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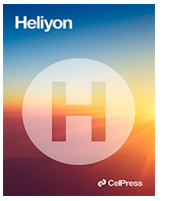

Research article

Does the education system matter? Exploring in-depth joint school attendance, hazardous and non-hazardous activities in artisanal and small-scale mining in the Democratic Republic of the Congo

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ABSTRACT

Purpose: This paper explores the deconstruction of child labour in artisanal and small-scale mining (ASM) sites, highlighting different perspectives. Despite the economic benefits to the Democratic Republic of the Congo (DRC), ASM poses challenges, particularly where children are concerned.
Method: ology: Our study uses a convergent parallel mixed methods approach to interpret qualitative and qualitative data based on the conceptual framework of human capital. Trivariate probit and Tobit models were used for quantitative data and content analysis was employed for qualitative data. We collected primary data by interviewing children involved in artisanal mining activities. Interviews were conducted with consent from the children and their parents or guardians. We adopt snowball sampling due to the lack of a database. The Centre of Expertise on Mining Governance (CEGEMI) developed the data collection instruments in collaboration with Inner City Fund (ICF) International and validated by the United States Department of Labour.
Findings: We found that limited access to education leads to decreased school attendance rates among children, pushing them towards engaging in hazardous and non-hazardous economic activities within the DRC's mining areas. Moreover, excessive working hours negatively impact children's academic performance. Consequently, there is a trade-off between attending school and engaging in child labour at ASM sites in the DRC.
Limitations: This study did not consider domestic activities carried out by children. This could give even more detailed results.
Public policy implications: Governments and partners must prioritise creating a comprehensive list of hazardous activities for children in the ASM context. Careful conceptualisation is necessary to ensure the clarity and effectiveness of this list. Raising awareness about the merits of removing children from activities related to mining is important for households living in and around ASM sites. Interventions aiming to reduce child labour and increase school attendance in ASM zones must remain mindful of the socio-economic and school infrastructure needs.

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1. Introduction

Although International Labour Organization (ILO) Convention 138 emphasises that education should be the primary focus for children [1,2] many regions around the world have not adequately met this global requirement in their education systems [3]. Economists have long argued that access to education serves as a crucial solution to combatting child labour [4–8], particularly addressing the worst forms of child labour highlighted by ILO Convention 182. However, ▣Invernizzi [9] questions the notion that mandatory education can eradicate child labour, as global perspectives assert. ▣Bonnet and Schlemmer [10] propose that instead of solely focusing on eradicating child labour itself, it is more effective to implement policies targeting its underlying causes.

The Democratic Republic of Congo (DRC) operates in a challenging economic environment, compounded by conflicts caused by armed groups. The high level of poverty among the population hinders progress in providing universal education for children. It is concerning that a significant proportion of school-aged children are not enrolled in school, and those who do attend often do so irregularly [11]. The DRC has experienced a deep crisis with distant roots that has affected all sectors of life, including the education system. The country was on the verge of bankruptcy when it was placed under a structural adjustment programme in 1982 before the economy was definitively dislocated around the 1990s. The government's inability to continue paying teachers quickly proved lasting and definitively undermined the State's ambitions to reform its education system. Around 1992, following a widespread strike by unpaid teachers, the Episcopal Conference of Zaire at the time and the national parents' association endorsed the support of teachers by parents in the form of a motivation bonus known as the prime of motivation [11]. Thus, the support of teachers by parents constitutes a major challenge for the Congolese population in a country where education is a hybrid system, including schools managed by the State with the help of religious organisations and purely private schools. Contrary to Article 43 of the Constitution of the DRC which stipulates that primary education is compulsory, ▣Murhi Mihigo and Bucekuderhwa Bashige [3] argue that the increase in school fees is a major obstacle which prevents many children from accessing primary education. As a result, several million children of primary school age do not attend. This makes the DRC one of the countries with the largest number of out-of-school children [3,12]. This situation forces several Congolese households to allocate part of their income to the educational investment of their children [11]. There is a lack of school infrastructure in many areas, but the inequalities are more glaring, particularly between urban and rural areas. In rural areas, there are no schools and pupils are forced to study on the ground and under a tree. It's also in rural areas that we see the highest number of cases of teachers not being paid by the state (teachers who have been working for years but are not on the payroll).

Household investment in education plays a crucial role in sustaining the modest expansion of the education system and preventing its decline. Despite limited government funding and support from external partners, the Congolese education system continues to face numerous challenges. In many areas, schools are scarce, while in others, children have to travel long distances to reach school. Bhukuth [6] argues that the decision between child labour and education depends on how parents perceive the current state of the education system. These circumstances may reinforce child labour, as children have no other option but to work for survival. For them, work becomes not a form of exploitation but a means of acquiring essential income for survival [13] and a way of participating within their community [9]. However, it is important to analyse the issue of child labour objectively rather than reacting emotionally.

School attendance and child labour are generally understood as decisions made by parents based on their assessment of human capital investment opportunities [14]. Parents consider factors, such as family consumption patterns, available resources and preferences when deciding how their children should spend their time, whether it be attending school or working [15].

The relationship between education and work for children in the ASM sector is complex. According to Faber et al. [16], engaging in work hurts children's attendance and performance in school. Balancing both work and school can even lead to dropout rates as children prioritise earning money [2,17,18]. However, working and earning money can also provide the means to afford school fees, since education is generally not free [19]. Another perspective argues that child labour is seen as a form of socialisation rather than purely a means for financial gain in Africa [8,9]. ▣Orazem et al. [20] shows for example that living in refugee camps is an element that deprives children of an adequate education.

Children who combine school with economic activities in mining areas attend full-time schooling while working before or after class. This situation inevitably affects their school attainment and may have long-term negative consequences. Scholars have demonstrated the link between child labour and schooling [5,14,21], but it remains to be shown whether living in specific environments, like artisanal mining zones, can influence both children's education and involvement in child labour.

Notwithstanding that poverty is an obvious contextual factor that dominates and pushes many children into child labour [15,16,22], the living environment, such as proximity to certain activities (for example, the presence of artisanal and small-scale mining activities), may be among elements justifying child labour [2]. The lack of economic opportunities is another reason for the prevalence of child labour in ASM sites. Nevertheless, working in the ASM sector requires a lot of effort and energy [18]. The fact that a child works in such an area leads to the qualification of this work as one of the worst forms of child labour [2,17,18]. The statistics reveal that 73 million children around the world work in mines and fields or factories where they are exposed to pesticides and other toxic substances, with adverse consequences for their physical, mental, moral, and psychological development [23].

ASM refers to the mineral extraction undertaken by people or small groups of people working with hand tools or very rudimentary forms of mechanisation [8,24]. Children working in this sector are mostly unregistered miners [2,17,12]. ASM generally encompasses informal, and illegal miners who use rudimentary methods and processes to extract different mineral substances. ASM symbolises the mining processes defined by two striking characteristics: labour and simple procedures. These different characteristics of ASM mean that child labour is particularly abundant in this field of work. Dessy and Pallage [25] point out that children mostly perform in the informal markets and are there because of the poverty of their households.

Among the economic activities in which children are involved in the mining sector, we distinguish between those considered hazardous on the one hand and those that are non-hazardous on the other hand. In this way, we try to contribute to the understanding

of what international opinion describes as one of the worst forms of child labour worldwide. To our knowledge, no study to date has directly addressed the difference between hazardous and non-hazardous activities and schooling in the ASM sector in the DRC. Existing literature tends to show that the ASM sector simply hurts children's schooling [2,16]. However, this view can be moderated by taking the context into account.

In this research, we aim to gain insight into the activities that children engage in within the ASM sector, based on their perspectives. Additionally, we aim to establish a connection between school attendance and these ASM activities in the context of the DRC. Our goal is to explore how the absence of schools in mining areas relates to schooling and child labour. Lastly, we will assess the correlation between child labour and academic performance.

The hypothesis we put forward here is that the dysfunction of the education system in the ASM zone would lead children to go to work instead of going to school. It is the failure of the supply of education.

