MINING A MIRAGE?

Reassessing the shared-value paradigm in light of the technological advances in the mining sector

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International Institute for Sustainable Development

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September 2016

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Perrine Toledano, Jeff Geipel and Martin Dietrich Brauch

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Executive Summary

Introduction

The concept of shared value is becoming a linchpin of the modern mining sector. It goes beyond companies focusing on community investment and philanthropy approaches, and argues that firms can bring value to both themselves and their host communities, regions and countries by any of three different means:

1) Reconceiving products and markets, innovating to ensure that their products serve market needs and do as little harm as possible.
2) Redefining productivity in the value chain, looking for improvements in logistics and in the use of energy and other resources.
3) Building supportive industry clusters at the company's locations, focusing on mutually beneficial improvements in infrastructure, supplier capacity and human resources.

In this paper, we consider what changes in technology might mean for the third of these avenues, focusing specifically on the ways in which firms add value to economies through their procurement of goods and services, and through employment. These categories of expenditures in our two case studies amounted to 30 per cent and 80 per cent respectively of total expenditure, while payments of royalties and taxes to government—a category of value on which there is often greater focus—amounted to 3 per cent and 15 per cent respectively.

Any disruptions to these major streams of expenditure may have important repercussions: the shared-value paradigm, by promising to deliver benefits to host communities, regions and countries, has become increasingly critical for mining companies in securing their social licence to operate.[1] The delicate balance inherent in the shared-value paradigm is especially relevant for developing countries and other states where poverty eradication, social development and environmental protection are urgent development challenges.

The research question we ask in this paper is: *In the near and medium terms, what will happen to the local employment and procurement components of the shared-value paradigm—and, by extension, to the mining companies' social licence to operate—if technological change radically alters the amount of money mining firms are spending on hiring, procurement and other practices regarded as creating shared value?*

Technological Advances Driving Automation

Recent decades have seen ample productivity-increasing innovations at mine sites, such as larger, more durable and efficient shovels, haul trucks, crushers, grinding mills and flotation cells; and better chemistry to improve processing recoveries. In the long run, we will probably see technologies or practices that will radically change how mining is done, such as deep-sea mining, asteroid mining and microbe mining. Given the fundamental uncertainty and long-term nature of such technologies, we do not focus on them in this study, instead assessing new technologies that are being piloted today, which will be carried forward in the near-to-medium term. These technologies include:

1. *Autonomous haul trucks and loaders*: One person alone can already remotely operate a small fleet of these autonomous trucks. Improvements in software are likely to allow this to be performed even more efficiently by algorithm-driven computer programs. Driverless technology can lead to a 15 to 20 per cent increase in output, a 10 to 15 per cent decrease in fuel consumption and an 8 per cent decrease in maintenance costs.

[1] Social licence to operate is defined herein as a minimum and broad-based level of legitimacy, trust, acceptance and support of local stakeholders (including the host community, local leaders and civil society organizations) that a mining company requires for the operation of a mine.

2. *Autonomous long-distance haul trains*: Technologies are being piloted that allow long-haul trains carrying bulk commodities to run fully automated from the mine site to the port.
3. *Tele-remote ship-loaders*: Fitted with video cameras, thermal imagers, lasers and sensors, tele-remote ship-loaders are operated from a control room with a line-of-sight view. This type of automotive technology is unlikely to have an adverse net impact on employment, given that the operator is just moved from the cabin of the ship-loader to the control room, but the skill set changes.
4. *Semi-autonomous crushers, rock breakers and shovel swings*: These machines reduce the size of large rocks and scoop up the ore at the location of extraction. The mobile crusher performs two tasks simultaneously as it transfers the crushed rock directly for processing via conveyors, eliminating the need for haul trucks within a mine.
5. *Automated drilling and tunnel-boring systems*: These are used in open-pit mining and exploration activities. One operator can monitor up to five machines from a remote monitoring station. The remote operator needs only an interface with the machine to tell in what order the drill pattern should be drilled. The tunnel-boring machines significantly reduce the time, cost and risks involved to build and expand an underground mine. They are likely to halve the number of contractors involved in drilling and blasting, and those required during the construction phase.
6. *Automated long-wall plough and shearers*: This technology is being implemented in the coal mining sector. Before automation, workers manned the long-wall roof supports on hydraulic jacks, called shields. Similar to the automation of blast-hole drills, remote operation keeps workers out of harm's way near the drills and potential falling debris.
7. *Geographic information systems (GIS) and Global Positioning Systems*: GIS is now commonly used in almost all aspects of mining, from initial exploration to geological analysis, production, sustainability and regulatory compliance. Over time, however, as the use of GIS becomes more evenly dispersed on a global scale, old procedures for mine surveying will become redundant. Automated positioning systems can manage and improve the safe operation of heavy equipment such as dozers, drills, excavators, loaders, scrapers, graders, soil compactors, off road trucks and light vehicles.
8. *Autonomous equipment monitoring*: Using many different technologies, from cameras and thermal imaging to self-aware machinery able to report its progress, equipment monitoring is extremely important, as preventive maintenance workers can make up a large proportion of the workforce on a mine site.
9. *Programmable logic controllers (PLCs)*: Flexible PLCs are digital computers that typically automate industrial electromechanical processes and replace relays, timers, counters and sequencers. They are an enabling tool for improved process control. Once installed, they can be reprogrammed to improve the control of processes across the full spectrum of industry activity. This technology is the most crucial in the automation revolution and arguably the most important in taking away semi-skilled onsite jobs.
10. *Control systems*: Offsite control rooms are becoming bigger and more complex as mines become automated. Today, only mining companies with the most advanced technology have control systems that employ a substantial number of workers.

It is difficult to predict the speed at which these technologies will be rolled out, but the automation literature suggests that we are entering an era in which the availability of automation technology is accelerating rapidly. The technologies described above, all of which are in use now, are likely to reach their peak rates of deployment in the next 10 to 15 years. The commodity price downturn seems to have accelerated the move towards automation as companies are looking to increase mining productivity while reducing spending on staff, capital and energy.

Types of Occupations Most Affected and New Ones Created

New technology will change the nature of mining personnel tasks, whereby workers become passive supervisors of the process rather than active operators of equipment. Automation will reduce the number of operational jobs in areas such as drilling, blasting, and train and truck driving—areas that typically constitute over 70 per cent of employment in mines.

New roles will be created in the development, observation, servicing and maintenance of remotely controlled autonomous equipment as well in data processing and systems and process analysis. Consequently, workers with specialized skills in remotely controlled and automated systems will be in demand as automation increases, while current employees will need retraining, re-education or both to keep their jobs.

Results

There are many ways in which we might assess the impacts of a mining operation on its host community and host country, standard among which are:

- GDP, or gross value added: the amount of economic value the mining operation brings to the economy
- Employment: the number of jobs created by the mining operation
- Government revenues: the amount of revenue generated for the host governments by the mining operation.

We will use these three metrics in the analysis. Using expenditure data furnished by two companies and four mines—one located in a lower-middle-income country and three in a high-income Organisation for Economic Co-operation and Development (OECD) country[2]—we will estimate the magnitude of impacts to be expected in a typical mining operation.

This will necessarily be an imprecise exercise, and Appendix 1 lays out our assumptions and caveats. Ultimately our aim is to give the best possible indication of the magnitude of impacts to be expected, given the constraints.

The Baseline Cases

Both case study firms are mining entities, with some basic processing (concentration), and both have total annual expenditures exceeding USD 600 million.

The distinction between local and international procurement is worth noting.[3] For the high-income OECD country mines, local procurement amounted to 58 per cent of total operational expenditures. The lower-middle-income country operation, by contrast, procured only 12 per cent of its goods and services within the host country.

The Impacts of Automation

While there is not enough research into the impacts of automation on the size of the mining workforce, we have two broad estimates on which to base our scenarios. McNab et al. (2013) suggest that introducing fully autonomous equipment "would reduce the workforce of a typical open-cut, iron-ore mine by approximately 30 to 40 per cent." In another report, Accenture (2010) evaluates the economics of three types of equipment (trucks, dozers and drills),

[2] The companies involved have agreed to share procurement and other data with the researchers only on the condition that their names and commercially sensitive details be kept confidential.
[3] In this paper we define *local* as sourced within the country of operations.

suggesting that automation could reduce the number of operators in open pit mines by up to 75 per cent. We build three scenarios of workforce reduction through automation, bracketing the two estimates cited above with rates of 30, 50 and 70 per cent. Doing so involves going through the detailed procurement accounts for each firm and deciding which would be sensitive to changes in workforce size.

Beyond the impacts of workforce reduction, we noted above that driverless technology using equipment under control (EUCs) will have impacts by saving on fuel consumption. Spence (2014) estimates that driverless technology can bring about a 10 to 15 per cent decrease in fuel consumption. We assume a 12.5 per cent decrease in diesel consumption in our scenarios. In addition, assuming that haul trucks in the mine are using EUCs and using the rate calculated by Fortescue in its iron mines in Australia, an extra 2.3 per cent in fuel savings could be achieved if they are installed in trucks (Australian Government, Department of Resources, Energy and Tourism, 2014). As such, we assume that mines could save 14.8 per cent in fuel used for hauling if they implement autonomous systems and EUCs. We also assume that 50 per cent of diesel in our sites is dedicated to hauling (a conservative estimate), and therefore subject to reduced demand under automation.

GDP Impacts

We combine the three scenarios (reductions in workforce of 30, 50 and 70 per cent) with savings of 14.8 per cent in fuel locally purchased. The highlights of the GDP impact results are:

- Impacts relative to total procurement are small: local procurement drops by 2, 3 and 4 per cent in the high-income OECD case, and in the lower-middle-income country case, the corresponding figures are 6, 9 and 11 per cent.
- Absolute impacts may be significant, particularly in the local communities: between USD 7.2 million and USD 15.8 million less spent in-country in the high-income OECD case, and between USD 4.6 million and USD 8.9 million less spent in the lower-middle-income country case.
- Worker-related procurement, such as housing expenditure, is the most significant element of the predicted reductions. Fuel savings are relatively small.

These results only cover a portion of the total impacts of mining automation, as they include neither the direct loss of wages and salaries for mine employees, nor the indirect and induced impacts of reduced spending.[4]
These elements are introduced in turn below.

Including salaries and benefits paid to mining workers in the analysis gives us:

- In the high-income OECD case, the mines' contribution to GDP in the three scenarios drops by between 9 and 20. The corresponding reductions for the lower-middle-income case are higher: from 13 to 31 per cent.
- While procurement drops in all three scenarios, the impacts of reduced payroll are much more significant. In the high-income OECD country case, reduction of wages and benefits are responsible for 86 per cent of impacts; and in the lower-middle-income country case, they are responsible for 92 per cent.

[4] Indirect impacts result from the spending that suppliers must do to meet direct demand from the mining operation. Induced impacts are the result of consumer spending by employees of the mine.

When we add both indirect and induced effects to the analysis, we get the following results:

- An absolute reduction in contributions to the national economies of the host countries ranging from USD 92 million to USD 284 million.
- As a percentage of GDP in the respective host economies, this translates into small impacts: at most just exceeding 0.01 per cent in the high-income OECD. In the lower-middle-income country, the percentage is higher, ranging from just below 2 per cent to just below 4 per cent of national GDP.
- In terms of reductions to the overall value contributions made by the individual mining operations, the results are more significant: In the high-income OECD case, the percentage decrease ranges from 8.5 to 19.6 per cent, while the lower-middle-income country range is from 6.2 to 14.1 per cent.

Note that procurement and employment are not the only way that mining operations contribute to the well-being of their host communities, regions and countries. As discussed above, the shared-value paradigm also conceives of other important classes of spending—on infrastructure like roads that are shared by the general public, for example, or on downstream processing and beneficiation operations. It is not envisioned that automation will significantly affect these categories of spending.

Employment Impacts

Another way of assessing the impacts of mining expenditure is by measuring the number of jobs created.[5] Direct employment in the high-income OECD country was 1,457 jobs, of which all were domestic. We estimate this number increases to 4,801 when indirect and induced effects are considered. In the lower middle-income country, the corresponding figures are 2,550 jobs, of which 2,470 are domestic, and 5,100 jobs if indirect effects are considered.[6]

These baseline case figures for jobs created can be modified using the three scenarios for job loss to get a picture of the types of impacts automation might have in terms of employment. Only direct and indirect effects are considered; if induced effects were included the numbers would be higher.

- Job loss in the high-income OECD country ranges from 1,016 to 2,372.
- Job loss in the lower middle-income country ranges from 1,530 to 3,570.

Government Revenue Impacts

The final category of impact is government revenue. This includes taxes, royalties and dividends paid by the firm to all levels of government in the host state. We also include, separately, estimated value of personal income tax paid by employees as a result of mine employment. We have assumed that the former will not change significantly as a result of automation, though that assumption is surely wrong: we expect automation to increase profitability, and corporate income tax and dividends are linked to profits. It would be difficult, however, to make any meaningful estimates as to their magnitude and nature, as they will depend so critically on the specific context of each operation.

In the baseline case, government revenues from payments made to government and personal income taxes of mine employees are twice as high in the lower-middle-income country case, driven by higher payments to government. Employee personal income tax rates are almost double in the high-income OECD case, and the average salary is twice as high, but that is not enough to mitigate the effect of the large difference in direct government payments; the latter are 4.5 times higher in the lower middle-income country case.

[5] Employment is expressed in terms of full-time equivalent staff and does not count foreign head office employment or contractors.
[6] We were unable to derive an estimate of induced employment effects, not having an appropriate employment multiplier.

The impacts of automation on the baseline cases, considering direct, indirect and induced effects:

- In the high-income OECD country, higher wages and higher personal income tax rates make the lost tax revenue much more significant, with a range of reduction from 25 to 58 per cent
- In the lower-middle-income country case, the corresponding reductions are much lower at 6 to 15 per cent.
- In absolute terms, the reduction in government revenues, including direct, indirect and induced personal income tax revenues, ranged from USD 7.6 million to USD 17.8 million in the lower-middle-income country case and from USD 31.7 million to USD 74.0 million in the high-income OECD country case.

