Economics of Child Mining Labor: Estimation of Corporation's Profits

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Abstract

This article estimates the contribution of child labor to the production of mined minerals and calculates the profit made by manufacturers involved in the supply chains of child-labor minerals. Several thousands of children in the Democratic Republic of Congo (DRC) work in the artisanal and small-scale mines under dangerous conditions to extract a variety of minerals, including those used in the fabrication of modern electronics. But there is no detailed data on the scope of productivity of child-miners, the value of their production at the world market, and the profit made by those buying and using their minerals. The lack of data on this issue is occasioned by the quasi-secrecy surrounding the supply chains of child-labor minerals. The paper uses a simple method of estimation based on economic assumptions and available data to calculate the contribution of child-miners in the DRC to the cobalt production at the national and international level, and to estimate the profit made by electronic manufacturers that use cobalt tainted with child-labor in their products.

Résumé - Economie du travail des enfants dans les mines: Estimation des bénéfices des sociétés

Cet article évalue la contribution du travail des enfants à la production de minéraux et calcule les bénéfices réalisés par les manufacturiers impliqués dans les chaînes d'approvisionnement des minéraux émanant du travail des enfants. Plusieurs milliers d'enfants, en République Démocratique du Congo (RDC), travaillent dans des conditions dangereuses dans les mines artisanales et à petite échelle pour extraire plusieurs variétés de minéraux, en ce compris ceux utilisés dans la fabrication des appareils électroniques modernes. Cependant, il n'existe pas de données détaillées sur la portée de la productivité des enfants travaillant dans les mines, la valeur de leur production sur le marché mondial, ainsi que les bénéfices réalisés par ceux qui achètent et d'utilisent leurs minéraux. L'inexistence de données sur cette question est occasionnée par le quasi-secret qui entoure les chaînes d'approvisionnement des minéraux provenant du travail des enfants. Ce papier utilise une méthode d'estimation simple basée sur des hypothèses économiques et des données disponibles aux fins de calculer la contribution des enfants en RDC dans la production de cobalt sur le plan national et international, et d'estimer les bénéfices réalisés par les manufacturiers des appareils électroniques qui utilisent du cobalt entaché de la main-d'œuvre enfantine dans leurs produits.

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Introduction

The term "child labor" refers to work that deprives children of their childhood, their potential and their dignity, and that is harmful to physical and mental development.[2] The recent statistics from ILO reveals that there are about 162 million child-laborers in the world,[3] and more than half of them work in hazardous industries, such as mining.[4]

In the Democratic Republic of Congo (DRC), the prevalence of child labor is very high in the artisanal and small-scale mines. Although the lack of official data on the number of all child-miners in the country, local and international organizations working in the field of child protection estimate that children represent about 40% of laborers in artisanal mines.[5] This is the case in the cobalt artisanal mines in the DRC's province of Katanga where out of 100,000 to 150,000 artisanal-miners,[6] 40,000 to 55,000 of them are children.[7]

The DRC ratified a number of international instruments protecting children against labor exploitation including the UN Convention concerning Minimum Age for Admission to Employment of 1973 (No 138)[8] and the Convention against the Worst forms of Child Labor of 1999 (No 182).[9] At the domestic level, the country also adopted laws and regulations prohibiting child labor and worst forms of child labor including the Law on the Protection of the Child of 2009, the Labor Code of 2002, and the Ministerial Order of August 2008 regulating the Working Conditions of Children in the DRC. The country's Law on the Protection of the Child establishes the minimum age for employment at 16 years, and sets some

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[2]ILO, "Child Labour: A Textbook for University Students", p.16. Available at: http://www.ilo.org/ipec/facts/lang--en/index.htm (last accessed 12 June 2014).

[3] ILO, "*Marking progress against child labour - Global estimates and trends 2000-2012*" (ILO-IPEC, 2013). Available at: http://www.ilo.org/global/topics/child-labour/lang--en/index.htm (last accessed 11 June 2014)

[4] Ibid.

[5] World Vision, "Child Miners Speak: Key Findings on Children and Artisanal Mining in Kambove DRC" (March 2013), p.10. See also: R.C. Liwanga, "Child miners face death for tech". Available at: http://thecnnfreedomproject.blogs.cnn.com/2013/06/26/child-miners-face-death-for-tech/

[6] S. Nordband and P. Bolme, "Powering the Mobile World: Cobalt Production for Batteries in the Democratic Republic of Congo and Zambia" (November 2007), pp.30-32.