We use both quantitative and qualitative data obtained directly from children, unlike other studies which go through adults to obtain information about their children. The fact that children do not have the opportunity to tell their stories about so-called "child labour" can lead to erroneous conclusions and biased policy recommendations. For the data processing, the paper uses a content analysis for the qualitative data, a trivariate probit analysis and a censored Tobit model for the quantitative data. This analysis is based on cross-sectional data collected and individual interviews from ASM camps in three provinces (Haut-Katanga, Lualaba and South Kivu) in the DRC. These data were collected between July and December 2022. The respondents were children working in the mining sector, ranging in age from 7 to 17. Prior to interviewing with a child, a procedure was followed to obtain the consent of the child's parents (or their guardians) as well as that of the child. For this study, taking into account the data collected under Congolese law, any person under the age of 18 is considered a child.[1] Unlike previous studies on the DRC (see Refs. [16,17,26] for example) which investigated child labour participation in the ASM sector, this study attempts to deepen the understanding of the effect of children working on school attendance. This work contributes to the existing literature by dissociating hazardous child labour from non-hazardous work within the ASM sector.

In this study, we use the theoretical approach of the trade-off between child labour and education [6,27], which is a dynamic analysis, in contrast to the static analysis of Basu and Van. In this model, it is no longer leisure that is taken as an alternative to child labour but rather schooling. With a trivariate probit model, the evidence suggests that school attendance and hazardous and non-hazardous activities are simultaneously linked in the DRC's ASM areas. The poor education policy reflected in the virtual non-existence of schools in artisanal mining sites harms children's schooling attendance. From the censored Tobit model, the time a child spends in economic activities in the ASM sector negatively influences their academic attainment.

2. Literature review

2.1. Overview

Child labour is one of the most significant social issues affecting children's lives worldwide. There are several industries in which children are employed, and mining is one of them [23]. Mining activities pose significant risks to children and have long-term consequences on their health, education, and overall development. Mining activities involve hazardous work conditions, and children are often employed to work in mines due to their small size and cheap labour. More than a million children work in mines worldwide, and the majority of them are engaged in hazardous and exploitative work practices [23]. In the DRC, households with children working in mining have a higher number of children [16], and figures must be underestimated when we know how artisanal mining occupies a large part of the population, especially in the eastern part of the country. Children working in mines are exposed to a range of health risks, including respiratory problems, musculoskeletal disorders, and skin diseases [16]. Moreover, mining activities also lead to accidents and fatalities, with children being more vulnerable to such incidents due to their lack of experience and training.

The impact of child labour on children's education is also significant. Child labour deprives children of their right to education [28] and limits their opportunities to acquire skills and knowledge necessary for their personal and professional growth. Children who work in mines are often unable to attend school regularly, leading to high dropout rates and lower levels of educational attainment [2,29]. Moreover, children working in mines often suffer from physical and mental exhaustion, which affects their concentration and ability to learn.

Indeed, the economy of the DRC largely depends on the extraction of minerals and many other natural resources [24], as is the case in many developing economies [2,30]. Several thousand people are involved in mining activities, including children, especially in ASM [8,12]. The contribution of artisanal mining to the DRC's economy is estimated between $149 million and $324 million per year [24]. Studying child labour in the ASM sector is a sensitive subject, given that this activity is deemed illegal.

Although legislation is increasing to prohibit the exploitation of children, scholars confirm the presence of child labour in ASM in the DRC [16,17,26]. In a study conducted by the Centre for Effective Global Action in mining communities in the copper-cobalt belt (Haut-Katanga and Lualaba), 11 % of children were found to be working outside of the household. Twenty-three percent of the children working outside the household were found to be engaged in work within ASM [16].

Further research is needed to understand the characteristics of child labour in ASM in the DRC, it is known that large-scale mines

[1] Article 58 of Law n°09/001 of 10 January 2009 on the protection of children in the Democratic Republic of Congo prohibits all forms of economic exploitation of any person under the age of 18. (see No, L. 09/001 du 10 Janvier 2009 Portant Protection de l'enfant. *http://www.leganet.cd/Legislation/JO/2009/L*, *9*(10.01), 09.).

also source and process materials from ASM which use child labour [26]. Additionally, allegations regarding the presence of hazardous forms of child labour have also been made against mining activities [18,23]. The ILO definition of the worst forms of child labour includes "work that deprives children of their childhood, their potential and their dignity, and which harms physical and mental development" [31]. The focus is on protecting children under 18 from economic exploitation. However, in this definition, nothing is mentioned concerning the fact that prohibiting a child from working in a given context can be as dramatic as leaving them in certain activities facilitating them to combine school and work.

Within the ASM sector, children perform various activities [23,12]. Children's engagement in these activities not only poses an extreme danger to their health and safety [18,26] but also decreases the opportunity to attend school [32]. Edmonds [33] stresses that the future well-being of the child is from having attended school. The prevailing consensus is that people aged between 5 and 17 should not work but must go to school. Child labour and school attendance are usually studied as conflicting alternatives [14], although one does not exclude the other and they are often combined in certain circumstances [22]. Some of the factors driving the presence of child labour in ASM include issues such as insufficient efforts in implementing child labour risk mitigation plans [23,26]. Other factors driving child labour in ASM zones are poverty [13], the lack of basic services found in rich countries [24], such as child care (forcing parents to decide to bring their children with them to the mines), the lack of funding for education and affordable education for children, as well as the broad understanding within the local context that child labour in mining communities is culturally acceptable [1,16]. Sovacool [24] also reveals that corruption keeps children involved in ASM activities in the DRC. According to Sovacool, children often pay bribes to local government authorities to let them work despite the law prohibiting them from doing so. Analysing the phenomenon of the presence of children in the ASM sector is a restrictive way of understanding the problem and can lead to erroneous conclusions. Another element that increases the presence of working children in the ASM sector is the failure of the education system.

The absence of schools in a given area, the distance between the house and school, and in general, the education system management, may influence households' decisions on whether to send their children to school (rather than to work), all things remaining equal. Therefore, the issue of access to formal education in the ASM sector is important in the DRC context. Indeed, in most ASM sites in the DRC, schools are practically non-existent. In the few places where schools exist, they are either in disrepair or not built to standard. Some schools even operate under mango trees and are often very far from people's houses. Access to school is not free in the DRC. Parents have to bear several costs for their children to study [11]. Haile and Haile [14] emphasise that improved access to formal education translates into reduced child labour. However, this is not always the case everywhere [9]. For instance, it is not enough for a child to be enrolled in school; they must also remain there until the end of the curriculum [3]. The gains in school attendance resulting from improved access are mainly among inactive children (means, those who were counted as neither in school nor working) rather than working children [34].

Discussions on different schools of thought on child labour have been extensively debated by policymakers, activists, and scholars. Literature on the allocation of children's time in poor economies points out several determinants of child labour. These determinants are grouped into two schools of thought, economically speaking. The first school of thought is based on the demand theory of education formulated by Becker in 1967 [35]. For Becker, child labour can be seen as an optimal response to a trade-off between the returns and costs of education. If the returns to education are too low, concerning its main component, the opportunity cost (the wage not received by the child during the hours when they are studying), then parents make the trade-off between school attendance and child labour [14,36]. In the same line of thought, other authors show that child labour may be an optimal choice when specific knowledge or experience is more profitable than education [35] or when, due to a lack of coordination, agents and firms find themselves in an equilibrium characterised by a low level of education [25]. In these considerations, the level of education attained by a job seeker is not a fundamental criterion for occupying a position. This way of considering that children and adults have the same profile in the labour market poses a moral problem.

The second line of thought highlights the impact of various constraints on the supply of household labour, especially children. Thus, scholars show that imperfections in the adult labour market [37] and poverty [13,15,16,22] may favour the emergence of child labour. One criticism that can be levelled at these approaches is that there is no guarantee that, if the above-mentioned markets were perfect, the funds would necessarily be channelled into getting children into school.

From a household poverty perspective, two perspectives have been developed [6]: that of household welfare and that of child welfare. The first considers the child as an asset that the head of the household can use whenever the survival of the household is in danger. This line of thought makes the child the private property of the head of the household, yet the child is the property of society. The second perspective points out the reasons why a household with insufficient income does not invest in its child's education [13]. Even in an environment where children's education is publicly funded, there are still indirect costs that the household must bear. These indirect costs can limit the willingness of poor households to invest in children's education. These different perspectives highlight the complexity of the child labour issue and the need for nuanced approaches that balance the rights of children with socio-economic contexts.

