans, which are relatively quicker, involve cheaper initial transaction costs, and lack the burdensome collateral requirements (Eniowo et al., 2022a; Spiegel, 2012). Also, while the BOI fund, like other formal monetary interventions, may offer lower interest rates, the extended loan processing timeline may not fit into the planning schedule of a typical small-scale mining operation. ASM miners are not preferable clients to lenders because they are assumed to carry more credit risks. It is therefore important to briefly go through the process of credit risk estimation adopted in this study.

Methodology

The study involves two phases. The goal of the first phase is to collate the key variables that influence creditworthiness of a viable ASM operation. This phase of the study adopts a qualitative approach, which was used to collect data through primary and secondary sources. The primary source of collection involves face-to-face interviews conducted with two groups of respondents. The interviews with the first group of respondents were conducted between September 2021 and November 2021 with bank authority, to find out about the policies that guide bank loans, especially to ASM operators. A follow-up interview was conducted in October 2022. The bank was purposively selected because, unlike the commercial banks in the study area, the bank is disposed to providing loan packages for ASM operations. The secondary source of data include documents retrieved from this bank, such as a loan application form checklist, which helped in identifying the key parameters required by the bank for a competent loan application by an ASM operator. The second group of respondents in the first phase of this study involved a selected sample of ASM operators from South West Nigeria who provided insights on the factors that affect access to credit in the industry. South West Nigeria was purposely selected for the study because it hosts various types of mineral resources commonly mined through ASM operations, which include gold, gemstones, industrial minerals, sand, and laterite (Nigeria Ministry of Foreign Affairs, 2022).

The second phase of the study adopts a quantitative approach. In this phase, data were obtained from a total of 100 purposively selected ASM establishments in the southwest region of Nigeria using a well-structured questionnaire. While previous studies on credit risk modelling for small-scale companies adopt the use of historical data, the unavailability of such data on the operations of the Nigerian ASM industry necessitates the use of current data. The major criteria for selection of respondents include the level of operation (artisanal operations that use manual methods of operation were targeted). One copy of the research questionnaire was issued to each of the sampled operations. Out of the operations sampled, only about 20% have had previous access to formal sources of loans to fund their operations. A multiple logistic regression model was then developed to predict the creditworthiness of a small-scale mining operation using the identified credit risk variables. The adoption of logistic regression follows the use of logit scoring models to predict credit default risks of small and medium-sized businesses (SMEs). This method was used in Behr and Güttler (2007), Altman and Sabato (2007), and Kanapickiene and Spicas (2019) to measure individual credit risks. In logistic regression models, the dependent variable is binary or dichotomous. The model analyses the relationship between multiple independent variables and a categorical dependent variable and estimates the probability of occurrence of an event by fitting data to a logistic curve (Park, 2013). The models are sometimes called logit models. These models can be classified into two types, binary logistic regression and multiple logistic regression.

In this study, the regression analysis was done in R studio, and the results were verified through an analysis done on SPSS software. In the multiple logistic regression, identified variables from phase one of this study (predictor variables) were regressed with access to formal fund (dependent variable) to determine the effect of the identified variables. The dependent variable is a dummy variable that takes value 1 if an ASM operator receives a formal loan and 0 otherwise. The predictor variables are the potentially relevant parameters that may drive creditworthiness. Specifically, based on the first phase of this study, seven parameters were identified to be critical in assessing creditworthiness for ASM loan applications. They include availability of mining license (and land tenure), availability of a minimum required reserve estimate to guarantee continuity of operations, ability to pay the 5% interest rate required by the BOI for ASM loans, ability to provide a guarantor, availability of a feasibility report, proof of membership of a registered mining cooperative society, and proof that the operation is brown field (the mine site must have been running successfully for at least a year). After retrieval of the completed research questionnaire from the sampled group of respondents, it was discovered from preliminary analyses that all the respondents had licenses and land tenure (expectedly, since the list of ASM establishments was accessed through the government ministry of solid minerals). Also, about 99% of the miners within the sample group have operated their mine sites for more than the required one-year period. Similarly, the variable "availability of a feasibility report" was found to be non-statistically significant in this study, as most of the miners argued that even though they did not have this document at the time this study was conducted, they could access it through the accountant in their cooperatives who provides financial advice and documentation for loan applications. Therefore, these three parameters were kept as constant for the purpose of the regression analysis. The form of the basic logit model is shown as:

$$\frac{p}{1-p} = a + \beta X + e \quad [1]$$

where **P** is the probability that a small-scale mine operator will receive a formal loan; a is the coefficient of the constant term; β is a vector of coefficients of the independent variables; X is a vector of independent variables, and e is the error term that is lognormally distributed by assumption. The coefficient of the constant and the vector β are estimated through maximum likelihood estimation. The transformation of the dependent variable constrains P to be in

the interval [0,1]. This standardisation is one of the main advantages of logit regression models and allows for the computation of P by a borrower by simply plugging the borrower-specific variable values into the estimated logit function (Behr, Güttler, 2007).

Hypotheses

The dependent variable in the logistic regression model is the observed access to credit. The following independent (predictor) variables were used in the logistic regression analysis: availability of a minimum reserve to guaranty continuity of operation and availability of a guarantor to stand as surety for the loan sum (a form of collateral security in the absence of physical collateral). Others include the ability of the applicant to afford the bank's interest rate, and the confirmation of the miner's membership in a registered cooperative society (this is considered a form of social collateral). The four predictor variables are categorical and binary in nature (true/false, 0/1). The simplicity of the question-types helps the miners to be able to provide accurate responses, which are valuable for the purpose of the analysis. This also helps to improve the interpretability of each predictor in the multivariable model and reduces the impact of outliers, as seen with continuous variables. Thus, the choice of adoption of binary predictors is borne out of the need to ensure future replication of this methodology while considering the peculiarities of the artisanal and small-scale mining industry.

Minimum reserve

The concept of 'minimum reserve and replication' as proposed by Marin et al. (2016) and Seccatore et al. (2014) in estimation of the viability of an artisanal and small-scale mining operation is based on a main differential from large-scale mining. According to Marin et al (2016) and Seccatore et al. (2014), the attractiveness for external investment only lies in proving, in the early stages of the business, a minimum mineral reserve that can rapidly return the investment committed to upgrade an artisanal operation into a small-scale industrial one, with an attractive profit. In this study, to evaluate the effect of possessing a minimum reserve to guarantee the continuity and longevity of an operation in order to obtain access to formal credit, the following hypothesis was developed:

H_1 = *Operations with a minimum reserve to return investment have a better chance of attracting formal credit.*

Miners were asked to complete the research questionnaire, and they were guided through unstructured interview questions on whether they have adequate ore reserve to provide for profit and continuity of the operations. The result of analysis of the responses shows a p-value of 0.000554 which falls within the confidence level of 0.05, indicating that the model is statistically significant and as such, availability of minimum reserve is a good predictor of access to formal funds.

Availability of a loan guarantor (collateral security)

A bulk of existing literature on ASM pinpoints the itinerant nature of many artisanal miners (Eniowo, Meyer, 2020; Van Bockstael, 2014). This, amongst others, occasions the apprehension of lenders in relation to ASM lending. To minimise the risk of lending to the operators, lenders seek a guarantor who will indemnify the bank against any loss that may arise from such lending. As an illustration, one of the conditions listed by the BOI for ASM-related loans is the availability of a "competent" guarantor. Usually, the bank only accepts guarantors who fall within a certain social status: some of the permitted potential guarantors include royal fathers, high ranking political office holders, and civil servants above grade 12 in the Nigerian civil service. In this study, to examine the effect of the availability of a loan guarantor on a miner's access to formal credit, the following hypothesis was tested:

H_2 = *An Operator who has a competent loan guarantor has a better chance of attracting formal credit.*

In the survey, the sampled ASM group were simply asked if they have a guarantor who could provide surety for their loan application. The miners were then asked to name the profile of their potential guarantors and if they have any potential guarantor who matches the status requested by the BOI. It was observed from the result that the p-value for the model is 0.00648, which falls within the confidence level of 0.05, indicating that the model is statistically significant and as such, the availability of a loan guarantor is a good predictor of access to the formal fund.