Conclusions

Our analysis suggests that host countries will be increasingly at risk of reduced socioeconomic benefits from mining as existing new technologies are further rolled out. The impacts will be primarily in terms of lost local employment and personal income tax revenue, but will also come from reduced employment-related local procurement.

The significance of these impacts will vary from case to case. At first blush, several factors seem to indicate that the effects will be more significant in developed countries, since baseline local procurement is higher there, as are personal income taxes, and since labour-saving technologies will be more quickly deployed where wages are highest. That said, there are reasons to believe that developing countries will feel the impacts more strongly, since more of them are over-dependent on the extractives sector, since adapting to change demands financial and technical capacity that many developing country governments lack, and in light of the expected shift from low-skills to high-skills jobs. As well, even though wage levels are lower in developing countries, there still may be incentives to introduce labour-saving technology; reducing employment there may serve other objectives, such as addressing skills shortages or circumventing strong unions. Finally, it is likely that the mine of the future will involve decreased local equipment-related procurement, as new, more complex operating systems are imported and serviced under contract from abroad.

We noted that much of the social licence to operate may depend on the degree to which the shared-value proposition holds true. As such, the predicted drop in benefits derived from local procurement and employment should be a concern for firms and host countries and communities alike. It should also be a warning of the need for firms and governments to focus on other ways in which mining can contribute to the host economy and host communities.

Outside of the realms of procurement and employment, there are four other avenues through which shared value can be created:

1. *Downstream (forward) linkages* relate to the beneficiation of extracted commodities through refining, smelting and further downstream processing of the commodity before reaching the final consumer.
2. *Horizontal (lateral) linkages* relate to the development of new non-mining-related industries adapting the capabilities developed to serve the mining-related value chain.
3. *Knowledge (technological) linkages* relate to the transfer of knowledge and technological know-how to state-owned companies, the employees of the mine and to the labour force involved in the mine's value chain.
4. *Spatial (infrastructure) linkages* relate to the benefits associated with the infrastructure developed for an extractive-industry project (such as railways) profiting other actors in the economy.

The potential for each of these linkages is very context specific, and none is simple to realize. However, the trends surveyed above enhance the importance of assessing these alternative types of linkages.

There might also be efforts to revise the fiscal element of shared value. Most straightforward would be the passive receipt of the increased taxes, dividends and possibly royalties that should come from automation-driven improvements in productivity and profits. This may come in the form of higher tax levels on profits, or higher royalties on production.

There may also be options for governments that pursue newer approaches to managing the fiscal regimes in relation to mining by, in particular, adopting fiscal regimes that are more progressive with respect to prices, costs and time, and that tax away the rent as a resource rent tax would do.

Another set of options involves changes to the fundamental relationship between investor and host governments, with the latter considering new ownership structures ranging from, for example, increasing their equity share to maintaining full ownership of the resource and mining operation. These would imply more fundamental changes and alternatives to the prevalent concession agreement model, changes that have already been more common to the oil and gas sector. This could include forms of production-sharing agreements or fee-for-service contracts, for example. New combinations of changing ownership and contractual models may also arise. While none of the possibilities discussed here is straightforward, this set of options involves approaches with a record of successes and failures, and the lessons of history (both positive and negative) will be important for governments exploring these routes.

It is worth noting that government ownership of the resource would likely expand options for enhancing value in other parts of the shared-value paradigm, especially if linked with other government policies on training and local economic development. This would be subject to realistic appraisals of how to optimize value without putting at risk the value of the mining operation itself.

One clear lesson not explicit in the analysis above stems from the lack of readily available data on procurement. We found it exceedingly difficult to access data from companies on the kinds and volumes of goods and services they purchase at mine sites, for a host of reasons, despite good intentions on the part of a large number of firms. Similar projects and research the authors have engaged with have encountered similar challenges. Those problems go well beyond creating challenges for the present study. Not understanding what mining companies purchase locally has negative implications for corporate management, partnership building and government policy-making. A good starting point might be an effort by the industry to standardize the reporting in this area, if not for the sake of internal intelligence then in pursuit of ways to salvage the shared-value proposition.

There is clearly a need for further research in this area, both in confirming our basic findings and in exploring the nuances of the relationship we have identified. Does it matter, for example, if we are looking at open-pit or underground operations? Would different minerals yield significantly different results? It would also be interesting to explore more fully the relationship between the host country income level and the impacts of technology, both confirming the distinctions we observed and considering middle-income or emerging country cases; our two cases are situated toward the ends of the country income spectrum.

We expect that more research will sharpen our sense of what to expect as the advent of new technologies changes the way mining investment interacts with host countries, regions and communities. The better we understand the changing realities, the better both firms and host countries can ensure the continued relevance of the promise of shared value.

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1.0 INTRODUCTION

1.0 INTRODUCTION

The concept of shared value has become a linchpin of the modern mining sector. It has become a core concept to ensure that resource-rich countries gain the maximum benefit from the extraction of their resources, while ensuring that the private sector has a legitimate opportunity to extract the resources on a for-profit basis.

At its heart, the notion of shared value pertains to the sustainable development of the host state and host community. It involves issues of local procurement of goods and services, local employment, downstream uses of natural resources, uses of other resources surrounding the mine and mining community, and government revenue.

The delicate balance involved in the development of the shared-value paradigm, reviewed in more detail below (Section 2), is especially relevant for developing countries and other states where poverty eradication, social development and environmental protection are critical development challenges. The McKinsey Global Institute (2013) identified that in 2011 there were 81 resource-driven economies—where the mining and oil and gas sectors represent a significant part of GDP, exports and government revenue. The vast majority are developing countries, and almost 80 per cent have a per capita income below the global average. Roughly 69 per cent of the people living in extreme poverty in 2010—843 million people—were in resource-driven countries (McKinsey Global Institute, 2013). These figures illustrate the development challenges of resource-rich countries and explain the expectation that, through the application of the shared-value paradigm, the mining sector would bring substantial developmental benefits to large populations.

Beyond widespread endorsement and use by the industry, the shared-value paradigm has become ubiquitous in the literature and public discourse about mining and sustainable development. It has become a mainstay of major mining policy frameworks, such as the Africa Mining Vision (African Union, 2009), the Mining Policy Framework (Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development [IGF], 2012) and the Organisation for Economic Co-operation and Development's (OECD) Framework on Public-Private Collaboration for in-Country Shared Value Creation from Extractive Projects (OECD, 2016). Industry organizations such as the International Council for Mining and Metals (ICMM) also reference the shared-value concept in their good practice guidance (see, for example, ICMM, 2015). Furthermore, leading civil society organizations working in the area of mining and sustainable development have fully subscribed to it (see, for example, Columbia Center on Sustainable Investment [CCSI], 2015; Wilson & Kuszewski, 2011, published by the International Institute for Environment and Development [IIED]; International Institute for Sustainable Development [IISD], 2014; Natural Resource Governance Institute [NRGI], 2015).

At the same time, the mining industry has been embarking on an unprecedented research and development program to vastly increase the use of high technology in the sector (as described in further detail in Section 3 below). This could lead mining companies to depend more on high-technology suppliers and skills that are only available in their home economies or in other more advanced economies; they would rely less on local labour, suppliers of goods and services, and other resources in the host community and state. Thus, technological improvements could drastically reduce the opportunities identified in the literature for mining companies to create shared value that supports the sustainable development of host communities and states, particularly through employment and procurement.

In this paper, we examine whether the local employment and procurement components of the shared-value paradigm will be able to survive the ongoing and expected technological improvements in the mining sector and, if so, how it may need to adapt so that high-technology mining companies may still be able to create shared value. Our analysis questions whether the paradigm is a viable policy framework for the future, or whether it is a strategy that would have worked in old-style labour-intensive mines but cannot work in new-style mines based on high technology and automation. Is the mining industry embarking on technological processes that will make the local employment and procurement components of the shared-value paradigm obsolete, causing the sustainable development benefits of the activity to disappear—like a mirage?

Specifically, the research question we ask is: In the near and medium terms, what will happen to the local employment and procurement components of the shared-value paradigm—and, by extension, to the mining companies' social licence to operate—if technology change radically alters the amount of money mining firms are spending on hiring, procurement and other practices regarded as creating shared value?

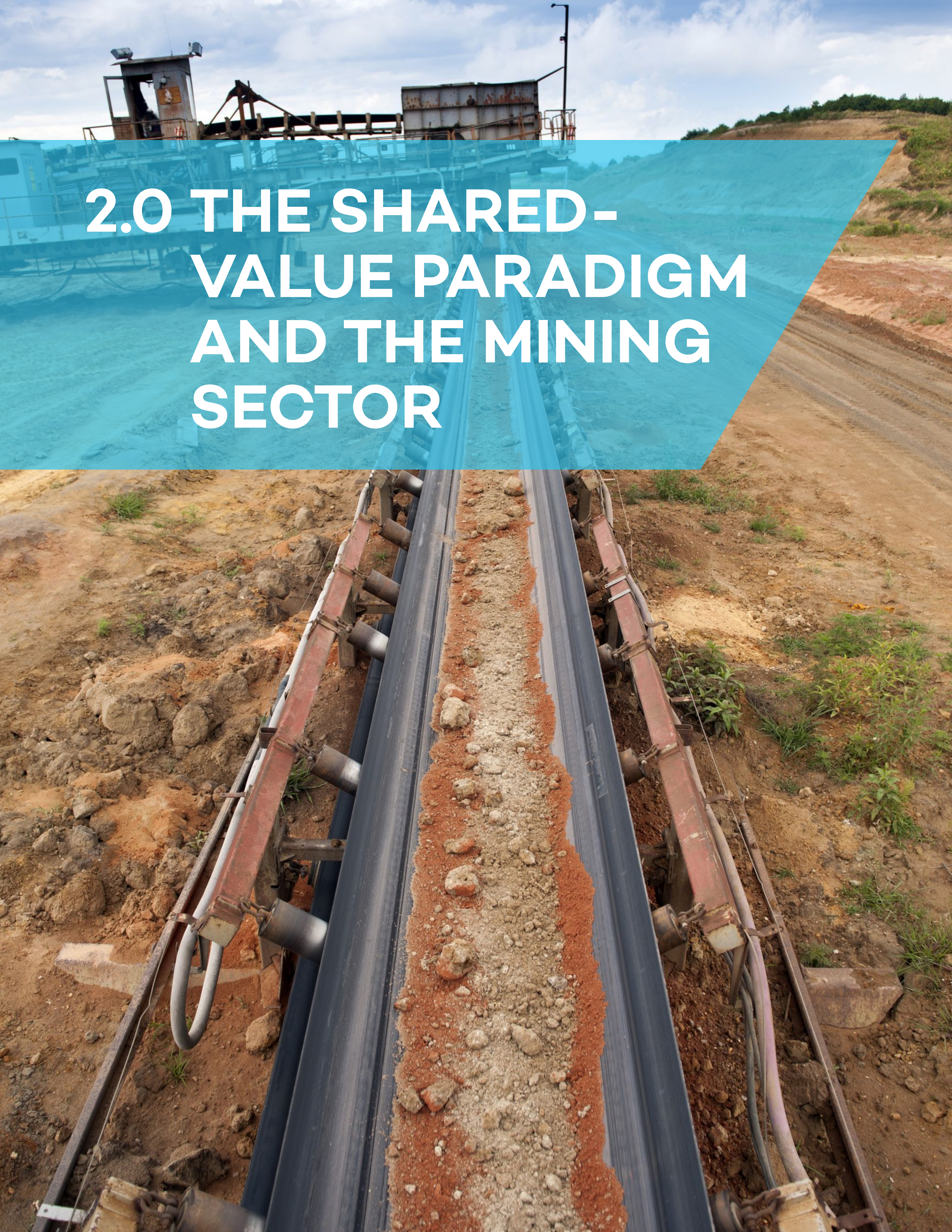
The issue is critical for all stakeholders:

- It is essential to local communities and generally to citizens of resource-rich countries, who expect their natural resources to generate value that supports their development objectives.
- Mining companies must consider whether and how they contribute meaningfully to addressing societal concerns—much beyond the goal of generating profits for their shareholders—as a requirement to earn and keep their social licence to operate.[7]
- Civil society organizations may need to reassess their level of commitment to the local employment and procurement components of the shared-value paradigm, asking whether they have become complicit in endorsing a paradigm that in the future will be unable to deliver as promised.
- It is also important to governments at the local and national levels, as they formulate and implement policies: if technological change significantly affects the shared-value paradigm, does this imply the need to change policies such as performance requirements, whose success is based on exploiting the gains from an increasingly smaller source?

In this paper, we explore these issues by first examining the shared-value paradigm and its application to the mining sector (Section 2). We then assess the impending technology changes in the mining sector (Section 3) and consider their implications on local employment and procurement, critical components of the shared-value paradigm. Our analysis, laid out in Section 4, suggests that these implications will be towards significant downward trends in numbers of employees, and less opportunity for local procurement of good and services. Given this result, we turn to some options that governments and industry ought to consider (Section 5), whether separately or in partnership, to address what we see as the likely impacts of seeking to implement technological improvements in a shared-value paradigm. Appendix A lays out the assumptions we made and caveats necessary in view of the difficulties we encountered in obtaining relevant data—a challenge facing researchers as well as policy-makers who aim to study the impacts of technological shifts and other significant changes at the macro-level.

[7] Social licence to operate is defined below as a minimum and broad-based level of legitimacy, trust, acceptance and support of local stakeholders (including the host community, local leaders and civil society organizations) that a mining company requires for the operation of a mine.

2.0 THE SHARED-VALUE PARADIGM AND THE MINING SECTOR



2.0 THE SHARED-VALUE PARADIGM AND THE MINING SECTOR

Shared value goes beyond companies focusing on community investment and philanthropy approaches, and argues that firms can bring value to both themselves and their host communities, regions and countries through enhanced local procurement of goods and services, local employment, downstream uses of natural resources, uses of other resources surrounding the mine and mining community, and government revenue.

2.1 From Corporate Social Responsibility (CSR) to Creating Shared Value (CSV)

Companies have long attempted to use community investment and philanthropy to create benefits for the societies in which they operate. In many cases, these initiatives have arisen in response to external pressure to make companies responsible for correcting the failures resulting from economic activities conducted to the detriment of the society's broader economic, social and environmental concerns.