2.2. Conceptual framework

School attendance and child labour are always analysed within the conceptual framework of human capital with a narrative approach. The net return on human capital investment is low compared to investments in other assets. The accumulation of human capital brought about by schooling is felt both at the individual level in terms of children's earnings, and at a macroeconomic level for the country concerned, particularly in terms of economic development or economic growth [6,24]. A child who has not accumulated sufficient knowledge in terms of human capital will be condemned to work only in the informal sector. Ahad et al. [28] demonstrate

that children who work in the informal sectors are subject to maltreatment.

The conceptual framework of human capital emphasises the idea that individuals' knowledge, skills, and abilities contribute to their economic productivity and overall well-being [35]. This framework recognises education as a crucial factor in enhancing human capital and promoting economic growth. However, the presence of child labour poses significant challenges to the development of human capital [15] as it deprives children of educational opportunities and hinders their long-term prospects. Numerous studies have demonstrated the adverse effects of child labour on human capital development. Child labour often leads to limited access to education, inadequate skill development, and reduced cognitive abilities. These factors contribute to a diminished human capital pool, hindering economic progress and perpetuating cycles of poverty [38]. Schooling plays a pivotal role in countering the negative impact of child labour on human capital. Access to quality education equips children with essential knowledge, skills, and competencies, enabling them to break free from the cycle of poverty and contribute positively to society. Moreover, education empowers individuals to make informed choices, leading to improved labour market outcomes and increased productivity.

Econometric strategies, such as the instrumental variable method, three-stage least squares, the difference-in-differences method, bivariate probit, trivariate probit, and censored Tobit models, have been used to analyse the relationship between child labour and school attendance. The use of these models provides a more nuanced understanding of the relationship between these two aspects, taking into account the potential correlations between different factors affecting these variables, as well as the influence of child labour and school attendance on continuous variables, such as earnings.

3. Materials and methods

3.1. Participants

The specificity of this study is that it took account of children's arguments, unlike other studies which analyse child labour through information provided by adults. A total of 461 children were included in the study, 175 in Haut-Katanga province, 109 in Lualaba province and 177 in Sud-Kivu province. Among the 461 involved in the quantitative survey, 20 of them also accepted to participate in the interviews and 18 in the focus groups. Three focus groups were organised with one focus group per province.

3.2. Study design

We are interested in the schooling of children and the economic activities in which they find themselves at artisanal mining sites. In some existing studies, work at artisanal mining sites is considered hazardous [2,13,23,29] and hinders children's schooling. However, there is still no unanimity in the definition of the worst forms of child labour [1,8,9,31]. These judgements, which we describe as moral, about children's activities in ASM do not help improve children's survival. Rather, in our view, it is a question of understanding the activities in which they are involved and knowing why and how children come to make the choice.

While keeping other factors constant and refraining from challenging international opinions, it is important to consider that within the various activities in which children engage in ASM, some activities are deemed hazardous, while others are not. In the literature on child labour and schooling, four commonly proposed hypotheses are presented [27]: the child only works, the child only goes to school, the child combines work and school, or the child does not work and does not go to school. In this study, because we have three activities that can be simultaneous, eight assumptions are possible. The development of these eight assumptions is as follows:

Let us note by:

S: School attendance.

H: Hazardous work.

N: Non-hazardous work.

The eight assumptions are expressed as follows:

P1= The child only goes to school.

P2= The child is only involved in hazardous economic activities in ASM.

P3= The child is only involved in non-hazardous economic activities in ASM.

P4= The child combines school and hazardous economic activities.

P5= The child combines school and non-hazardous economic activities.

P6= The child combines hazardous and non-hazardous economic activities.

P7= The child combines the three activities (school, hazardous and non-hazardous economic activities)

P8= The child does not go to school and is not involved in any economic activity.

The results of these conditional probabilities are presented (Fig. 2).

4. Instruments

To collect data on artisanal mining in the DRC, this study relies on a mixed methods research design involving children's interviews, quantitative data collection, and a literature review. A convergent parallel mixed methods study design was used to collect and interpret quantitative and qualitative data. A quantitative questionnaire and qualitative child mining worker interview guide captured information from children regarding the following overarching information: (1) basic demographic characteristics, (2) mining work activities and habits, (3) daily routine habits, (4) recruitment/work entry experience, (5) working conditions, (6) earnings, and (7) school attendance habits and history. In total, the questionnaire consisted of 83 questions divided into these seven modules. The

information concerning modules (1), (2), (5) and (7) are used in this study.

The basic demographic characteristics module includes variables such as the child's age, sex, ethnicity, religion, living with parents, envy, living with the biological family, migration, etc. In the module on mining work activities and habits, the variables included are of a nature such as working hours, the different activities that exist on the mining site, the activity in which the child spends the most time, etc. In the module on working conditions, we include variables such as the child's age, sex, ethnicity, and religion. In the working conditions module, we have variables such as the activity carried out by the child, the tools used to work, the activities of parents and other family members, the type of food, various illnesses, accidents at work, etc. Finally, in the module on school attendance habits and history, we included variables such as school attendance, the distance between school and home, the class attended last year, the class attended at the time of the survey, the number of schools in the region, etc. The questions in the quantitative questionnaire were based on the child's level of education. The questions in the quantitative questionnaire were all closed and coded. The interview guide for collecting qualitative data was based on the seven modules of the quantitative questionnaire but with open-ended questions such as "Can you describe what the place where you work looks like?" The use of quantitative and qualitative data on the same children allows triangulation and avoids interpretation bias.

4.1. Data collection procedure

The data used in this study are from data conducted by CEGEMI in collaboration with ICF International and validated by the United States Department of Labour (USDOL), with supplemental funding from Enabel-DRC. This survey collected both qualitative and quantitative data to understand the characteristics of child labour in the copper (Katanga and Lualaba) and cassiterite-coltan-gold (South Kivu) in the DRC. The quantitative questionnaire and interview guides were developed by the two institutions mentioned above (CEGEMI and ICF International, Inc.).

The study aims to highlight exploitative child labour practices and working conditions of children in these artisanal industries and to show at what stage of the production process they occur. The study parameters and research instruments were reviewed and approved by the Institutional Review Board of ICF in the USA and by the Ethical Review Board of the *Université Catholique de Bukavu (UCB)* in the DRC (called Comité Institutionnel d'Ethique de la Santé-CIES). Informed consent was obtained from all child study participants. Before a survey or interview, the researcher read a consent statement that described the objectives of the study, the risks, and benefits of participating in the study, the assurance of confidentiality of any information collected, and explained that participation in the study was voluntary. Participants were then allowed to ask any questions they wished before giving their oral consent to participate in the study if they voluntarily agreed to do so. The adults (those responsible for the youngsters at the mining site) were contacted ahead of time and gave their permission for the investigator to question the child. The goal of the project was explained, and the research procedure was read aloud. Following approval, the investigator and the adult signed a consent form (anonymous) at the same time. To be selected for the quantitative survey, the inclusion criteria meant that the youths had to have carried out an activity linked to artisanal mineral extraction for at least six months on the date of the survey and had to be aged 7 to 17. The children had the choice to participate in the qualitative interview or not after having freely agreed to answer the questions in the quantitative analysis. The first child encountered and who met the conditions for inclusion in the sample was interviewed. This age group was chosen because the official age for starting primary school in the DRC is six. Thus, to find out whether a child has been enrolled in school and continues to attend, it is convenient to do this at least a year after their first enrolment. As there is no database of children working in the mines in DRC, the technique used to survey children was snowballing.[2] From an ethical consideration, as indicated above, we have obtained authorisation from the CIES of UCB. We have sent the ethical clearance letter to the editorial board of the Heliyon journal. The reference number is N/Ref:UCB/CIES/NC/008/2022 dated April 05, 2022. The datasets used in this study received approval in terms of consent from the parents and children involved in the investigation. The data was collected using the Kobocollect and SurveyCTO data collection tools. At the end of the survey, these tools provide data in Excel format that can be transferred to any other software.