[7] Ibid. See also: UNICEF, "In DR Congo, UNICEF supports efforts to help child labourers return to school". Available at: http://www2.unicef.org:60090/infobycountry/drcongo_62627.html.

[8] The UN Convention concerning Minimum Age for Admission to Employment of 1973 (No 138), ratified by the Democratic Republic of Congo June 20, 2001

[9] The UN Convention against the Worst forms of Child Labor of 1999 (No 182), ratified by the Democratic Republic of Congo on June 20, 2001.

restrictions concerning the nature of work to be performed by children.[10] Children aged between 16 and 18 years old are prohibited from engaging in dangerous or unhealthy work.[11] The Ministerial Order regulating the Working Conditions of Children in the DRC lists mining work in the catalogue of dangerous activities for children.[12]

Despite the legal prohibition, numerous children are still involved in mining activities. This may be explained by the fact that the root causes of child mining labor in the DRC are mainly linked to poverty and a lack of free schools which together forces children to drop-out of school and begin working. Countless children work along with their family members or for themselves in the DRC mines while others work for mine-traders who supply them with cash advances or tools, and to whom they have to sell their mined minerals at very low prices.[13] The working conditions in the artisanal mines are dangerous and unhealthy for children, exposing them to the risk of fatal accidents and injuries. Child-miners in the DRC exploit a variety of ores, including coltan, cobalt, gold, diamond, and cassiterite, among others. Some of these minerals, of which the DRC possesses some of the world's greatest reserves such as coltan and cobalt,[14] are fundamental materials in the fabrication of modern electronics.[15] For instance, cobalt is used to produce batteries for smart-phones, laptop, tablets, electric hybrid vehicles and others.

While the supply chains of child-mined minerals can be mapped (from child-miners to intermediaries to smelters to export to world market to manufacturers), the scope of child productivity and the profit made by those buying and using child minerals are still unknown. The principal difficulty encountered with quantifying child production and estimating the profit made from child labor is that the quantity of minerals produced by child-miners in the DRC are not recorded and are often mixed with minerals not tainted by child labor before being indistinctly exported, processed or sold at the world market. This bundling of minerals from

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[10] Article 50 of the Law 09/001 of January 2009 on the Protection of the Child. See also Article 6(2) of the Law 015-2002 of October 2002 on the Labor Code.

[11] Article 54 of the Law 09/001 of January 2009 on the Protection of the Child.

[12] Article 13 of the Ministerial Order No 12/CAB.MIN/TPSI/045/08 of August 2008 regulating the Working Conditions of Children in the Democratic Republic of Congo.

[13] US Department of State, "Trafficking in Persons Report 2011-Country Narratives" Available at: http://www.state.gov/j/tip/rls/tiprpt/2011/164231.html

[14] University of Michigan, "Computer Industry Impacts on the Environment and Society". Available at: http://sitemaker.umich.edu/section002group3/coltan_mining_in_democratic_republic_of_the_congo.

[15] Ibid. See also: Amnesty International, "Exploitation in the DRC fuels mining trade: Apple, Dell look the other way". Available at: http://blog.amnestyusa.org/business/exploitation-in-the-drc-fuels-mining-trade-apple-dell-look-the-other-way//

different production sources makes it almost impossible to disaggregate the minerals produced by child labor from the rest. Additionally, smelters or electronic/ automobile manufacturers, who source directly or indirectly from child-miners, never disclose data on the total revenue for the sale of their products or parts of devices tainted with child labor.