Ability to afford the interest rate

Informal non-banking sources that supply mainly short-term credit usually charge higher interest rates than formal banking sources (Sarma, Pais, 2008). In the case of the BOI, the formal lender, which was adopted for this study, a blanket interest rate of 5% is usually required to be paid by applicants from the small-scale mining sector. Literature has shown that such a "moderate" interest rate could potentially be costly for miners who fall within the artisanal level of operation even though a typical small-scale operator would ideally be able to afford it. As an illustration, a study by Siwale and Siwale (2017) narrate how emerald miners in Zambia were unable to afford a European Union credit scheme set at a 5.8% interest rate, which was funded by the European Investment Bank (EIB). The study further asserts that, even when the rates were further reduced, the "neediest" miners could not afford it, and only the "medium-sized" miners eventually benefitted (Siwale, Siwale, 2017). In this study, to examine the effect of a miner's ability to pay the required interest rate for a small-scale mining loan on the miner's access to formal credit, the following hypothesis was tested.

H_3 = *An Operator who could afford the bank's interest rate on a loan sum has a better chance of attracting formal credit.*

The miners were informed of the BOI's loan requirement in terms of interest rate, and were asked if they could afford the required 5% charged by the bank, based on their current earnings. Miners who could afford to pay up to the 5% interest rate were coded as "yes" in the analysis while miners who could not afford up to that rate were coded as "no". It was observed that the p-value for the logit model is 0.0319, which falls within the confidence level of 0.05, indicating that the model is statistically significant and as such, a miner's ability to afford the interest rate is a good predictor of access to formal funds.

Membership of the cooperative society (social collateral)

The literature has shown how belonging to a recognised cooperative society could be considered a form of social collateral, which is an essential condition to access funding in a predominantly informal economic activity (Eniowo et al., 2022a; Postelnicu et al., 2014). Social collateral is more important in a sector such as ASM, where physical collateral, such as assets and properties that may be used to access credit, is usually scarce. This ideology had been embraced by the artisanal and small-scale mining division of the Nigeria Ministry of Mines and Steel Development. Miners who do not have the individual capacity to secure a small-scale mining lease

are encouraged to merge with other miners to be registered with the Ministry as a cooperative society. There are several benefits to being a member of a registered cooperative society. One, it enables such miners to acquire the financial capacity to secure a license. Such license is acquired in the name of the registered cooperative. In addition to this, members of each cooperative do contribute amongst themselves to access mining equipment such as excavators and bulldozers on lease, which may be otherwise too expensive for individual miners to acquire. Based on the foregoing, it is expected that a miner who belongs to a registered cooperative society would have a better chance to access formal sources of credit. Hence, the study tested the following hypothesis:

H_4 = An operator who is a member of a registered cooperative society has a better chance of attracting formal credit.

To evaluate this parameter, each miner was asked if they belong to a cooperative society, and if such cooperative society is registered with the government's Ministry of Solid Minerals. It was observed that the p-value for the model is 0.000554, which is lower than the confidence level of 0.05, indicating that the model is statistically significant and as such, being a member of a recognised cooperative society is a good predictor of access to formal funding.

The result of the logit model is summarised in Table 1.

Figure 2 shows the odds ratio plot for the four predictors. The points represent the odds ratios, while the error bars indicate the confidence intervals for each. The vertical dashed line at 1 represents the point of no effect, where the predictor does not influence the odds. The x-axis is shown on a logarithmic scale for a better visualisation of the odds ratio.