4.2. Data analysis

The data from the survey questionnaire is analysed quantitatively while the interview data is subjected to content analysis. Content analysis allows us to go beyond the manifest content to make explicit the latent content of the data collected. In this sense, analysis does not limit us to a simple description of the "what" and the "how" of the data at our disposal. Content analysis helps to understand the "why" and the meanings of the data that are not directly revealed. The quotes from the children have been reproduced verbatim (translation from Swahili into English). To analyse the quantitative data, in addition to the description, we use a trivariate probit regression and a censored Tobit regression.

4.2.1. Trivariate probit

This analytical strategy diverges from previous research in important ways. Schooling and children's labour force participation in hazardous and non-hazardous activities in the ASM sector are represented as joint outcomes. Many studies have focused on children's schooling or market work [1,4,25,33,34,36–38], but have not considered the probable interdependence among these joint outcomes of

[2] Snowball sampling is a non-probability sampling technique where new units are recruited by other units to form part of the sample. Snowball sampling is generally a useful way to research people with specific traits who might otherwise be difficult to identify.

family decisions. The household's ability to make choices regarding children's schooling and engagement in hazardous and non-hazardous activities within ASM zones adds to the significance of exploring the use of simultaneous equation models. It also emphasises the need for careful interpretation of results obtained from single-equation models, as they may be subject to bias [39].

The analysis incorporates the simultaneity of schooling, and children's labour force involved in hazardous and non-hazardous activities using a three-equation multivariate probit model as underlined by Refs. [39,40]. As is well known, reduced-form equations can be estimated by standard methods because no endogenous right-hand-side variables are present [39,41,42]. Since all the observed outcomes are dichotomous, it is necessary to use a model that allows discrete dependent variables rather than ordinary least squares regression. To account for the interrelationship between decisions concerning work in ASM hazardous, ASM non-hazardous activities and schooling, the empirical analysis estimates participation in these three activities simultaneously, in the form of a trivariate probit model.

Let us assume the existence of three latent variables described by a vector of regressors, X_{ij}, and a stochastic term, ε_{ij}, j = 1,2,3. In general, the specification of the trivariate probit econometric model is described as follows, as adapted from Refs. [39,41,42], [39]:

$$S_{i1}=X_{i1}\beta+\varepsilon_{i1} \quad [1]$$

$$H_{i2}=X_{i2}\beta+\varepsilon_{i2} \quad [2]$$

$$N_{i3}=X_{i3}\beta+\varepsilon_{i3} \quad [3]$$

To jointly estimate β_1, β_2 and β_3, the Maximum Likelihood method is applied. To do so, the following assumption is made:

$$\varepsilon i=\begin{vmatrix}\varepsilon_1\\ \varepsilon_2\\ \varepsilon_\varepsilon\end{vmatrix}\sim N\begin{vmatrix}0\\ 0\\ 0\end{vmatrix},\begin{vmatrix}1 & \rho 12 & \rho 13\\ \rho 21 & 1 & \rho 23\\ \rho 31 & \rho 23 & 1\end{vmatrix} \quad [4]$$

Where,

Equation (1) describes whether the child is currently attending school,

Equation (2) describes whether the child is participating in ASM hazardous work,

Equation (3) describes whether the child is participating in ASM non-hazardous work.

In the first three equations, X_{i1}, X_{i2} and X_{i3} are row vectors of exogenous variables that determine, respectively, the propensity of schooling, participation in ASM hazardous and participation in ASM non-hazardous work.

In equation (4), ρ_{12} is the coefficient of correlation between ASM hazardous activity and school attendance.

ρ_{13} is the coefficient of correlation between ASM hazardous activity and labour force participation in ASM non-hazardous activity.

ρ_{23} is the coefficient of correlation between school attendance and labour force participation in ASM non-hazardous activity; and $\varepsilon_{i1,}$ $\varepsilon_{i2,}$ $\varepsilon_{i3,}$represent unmeasured variables in schooling, labour force participation in ASM hazardous activity and labour force participation in ASM non-hazardous activity equations, respectively.

The assumption $\mathrm{Var}(\varepsilon_{ij}|X_{i1}, X_{i2}, X_{i3})=1$ for $j=1,2,3$ resolves the scalar identification problem.

To perform the Maximum Likelihood estimation, the function $L(\beta_1, \beta_2, \beta_3, \rho_{12,} \rho_{13,} \rho_{23}|X_{i1}, X_{i2}, X_{i3})$ is given by equation (5) below:

$$L(\beta_1, \beta_2, \beta_3, \rho_{12,} \rho_{13,} \rho_{23}|\, X_{i1}, X_{i2}, X_{i3})=\prod_{i=1}^{I}\Pr(y_{i1}>0,\, y_{i2}>0,\, y_{i3}>0|\, X_{i1,}\, X_{i2,}\, X_{i3})^{yi1yi2yi3}$$

$$.\Pr(y_{i1}>0,\, y_{i2}>0,\, y_{i3}\leq 0|\, X_{i1,}\, X_{i2,}\, X_{i3})^{yi1yi2(1\text{-}yi3).} \quad [5]$$

$$.\Pr(y^{*}_{i1}>0,\, y^{*}_{i2}\leq 0|\, X_{i1,}\, X_{i2,}\, X_{i3})^{yi1(1\text{-}yi2)}$$

$$.\Pr(y^{*}_{i1}\leq 0|\, X_{i1,}\, X_{i2,}\, X_{i3})^{1\text{-}yi1}$$

As school attendance, ASM hazardous and ASM non-hazardous activity are the corresponding dummy variables, we then have the results from equations (6)–(8):

$$\Pr[\text{School attendance}=1]=\Pr[S^{*}>0]=\Pr[\beta'_1\, x_{i1}+\varepsilon_{1i}>0]=\Pr[\varepsilon_{i1}<\beta'_1\, x_{i1}], \quad [6]$$

$$\Pr[\text{Hzardous work}=1]=\Pr[\varepsilon_{i2}<\beta'_2\, x_{i2}], \quad [7]$$

$$\Pr[\text{Non-hazardous work}=1]=\Pr[\varepsilon_{i3}<\beta'_3\, x_{i3}]. \quad [8]$$

Equations (6)–(8) denote the mathematical conditions of the probability for each of the independent variables to be observed in the population i.e. to take the value 1. The coefficients $\rho_{\ ij}$ (with $i\neq j$) (in equation (5)), reflect the correlation that may exist between the errors of the three equations. When these choices are independent, the coefficients are zero. On the other hand, if these choices are statistically and significantly different from zero, we conclude that these choices are interdependent. The likelihood function, as well as these different contributions, is maximised according to the Geweke, Hajivassilou and Keane (GHK) method [39–41,43]. The three dependent variables are detailed in Table 3.

4.2.2. The censored Tobit regression model

The amount of time a child spends at work can influence school performance and attendance [4,14,36]. Particularly regarding

children's work in ASM, where considerable effort is required, exhaustion due to long working hours can lead to a lack of concentration in school activities and thus negatively impact school performance. To assess the trade-off between the child's educational level and working hours, we specify a Tobit model also known as the censored regression model. This model belongs to the family of models with limited dependent variables, i.e., those for which the dependent variable is continuous but only observable over a certain interval. The general formulation of the model is inspired by Greene's book [44] and is described by equation (9) as follows:

$$Y_i^* = X_i'\beta + \varepsilon_i \quad [9]$$

$$Y_i = 0 \text{ if } Y_i^* \leq 0 \quad [10]$$

$$Y_i = Y_i^* \text{ if } Y_i^* > 0 \quad [11]$$

In equation (9), X_i is a vector of explanatory variables, β is a vector representing the parameters to be estimated, Y_i is a latent variable and ε_i is the error term assumed to be normal distributed with mean equal to zero and homoscedastic variance σ^2. For this study, let EL denote our latent variable, HR denotes the time the child spends working in ASM and X_i denotes the other control variables. The different variables used in this study are described in Table 1. By adapting equation (9), we derive equation (12):

$$EL_i^* = \alpha HR_i^* X_i'\beta + \varepsilon_i \quad [12]$$

This allows us to identify the following criteria defined in equations (10) and (11), and based on equation (12), we obtain:

$$EL = \begin{cases} 0 \text{ if } EL^* = 0; \\ GAGE \text{ if } EL^* > 0; \end{cases} \quad [13]$$

Where $HR = \begin{cases} HR \text{ if } HR^* = 0; \\ 0 \text{ otherwise}. \end{cases}$ which is a logical consequence of the result from equation (13).