Porter and Kramer (2006, 2011) propose going beyond philanthropic approaches unrelated to the firm's core business rationale and activity. The authors (2006, p. 84) first suggest a so-called "strategic corporate social responsibility" (CSR) framework, introducing the concept of shared value—"a meaningful benefit for society that is also valuable to the business." Later they develop the concept further, proposing creating shared value (CSV) as a paradigm intended to supersede what they see as the narrow business logic of profit maximization and CSR, as they define it[8]:

> The concept of shared value can be defined as policies and operating practices that enhance the competitiveness of a company while simultaneously advancing the economic and social conditions in the communities in which it operates. Shared value creation focuses on identifying and expanding the connections between societal and economic progress. (Porter & Kramer, 2011, p. 6)

The shared-value paradigm recognizes that the factors of successful long-term business performance include not only financial aspects, but also consumer and societal needs, community concerns, environmental sustainability and well-functioning supply chains, among other elements. It considers that markets are defined by societal needs just as well as by conventional economic needs. According to the authors, if businesses take decisions based on the shared-value paradigm, they can generate innovation and growth for the benefit of companies and society in an integrated manner (Porter & Kramer, 2011).

[8] In their work Porter and Kramer (2011) define CSR as consisting of philanthropic approaches including donations and community investment. However, several commentators (see, for example, Crane, Palazzo, Spence & Matten, 2014) argue that their portrayal of CSR in this way is an intentional "straw man" definition that narrows it to these philanthropic approaches and point out that most other definitions include general corporate behaviour and ethics.

More specifically, Porter and Kramer (2011, p. 7) indicate that shared value can be created through business activity under three categories of opportunities: "by reconceiving products and markets, redefining productivity in the value chain, and building supportive industry clusters at the company's locations."

To create shared value by reconceiving products and markets, companies should constantly look at the needs, benefits and harms embodied in their products, and explore opportunities for market innovation, repositioning and expansion. For example, reaching underserved markets (consumers in poor and disadvantages communities, in both developing and developed countries) could generate large societal benefits and substantial company profits (Porter and Kramer, 2011).

Redefining productivity in the value chain, the second category of shared-value creation, can be done through improvements in logistics and in the use of energy and other resources (water, raw materials, packaging). Adopting better technologies, reducing or rationalizing the use of resources and promoting recycling practices can create shared value across the value chain. Companies can also help develop marginalized suppliers—through providing access to inputs, technology and financing—thus encouraging them to improve their quality and guaranteeing growing volume of supply. Porter and Kramer (2011) offer examples of shared-value creation through rethinking procurement strategies, distribution practices, employee productivity incentives and locational choices.

The third way to create shared value, according to Porter and Kramer (2011), is to enable the development of local clusters, in view of the recognition that a company's performance depends on the surrounding infrastructure and supporting companies. To help develop clusters, the companies should try to identify local gaps in areas including infrastructure, suppliers and educational institutions; consider which areas represent the greatest constraint to the company; and assess where the company may create shared value by direct influence or in collaboration with other actors.

Criticized by few (Beschorner, 2014; Crane, Palazzo, Spence & Matten, 2014; Hartman & Werhane, 2013), the shared-value proposition gained broad endorsement in the literature as an important development in business management (see, for example, Ajith, 2014; Atiq & Karatas-Ozkan, 2013; Palmer, 2012; Pfitzer, Bockstette & Stamp, 2013; Pharoah & Walker, 2015; Solís & Moroka, 2011).

In this paper, when we refer to shared value, we mean opportunities to align society's interests with core business objectives and expertise. We do not, however, presume that such opportunities exist in all cases, or that shared value can in all cases obviate the need for the philanthropic version of CSR (Geipel, 2015).

2.2 Making the Shared-Value Paradigm Work in the Mining Sector

The categories indicated by Porter and Kramer (2011) for creating shared value translate into tangible opportunities for mining companies. They can create shared value in their activities by conducting local procurement of goods and services and supporting the development of local suppliers; creating local employment; developing local skills through education and training; building or improving local infrastructure and logistics networks; supporting local enterprises for downstream uses of natural resources; and ensuring stable sources of tax and royalty revenues for governments (Dodd, Jakobsen, Dietsche & Macdonald, 2015; Hidalgo, Peterson, Smith, & Foley, 2014).

The literature and the mining industry itself increasingly recognize that mining companies must obtain and maintain the so-called social licence to operate (Mann, 2015). The concept, difficult to define and still evolving, can be understood as the minimum and broad-based level of legitimacy, trust, acceptance and support of local stakeholders (including the host community, local leaders and civil society organizations) that a mining company requires for the operation of a mine (Mann, 2015; Dodd et al., 2015).

By enabling mining companies to use their activities and resources to contribute meaningfully to the sustainable development of host communities, the shared-value paradigm became key for mining companies to secure their social licence to operate. Many mining companies have endorsed the paradigm, embracing it as a chance to regain the trust they had lost as communities increasingly blamed their activities for economic, social and environmental problems. The literature provides a wealth of examples of how mining firms can engage and have engaged in creating shared value through their activities (see, for example, Bastida, 2014; Hidalgo et al, 2014; Hope & Kwarteng, 2014; Svensson & Barnard, 2015).

Figure 1 illustrates the importance of a broad understanding of how the mining sector can contribute to the well-being of local communities and host states. If we take these expenditures as, in rough measure, typical of a large mine, we see the importance of moving beyond the traditional focus on direct government revenues—taxes and royalties—to capturing a significant part of the supplies and services expenditures of a mine operation.

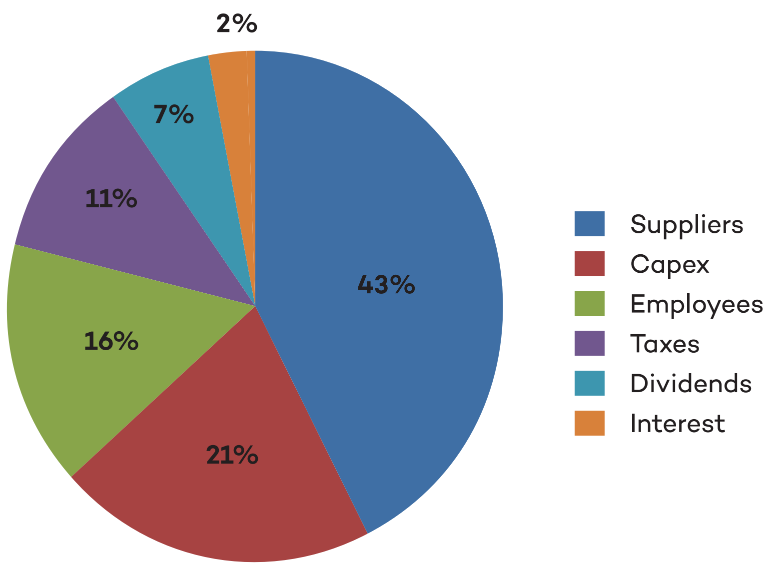


Figure 1. Anglo American Expenditures 2014

Source: Anglo American plc (2014)

In this case, we see that total expenditures on taxes and royalties are at about 11 per cent of total expenditures by the company.

A second traditional focus of governments for revenues has been dividends. Here, we see about 7 per cent of total expenditures, but these are dividends for all shareholders, not just for government. If we assume for the sake of illustration that governments have a 15 per cent equity stake, then about 1 per cent of the total expenditure goes back to government from dividend spending. And unless government representatives control 50 per cent of the board of directors, the allocation of any dividends generally remains an issue fully within the control of the investor itself.

In the case of both taxes and dividends, the percentages pale in comparison to the labour and purchasing components, at 15 and 43 per cent of company expenditures, 58 per cent when combined. For shared value to have a really significant meaning (in the context of employment and procurement), significant proportions of these two parts of the pie must accrue to the host state.

In addition to their direct benefits to the local community and national manufacturing sector, the multiplier effects of these components are the most important of the economic spin-offs from mining. Procurement of goods and services from local suppliers strengthens local manufacturers and service providers, enabling them to maintain and progressively increase re-investment, employment opportunities and wages. In the best of cases, those suppliers become globally competitive exporters of their products. As consumers, the employees of these local suppliers also spend their wages in the local economy, thus helping stimulate the maintenance and development of other economic sectors. Taxes on local goods and services and on the income of local employees help ensure and progressively increase government revenues, which can in turn revert in favour of the local communities in the form of social policies, infrastructure and public services, among others.

3.0 TECHNOLOGICAL ADVANCES DRIVING AUTOMATION

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3.1 Scope, Scale and Timing

Mining productivity has increased over the years (Figure 2). While recent decades have seen a lot of innovation to increase productivity at mine sites (such as larger, more durable and efficient shovels, haul trucks, crushers, grinding mills and flotation cells, and better chemistry to improve processing recoveries), automation is expected to rapidly increase productivity between 7,000 and 8,000 tons/person-year.

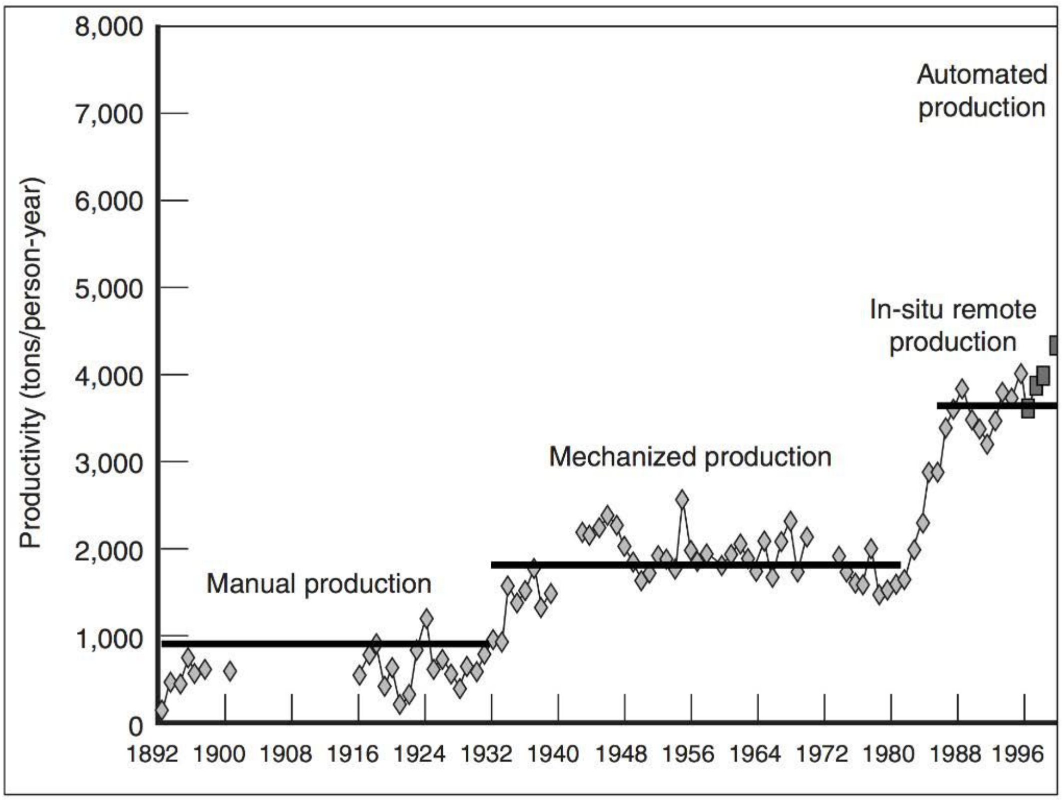

Figure 2. Past productivity and anticipated productivity from technology change

Source: Peterson, LaTourrette & Bartis (2001, p. 49). Image reproduced with permission from Rand Corporation.

The mine of the future may implement technologies or practices that will fundamentally change how mining is done, such as deep-sea mining, asteroid mining and microbe mining. Given the fundamental uncertainty and long-term nature of such technologies, we do not focus on them, instead assessing the technologies that are being piloted today, which will be carried forward and drive automation in the near-to-medium term (IBM, 2009).
These technologies can be sub-divided into three categories:

a) *Tele-operations* refer to mining vehicles controlled by an operator at a remote location with the use of cameras, sensors and possibly additional positioning software. Joysticks or other handheld controls are still used to control the vehicle's functions, and operators have greater access to vehicle telemetry and positioning data through the tele-operation software.

b) *Semi-automation* refers to partly automated control of mining machines. Only some of the functions are automated, and operator intervention is needed. Remote control technology is generally used to enable mining equipment to operate in dangerous conditions such as unstable terrain, blast areas, high-risk areas of falling debris and underground mining.

c) *Full automation* refers to the autonomous control of one or more mining vehicles. Robotic components manage all critical vehicle functions, including ignition, steering, transmission, acceleration and braking, and implement control (that is, blade control, dump bed control, excavator bucket and boom, etc.) without the need for operator intervention.

This sub-categorization is of interest, because tele-operations are unlikely to lead to a fall in workforce, but rather require a different skillset by the operators. Semi-automation and full automation, on the other hand, will not only require a different skillset by the operators, but also reduce the number of workers required to operate the mine. All these categories will require sourcing technologically more advanced goods and services. It should be noted though that in many instances technological advances go through all these three categories starting off with tele-operations, moving to semi-automation and ultimately to full automation.

Below we present the key technologies being piloted that are currently driving the automation process. Apart from highlighting the current state of these technologies and likely development going forward, we also discuss the probable impact on employment resulting from these technological advances.