The knowledge of the child mining productivity in the DRC and the profit generated from using child-labor input is very important because it helps to persuade those unethically benefiting from child labor to change their policies, through tracing their supply chains, providing financial incentives to poor families to send their children to schools, and supporting local authorities to improve educational systems.[16] For that purpose, this paper assesses the economic profit of child mining labor in the DRC by: 1) estimating the quantity of minerals produced by child-miners and the value of child-miner's production at the world market, and 2) calculating the profit made by the smelters and manufacturers involved in the supply chains of child mined minerals. The paper uses a simple method of estimation based on available data and basic economic assumptions. In estimating the corporation's profits for using child mined minerals in their products, this study focuses its analysis on one type of ore [cobalt], one kind of electronic device [the smart-phone], and one electronic manufacturer [Apple]. The rationale for choosing cobalt is because cobalt ores are used to make batteries for smart-phones, which are some of the most popular consumer devices. Likewise, the preference for Apple as a case study is solely motivated by the availability of Apple's published data on the production of its smart-phones.[17]

This paper is divided into two sections. The first section relates to the understanding of the context of child mining labor in the DRC. It provides an overview of the mining industry in the DRC, tracks down the root causes of child mining labor, and assesses the consequences of mining activities on children. The second section deals with the financial side of child labor. It addresses the issues of child-miner's productivity, and calculates the profit made by electronic manufacturers involved in the supply chains of child mined minerals.

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[16] V Edmonds and N Pavcnik, "Child Labor in the Global Economy" (2005), Vol. 19, Num. 1, *Journal of Economic Perspectives*, pp.199-220.

[17] It is very important to mention that this paper is not intended to assert that Apple uses child labor or to show the amount of financial benefit that Apple receives from child labor. This study could also focus on any electronic or automobile manufacturers that use cobalt ores in all or part of their products.

I. Understanding the context of child mining labor in the DRC

I.1. Overview of the mining industry

The mining sector in the DRC currently accounts for about 12% of the country's GDP.[18] Before the adoption of the 2002 Mining Code, state-owned mining companies had a monopoly of mining exploitation in the country. With the adoption of the new Mining Code, the monopoly of state-owned companies was suppressed, and artisanal mining exploitation was legally recognized.[19] Consequently, the mining industry in the DRC is now divided into two sectors: industrial mining which is dominated by state-owned and private companies that use industrial and modern methods of mining exploitation; and artisanal mining that uses rudimentary methods to extract and process minerals, and dominated by cooperatives of artisanal miners.

Mining exploitation in the DRC is conducted in the mines and quarries owned by state-owned mining companies, private companies that have signed partnership contracts or joint-ventures with state-owned companies,[20] and cooperatives of artisanal miners having received artisanal mining zones (*zone d'exploitation artisanale*) from the government.[21]

With regard to the artisanal mining zones, the Mining Code stipulates that these zones should be created where mineral deposits are not suitable for industrial or semi-industrial exploitation but are still viable and lucrative for artisanal mining.[22] Not surprisingly, in the circumstances where some artisanal mining zones have geological problems, many artisanal miners (illegally) take over "abandoned" or "unexploited" mining lands belonging to industrial mining companies to conduct their mining activities. There are also cases where industrial mining companies authorized artisanal miners to extract minerals from their mining lands in exchange for selling their products to those companies.

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[18]Michigan State University, "The Democratic Republic of Congo: Economy". Available at: http://globaledge.msu.edu/countries/democratic-republic-of-the-congo/economy (last accessed 11 June 2014).

[19] Article 109 of the Law 007/2002 of July 2002 on the Mining Code.

[20] With the liberalization of the mining exploitation in DRC, state-owned companies (such as Gecamines and MIBA) signed numerous partnership contracts or joint-ventures with private companies (Congolese and foreigners) in order to exploit deposits located within their mining concessions.

[21] The artisanal mining cooperatives are associations of artisanal miners that conduct artisanal mining exploitation in artisanal mining zones allocated to them by the Ministry of Mines. Unlike the public/private mining companies, artisanal miner's cooperatives are legally considered to be nonprofit organizations (Association sans but lucrative "ASBL") rather than mining companies. Artisanal miners are free to join any cooperative of their choice. However, many artisanal miners have not adhered to cooperatives, and they work independently.

[22] Article 109 of the Mining Code.