Based on the study by Haile and Haile [14], adjusted age child allows capturing of the school attainment of a child (GAGE) in equation (13). GAGE is computed as follows:

$$GAGE = \left[\frac{G}{A-E}\right] * 100 \quad [14]$$

In Equation (14) G is the highest class of education achieved by the child, A is the child's age, and E is the official school entry age. Thus, in our sample, G runs from zero to nine, with zero representing the child who has never been to school and nine representing the third year of secondary school. Note that in the DRC the official school entry age is six years.[3] During the computation of the GAGE, as prescribed in equation (14), four potential outcomes can be obtained:

$$GAGE = \begin{cases} = 0 \text{ if the child has non school attainment}; 0 < GAGE < 100 \text{ if the child is below the normal school attainment}; \\ = 100 \text{ if the child has a normal school attainment}; \\ > 100 \text{ if the child is above a normal school attainment}. \end{cases}$$

Depending on the GAGE value four possible cases.

- The child has never been to school at all.
- The child is older than the class he or she is attending.
- The child is in the class corresponding to his or her age.
- The child is in a class ahead of his or her age.

In Stata software, we simply add "vce(robust)" at the end of the regression syntax (both for the trivariate probit and the Tobit model) returns robust standard errors. The quantitative data were entered and processed in Stata 17 for analysis.

4.2.3. Descriptive statistics

Children, both girls and boys, are actively engaged in various activities at ASM mine sites. Ten main activities have been identified and are presented in Table 2 and Fig. 1. Among these activities, children participate in ASM operations, including collecting abandoned mineral-containing stones.

These stones are then washed, and valuable materials extracted from them are sold by the children to traders. It has been reported that children sometimes stay at the mine site during night-time to safeguard the materials or continue working in the pits. It is predominantly boys who undertake underground work and perform tasks within the pits, and it should be noted that this type of work carries significant risks. Moreover, some older children also take part in mineral extraction activities.

Among the various activities at mining sites, there are three in particular that involve a significant number of children. These

[3] see the Ministry of Primary, Secondary and Technical Education (MINEPST) https://www.eduquepsp.education/v1/programme-scolaire/.

Table 1
Data description and summary of statistics.

Variables	Data description	Mean & Std. Dev.
Child age	Within the range from 7 to 17	14.974 (1.928)
Gender	Dummy: Boy = 1; Girl = 0	0.677 (0.468)
School attendance	Dummy: Enrolment = 1; 0 if not	0.597 (0.491)
The absence of schools in the region	Dummy: School nearby = 1 and 0 otherwise	531 (0.5)
Hazardous work	Dummy: Involved in hazardous work = 1 and 0 otherwise	0.616 (0.487)
Non-hazardous work	Dummy: Involved in non-hazardous work = 1; 0 otherwise	0.382 (0.486)
Migrant	Dummy: Lives permanently in the community = 1, 0 if migrant	0.581 (0.494)
Total hours per week	Hours worked last week	37.517 (21.871)
Orphan	Dummy: At least one of the child's parents is not alive = 1; 0 otherwise	0.891 (0.311)
Family member in mining	Dummy: One family member works in mining = 1; 0 otherwise	0.577 (0.495)
GAGE	Education attainment by a child from 0 to 166.67 %	47.014 (34.044)

This table shows the different variables used in this study, their nature, and the way in which they were captured.

Table 2
Main activities in which children perform in ASM.

	Girls		Boys		Type of work	
Activities	Yes	No	Yes	No	H	N
Collecting ores on the surface	112	37	252	60	Yes/No	Yes/No
Washing of ores	112	37	231	81	Yes/No	Yes/No
Digging ores out of pits	62	87	154	158	Yes	No
Moving ores within the pit or outside the pit	58	91	117	195	Yes	No
Ore crushing	83	66	190	122	Yes	No
Purchasing of ores	78	71	199	113	Yes/No	Yes/No
Sale of ores	61	88	149	163	Yes/No	Yes/No
Sale of water, food and other items	28	121	75	237	No	Yes
Guarding of mining sites	34	115	82	230	No	Yes
sale or transport of building materials	107	42	212	65	Yes	No

H=Hazardous work; N= Non-hazardous work. Here we list the different activities in which the children are found in the ASMs. Among these activities, we have made a classification according to whether we consider that one activity requires more energy than the other.

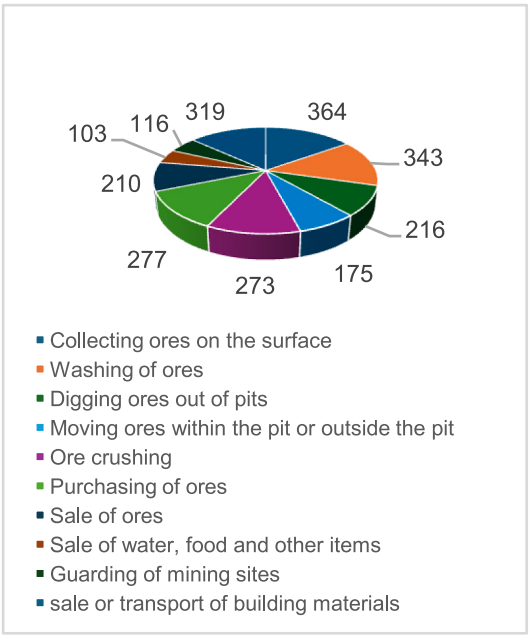

Fig. 1. Main activities in which children perform in ASM in the DRC.

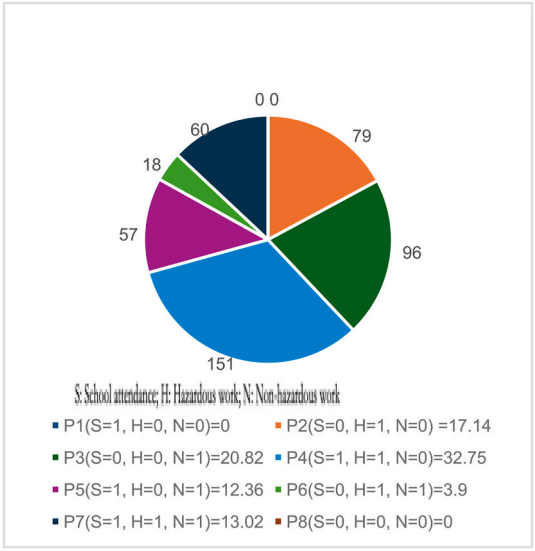

Fig. 2. Conditional probabilities with the eight hypotheses.

activities include mineral collection, where 112 girls out of 149 and 252 boys out of 312 are involved; mineral washing, with 112 girls out of 149 and 231 boys out of 312 participating; and the sale and transport of building materials, which includes the participation of 107 girls out of 149 and 212 boys out of 312. These statistics highlight that children in the DRC's ASM sector are more likely to be engaged in hazardous work. Thus, as we show in Tables 2 and it is not every activity which the child undertakes in and around artisanal mining sites that can be called a hazardous activity. What we call non-hazardous work is light work that can be authorised for children for a limited number of hours and that cannot harm their health, safety or school attendance and achievement.

The results of the conditional probabilities (Fig. 2) show that the probability that the child goes to school and is involved in dangerous activities is very high (32.72 %). The probability that a child works in non-hazardous activities without going to school and without entering dangerous activities is also non-negligible (20.83 %). On the other hand, the probability that the child will not carry out any activity in the mining sites is zero. It means that the child practices at least one of the two sub-study activities.

The lack of understanding regarding child labour dynamics within ASM has resulted in policies and programmes that may negatively impact families who rely on these activities for their subsistence economy. It is important to note that based on this finding, no activity undertaken by a child at mining sites can be considered safe or non-dangerous. According to children from one of the focus groups interviewed, children below the age of 18 refrain from engaging in hazardous work as it is strictly prohibited by the quarry management,

> "As individuals under the age of eighteen, we are prohibited from entering the pits for digging. Instead, we remain here and explore alternative options, such as engaging in activities at the restaurant or depot. This way, we can avoid the physically demanding work that takes place in the pits."