1. *Autonomous haul trucks and loaders*: The most publicized of all the mining automation technologies are driverless haul trucks. One person alone can already operate remotely at one time a small fleet of these autonomous trucks. Improvements in software are likely to allow this to be performed even more efficiently by algorithm-driven computer programs. By allowing a fleet of haul trucks to run autonomously, the safety, maintenance requirements, efficiency and environmental concerns of a mine site can be improved. According to researchers from the University of British Columbia, driverless technology can lead to a 15–20 per cent increase in output, a 10–15 per cent decrease in fuel consumption and an 8 per cent decrease in maintenance costs (Spence, 2014). Rio Tinto announced that the "effective utilization" of autonomous trucks in the Hope Downs 4 iron ore mine was 14 per cent more productive "than in the best human-staffed mine in the Pilbara" (Ker, 2015), and 13 per cent less expensive in terms of load and hauling costs (Rio Tinto, 2014). Rio Tinto's Pilbara mine is the poster child for driverless haul trucks. To develop its autonomous trucks, Rio Tinto collaborates with Komatsu Ltd, a Japanese corporation that manufactures construction and mining equipment. The other company whose mines have incorporated driverless haul trucks is BHP Billiton, which has been working with Caterpillar since 2007 to produce autonomous driver technology (Ker, 2015). Beyond Australia, Sandvik, a supplier of equipment for mines has developed Sandvik Automine, which is an automated loading and hauling system for underground hard-rock mining. It has been used at a Codelco mine in Chile (since June 2004), a mine in Finland (since January 2005), a mine in South Africa (since August 2005) and a mine in Canada (since June 2007). Atlas CopCo, another supplier of mining equipment, has also tested remote haulage zones with two fully automated trucks at Nordana's Brunwick ore mine in Quebec, Canada (Horberry & Lynas, 2012).

   Haul truck automation currently appears to have the greatest direct impact on mine employment. The technology has seen greater implementation than the other ones mentioned below, and truck drivers comprise a large portion of the workforce on the average mine site. Automating the haulage process by letting computer algorithms control the trucks nullifies the need for the haul truck drivers. Only a few job openings can be expected as a result of full truck haulage automation (more jobs in the semi-automation stage when operators control a small fleet of trucks). These operator jobs will require a different skillset from those of the truck drivers.

2. *Autonomous long-distance haul trains*: Technologies are being piloted that allow long-haul trains carrying bulk commodities to run fully automated from the mine site to the port. Rio Tinto has designed a fully automated train network for its iron ore mines in Western Australia's Pilbara region. At the time, the project was estimated to cost USD 518 million. The company stated that automated trains would help address a significant skills shortage facing the industry while improving productivity at its iron ore operations (Ker, 2015). Rio Tinto planned to have 41 trains hauling its iron ore. With three high-paid drivers per train being nullified by automation, along with additional operators and staff who keep these trains running, the company announced that up to 500 employees could lose their jobs (Taylor, 2012).
3. *Tele-remote ship-loaders*: Fitted with video cameras, thermal imagers, lasers and sensors, tele-remote ship-loaders are operated from a control room with a line-of-sight view. Rio Tinto is implementing the technology at Dampier port (Mills, 2010). This is an example of the type of automotive technology that is unlikely to have an adverse impact on employment, given that the operator is just moved from the cabin of the ship-loader to the control room.
4. *Semi-autonomous crushers, rock breakers and shovel swings*: These are machines designed to reduce the size of large rocks and scoop up the ore at the location of extraction. The mobile crusher performs two tasks simultaneously as it transfers the crushed rock directly for processing via conveyors, eliminating the need for haul trucks within a mine. The mobile crusher was, for instance, implemented at Peppertree Quarry in New South Wales, Australia (Process Online, 2013). Semi- and fully autonomous shovel swing loading systems have been tested and implemented in Australia.
5. *Automated drilling and tunnel-boring systems*: Automatic drilling machines are used in open-pit mining and exploration activities. One operator can monitor up to five machines from a remote monitoring station. The remote operator needs only an interface with the machine to tell in what order the drill pattern should be drilled (Fiscor, 2009). Atlas CopCo has tested fully automated surface drilling technology at the Rocktec Application Centre in Perth, Western Australia (Horberry & Lynas, 2012). The tunnel-boring machines can significantly reduce the time and associated cost to build and expand an underground mine while doing it safely. Atlas Copco's modular boring machines have achieved more than 10 metres a day, which is almost twice the rate achieved by conventional methods (Mining-technology.com, 2014). The technology is likely to reduce by half the number of contractors involved in drilling and blasting and required during the construction phase.
6. *Automated long-wall plough and shearers*: This technology is being implemented in the coal mining sector. Before automation, workers manned the long-wall roof supports on hydraulic jacks, called shields. Similar to the automation of blast-hole drills, remote operation keeps workers out of harm's way near the drills and potential falling debris. While increasing workers' health and safety, this process has reduced the number of workers in underground coal mines since the 1990s. The more recent technologies require less manual support, and these technologies have improved productivity by up to 10 per cent (CSIRO, 2015).
7. *Geographic information systems (GIS) and Global Positioning Systems (GPS)*: Geospatial professionals with engineering and design firms have long had a traditional role in pre-mining stages of surveying, exploration, land rights management, environmental impact assessment and construction. GIS is now commonly used in almost all aspects of mining, from initial exploration to geological analysis, production, sustainability and regulatory compliance. Over time, however, as the use of GIS becomes more evenly dispersed on a global scale, old procedures for mine surveying will become redundant. Automated positioning systems

have produced GPS technology and location-based services "to manage and improve the safe operation of a wide range of earthmoving and heavy mobile equipment from single machines to entire fleets including dozers, drills, excavators, loaders, scrapers, graders, soil compactors, off road trucks and light vehicles" (Horberry & Lynas, 2012, Appendix 1, p. 5). These systems have been implemented in Australia at the North Curragh and Cloudbreak mines (International Mining, 2012; Wirtgen, 2011). GPS and equipment sensors combined with wireless communication technology can be used as a "passive" collision avoidance system (Horberry & Lynas, 2012).

8. *Autonomous equipment monitoring*: The technology is integrated in most new mining equipment. Using many different technologies, from cameras and thermal imaging to self-aware machinery able to report its progress, equipment monitoring has an important role in optimizing mining (Fischer & Schnittger, 2012). This is a very broad category of automation, but is extremely important, as preventive maintenance workers can make up a large proportion of the workforce on a mine site. With this technology, predictive maintenance replaces preventive maintenance (Maras, 2013).
9. *Programmable logic controllers (PLCs)*: Flexible PLCs are digital computers that typically automate industrial electromechanical processes and replace relays, timers, counters and sequencers. PLCs are an enabling tool for improved process control. Once installed, they can be reprogrammed to improve the control of processes across the full spectrum of industry activity. Therefore, their flexibility enables an organic growth of automation capability (Horberry & Lynas, 2012). Above all other technological advancements, this is the most crucial in the automation revolution and arguably the most prevalent in taking away semi-skilled onsite jobs.
10. *Control systems*: Offsite control rooms are becoming bigger and more complex as mines become automated. Today, only mining companies with the most advanced technology, such as Rio Tinto, have a control system that employs a substantial number of workers (Lynas & Horberry, 2011).

Based on the literature reviewed, Figure 3 plots each of the above technologies—identified by its respective number—along a horizontal timescale and a vertical scale of employment impact.

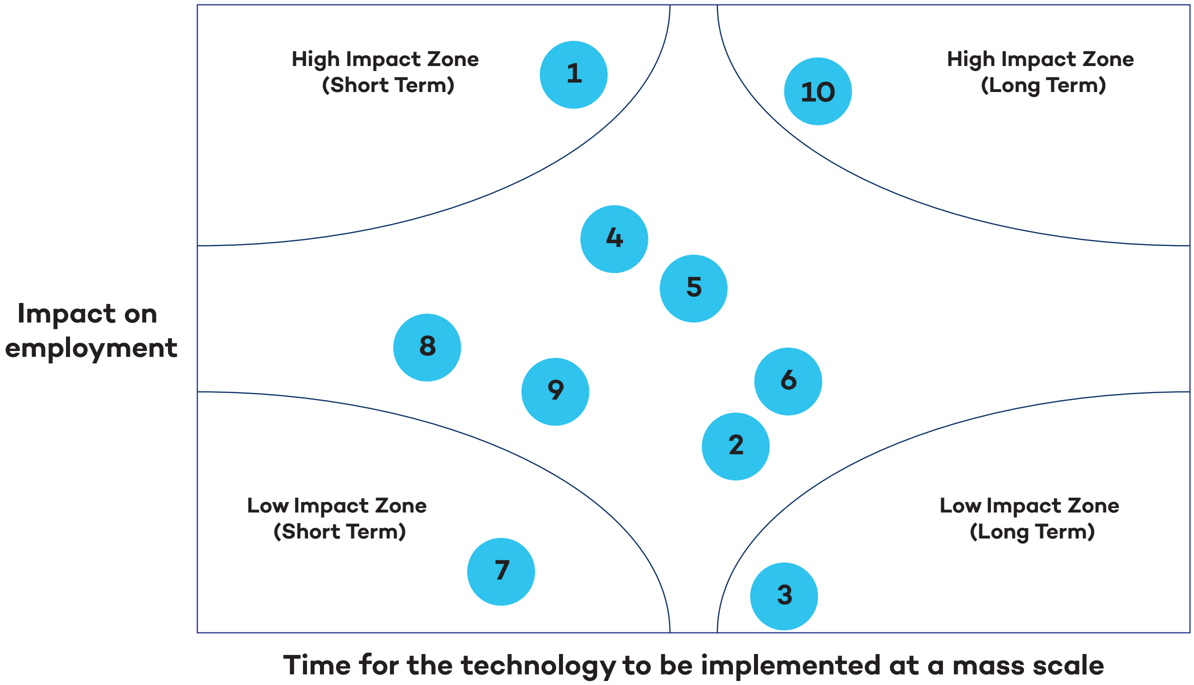

Figure 3: Estimated relative impact of technological changes and impact on employment

Source: The authors

The automation of haul trucks (1) will have a high impact on employment in a relatively short term, given that existing mines have been testing these technologies successfully and have benefitted from a large fall in operating costs. GIS and GPS technologies (7) are already being rolled out in most mine sites, but these improvements are unlikely to have a large impact on employment. The rolling out of automated ship-loaders (3) is likely to take longer, given that the technology is still in its infancy, and tele-operations that are implemented are unlikely to have a drastic impact on employment. Considering that the increasing adoption of highly advanced control systems (10) will depend on the rolling out of all other automation technologies, it is likely that these will take time to be common among mine sites. Moving in-pit staff into control centres will have a significant impact on employment.

The speed at which these technologies are going to be rolled out is difficult to predict, but the automation literature suggests that we are entering an era in which the availability of automation technology is accelerating rapidly. Currently in Australia, automation is engaged on a small scale relative to the existing number of mines, processing plants and export facilities. There are close to 500 sites associated with the resource industry. While some may be engaging in automation, only a handful of pioneering trials can claim automation as an operational concern. The commodity price downturn seems to have accelerated the move towards automation as companies are looking to increase mining productivity while reducing spending on staff, capital and energy (Deloitte, 2015). As indicated in the research performed by the Mining Industry Skills Center Inc. (2010), the strongest growth in automation is anticipated to take place over the next decade. The movement of all sites toward automation is foreseeable, and the rate of uptake is likely to be greatest over the next 15 years. The bell curve in Figure 4 demonstrates the expected progression in the amount of uptake of automation over the next 20 years in the Australian mining industry.

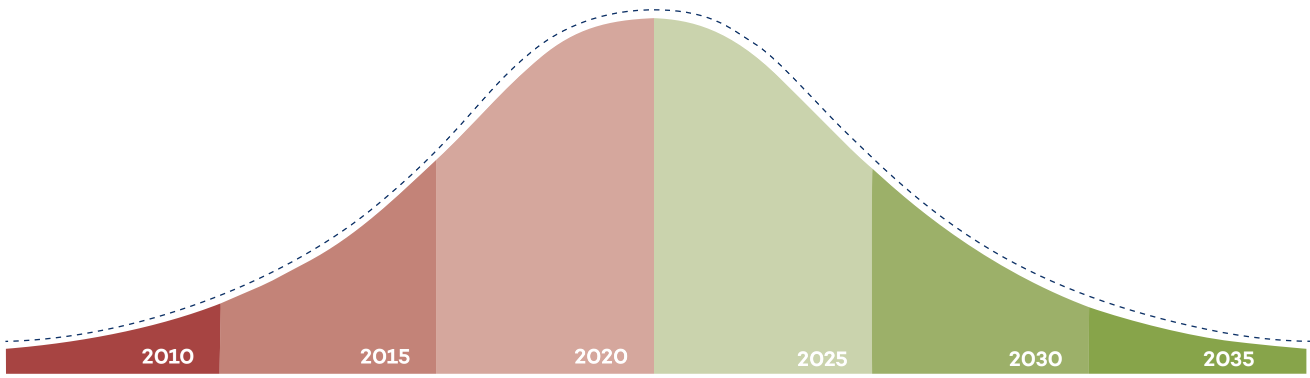

Figure 4. Expected automation in the mining industry, Australia, 2010–2035

Source: Mining Industry Skills Center Inc. (2010)

3.2 Types of Occupations Most Affected and New Ones Created

New technology is almost certain to change the nature of mining personnel tasks whereby the human often becomes more of a passive supervisor of the process rather than an active operator of equipment. Automation will reduce the number of operational jobs in areas such as drilling, blasting, and train and truck driving—areas that constitute a high proportion of the mining workers, as can be seen in Figure 5.

New roles will be created in the development, observation, servicing and maintenance of remotely controlled autonomous equipment as well in data processing and systems and process analysis. Other traditional roles will however remain, relating to site rehabilitation, road building and other site works in particular (McNab et al., 2013). Consequently, workers with specialized skills in remotely controlled and automated systems will be in demand as automation increases, while current employees will need retraining, re-education or both to keep their jobs (Somarin, 2014). Those specialized skills rely on knowledge of mathematics and science and an ability to use information technologies (McNab et al., 2013).