As stated above, in addition to their poor level of mechanization and lack of minimum standard of health and safety, artisanal mines are characterized by the large presence of children, aged between five and 17 years. There is no official data on the number of artisanal miners, both children and adults, operating in the DRC. The Mining Code requires adult artisanal-miners to hold valid cards authorizing them to conduct artisanal mining[23] but very few of them possess those cards, making their identification difficult. According to the World Bank, there are approximately two million artisanal miners across the DRC,[24] and child protection NGOs estimate that 40% of artisanal miners are children.[25] Child-miners are involved in all processes of mining exploitation, including digging, sifting, washing and transporting ores. Indeed, mining extraction in the artisanal mines is conducted by bare hands and feet, and with picks, shovels and buckets. Child-miners also use heavy metal tools to crush ores, which are transported on head or shoulder from the mines to the rivers, which serve as washing sites. Many child-miners interviewed said that they work more than 8 hours per day and earn between $0.75 and $3 per day.[26] These working conditions are dangerous and unhealthy for children and expose them to the risk of fatal accidents, injuries and sicknesses.

Even though the Mining Code distinguishes industrial mining from artisanal mining, both sectors are not separated in practice. Many industrial mining companies buy minerals from artisanal miners to supplement their production. The supply chains of minerals coming from the artisanal mines can be illustrated as below.

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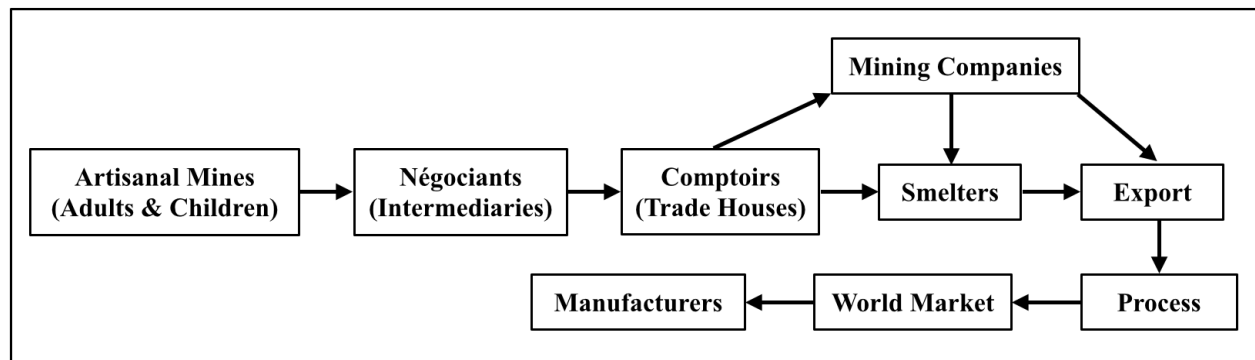
[24] World Bank, "Democratic Republic of Congo Growth with Governance in the Mining Sector" (May 2008), Report No. 43402-ZR. Available at: https://openknowledge.worldbank.org/bitstream/handle/ 10986/8072/434020Revised010Box327409B01PUBLIC1.txt?sequence=2 (last accessed 11 June 2014).

[25] World Vision, "Child Miners Speak: Key Findings on Children and Artisanal Mining in Kambove DRC" (March 2013), p.10.

[26] R.C. Liwanga, "Child Miners Face Death for Tech". Available at: **http://thecnnfreedomproject.blogs.cnn.com/ 2013/06/26/child-miners-face-death-for-tech/**

As illustrated above, artisanal- miners, including child-miners, extract raw ores and sell them to *négociants* (intermediaries), *négociants* re-sell the minerals to trade houses (*comptoirs*), smelters or mining companies purchase minerals from the *comptoirs*, and they then either slightly process the raw ores or export them to be (further) processed and sold on the world market.

After providing an overview mining industry in the DRC and the role of child-labor, the paper will now examine the reasons driving children to work in the mines.

I.2. Causes of child labor in the mines

The principal reasons driving children into mines in the DRC include poverty, lack of educational opportunities, and lack of legal enforcement.

A. Poverty and socio-cultural factors

The DRC ranks 228 out of 229 on the list of countries by GDP (gross domestic product) per capita,[27] and 73% of its active population is unemployed.[28] Additionally, the World Bank reports that more than 71% of the DRC's population is living on less than $ 1.25 per day.[29] In this context of poverty, poor families living in the mining regions are forced to work in artisanal and small-scale mines as a principal source of revenue. Children are often encouraged to work to contribute to the household's income. Some children work along with their parents, while others work alone to take care of their own basic needs.