Discussion and concluding remarks

Artisanal and small-scale mining operations (ASM) have suffered from lack of access to formal sources of financing because primarily, formal lenders perceive the operations to be financially risky. The situation is further compounded by the unavailability of a documented mechanism for estimating the credit risks of ASM operations. It is noteworthy that banks have specific methodologies for evaluating the viability of mining investment, which usually require detailed financial models. The unavailability of such models required by banks renders ASM out of reach of formal bank investment. Considering its peculiarities, credit risks for ASM operations need to be modelled separately from those of large-scale operations. The importance of creating a separate credit risk model for small-scale investments has been identified and tested through empirical study (Altman, Sabato, 2007; Behr, Güttler, 2007). A similar study in the mining sector that developed credit risk models, specifically for ASM operations, remains scarce in the body of literature. Thus, this study provides a simplified methodology for estimating the risks of lending to reasonable small-scale mining operation. The study identified four key variables that are critical for predicting the credit risk of a responsible small-scale mining operation. They include availability of minimum reserve to guarantee continuity of operations, ability to afford the required loan interest rate, availability of a collateral security (or a competent loan guarantor) and availability of social collateral. This methodology is designed specifically for the estimation of expected risks of lending to ASM operations based on the factors that qualify as risk criteria in a "not so formal" industry such as ASM.

The findings of this study will help the operators of ASM activities to identify the level of the creditworthiness of their operations and help lenders to identify and adequately weigh the risk of lending to ASM operations. This study therefore concludes that the path towards upgrading ASM operations to a more sustainable form of mining should involve an effort towards improving their ability to attract formal funding. It is recommended that future study direction should consider modifying, scaling, and improving available models for proving the viability of ASM operations. In this direction, considering the nature of ASM, such

Table 1

Determinants of access to credit

Variable	Estimate	Std. Error	Odds Ratio	CI Lower	CI Upper
(Intercept)	-4.413	1.416	0.012119	0.000755	0.194438
Minimum reserve availability	2.003	1.03	7.411257	0.984324	55.80146
Collateral security (loan guarantor)	1.991	1.02	7.322853	0.991834	54.0657
Interest affordability	1.238	1.123	3.448709	0.381715	31.15828
Social collateral	2.732	1.046	15.36358	1.977513	119.3619

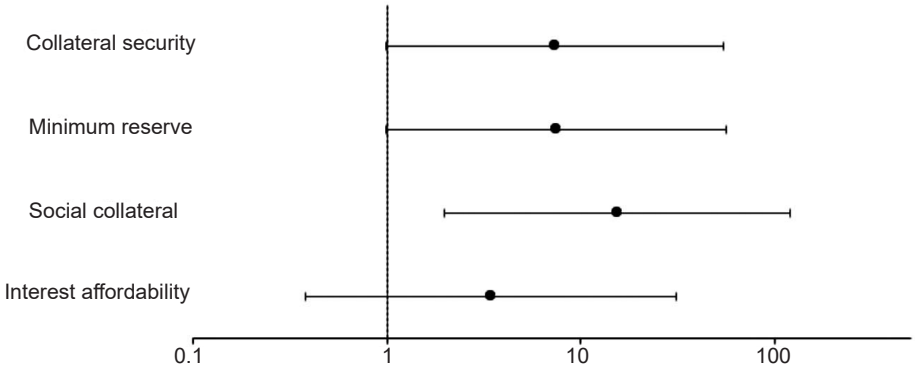

Figure 2—An odds ratio plot of the four predictors

models must not be developed using the methodology used in proving the viability of large-scale mining operations, which usually take several years to construct.

It is important that the scope of ASM formalisation efforts is expanded to expose ASM operators to the credit risks inherent in their operation. They should also be trained on mechanisms with which such risks could be abased. Also, for effective formalisation drive, one key initiative that may play a sustainable role in enhancing ASM operators' access to credit is the strengthening of associative entrepreneurship movements such as miners' cooperatives (Eniowo, Meyer, 2020). Firstly, this form of association would help miners to accumulate enough capital with which they could engage in more viable and safer operations (Saldarriaga-Isaza et al., 2013). Additionally, due to the perceived itinerant nature of artisanal mining, such associations provide a face for artisanal miners, a governing structure, and an avenue through which miners could be held accountable for excesses in their operations.

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