All in all, some studies anticipate that, as a result of this revolution, "autonomous technologies seem likely to reduce additional jobs created through mining industry growth, rather than leading to a net reduction in mining employment" (McNab et al., 2013)

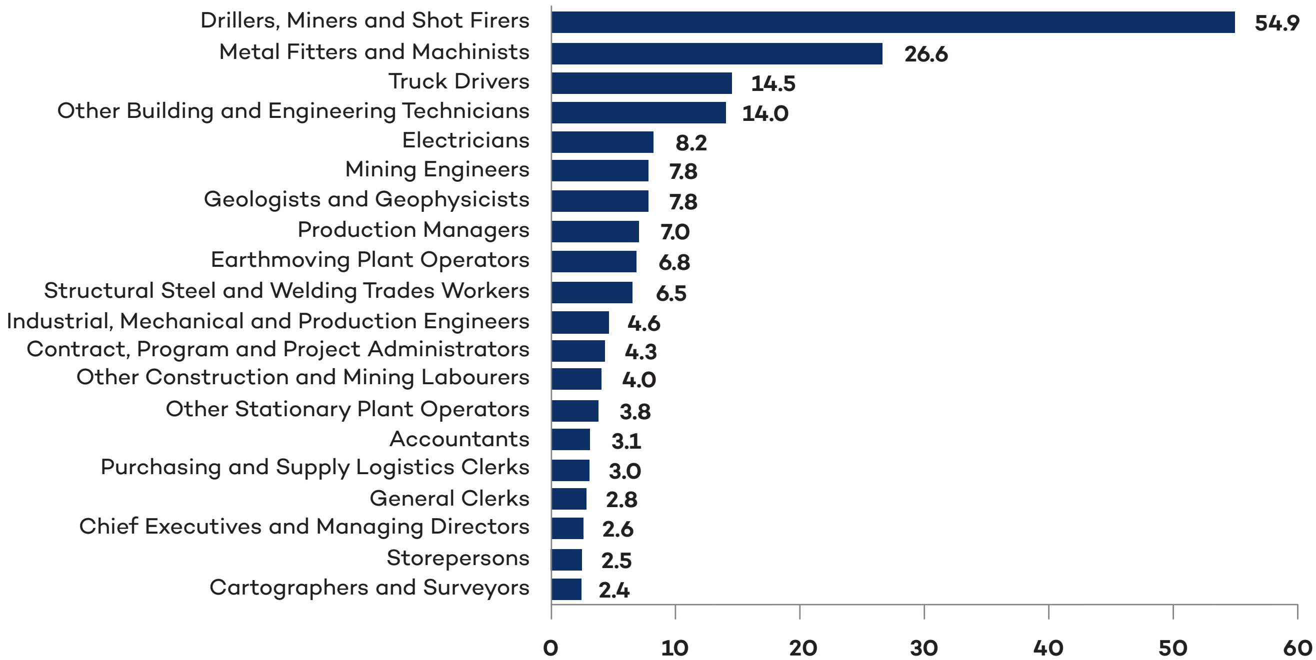

Figure 5. Main employing occupations in the mining industry (x 1,000)

Source: Australian Government, Department of Employment (2014)

3.3 Expected Impacts in Developing and Developed Countries

The impact of automation might be felt differently between developing and developed countries if we consider a series of factors working in opposite directions.

The first factor is the cost of labour. We can assume that mining companies are more motivated to save on employment in areas where the labour is more costly and salaries are higher. For this reason, Australia and Canada's workforces could be more threatened by automation than those in developing countries.

The second factor is the search for higher safety, which is a unanimously accepted benefit of automation. "Reducing the numbers of people involved on the field mechanically reduces the probability of having accidents, especially considering that the mining industry will extract commodities from deeper and more complex ores in the future" (Mining Global, 2014). This factor would have disparate impacts if there were significant country-level differences between worker safety laws and regulations.

A third factor is driven by the shortage of skilled labour in some countries. Some in the industry have described automation as a partial solution to the perennial problem of skills shortages: "By providing a safer working environment, the mining industry might be able to tackle the current labor shortage and attract high potential profiles" (Mining Global 2014). This might point toward developing countries being at a higher risk of witnessing automation roll-out than developed countries, given that the skills shortages there tend to be more acute.

The fourth factor is the country's capacity to deploy policy instruments to mitigate unemployment resulting from automation. These policy instruments range from training programs and tax credits to incentives that support self-employment. Figure 6 features a range of policy instruments on which the institutional investors of CitiBank were surveyed; investment in education, support to self-employment, active labour policies and funding for research appear as the policies having the most successful impacts in mitigating the negative impact of automation on labour, irrespective of the sector. These policy instruments are expensive to implement and their infrequency in developing countries affected by automation might reinforce the differentiated impact between developing and developed countries (Frey & Osborne, 2016).

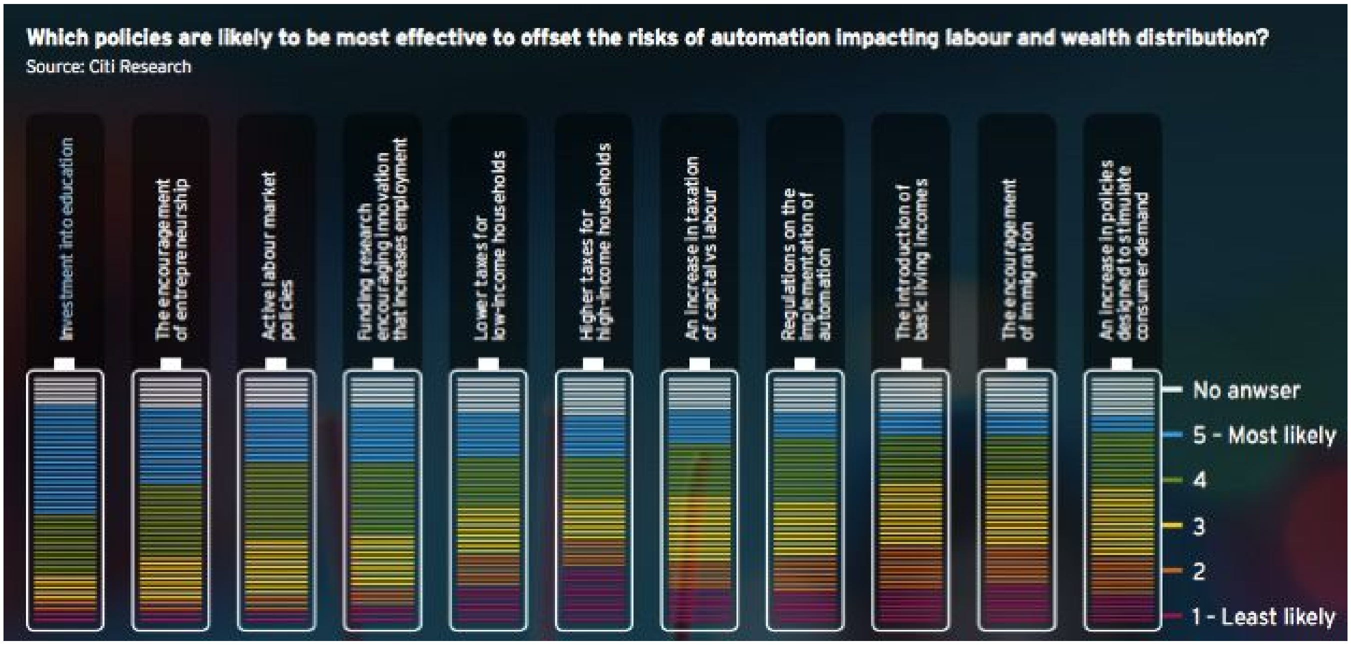

Figure 6. Policies likely to be most effective in offsetting the risks of automation impacting labour and wealth distribution

Source: Image reproduced with the permission of Citi GPS (2016).

The fifth factor relates to workforce acceptance, materialized in particular by the unions' resistance. This is, of course, not new: in the 20th century, labour unions resisted production technology in mining, shipbuilding, car-making and cotton weaving. The responsibility for the declining technological dynamism of post-Victorian Britain is often attributed to the growth of the labour movement's power. In the 1930s, Indian trade unions resisted a technical and administrative rationalization of cotton mill practices, which made India lose its market share. In the European and American auto industry, unions have opposed the closing of out-dated plants and the introduction of efficient practices of Japanese car manufacturers. Not all unions are conservative, and those in Germany and Sweden have historically shown more support to technology progress than elsewhere (Mokyr, 1997). Developing countries also boast strong unions, as the 2012 riots at South African mining sites highlighted, so it is unclear whether higher social and political resistance will occur in developing or developed countries. While it may be harder to implement job cuts in places where trade unions are stronger, there is a larger incentive for mining companies that develop new projects to implement new technologies that minimize labour at their mine site in order to have more control over operations.

There are, of course, many ways in which automation and other new technologies will affect developing and developed countries alike. This is the case, for example, when automation is deployed not only to replace current tasks but also to enable "operations to reach mineral deposits that cannot be economically extracted under existing methods and mine layouts" (Anglo American, 2013).

4.0 RESULTS

4.0 RESULTS

The research question pursued in this project is: What are the impacts of mining operations on local and national host economies if current trends in automation continue? In the previous section, we surveyed the changes in technology that we can reasonably foresee for the mining industry. Of those, we noted several with potential to alter the level of local spending in the operational phase of mines.

There are many ways in which we might assess the impacts of a mining operation on its host community and host country, standard among which are:

- GDP, or gross value added: the amount of economic value the mining operation brings to the economy
- Employment: the number of jobs created by the mining operation
- Government revenues: the amount of revenue generated for the host governments by the mining operation

In what follows, we will use these standard metrics to estimate the impacts of automation. Using expenditure data from two companies and four mines—one located in a lower-middle-income country and three in a high-income OECD country[9]—we will indicate the magnitude of impacts to be expected in a typical mining operation.

This will necessarily be an imprecise exercise. First, our sample size is small (we discuss in Section 6.1 the difficulties in obtaining data). Second, the nature of the technological advances driving changed impacts is unknown, and we will need to make reasonable assumptions based on the technology survey presented in Section 3. Third, even if future technological developments were fully known, the impacts of those developments on any individual mining operation would be a function of many context-specific factors, among them: the income level of host country, the type and scale of operation and the mineral or metal mined. We discuss these caveats more fully below, and give a detailed description of methodology and assumptions in Appendix 1. Ultimately, our aim is to give the best possible indication of the magnitude of impacts to be expected, given all the significant constraints on precise calculation.

4.1 The Baseline Cases

We start with data from two country cases, one in a lower-middle-income economy and one in a high-income OECD economy. Both are mining entities, with some basic processing (concentration). The operational expenditures from the two cases are shown in Figures 7 and 8.

[9] The companies involved have agreed to share procurement and other data with the researchers only on the condition that their names and commercially sensitive details be kept confidential.

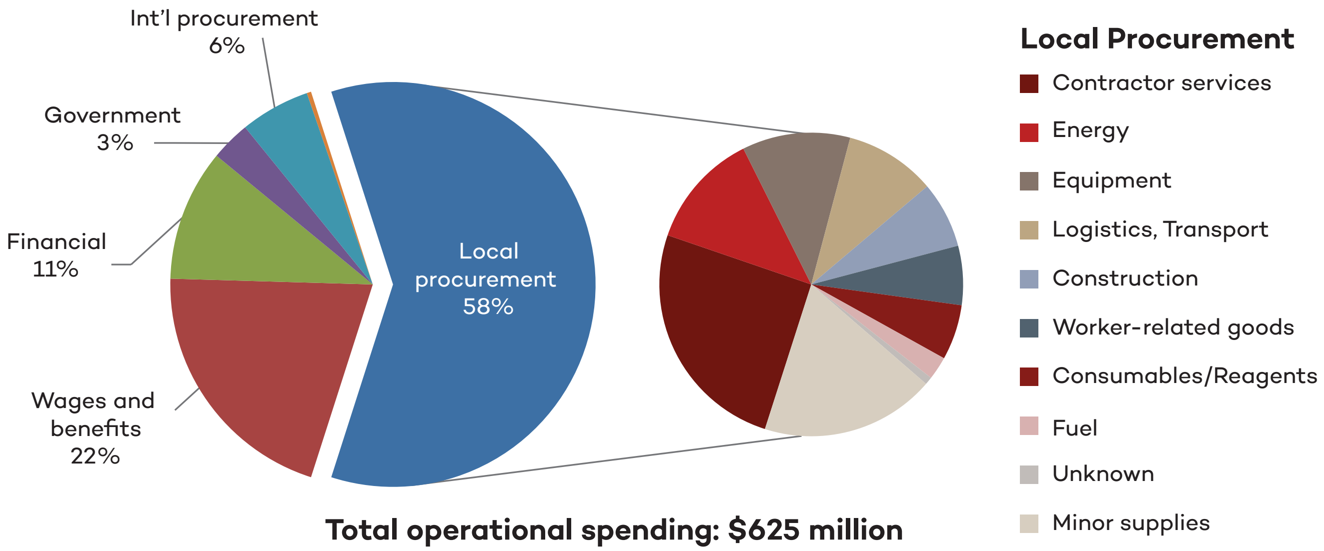

Figure 7. High-income OECD country case

Source: Procurement figures from company-furnished data. All other figures from 2014 corporate reports.

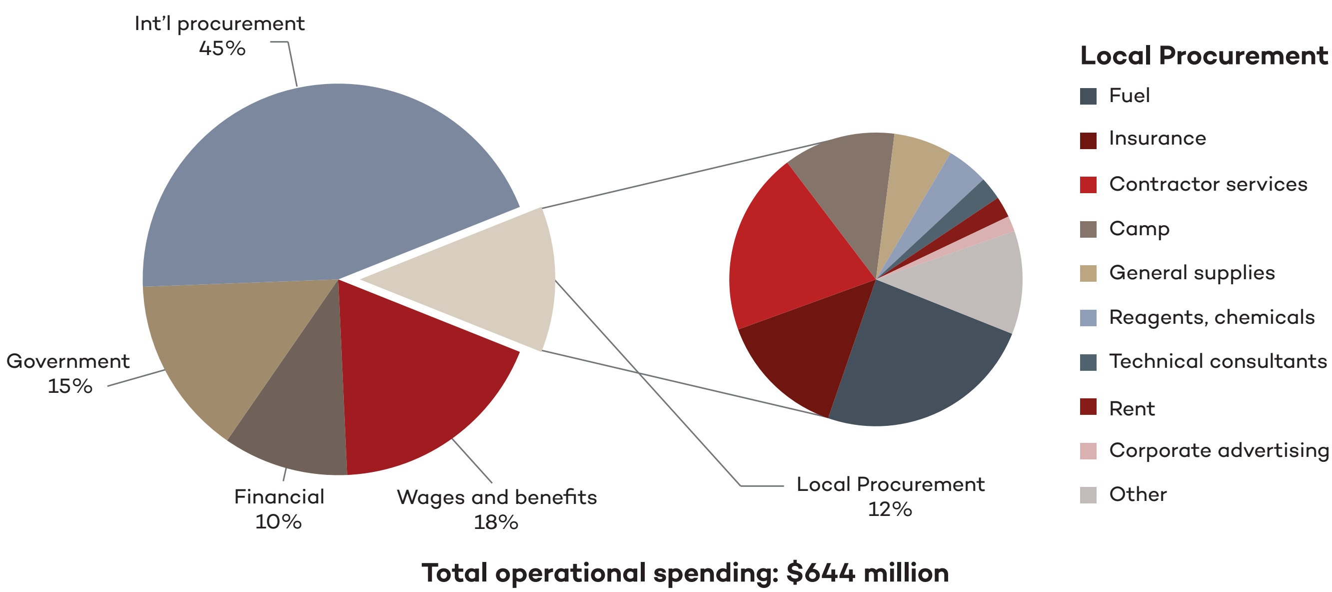

Figure 8. Lower-Middle-Income Country Case

Source: Procurement figures from company-furnished data. All other figures from 2014 corporate reports.