Certainly, these two activities are not mutually exclusive. However, some children are solely engaged in activities that can be described as "light work" by the ILO. There are certain domestic activities seen as light by the ILO that are hard compared with what children do on mining sites. Instead of viewing these activities as child labour, one may see them as a form of learning, especially when they enable children to attend school.

It is important to note that the prohibition on children engaging in hazardous work is primarily enforced in formal sites where their presence is essentially forbidden. The concept of hazardous work in which children are involved in ASM should be re-evaluated. While it is true that artisanal mineral exploitation requires significant physical exertion, categorising all these activities together would be a misjudgment. If a child's survival depends on their involvement at ASM sites, it would be a grave mistake to remove them without implementing other accompanying measures under the claim of protecting them from the worst forms of work. Children's work may play a vital role in contributing to household food security in certain circumstances.

Table 3 presents the descriptive statistics for our three dependent variables for the trivariate probit analysis. About the first dependent variable, over half of the children (275 or 59.65 %) reported attending school during the survey period. Concerning the economic activities carried out by children at mining sites, a majority of them (284 out of 461 or 61.61 %) believed that they were engaged in activities deemed dangerous (second dependent variable), while only 176 out of 461 (38.18 %) considered their involvement as non-hazardous.

5. Econometric results

5.1. School attendance, hazardous and non-hazardous activities

Likelihood ratio tests are used to measure the significance of correlation coefficients. The results of the trivariate probit, GHK simulator outcome (Table 4), show that this null hypothesis is rejected as $\rho12 \neq \rho13 \neq \rho23 \neq 0$ ($\rho12 = -0.1531$; $\rho13 = -0.225$ and $\rho23 = -0.619$). These results provide evidence for a positive relationship between children's school attendance and their engagement in hazardous and non-hazardous activities. Furthermore, the statistical analysis reveals that these relationship coefficients are significant, suggesting strong and reliable findings.

In practical terms, these results indicate that a child attending school does not exclude their involvement in income-generating activities at mining sites. These results show an opposition between child labour and education. Although, the involvement of children in ASM activities can enable children to continue school attendance, but only in the short term. In the long run, many children drop out of school and devote themselves entirely to work that allows them to earn money. "*Ceteris paribus*", it is important that parents face a trade-off between children's schooling attendance and child labour. Subsistence needs force households in the ASM sector, particularly the poorest, to trade child labour for schooling. As there are virtually no schools in these areas, parents make their children work instead of sending them to school. In addition, parents working in artisanal mining have cultural beliefs that negatively influence their decision to send their children to school. The search for a livelihood is often cited as a possible explanation for the presence of children in various ASM activities. Unfortunately, this perpetuates the cycle of poverty as a long-term consequence.

This highlights the specific context in which children live in and around artisanal mining sites in the DRC. This quantitative finding aligns with the experiences on the ground, as some of the interviewed children explained that engaging in such activities is necessary to afford school fees and other expenses. Although participating in-generating activities may increase the risk of dropping out of school in the long run, it is important to consider the challenging circumstances faced by children living in mining areas. Limited access to education often leads them to engage in money-making endeavours as a means of survival. In such difficult contexts where educational opportunities are scarce, it becomes common for children to be involved in income-generating activities alongside their schooling commitments.

Children are conscious of the detrimental consequences associated with their participation in certain activities connected to artisanal mining exploitation, but their options are constrained. This outcome indicates a lack of rivalry between schooling and labour in artisanal mining areas in the short run.

The lack of exclusivity in these three activities is also reflected in one of the children's statements to Numbi,

> "The level of courage varies from person to person. Although I am only 13 years old, I consider myself a grown-up. Despite having ventured down into the pits multiple times before, it does not hinder me from engaging in other activities, like bartering clothes and even selling juices. In this place, nobody is permitted to work except for girls who are strictly prohibited from entering the pits to dig. I attend school in the morning and head to the quarry in the evening to earn some money."

This statement albeit with some minor differences in most outcomes and initiatives aimed at eliminating child labour. Despite the potential negative impact on school achievements, children can engage in both work and schooling simultaneously.

> "Sometimes, when we leave school, we realise that we have not accomplished much. Since the river is close to our houses, we often go there with our friends to search for gold. There are times when we find something valuable and other times when we come up empty-handed. It can be quite exhausting if we spend a lot of time without any success, which can make us wake up feeling tired the next day. Although we may want to skip school as a result, fear of punishment forces us to attend anyway. During holidays, however, we put in a lot more effort since we don't have school obligations. Some of us even work in the evenings or start as early as 5 o'clock in the morning so that we can finish our work by 11 o'clock and still make it to school on time."

Additionally, there is a positive and simultaneous correlation between hazardous and non-hazardous work for children. This means that a child engaged in hazardous work can also be involved in non-hazardous work, and vice versa.

The main control variable 'absence of schools in the region' as an indication of the education system's failure can be analysed at three levels. The negative sign indicates that the lack of school infrastructure within the ASM sector denies many children access to

Table 3
Distribution of the dependent variables.

School attendance				
Yes		No		Total
[a] of observations	% of observations	# of observations	% of observations	[a] of observations
275	59.65	186	40.35	461
ASM Hazardous work rowhead				
284	61.61	177	38.39	461
Non-hazardous work rowhead				
176	38.18	285	61.82	461

These statistics provide further evidence supporting our hypothesis that schooling and artisanal mining activities coexist for children.
[a] means number and % percentage. This table is based on the classification in Table 2 of activities deemed hazardous and non-hazardous.

Table 4
Trivariate probit, GHK simulator on the absence or not of schools in the ASM regions.

	School attendance	Hazardous work	Non-hazardous work
The absence of schools in the region	−0.329[b]	0.142[a]	0.1763[a]
	(0.106)	(0.114)	(0.121)
Intercept	0.372[a]	9.6[a]	−0.369[a]
	(0.074)	(0.081)	(0.089)
Rho ($\rho_{12};\rho_{13};\rho_{23}$)	0.1531[c] (0.078)	0.225[b] (0.076)	0.619[a] (0.083)
Prob > chi2		0.0082	
Wald chi2(3)		11.78	
Log-pseudolikelihood		−870.34	
Observations		461	

Robust standard errors are in parentheses.
[a] *p*<.01.
[b] *p*<.05.
[c] *p*<.1.

education.

To ensure more comprehensive results, additional control variables were introduced (see Table 6). In line with our hypothesis regarding the Congolese artisanal sector, the findings reveal that younger children have a higher likelihood of engaging in non-hazardous activities but a lower likelihood of participating in hazardous ones. When children start working at a relatively young age in mining zones, they are still attending school. Conversely, those who have spent several years in the sector have gained experience and consequently show no desire to leave (which is typically observed among children aged 12 to 17). These children have either dropped out or never enrolled in school.

The relationship between age and children's participation in non-hazardous activities reveals a similar pattern. Younger children tend to be the ones engaging in these economic activities, and this correlation is statistically significant. This can be attributed to the fact that children aged 7 to 13 have not yet fully developed their muscles and are typically not permitted to engage in physically demanding tasks, such as digging pits officially. However, older children, between the ages of 14 and 17, often consider themselves as adults when working at mining sites.

Being an orphan greatly reduces the chances of a child receiving an education. The loss of a parent can be highly demotivating for children in school and may push them to start working to support themselves. This finding challenges the rationality hypothesis put forth by ▣Basu and Hoang Van, who suggest that it is parents who decide whether to send their children into the labour market. Some children even express this sentiment,

Image of a primary school in Kolwezi in Lualaba province

> "(…) parents discourage us from engaging in this activity, but when we go to school and see our student friends also going to the mines to earn money, it encourages us to do the same. Although it is not an easy task, it provides us with financial means. If my father remains adamant about it, I choose to work far away from his workplace so that he won't notice me. I can bring home the money earned, but he may punish me if he discovers my involvement in mining activities. Despite my father's refusal, we still work during holidays. Why should I stay at home when all my friends are out there seeking and finding ways to earn money? After all, it is through such laborious efforts that we can secure our financial needs (….)."