Community norms also influence the decision of children to work in the mines. Child labor has become a social norm in some mining regions in the DRC to the extent that society tolerates children's involvement in mining activities and non-worker children are sometimes subjected to derogative epithets. For example, in some communities in the DRC's province of Katanga, non-worker children are called *wabulé* (meaning derogatively a weak or useless person in the Swahili language), in contrast to *mwana-umé* (meaning a "brave child") which is used to

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[27] CIA, "The World Factbook" Available at: https://www.cia.gov/library/publications/the-world-factbook/rankorder/2004rank.html (last accessed 11 June 2014).

[28] AFDB/OECD 2012, "Congo, Democratic Republic" (2012) Available at: http://www.africaneconomicoutlook.org/fileadmin/uploads/aeo/PDF/Congo%20Democratic%20Republic%20Full%20PDF%20Country%20Note.pdf (last accessed 12 June 2014).

[29] Ibid.

describe children who work in the mines and contribute to the family's household income.[30]

B. Lack of educational structure

The DRC Constitution guarantees free and compulsory primary education for every child.[31] Unfortunately, these constitutional provisions are not yet fully enforced. There are no schools in most remote mining areas, and where schools exist, primary education is often not free. Primary school-aged children are often required to pay school fees in both private and public schools, and if they cannot pay they are forced out of the school. Some child-miners try to both work in the mines and attend school. These structural issues with the education system have contributed to children to work in the mines and to a dramatic decrease in school enrollment in the country, falling from 90% in the 1980s to 58% in 2008.[32]

C. Lack of legal enforcement

The Labor Code and the Law on the Protection of the Child prohibit children from engaging in dangerous and unhealthy work, including mining labor.[33] Articles 162 and 187 of the Law on the Protection of the Child respectively punish cases of child trafficking with imprisonment up to twenty years, and cases of the worst forms of child labor with imprisonment up to three years. Despite the existence of these legal provisions, no single prosecution has ever been initiated against child labor offenders.[34] Impunity of child labor offenders permits the persistence of child exploitation in the mines in the DRC. Three reasons explain the impunity of perpetrators of child mining labor offenses, namely: the inefficient training of law enforcement to investigate and prosecute cases of child labor offenses;[35] the

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[30] R.C. Liwanga, "Adopting an Anti-Human Trafficking Law in the DR Congo: A Significant Step in the Process of Combating Trafficking" (2014), Vol. 1, Iss.1, *Slavery Today Journal- A Multidisciplinary Journal of Human Trafficking Solutions*, pp.13-45.

[31] Article 43(5) of the Constitution of the Democratic Republic of Congo of 2006.

[32] UNESCO, " L'évaluation de l'éducation pour tous à l'an 2000 : République Démocratique du Congo". Available at: http://www.unesco.org/education/wef/countryreports/congo_dem/rapport_2.html (last accessed 12 June 2014).

[33] Article 53 of the Law on the Protection of the Child; Article 3 of the Labor Code.

[34] R.C. Liwanga, "Adopting an Anti-Human Trafficking Law in the DR Congo: A Significant Step in the Process of Combating Trafficking" (2014), Vol. 1, Iss.1, *Slavery Today Journal- A Multidisciplinary Journal of Human Trafficking Solutions*, pp.13-45.

[35] Ibid.

corruption within the justice system;[36] and the conflict between the need to survive versus the application of the rule of law which leads law enforcement officers to opt not to prosecute parents who exploit the labor of their own children for the best interest of the children.

I.3. Consequences of child mining labor

Mining labor has negative physical, psychological and developmental effects on children. The worst working conditions in the mines expose child-miners to the risk of injuries, sicknesses and fatal accidents. Many children are killed due to soil collapses while extracting minerals underground. [37] Others are infected with pneumonia for inhaling dust in the mines, or dysentery or toxic diarrhea for drinking non potable water in the mines.[38] A report from PACT also revealed cases where child-miners were injured due to rock falls in the mines, which left some of them with physical deformation preventing them from the possibility of working again in the future.[39] Additionally, girl child-miners are often sexually harassed by men and boys in the mines, and are often infected with HIV and AIDS or undesired pregnancies.[40] Children working in mines often dropout school or have irregular school attendance when school fees cannot be paid, limiting the child-miner's hope for a better life.[41]

II. Financial side of child labor

This section analyzes the economics of child mining labor. As previously mentioned, children are involved in the exploitation of numerous types of minerals in the DRC, but for the purpose of this study, the paper focuses exclusively on the exploitation of cobalt ores. This section seeks to answer the following questions: what is the estimate of the quantity of cobalt that child-miners produce in the

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[36] Ibid.