The distinction between local and international procurement is worth exploring. In this paper, we define local as sourced within the country of operations. Local spending by a mining operation plays a significant part in determining its contribution to the community, regional and national economies, in terms of both direct spending and the ripple impacts—indirect and induced impacts—of direct spending (discussed below).

There is a marked difference between the proportion of local and international spending in the two case study operations. For the high-income OECD country mines, local procurement amounted to 58 per cent of total operational expenditures. Of that, 12 per cent was local to the mine sites, 24 per cent was regional and 64 per cent was spent in the host country outside of the region. The lower-middle-income country operation, by contrast, procured only 12 per cent of its goods and services within the host country.

This finding is not surprising. We would expect to find greater capacity in domestic suppliers of goods and services in more developed countries. But it has important implications for the way in which the advent of automation will affect the contributions of mining to host country economies—a matter explored more fully below.

It is worth noting that even those items recorded as sourced locally will not contribute equally to the host economy. For example, the largest single item procured locally by the lower-middle-income country operation was diesel fuel for its fleet, at 24 per cent of local procurement.[10] As the host country produces almost no petroleum products, the main impacts of that "local" purchasing are probably benefits for local re-sellers—a modest economic contribution. In fact, each category of spending will have different "output multipliers." A dollar spent by a mine on excavator services has *direct* effects—the actual spending by the mining operator on goods and services. There are also *indirect* effects: the spending that must be done by suppliers of goods and services in order to meet the demand of direct spending. For example, a portion of a dollar spent on excavation demands some smaller portion of that dollar in turn spent by the supplier on machinery, fuel, maintenance, etc. Each dollar spent on a particular category of expenditure has associated with it a final dollar-value impact that is greater than one dollar, once all the direct and indirect impacts are added up; this is an output multiplier.

Spending that involves purchasing imports is not counted, since that money leaves the local economy. Items that involve few imports, such as locally produced food, may have a high output multiplier, while purchase of diesel from importers will have a very low output multiplier (close to 1.0). This is relevant because it suggests that the local procurement of the lower-middle-income country operation, low as it is at 12 per cent of operational spending, may have even less impact than it appears. The less developed the economy, the greater the need to rely on imports of intermediate and capital goods, as well as services. The high-income OECD country operation, by contrast, may be purchasing significant amounts of domestically produced intermediate goods, capital goods and services.

A broader output multiplier includes not only direct and indirect effects, but also *induced* effects of spending. Induced effects occur when the employees drawing pay from direct and indirect spending in turn spend their pay on other goods and services, adding another wave of impacts. If those workers save instead of spending their income, the effect is similar to that of imports—that money does not immediately contribute to the subsequent wave of ongoing economic impacts, and the multiplier effect is diminished.

The output multiplier that sums up direct and indirect effects is called the type I multiplier, and one that includes direct, indirect and induced effects is called the type II. Type I multipliers generally underestimate real impacts, since they ignore employees' spending as consumers, and type II multipliers tend to overstate real impacts because of rigid assumptions about labour income and consumer spending.[11] The two output multipliers are sometimes conceived of as the lower- and upper-bound estimates of output impacts. We will use both below to assess the impacts of automation on host economies.

4.2 The Impacts of Automation

The technology survey (Section 3) described a number of types of process changes that we might anticipate as drivers for change in the mining sector. It noted that, while there is not enough research into the impact of automation on the size of mining workforce, we have two broad estimates on which to base our scenarios. The

[10] According to the records, these purchases are only roughly 20 per cent of total fuel purchased—the remainder is recorded as purchased internationally.
[11] Type II multipliers treat household consumption as constant, with the ratio of expenditure-to-income fixed for all levels of income.

Cluster Research Report (McNab et al., 2013, p. 16) suggests that the introduction in mines of fully autonomous equipment "would reduce the workforce of a typical open-cut, iron mine by approximately 30 to 40 per cent." In another report, Accenture (2010) evaluated the economics of three types of equipment (trucks, dozers and drills), suggesting that automation could reduce the number of operators in open pit mines by up to 75 per cent. These two reports are not explicit about the geological and technical conditions of the mines evaluated, so the best employee reduction rate to be applied to our case study sites remains unclear. In order to have a general view of the impact of workforce reduction on local procurement, we build three scenarios of workforce reduction through automation, conservatively bracketing the two estimates cited above with rates of 30, 50 and 70 per cent.

Doing so involves going through the detailed procurement accounts for each firm and deciding which would be sensitive to changes in workforce size. This would be the case for worker-related goods such as food, clothing, safety equipment, housing and camp materials. Other categories of spending, such as workers' insurance, human resources and provided equipment such as cell phones, will also be affected.

Beyond the impacts of workforce reduction, we noted above that driverless technology using equipment under control (EUC) will have impacts by saving on fuel consumption. Researchers from the University of British Columbia estimate that driverless technology can bring about a 10–15 per cent decrease in fuel consumption (Spence, 2014). The size of the mining operation as well as the fleet, commodity and mining method are parameters that must be taken into account. However, since there is no literature available, these considerations are not included in this analysis, and we assume a 12.5 per cent decrease in diesel consumption in our scenarios. In addition, assuming that haul trucks in the mine are using EUC and using the rate calculated by Fortescue in its iron mines in Australia, an extra 2.3 per cent in fuel savings could be achieved if they are installed in trucks (Australian Government, Department of Resources, Energy and Tourism, 2014). Therefore, based on the literature review, we assume that mines could save 14.8 per cent in fuel used for hauling if they implement autonomous systems and EUC.

Our data set does not show what portion of purchased fuel is used in hauling activities, a figure that will vary from site to site depending on a host of factors. As well as hauling, diesel is used in generators in off-grid sites, and even as a processing fuel. We assume below that 50 per cent of diesel in our sites is dedicated to hauling, and apply a reduction factor of 14.8 per cent to this value. The 50 per cent figure is a conservative estimate that likely underestimates the impacts of fuel savings.

4.2.1 GDP Impacts

Figures 9 and 10 show the impacts on local procurement of the three scenarios described above: reductions in workforce of 30, 50 and 70 per cent, combined with savings of 14.8 per cent in fuel locally purchased in all cases. The results indicate minor impacts relative to total local procurement. In the high-income OECD case, local procurement drops by 2, 3 and 4 per cent respectively in the three scenarios. In the lower-middle-income country case, the corresponding figures are 6, 9 and 11 per cent.

The main elements of the reductions are employee housing-related expenses, including construction, but safety equipment and employee benefits also feature strongly in the high-income OECD country case. Fuel savings remain constant at a fairly low level irrespective of the workforce reduction scenario. But worker-related expenditures are not the most important elements of local procurement in either case. This is consistent with the data in Figures 7 and 8, where local procurement is broken down into its component parts for both operations.

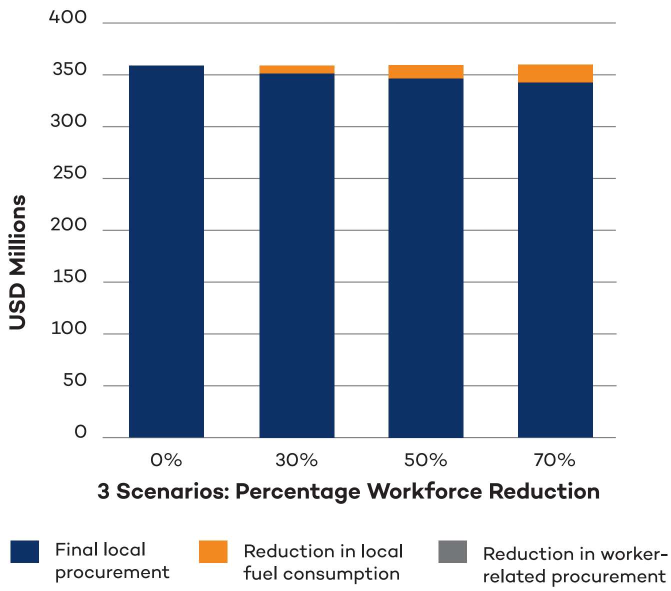

Figure 9. **Impacts Of Automation On Local Procurement (High-Income OECD Country Case)**

Source: The authors

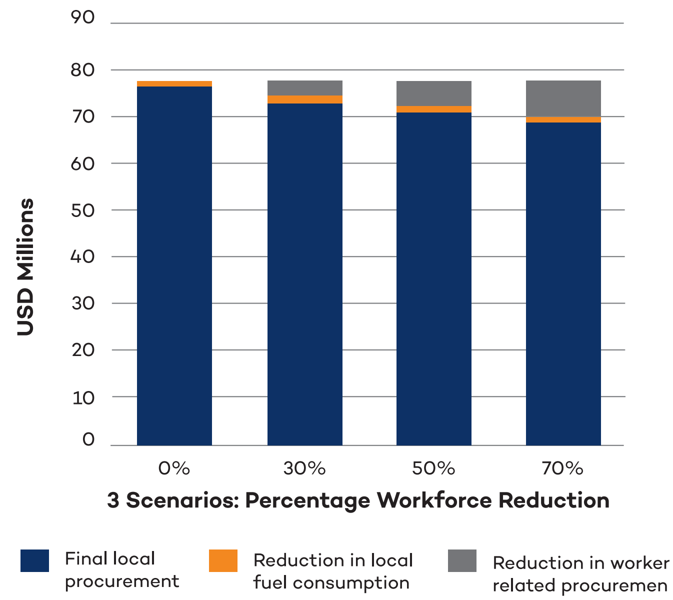

Figure 10. **Impacts Of Automation On Local Procurement (Lower-Middle-Income Country Case)**

Source: The authors

Where the operations constitute a large part of a community's economy—often the case in mining operations—the sort of reductions seen here may be significant at the local level: depending on the scenario, between USD 7.2 million and USD 15.8 million less spent in the high-income OECD case, and between USD 4.6 million and USD 8.9 million less spent in the lower-middle-income country case. In the high-income OECD case, under a 70 per cent scenario, we would see USD 3.3 million less spent in the local communities, and USD 7.6 million less spent in the region. The indirect and induced impacts would amplify these effects.

As noted above, not all withdrawals from a local economy will have equal impacts. At the community level, reductions in services such as construction will probably weigh much more heavily per dollar than reductions in fuel purchases, assuming that most of the value of the fuel is imported and most of the value of construction is in the labour provided, and thus is local.

While these impacts seem relatively small, they only cover a portion of the total impacts of mining automation. They do not cover the direct loss of wages and salaries for mine employees, and they do not cover the indirect and induced impacts of reduced spending. These elements are introduced in turn below.

Figures 11 and 12 show the impacts of automation when salaries and benefits for mine workers are included in the analysis. (Note that while spending on procurement and wages and benefits drops, we assume that payments to government are unchanged). These figures show clearly that while procurement drops in all scenarios, the impacts of reduced payroll are much more significant. In the high-income OECD country case, reduction of wages and benefits are responsible for 86 per cent of the impacts shown here, and in the lower-middle-income country case they are responsible for 92 per cent.

The final impacts are significant in terms of total GDP (output) contributions from the operations. The reduction in those contributions in the high-income OECD case ranges across the three scenarios from 9 to 20 per cent. The corresponding range for the lower-middle-income case is higher: from 13 to 31 per cent. This may seem strange; the latter operation's salaries are roughly half of the former's, so the impact of lost wages should be blunted relative to the high-income case. The explanation is that local (national) procurement is much lower in the lower-middle-income country operation (see Figures 7 and 8). So even though payroll is lower in that operation in absolute terms, it makes up a larger percentage of a mine's contributions to the national economy. Its loss is therefore more significant as a percentage of those contributions.