If the child's father and/or mother are deceased, the child may lack the necessary support to pursue their education.

Image of an Adventist school in Numbi in the South Kivu province.

When a family member is involved in artisanal mining, it not only reduces the probability of a child attending school but also raises the chances of their involvement in hazardous activities. A testimonial from children exemplifies this situation,

> "Being with our family members here restricts us from falling into despair; they ensure that our sole focus is on washing minerals. This is the reason why many of our acquaintances prefer to work in isolated areas where no one can control them. However, the issue arises when children are unable to directly sell the minerals to the mining cooperative, leading some youngsters to embezzle money from us. Hence, it becomes crucial to have someone trustworthy by your side."

It is a misconception to classify all activities performed by children in mining sites as hazardous, as many children are there with their families. These children engage in artisanal mining to earn extra income, driven by poverty, which is also the main reason why they are not attending school. However, this perspective needs to be reconsidered in the context of the DRC, where basic education is not free. In some conditions, children can use their earnings from work in the ASM sector to pay for school fees and other expenses.

5.2. The child's educational level and working hours

The children involved in this study range in age from 7 to 17. All the children worked for at least 1 h per week in mining or mining-related activities. The number of hours worked per week varied from 4 to 79, with an average of 37,517 h and a standard deviation of 21,871. These findings indicate that there is no bias caused by sample selection since all observations had non-zero working hours.

However, out of the total of 461 observations, the GAGE variable was zero for 80 observations, which account for approximately 17.35 %. This means that around 17.35 % of the surveyed children either never attended school or are significantly older than their

Table 5
Censored Tobit regression.

	(1)	(2)
	GAGE	GAGE
Total hours per week in logarithm	−8.313[a]	−8.437[a]
	(2.024)	(2.028)
The absence of schools in the region		−6.823[c]
		(3.753)
_cons	67.843[a]	64.625[a]
	(6.78)	(7.008)
/var(e.GAGE)	1559.145[a]	1548.503[a]
	(126.266)	(124.538)
Observations	461	461
Pseudo R^2	0.004	0.005

Robust standard errors are in parentheses.
[a] $p < .01$.
[b] $p < .05$.
[c] $p < .1$.

classmates. Shockingly, statistics reveal that out of the total sample size, around 44 children have never been enrolled in school at all, representing approximately 9.54 %. This result is deeply concerning as it highlights that almost ten per cent of children have not even had the opportunity to receive an education.

These figures emphasise how crucial it is to ensure that every child has access to education as they play a significant role in shaping a nation's future. The fact that such a substantial percentage of children are deprived of educational opportunities shows that achieving universal education remains an unfulfilled aspiration.

The results obtained from the Censored Tobit model (Table 5), using maximum likelihood estimation to adjust for age differences in educational attainment among children, further support these findings. The negative coefficient observed between working hours (logarithmically) and educational attainment indicates that as a child spends more time working at the mining site, their chances of acquiring a satisfactory level of education decrease significantly. In other words, there is a negative impact on school attainment due to increased working hours among children.

The time that a child devotes to activities related to mining conflicts with that devoted to school attainment. However, school attainment does not depend solely on the factor of time spent on activities linked to the artisanal exploitation of ores. When certain activities prevent children from going to school, some parents may choose the outright option of allowing their children to work full-time to the detriment of schooling. Attending school, under these conditions, is seen as an additional expense for parents, as there are school fees that households must bear.

Controlling for the absence of schools in the area, we find that this has a negative and significant impact on a child's educational achievement. This suggests that if schools are not easily accessible, it hampers a child's ability to attain a normal education level. Over the last three decades, the DRC has experienced wars that have had a negative impact on its economic fabric. The country no longer invested in building schools. In addition to this lack of government involvement in providing educational services, the involvement of private and non-profit organisations in building schools should be acknowledged. Non-governmental organisations help in various ways in the field of education. This is for example the case of the training of out-of-school children in informal education.

It is also important to recognise the efforts made by parents who, despite their limited income, make sacrifices to pay for their children's school fees. To show that the results obtained are robust and reduce the effect of missing variable bias, other variables have been added to the model (Table 7). Overall, being an orphan has a negative impact on a child's academic performance. Orphaned children run the risk of having their school attendance interrupted only a few years after their first enrolment. The lack of schools has a much more negative impact on the school attainment of children in Katanga province than in Lualaba and South Kivu. Indeed, Katanga is said to have been the largest mineral-producing province. The discovery of minerals in other provinces only came later. With the liberalisation of the mining sector for the benefit of artisanal miners, many have considered this activity their El Dorado. Several children have thus joined mining activity to the detriment of their school attendance.

Table 6
Trivariate probit, GHK simulator on the absence or not of schools in the ASM.

	School attendance	Hazardous work	Non-hazardous work
The absence of schools in the region	−0.741[a]	−0.209[c]	0.207
	(0.118)	(0.121)	(0.127)
Age	−0.518	−1.064[b]	0.756[b]
	(0.381)	(0.499)	(0.345)
Age2	0.014	0.034[b]	−0.027[b]
	(0.013)	(0.017)	(0.012)
Sex of the child	−0.461[a]	0.038	0.023
	(0.127)	(0.127)	(0.133)
Migrant	−0.060 (0.127)	−0.105 (0.127)	−0.133 (0.132)
Orphan	−0.666[a]	−0.133	0.170
	(0.232)	(0.192)	(0.206)
Lives with family member in ASM	−0.298[b]	0.305[b]	0.213
	(0.139)	(0.136)	(0.142)
Haut-Katanga Dummy	Yes	Yes	Yes
Lualaba Dummy	Yes	Yes	Yes
Sud-Kivu Dummy	Yes	Yes	Yes
Intercept	7.135[a]	9.048[b]	−6.023
	(2.756)	(3.644)	(2.466)
Rho (ρ_{12}; ρ_{13}; ρ_{23})	0.071[b] (0.082)	−0.198[b] (0.084)	−0.579[a] (0.089)
Prob > chi2	0.0000		
Wald chi2(3)	143.92		
Log-pseudolikelihood	199		
Observations	461		

Robust standard errors are in parentheses.
[a] $p < .01$.
[b] $p < .05$.
[c] $p < .1$.

Table 7
Censored Tobit regression between GAGE with more controlled variables.

	All provinces	Haut-Katanga	Lualaba	Sud-Kivu
Total hours per week in logarithm	−8.99[a]	1.148	−4.394	−3.27
	(1.935)	(2.236)	(3.337)	(15.451)
The absence of schools in the region	−6.125[c]	−3.835	−14.863[b]	−6.212
	(3.59)	(4.391)	(6.221)	(6.808)
Age	7.131	16.346	41.869[b]	−68.612[b]
	(13.205)	(17.562)	(16.879)	(31.585)
Age2	−0.433	−0.822	−1.743[a]	2.226[b]
	(0.456)	(0.592)	(0.608)	(1.08)
Sex of a child	2.494	−0.54	10.685	2.038
	(3.879)	(4.694)	(6.658)	(7.528)
Migrant	−0.555	−7.059	−5.029	−0.802
	(3.637)	(4.303)	(8.686)	(6.644)
Orphan	−9.497[c]	7.881	−12.443[c]	−17.136
	(5.55)	(7.56)	(7.107)	(12.917)
Live with his family member in ASM	3.253	−5.611	5.057	−7.446
	(3.829)	(6.793)	(6.469)	(6.82)
Intercept	62.466	−1.56	−171.426	570.326[b]
	(96.46)	(131.387)	(117.971)	(236.634)
/var(e.GAGE)	1424.703[a]	837.228[a]	1024.299[a]	1647.107[a]
	(111.718)	(110.352)	(151.68)	(219.394)
Observations	461	175	109	177
Pseudo R^2	0.012	0.018	0.027	0.014

Robust standard errors are in parentheses.
[a] $p < .01$.
[b] $p < .05$.
[c] $p < .1$.