[37] R.C. Liwanga, "Child miners face death for tech" CNN Freedom Project: Ending Modern-Day Slavery, June 26, 2013. Available at: http://thecnnfreedomproject.blogs.cnn.com/2013/06/26/child-miners-face-death-for-tech/ (last accessed 26 June 2014).

[38] World Vision, "Child Miners Speak: Key Findings on Children and Artisanal Mining in Kambove DRC" (March 2013), pp.29-31. See also: J Sweeney, "Mining giant Glencore accused in child labour and acid dumping row". Available at: http://www.theguardian.com/business/2012/apr/14/glencore-child-labour-acid-dumping-row (last accessed 26 June 2014).

[39] PACT, "Breaking the Chain: Ending the Supply of Child-mined Minerals" (2013), p.24..

[40] Ibid.

[41] Ibid.

DRC? And what is the approximate profit made by electronic manufacturers involved in the supply chains of cobalt produced by child-miners?

II.1. Estimation of child cobalt productivity

In order to determine child's cobalt productivity in the DRC, the paper uses a simple method of estimation based on available data. It also assumes the child's daily production as a quasi-fixed factor.

A. Facts

The World Production of cobalt in 2012 was estimated at 110,000 tons (T),[42] of which 60,000 tons were produced by the DRC alone (representing 55% of the World Production).[43]

According to the World Bank, about 75-80% of the DRC production of cobalt comes from artisanal mining.[44] Additionally, approximately 100,000 to 150,000 people work in the cobalt artisanal mines in the DRC,[45] of which 40,000 to 50,000 are children.[46]

B. General assumptions

Assume that C_p represents the total quantity of 60,000 tons (T) of cobalt produced by the DRC in 2012, and that C_{pa} corresponds to 75% of the DRC production of cobalt coming from the artisanal and small-scale mines. If we multiply C_p by 75%, we can calculate the exact value of C_{pa}. The following equation calculations can be made:

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[42]U.S. Geological Survey, "Mineral Commodity Summaries" (2013). Available at: http://minerals.usgs.gov/minerals/pubs/commodity/cobalt/mcs-2013-cobalt-pdf.

[43] Ibid.

[44] World Bank, "Democratic Republic of Congo Growth with Governance in the Mining Sector" (May 2008), Report No 43402-ZR, pp.56-57. See also: E&MJ, "Mining in the Democratic Republic of Congo: A Journey to Africa's Mineral Heartland". January 2013, pp.4-5.

[45] S. Nordband and P. Bolme, "Powering the Mobile World: Cobalt Production for Batteries in the Democratic Republic of Congo and Zambia" (November 2007), pp.30-32.

[46] Ibid. See also: UNICEF, "In DR Congo, UNICEF supports efforts to help child labourers return to school". Available at: http://www2.unicef.org:60090/infobycountry/drcongo_62627.html.

$C_{pa} = C_p \times \dfrac{75}{100}$. This implies $C_{pa} = \dfrac{60,000T \times 75}{100} =$ **45,000T** of cobalt produced by artisanal miners (Equation 1).

Assume e is the total number of 45,000 children working in the cobalt artisanal mines, and that each child-miner produces 0.5kg of cobalt per day (c/d).[47]

Assume that C_{pe} is the quantity of cobalt produced by of each child-miner per year. If we multiply (c/d) by 365 (representing the number of days per year), we can calculate how many of C_{pe} there are.   The following equation calculations can be made:

$C_{pe} = c/d \times 365\,days$. This implies $C_{pe} = 0.5kg \times 365 =$ **182.5 kg** per child per year (Equation 2).

Assume that Ct_{pe} is the total quantity of cobalt yearly produced by all child-miners (e). If we multiply C_{pe} by e , we can calculate how many of Ct_{pe} there are.   The following equation calculations can be made:

$Ct_{pe} = C_{pe} \times e$. This implies $Ct_{pe} = 182.5kg \times 45,000 =$ **8,212,500 kg (or 8,212.5 T)** (Equation 3).