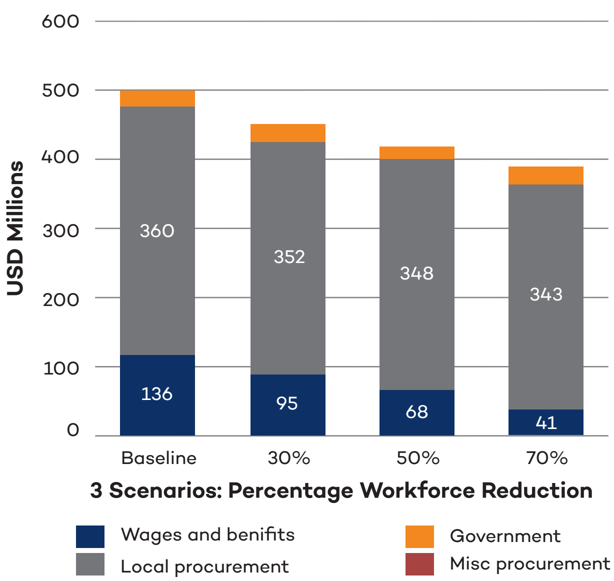

Figure 11. Impacts Of Automation On GDP Contribution (High-Income OECD Country Case)

Source: The authors

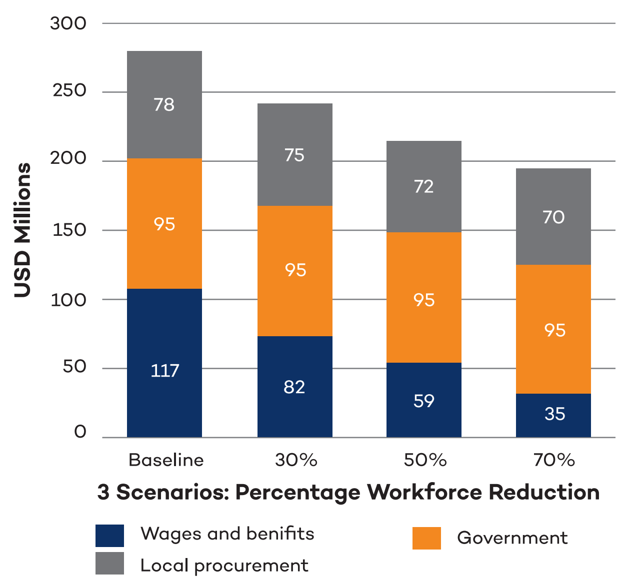

Figure 12. Impacts Of Automation On GDP Contribution (Lower-Middle-Income Country Case)

Source: The authors

The effects discussed up to this point have all been strictly direct impacts of mining expenditures. Indirect effects and induced effects are also appropriate to consider, and are routinely described in the literature assessing the beneficial impact of mining investment.

Table 1 shows the impacts of automation on national GDP, when output multiplier effects are included.[12] Again we considered the three workforce reduction scenarios.

[12] Appendix A discusses the limitations of the use of multipliers in this analysis.

Table 1. GDP Impacts, With Multipliers

	Direct Impact	Direct + Indirect	Direct, Indirect + Induced	Total impact as % of total multiplier effects of mine	Total impact as % of national GDP
High-Income OECD Country Scenarios					
30%	55,931,204	75,507,125	92,006,831	8.5%	<0.01%
50%	92,736,431	125,194,182	152,551,429	14.0%	<0.01%
70%	129,541,658	174,881,238	213,096,028	19.6%	>0.01%
Low Middle-Income Country Scenarios					
30%	39,843,100	103,592,059	124,310,471	6.2%	<2%
50%	65,474,572	170,233,887	204,280,664	10.2%	<3%
70%	91,106,044	236,875,715	284,250,858	14.1%	<4%

Note: Multipliers used are from the national accounts of the respective host countries.

Source: The authors

The results show a reduction in contributions to the national economies of the host countries ranging from USD 92 million to USD 284 million, when we consider direct, indirect and induced impacts. These are big numbers, but they are difficult to put into context without knowing the size of the national economy, or the total size of the contributions of those operations—the totals from which these reductions are subtracted. Table 1 helps on both counts. It shows that the reductions in terms of total national GDP are insignificant in the high-income OECD country, at most just exceeding 0.01 per cent. In the lower-middle-income country the percentage is higher, ranging from just below 2 per cent to just below 4 per cent of national GDP. Table 1 also shows the percentage reduction these impacts imply for the total contributions of the operations to their respective national economies. That is, if we consider the total impact of the mines' operations, including indirect and induced impacts, with and without the automation-related changes, what percentage change will we see? In the high-income OECD case, the percentage decrease ranges from be 8.5 to 19.6 per cent, while the lower-middle-income country range is from 6.2 to 14.1 per cent.

These figures should be put into the broader context dictated by the shared-value paradigm. Procurement is not the only way that mining operations contribute to the well-being of their host communities, regions and countries. As discussed in Section 2 above, the shared-value paradigm also conceives of other important classes of spending—on infrastructure like roads that are shared by the general public, for example, or on downstream processing and beneficiation operations. It is not envisioned that automation of the type surveyed above will significantly affect these categories of spending and, where they are present in any significant measure, the estimates derived above will overstate the relative magnitude of automation's impacts.

4.2.2 Employment Impacts

Another way of assessing the impacts of mining expenditure is by measuring the number of jobs created. Employment is expressed in terms of full-time equivalent staff and does not count head office employment or contractors. As with GDP measurement, impacts can be conceived in terms of direct employment, indirect employment by suppliers and induced employment as a result of direct employee spending. The direct impacts are straightforward, and are presented in Table 2.

Table 2. Employment Impacts

	Lower-Middle Income	High-Income OECD
Full-time-equivalent staff	2,550	1,457
Of which, domestic staff	2,470	1,457
Payroll (USD)	118,579,207	135,773,223
Average salary	46,502	93,176
Income taxes paid	11,857,921	25,693,953
Jobs created, direct and indirect	5,100	3,388
Jobs created, direct, indirect and induced	n/a	4,801

Source: Corporate annual reports from 2014.

These figures include employees but not contractors. They use sectorally applicable national employment multipliers from both countries' national accounts. Similar to output multipliers, employment multipliers tell us how many jobs are created for a given level of spending. A type II employment multiplier is not available for the lower-middle-income country case, but the total impacts would be significantly higher than those estimated by the type I multiplier alone.

These baseline case figures for jobs created can be modified using the three scenarios for job loss to get a picture of the types of impacts automation might have in terms of employment. Table 3 shows the baseline cases under the three scenarios used above, showing total job loss under each. Only direct and indirect multiplier effects are considered, as a type II employment multiplier is not available for the lower-middle-income country. The analysis here is necessarily crude, and these figures need to be taken as rough indicators only. The employment multiplier assumes a fixed ratio of additional jobs created per direct job created, using data that describes interrelationships with existing technologies. The assumption of existing technologies does not hold here, as the basic change we are positing is a less labour-intensive operation. The final impacts of any given reduction in workforce should therefore be less significant than what we might derive in this analysis. Given that the type I multiplier used here is, as noted above, a sort of lower-bound estimate of total impacts, however, the figures here can serve to give a rough idea of the magnitude of expected impacts.

Table 3. Employment Impacts, With Multipliers

	Lower-Middle Income			High-Income OECD		
	30%	50%	70%	30%	50%	70%
Baseline jobs, direct	1,785	1,275	765	1,020	729	437
Baseline jobs, direct and indirect	3,570	2,550	1,530	2,372	1,694	1,016
Direct and indirect job loss	1,530	2,550	3,570	1,016	1,694	2,372

Source: Corporate annual reports from 2014

4.2.3 Government Revenue Impacts

The final category of impact is government revenue. Here we include taxes, royalties and dividends paid by the firm to all levels of government in the host state. We also include, separately, the estimated value of personal income tax paid by employees as a result of mine employment. We have assumed that the former will not change significantly as a result of automation, though that assumption is surely wrong: we expect automation to increase profitability, and corporate income tax and dividends are linked to profits. It would be difficult, however, to make any meaningful estimates as to their magnitude and nature as they will depend so critically on the specific context of each operation. Personal income tax revenues, however, should change significantly.

The baseline case for government revenues is shown in Table 4. We averaged direct payments to government over three years of remittances (2012–2014) for each operation, and estimated income taxes paid by assuming all employees earn the average salary for both operations, assuming benefits are rolled into salary, and assuming no tax deductions. Average annual salary for employees in the high-income OECD country operations under these assumptions is USD 93,176, while average salary in the lower-middle-income country operations is USD 46,502. We then use the income tax regimes for both countries to derive the payments due at those salary levels.

Government revenues from payments made to government and income taxes of mine employees are twice as high in the lower-middle-income country case, driven by higher payments to government. Employee income tax rates are almost double in the high-income OECD case, and the average salary is twice as high, but that is not enough to mitigate the effect of the large difference in direct government payments; the latter are 4.5 times higher in the lower-middle-income country case. As Table 4 shows, some of the difference is made up when induced impacts are considered; in this case, the high wages and tax rates in the high-income OECD country case strongly influence the induced spending impacts.

Table 4. Government Revenue Impacts

	Lower-Middle Income	High-Income OECD
Direct payments to government	95,157,441	21,002,633
Income tax, direct employment	11,857,921	25,693,953
Total, direct revenues	**107,015,361**	**46,696,586**
Direct payments	95,157,441	21,002,633
Income tax (with total multiplier effects)	25,485,720	105,749,750
Total, direct and induced	**120,643,160**	**126,752,382**

Notes: Multiplier effects for the high-income OECD case use a type II national labour income multiplier. For the lower-middle-income case, a type II labour income multiplier is unavailable, and an output multiplier is used, adjusted upward by the ratio of the high-income OECD output and labour income multipliers.

Source: Corporate annual reports from 2014.

The impacts of automation on the baseline cases can be seen in Figures 13 and 14.

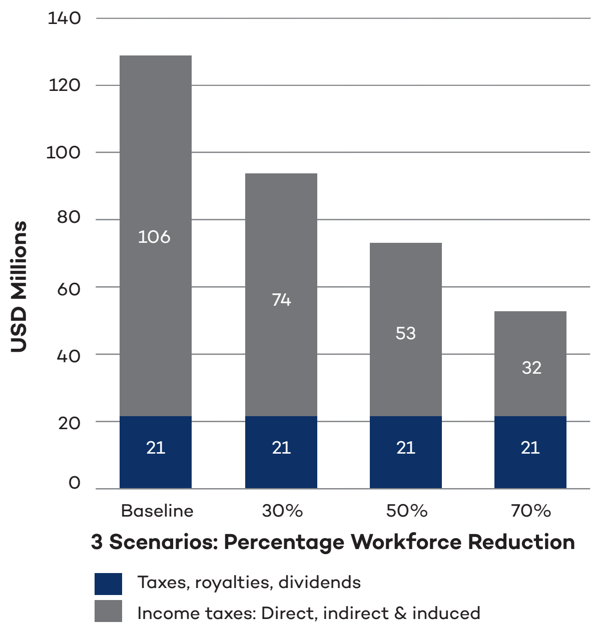

Figure 13. Impacts Of Automation On Government Revenue (High-Income OECD Country Case)

Source: The authors

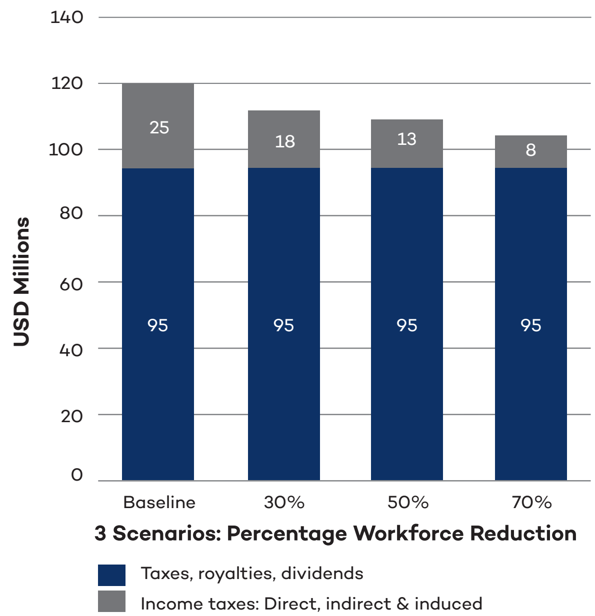

Figure 14. Impacts Of Automation On Government Revenue (Lower-Middle-Income Country Case)

Source: The authors

The final impacts are more significant in the case of the high-income OECD country; higher wages and higher personal income tax rates make the lost tax revenue much more significant there (despite a higher assumed labour income multiplier in the lower-middle-income country case), with a range of revenue drop from 25 to 58 per cent, depending on the scenario. The corresponding figures for the lower-middle-income country case are 6–15 per cent. This disparity underscores the sensitivity of government revenue streams to the structure of the tax regimes in the host country; the lower the direct charges (taxes, royalties and dividends) and the higher the levels of personal income tax revenues, the greater will be the impacts of labour-saving automation.

In absolute terms, the significance of the impacts will depend on the share of government revenue that is occupied by payments from mining operations. In our two cases, the reduction in revenues, including direct, indirect and induced income tax revenues, was USD 7.6 million to USD 17.8 million in the lower-middle-income country case and USD 31.7 million to USD 74.0 million in the high-income OECD country case.

5.0 CONCLUSIONS

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Our analysis suggests that host countries will be increasingly at risk of reduced socioeconomic benefits from mining as existing new technologies are further rolled out in the near and medium terms. The impacts will be primarily in terms of lost local employment and personal income tax revenue, but will also come from reduced employment-related local procurement.

The significance of these impacts will vary from case to case. At the community level they may be much more acute, while at the national level countries that depend more on mining economic activity will feel them more strongly. At first blush, several factors seem to indicate that the effects will be more significant in developed countries:

- The technologies surveyed will be more readily rolled out in high-wage host countries, where the economic proposition for investing to save labour is strongest.
- The largest absolute impacts on GDP and government revenue will come in countries where wages and personal income taxes are highest.
- Baseline domestic procurement tends to be higher in developed economies that are more capable of delivering local goods and services at qualities and quantities acceptable to the investors.

However, there are reasons to believe that developing countries will feel the social and economic development impacts more strongly than developed countries. First, we noted that most strategies for adapting to these types of changes are fiscally and technically demanding, and more likely to be successfully undertaken in developed countries. Second, more developing countries suffer from acute over-dependence on the extractives sector. Third, we noted that some types of technological change will involve no net loss in employment, but simply a shift to higher skills employment; for those host countries that struggle to supply high-skilled labour, this will exacerbate the problem of the sourcing of foreign workers. As well, even though wage levels are lower in developing countries, reducing employment there may serve other objectives, such as addressing skills shortages or circumventing strong unions. Finally, though our analysis was unable to confirm this, it is likely that the mine of the future will involve decreased equipment-related procurement from local vendors, as new, more complex operating systems are imported and serviced from abroad.[13] This will likely include original purchases as well as long-term maintenance and repair. If so, the source countries for such imports, including ongoing maintenance contracts, are likely to be developed.

Our framework for assessing these impacts is the shared-value proposition: the overall value received by governments and communities, including fiscal and non-fiscal social and economic development benefits derived from the core expertise and operation of mining firms. In essence, the shared-value paradigm broadens the traditional focus only on taxes and royalties to the full contribution a mine operation can create towards the sustainable development of their host economies.