6. Discussion

Our results show that there is an exclusion between hazardous and non-hazardous child labour. However, some children are solely engaged in activities that can be described as "light work" according to the ILO. Hilson [8] has already argued that there are domestic activities considered light by the ILO that cannot be equated with what children do on mine sites. Instead of viewing these activities as child labour, one may see them as a form of learning, especially when they enable children to attend school [31]. Baland and Robinson [38] have pointed out that a simple ban on child labour does not improve the market balance if the parents who must provide for the family's needs are still in an uncertain financial situation.

It is important to note that the prohibition on children engaging in hazardous work is primarily enforced in formal sites where their presence is essentially forbidden. The concept of hazardous work in which children are involved in artisanal and small-scale mining (ASM) should be re-evaluated. While it is true that artisanal mineral exploitation requires significant physical exertion, categorising all these activities together would be a misjudgment. If a child's survival depends on their involvement at ASM sites, it would be a grave mistake to remove them without implementing other accompanying measures under the claim of protecting them from the worst forms of work. Children's work plays a vital role in contributing to household food security [19].

Statistical results indicate that a child attending school does not exclude their involvement in income-generating activities at mining sites. These results contradict several previous findings [14,29,33] showing an opposition between child labour and education. This highlights the specific context in which children live in and around artisanal mining sites in the DRC. This quantitative finding aligns with the experiences on the ground, as some of the interviewed children explained that engaging in such activities is necessary to afford school fees and other expenses. Although participating in-generating activities may increase the risk of dropping out of school in the long run [45], it is important to consider the challenging circumstances faced by children living in mining areas. Limited access to education often leads them to engage in money-making endeavours as a means of survival [13]. In such difficult contexts where educational opportunities are scarce, it becomes common for children to be involved in income-generating activities alongside their schooling commitments. Owusu et al. and ILO with UNICEF [2,29], emphasise that child labour within ASM communities leads to high dropout rates.

When we analyse the weakness of the education system through the absence of schools, we find that such a system can encourage children to work instead of studying. Hossain [20] points out that if an education system lacks clear plans and a structured curriculum, may hinder the development of children's skills and competencies in the refugee in Bangladesh context. It is important to note that families involved in mining activities reside in remote areas. Moreover, the few schools that do exist are either located far away or lack proper resources. The deteriorating condition of these schools can also be demotivating for parents, children, and even teachers. This is why Admassie [5] explains that the lack of educational opportunities in certain regions can worsen the problem of child labour. This is also the case when the education system does not allow all children to enjoy the right to education [18]. In addition to the lack of adequate infrastructure, there is also the presence of unqualified teachers. This can also harm children's education. As noted by Hossain [20], the lack of competent teachers leads to poor learning outcomes. Njieassam [18] adds that the failure of the education system is one of the generally ignored causes of child labour in ASM sites.

Our results also highlight the fact that it is older children who work more on mining sites, generally, those who are already well-developed physically. Edmonds [33] discovered that older children tend to work more than their younger counterparts. In the ASM sector, there are cases where children may lack birth certificates, making it difficult to determine their exact age. Hence, a child can falsely declare their age. The absence of such documentation can contribute to the prevalence of child labour, as highlighted by Nkuba et al. [12]. The robustness of this result remains consistent regardless of the specification and sample utilised. When examining the results based on gender, it is evident that boys are frequently less inclined to attend school compared to girls. However, it is important to approach this finding with caution as it may not be immediately evident and requires careful consideration. It is well-established that mining areas have fewer girls and women [8]. However, Njieassam [18] emphasises that if nothing is done urgently, many more children will be seriously affected by child labour's scourge shortly.

Findings from Tobit model suggest a negative impact on school attainment due to increased working hours among children. For Faber et al. [16], children who work in artisanal mines generally underperform in school compared to those who do not work. Apart from the fact that the work is tiring, working in mines can expose children to toxic substances which have serious consequences on the nervous system, which in the long run can affect their intellectual capacity. Ahad et al. [28] underline that a child working in the informal sector (where they can be exposed to maltreatment) can lead to the long-term development of psychological trauma and therefore prevent the child from enjoying their future. These results align with previous studies [14,36], which also suggest an inverse relationship between the amount of time children spend working and their educational performance. It is like the adage that says: "You cannot chase two hares at a time". In his research conducted in the artisanal and small-scale gold mines of Tanzania, Metta et al. [13] found that there are parents who encourage their children to not perform well in their studies. Living in an area where schools are a long way from home can harm children's school attainment and reinforce the phenomenon of child labour. André and Godin [17] highlight that inadequate public investment in education is one of the contributing factors leading to increased child labour instead of attending school in the DRC. Murhi Mihigo et al. [45] reinforced this assertion by showing that the fact that parents have to pay for their children's schooling increases the likelihood of children working to the detriment of school attendance.

7. Conclusion, implication, and limitations

7.1. Conclusion

This study has focused on the nature of child labour in ASM sites across three provinces of the DRC. The objective was to understand the various activities children are involved in and how this affects their education. The literature often presents a negative perspective on working conditions within the ASM sector without distinguishing between different activities. In contrast, our research demonstrates the need to re-evaluate international opinions on this matter. We found that children engage in various activities at ASM zones, some of which are hazardous while others require reclassification as non-hazardous work.

Our findings show that children living near artisanal mining areas are at risk of becoming involved in these activities themselves. Thus, many children juggle both work and schooling. However, there is a negative association between working and attending school. Therefore, we conclude that there is a trade-off between children's work and education within ASM sites in the DRC context. Indeed, the involvement of children in activities linked to the artisanal mining sector can enable children to continue school, but only in the short term. In the long run, many children drop out of school and devote themselves entirely to work that allows them to earn money. All things remaining equal, it is therefore important that parents face a trade-off between children's schooling attendance and child labour. The long distances children must travel to reach school highlight inadequate educational infrastructure within mining areas. This paper contributes to the existing literature by revealing that not all activities involving children can be categorised as highly hazardous within the ASM sector. However, our results show that several other elements are worth analysing in the research that follows.

7.2. Implications

Public policies should focus on identifying regions lacking schools or basic social services where children have no choice but to work. In such conditions, it is crucial to improve access to free education for all children regardless of age or gender within artisanal mining sectors while also removing barriers hindering access. To ensure that children have access to education, governments should invest in schools and educational resources in mining areas. Companies involved in the extraction and commercialisation of mining goods must also be held accountable for their social responsibilities. Because a fraction of ores extracted artisanally are in the same circuit as those extracted industrially, mining company requirements must incorporate this dimension and invest in the battle against the presence of children in artisanal mines. Public awareness campaigns and vocational training programmes can help prepare young people for future employment. Child labour can be avoided by closely monitoring mining activities and establishing strict rules on firms. Public-private partnerships can assist in the development and implementation of effective policies, in the provision of resources for education and the construction of school facilities, as well as in the development of a clear and contextualised list of all risky practices in ASM areas. On ASM sites, many children (especially those aged between 15 and 17) can no longer attend formal school. It is therefore important that the public authorities, together with the local community, organise informal education (so that they learn to read and write at least) so that these adults of tomorrow do not see their future as a nightmare. Raising awareness is important for households living in and around ASM sites. It is appropriate to explain to them the short- and long-term danger that children may experience by working to the detriment of school attendance.

7.3. Limitations

Future research should compare working versus non-working children at artisanal mining sites in the DRC. It is important to understand how children's economic activities affect their schooling and performance, as well as compare various activities beyond those directly linked to artisanal mining. A new analysis of child labour will shed light on the work-education trade-off and highlight living conditions within artisanal mining sectors as a determining factor for child labour. Poverty can be seen as an indirect influence on child labour in these areas, sparking further debate and necessary exploration of this issue. It is therefore crucial to consider these diverse perspectives when formulating policies and interventions to address child labour effectively.

Data availability statement

The data used in this document is available on request from the corresponding author.

CRediT authorship contribution statement

Isidore Murhi Mihigo: Writing – review & editing, Writing – original draft, Visualization, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Guillaume Vermeylen:** Writing – review & editing, Visualization, Validation, Supervision, Project administration, Methodology, Conceptualization. **Deogratias Bugandwa Munguakonkwa:** Writing – review & editing, Supervision, Project administration.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Isidore Murhi Mihigo reports financial support was provided by Enabel-DRC and US Department of Labour. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e30771.

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