Based on the above calculations, about 8,212.5 Tons of cobalt were produced by child-miners in 2012. This represents approximately 14% of the DRC's total production and 7.5% of the World total production of cobalt.

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[47] The 0.5 kg of cobalt is a quasi-fixed factor that one assumes as a daily production of each child-miner. This assumption is just to facilitate the calculus of the approximate cobalt production by child-miners; and it should not be understood that every child-miner only produces 0.5kg of cobalt per day. In fact, most of the child-miners that the author interviewed in artisanal mines in the DRC's province of Katanga between January and February 2013 alleged that their daily production of *heterogenite* (which is a mineral rich in cobalt and copper ores) is much higher than 0.5kg.

II.2. Electronic manufacturer's profit from child labor

Under this section, the corporation Apple is used only as a case study to estimate the profit made by electronic manufacturers using child-tainted cobalt in the process of making their devices. It is understood that cobalt is used as the principal material to produce batteries for numerous electronic items; but in this case, the focus is made only on smart-phones. Therefore, Apple's total profit from child's cobalt is estimated by using simple method of calculation taking into account the company's data on its total revenue for the sale of iPhones, the quantity of iPhones sold, and the assumption of the quantity of iPhones containing child's cobalt.

A. Facts

The combined quarterly reports from Apple for the year 2013 reveal that the company sold about 150,257,000 iPhones and made about $ 91,279 million revenue for the sale of those iPhones alone.[48]

According to Oeko-Institute, there are 6.3 grams (g) of cobalt in batteries per smart-phone (including iPhone).[49]

B. General assumptions

Quantity of tainted materials used

Assume that Q is the quantity of cobalt used by Apple in the batteries of its 150,257,000 iPhones (iP), and that one iPhone's battery contains 6.3 g of cobalt (c_o). If we multiply iP by c_o, we can calculate how many of Q are used. The following equation calculations can be made:

$Q = iP \times c_o$. This implies Q = 150,257,000 x 6.3 g = **946,619,100 g (or 946.6 tonnes)** (Equation 4).

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[48] Apple, "2013 Unaudited Summary Data". Available at: http://images.apple.com/pr/pdf/q1fy13datasum.pdf. See also: http://images.apple.com/pr/pdf/q2fy13datasum.pdf, http://images.apple.com/pr/pdf/q3fy13datasum.pdf, and http://images.apple.com/pr/pdf/q4fy13datasum.pdf.

[49] Oeko-Institut e.V.. "Recycling critical raw materials from waste electronic equipment" (2012), pp.38-39. Available at:http://www.oeko.de/oekodoc/1294/2011-419-en.pdf.

Assume that only 1% of the cobalt used by Apple for its iPhones' batteries was coming from the DRC (Q_1). If we multiply Q by 1%, we can calculate how many of Q_1 are used. The following equation calculations can be made:

$$Q_1 = Q \times \frac{1}{100}.$$ This implies $Q_1 = \frac{946,619,199\,g \times 1}{100}$ = **9,466,191 g** (Equation 5).

Assume that only 14% of the 1% of the DRC cobalt (used by Apple) was tainted with child labor (Q_2). If we multiply Q_1 by 14%, we can calculate how many of Q_2 are used. The following equation calculations can be made:

$$Q_2 = Q_1 \times \frac{14}{100}.$$ This implies $Q_2 = \frac{9,466,191\,g \times 14}{100}$ = **1,325,266.7 g** (Equation 6).

Assume that iP_1 represents the number of the tainted iPhones (which are produced with child labor's cobalt), and that one iPhone contains 6.3g of cobalt (c_o). If we divide Q_2 by c_o, we can calculate how many of iP_1 are produced. The following equation calculations can be made:

$$iP_1 = \frac{Q_2}{c_o}.$$ This implies $iP_1 = \frac{1,325,266.7}{6.3}$ = **210.359.8 tainted iPhones** (Equation 7).

Profit made with tainted iPhones

Assume that R corresponds to the revenue of $91,279 million that Apple made by selling all of its 150,257,000 iPhones (iP) in 2013, and that Rm represents Apple's revenue for selling a single iPhone. If we divide R by iP, we can calculate the value of Rm. The following equation calculations can be made:

$$Rm = \frac{R}{iP}.$$ This implies $Rm = \frac{\$91,279,000,000}{150,257,000}$ = **$607** (Equation 8).

Assume that c represents Apple's costs in producing a single iPhone (including costs of parts, labor, distribution, intellectual property, and others), which is equal to 60% of the revenue made from selling one iPhone. If we multiply Rm by 60%, we can calculate the exact value of c . The following equation calculations can be made:

$$c = Rm \times \frac{60}{100}.$$ This implies $c = \dfrac{\$607 \times 60}{100}$ = **\$364** (Equation 9).

Assume Gp is Apple's gross profit for a single iPhone, and that Rm is Apple's revenue of \$607/iPhone and c represents the total costs for producing an iPhone. If we subtract Rm from c, we can calculate the value of Gp. The following equation calculations can be made:

$$Gp = Rm - c.$$ This implies $Gp = \$607 - \$364 =$ **\$243 per iPhone** (Equation 10).

Assume that out of all parts that comprise an iPhone (such as display screen, circuit board, keyboard, batteries and frame), the batteries (b) alone represent 11 % of the value of the iPhone;[50] and that Gp_1 is Apple's profit coming solely from the value of iPhone's batteries per iPhone sold. If we multiply Gp by b , we can calculate the value of Gp_1. The following equation calculations can be made:

$$Gp_1 = Gp \times b.$$ This implies $Gp_1 = \dfrac{\$243 \times 11}{100} =$ **\$26.73 per batteries per iPhone** (Equation 11).

Assume that P_e is Apple's profit for selling its 210,359.8 iP_1 (iPhones containing batteries made with cobalt tainted with child labor). If we multiply Gp_1 by iP_1, we can calculate the value of P_e . The following equation calculations can be made:

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[50] The Apple's online store advertises that the batteries' replacement for an iPhone costs \$79. See: http://www.apple.com/batteries/replacements.html (last accessed 24 July 2014).

$$P_e = Gp_1 \times iP_1$$. This implies $P_e = \$26.73 \times 210,359,8 =$ **\$5,622,917**
(Equation 12).

Based on the above calculations, Apple has made total profit of $ 5.6 million in 2013 selling iPhones with parts tainted with child mining labor. This amount may seem to be insignificant given the company's total annual revenue which is evaluated in billions of dollars. Nevertheless, it should be noted that the above estimated profit made from child-labor input only relates to one type of device produced (iPhone) and one part of that device (battery). In other words, electronic manufacturer's profit coming from child mining labor may be much higher if one takes into account that 1) child-labor cobalt is also used to produce batteries for the rest of devices such as tablets, laptop and others; and 2) despite the use of cobalt for batteries, child-miners also extract coltan ores which are utilized to make other parts of electronic devices including the circuit boards for smart-phones.

Conclusion

The purpose of this paper was to estimate the contribution of child labor to the production of mined minerals and calculate the annual profit made by manufacturers involved in the supply chains of child-labor minerals. This exercise was carried out using the simple method of estimation based on basic economic assumptions and available data on artisanal mining in the DRC.

According to the results, child-miners contributed approximately 14% of the DRC's total cobalt production and 7.5% of the world production of cobalt in 2012. The calculations also demonstrate that electronic manufacturers gain a yearly profit of several millions from the purchase of minerals tainted with child labor or for their use of child mined minerals in their electronic devices, such as smart-phones.

As mentioned earlier, the author chose to use Apple as a case study to estimate the profit made by electronic manufacturers using child-tainted cobalt in their products due to the wealth of data that the company provides to the public. Even though it is evidenced that child mined minerals are sold at the world market, it should not be understood that this paper suggests that Apple or its battery suppliers definitively sources all or parts of their cobalt ores from the DRC's artisanal mines where there is a prevalence of child labor. This paper only states that it is statistically likely, partly due to Apple's market share, that a significant amount of its raw minerals have been tainted in its production process.

The lack of transparency in the supply chains of child-labor minerals makes it difficult to determine the actual quantity of child minerals used by each electronic manufacturer. Therefore, all corporations involved directly or indirectly

in the supply chains of child-labor minerals should adopt effective policies to map the origins of their materials, ensure that they are free from child labor, and encourage their competitors in the industry to do the same.