The shared-value paradigm, as noted previously, was a response to the growth in resource nationalism in the 2000s, which in turn was a governmental response to what appeared to be imbalanced and inequitable value for governments for the minerals they are responsible for. The argument was simple; mining companies can, and must, ensure governments receive better value for the minerals that the governments are custodians of. The industry commitment to the shared-value paradigm was, in effect, reflective of the consent of the private sector to redress

[13] Confirming this possibility is beyond the scope of our analysis. We are confident that the mine of the future will use much more complex machinery and controls, perhaps produced by a smaller pool of innovative equipment manufacturers. As a general proposition, we see less possibility for local manufacturing and servicing as the product in question becomes more complex, and as original equipment manufacturers seek the long-term profits of technology service contracts, tie warranties to ongoing service, and seek to protect patented and higher-level technologies.

this actual or perceived imbalance. In this context, we have noted that much of the social licence to operate may depend on the degree to which the shared-value proposition holds true. As such, the predicted potential drop in benefits derived from local procurement and employment should be a concern for firms and host countries and communities alike.

We now see the pressure on the local procurement aspect of shared value as part of a larger worrying picture. Mining profitability and new capital investments have experienced a downward trend since 2007 (Walker, 2015) in an "unprecedented global supply restructuring" (EY, 2016: 4). In addition, the potential local benefits from even the existing local procurement have been proving more difficult to realize than had been appreciated during the boom-inspired years of revision to mining codes and regulations. BGR (2016) sets out a number of challenges to making procurement linkages work for host countries in the Southern African mining sector, and Cosbey and Mann (2014) enumerate the difficult prerequisites for the successful use of legislated performance requirements to the same end in the mining sector globally.

This set of dynamics highlights the need to redouble efforts to make local procurement and hiring work for the benefit of host countries. But it also points toward the need for firms, governments and communities to focus on other ways in which mining can contribute to the host economy and host communities. That may come in the form of re-weighting other aspects of the shared-value proposition (Section 5.1), or in the form of revised fiscal regimes (Section 5.2), or in the form of government policies that change in more fundamental ways the relationship between the host state and the mining company (Section 5.3). In other words, the notion of shared value is not likely to diminish, but the means to achieve it for governments may have to be refocused.

5.1 Other Avenues for Shared Value: Re-Weighting the Elements

We noted above that local socioeconomic benefits related to employment and procurement are only part of the shared-value proposition, and we predict that there will be pressure to find ways in which the shared-value proposition can make up the shortfalls that result from technological change.

Figure 15 illustrates the various avenues to realizing domestic benefits, by presenting the linkages to the mining sector that could lead to increased shared value. The mining project is located in the circle within the centre of the blue arrow that represents the mining value chain. This study suggests that automation will reduce the direct employment opportunities, which in turn will reduce the amount of money that employees working at the mine can spend in the local economy (consumption linkages) and the amount of personal income tax revenues to be collected from employees (fiscal linkages). It also suggests that automation is likely to reduce the opportunities for local procurement, particularly in developing countries (upstream linkages). This, in turn, will also adversely affect indirect job opportunities of suppliers. The orange rectangles indicate the reduced opportunities for shared value through the consumption and upstream linkage channel. The fiscal linkage channel is striped orange and blue, given that automation will on the one hand reduce the opportunities for collecting personal income tax payments, but on the other hand provide an opportunity to capture additional value by reconfiguring the fiscal regime (as highlighted in the next subsection).

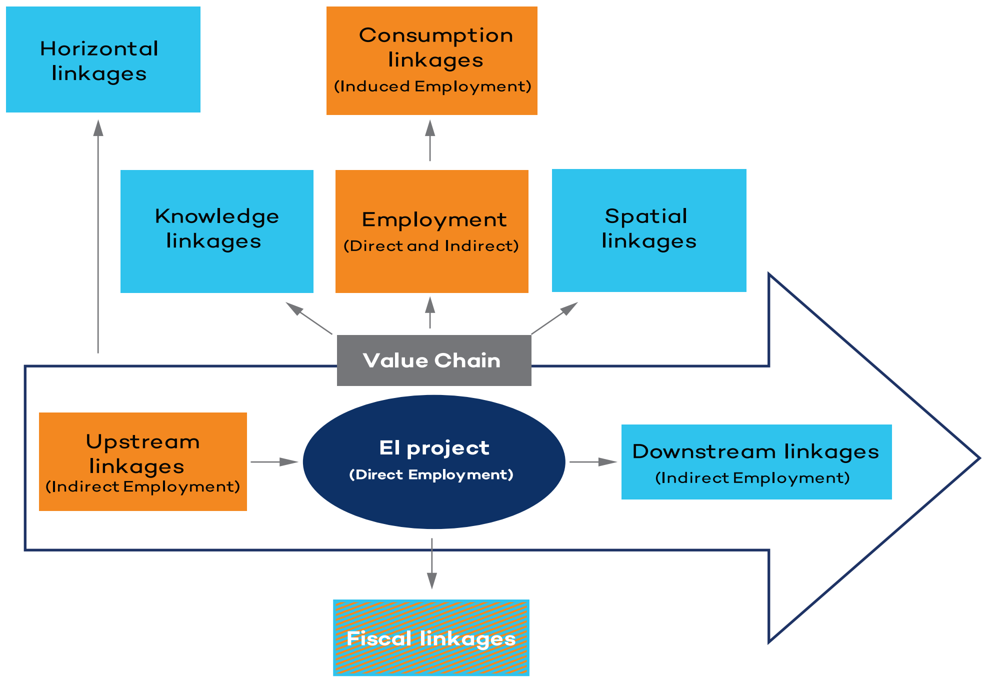

Figure 15: Potential Avenues Of Sharing Value Of Mining Projects
Source: CCSI & GIZ (2016)

Assuming that these three linkages will be adversely affected by automation, there are four other avenues through which shared value can be created—avenues on which we have not focused in this analysis. These are the blue rectangles in the figure above:

1. Downstream (forward) linkages relate to the beneficiation of extracted commodities through refining, smelting and further downstream processing of the commodity before reaching the final consumer. For example, 98 per cent of the world's mined iron ore is used to make steel and therefore needs to pass through a steel mill. Downstream benefits are, for example, a key strategy in the African Mining Vision and broader African economic visions of shifting to a more industrialized economy.
2. Horizontal (lateral) linkages relate to the development of new non-mining-related industries adapting the capabilities developed to serve the mining-related value chain. For example, mining trucks could be re-engineered and adapted to service the logging industry. But it is unclear if this will be limited to a repurposing of older technologies or an ability to utilize new technologies in other sectors.
3. Knowledge (technological) linkages relate to the transfer of knowledge and technological know-how to state-owned companies, the employees of the mine and to the labour force involved in the mine's value chain. For example, the state-owned company acquiring managing and technological expertise through a joint venture agreement with international investors. However, this may be more difficult when high-technology providers seek to protect those technologies.
4. Spatial (infrastructure) linkages relate to the benefits associated with the infrastructure developed for an extractive-industry project profiting other actors in the economy. For example, an iron-ore mine is likely going to require railway infrastructure. Other companies (from the mining sector and non-mining sectors) and passengers may benefit from this railway infrastructure if granted access.

The potential for each of these linkages is very context specific. Railway-sharing opportunities, for example, only exist for bulk commodity mining projects where such infrastructure construction is required, and to the extent that the transport route is valuable to non-mining interests. Downstream processing opportunities will largely depend on infrastructure and water availability (for example, smelting activities are very energy- and often water-intensive) and existing international production capacity (for example, currently there is excess capacity for steel production). Beneficiation (processing raw materials to consumer grade, such as diamond cutting) is notoriously difficult to foster via government policy, and difficult for firms whose core business is extraction and processing, but successful examples exist. However, the adverse impact of automation on employment and local procurement in developing countries enhance the importance of assessing these alternative types of linkages when seeking to maximize the impact of mining for broader development needs.[14]

5.2 Revising the Fiscal Element of Shared Value

Perhaps the least intrusive option for governments will be passive receipt of efficiency-driven revenues. The increased productivity and reduced costs resulting from automation should generate increased profits that are then taxable, as well as the possibility of increased dividends to government-held equity. There may also be increased volumes of production that are subject to royalties. This is the minimum response scenario in our view.

Beyond the straightforward formula that sees increased compensatory government revenues coming from increased efficiency and profits, it is likely that governments will seek added benefits to replace lost employment and to impose increased taxes or royalties. This may come in the form of higher tax levels on all profits, or higher royalties on production. This again would rely on traditional tools and approaches within national fiscal regimes.

There may also be options for governments that pursue newer approaches to managing the fiscal regimes in relation to mining. One such approach is to move to more progressive tax regimes in a much clearer way. Given the pressure for better and more transparent reporting practices (see Section 6 below), and as governments become more familiar with the modelling extractive industry projects,[15] it may be possible for them to implement and administer fiscal mechanisms that self-adjust to the profitability of the project, to changes in circumstances and to reduced risk over the life of a project by being progressive with respect to time, costs and prices. This type of fiscal mechanism, also called the resource rent tax or return-based sliding scale profit sharing arrangement, is indexed on the project returns and captures an increasing share of the project profits as these profits accumulate beyond a certain threshold, with the objective of taxing the rent.[16]

By ensuring predictable flexibility, this fiscal mechanism ensures stability of the investment but it also means that companies assume lower risks in case of lower profits (resulting either from price decreases or cost increases).[17] While such a mechanism is already widely implemented in oil fiscal regimes, given the higher rents, it has not managed to take a foothold in the mining sector. It was implemented in Australia in 2012, but repealed in 2014 in the face of declining commodity prices (Critchlow, 2014). It was similarly proposed in several other mining

[14] Assessing the impacts of automation on these other types of linkages is beyond the scope of this study. However, it is likely that automation will also have an impact on these. For example, knowledge and technology linkages are most likely to be successful if the "knowledge gap" between the international investor and the host country capacity is not too large. This gap will likely be exacerbated by automation, which might limit the knowledge transfer. This could be countered by public–private investments in technological training and education. Similarly, horizontal linkages may be affected, as the biggest potential for horizontal linkages originate from upstream activities, which are likely to be reduced due to automation.

[15] See the discussion at http://goxi.org/profiles/blogs/public-interest-modeling-don-t-let-the-perfect-the-enemy-of-the?xg_source=msg_mes_network.

[16] Rent is defined as the excess profit above what is necessary to cover the costs and the minimum return necessary to attract investment.

[17] An additional risk for the government generated by return-based fiscal systems is the risk of gold plating, or expenditure deliberately designed to make profits disappear. "The effects of gold plating are more severe if the benchmark rates [the various thresholds in the sliding scale at which the various tax levels kick in] are higher than the hurdle rate [the cost of capital under which an investor won't invest] and the profit differential is very large" (van Meurs, 2016). The recent Mexican shallow water production-sharing contract illustrates this issue: the benchmark rates of 25 per cent and 40 per cent are far over industry hurdle rates and the reduction of the profit share by 75 per cent is excessive by international standards. This system might lead contractors to embark on wasteful expenditure to improve their profitability by staying in low brackets. To anticipate and avoid gold plating effect through a well-designed sliding scale, fiscal modelling skills will be critical. (Ibid.)

jurisdictions prior the commodity price slump. Automation and its assumed associated increase in profitability combined with reduced benefits from the employment and procurement channels might generate renewed interest for this mechanism from the mining sector.

5.3 Challenges to the Current Shared-Value Approach

A more aggressive approach by governments would begin by asking a different question for the sector, one that essentially reverses the traditional basic question: instead of asking what share of its revenues the company should share with the government, the question could be reversed to ask what level of returns the company should receive. This reversal of the basic question opens governments to very different approaches that might challenge the current approach to shared value in more fundamental ways. For example, this might mean governments maintaining full ownership of the resources and the mining project, as compared to the predominant concession agreement model. This type of direction may be more likely today than it otherwise would be due in part to the difficulties administering tax regimes that are increasingly complicated by tax havens, transfer pricing and other tax base erosion practices, which can impact any fiscal approach to shared value.

An option short of full ownership would be increased ownership by governments—directly or through state-owned enterprises—of mining companies operating in their territories. Under the current model, the prevalent forms of state equity are (i) free equity giving rise to dividends without the governments contributing to the cost of the project; (ii) carried interest, whereby the investor lends money to the government in order for it to contribute to the costs; or, more rarely, (iii) paid-up equity, whereby the government contributes to the cost on equal footing with the investor. The merit of increased ownership for governments is subject to some debate. In particular, the value of such shares is usually based on the value of the dividends received, rather than any value of the equity holdings themselves, because, in most cases, shares cannot be sold to the public. In addition, unless the government has control of the board of directors, or of the parent company board in many instances, dividends remain an uncertain benefit dependent on the decisions of the board. The impacts this would have on increasing the other elements of the shared-value paradigm—local purchasing or downstream beneficiation, for example—are also unclear.

Moving towards alternatives based on maintaining full ownership of the resource and production processes has a history marked by significant failures in different parts of the world. However, experience from other natural resource and infrastructure sectors might be analyzed, and best practices for establishing politically independent and economically efficient enterprises can be applied, if the political will is present to avoid the types of nationalizations that occurred in the immediate post-colonial period. The experience in other sectors, the oil and gas sector for example, has seen a much more divergent set of government–company relationships, such as fee for service contracts and production-sharing contracts that have solidified the operations of state-owned enterprises as well.[18] These forms of government-company relationships start from the premise of the ongoing government ownership of the production process and its fruits, rather than the form of concession model that gives these rights to the company. Similarly, the wave of privatizations in many infrastructure service sectors, such as water supply and sanitation or energy provision in the 1990s and early 2000s, has also given way to alternative forms of service contracts. Indeed, the mining sector more than any other has stayed tied to this pre-colonial concession model of ownership, while other sectors have developed a greater range of options based on government (or state-owned enterprise) ownership.

[18] Technically PSC is about *sharing* of ownership and control between the investor and the host government as opposed to full government ownership. All the options discussed in this section can be applied with slight variations to concession contract models or to full ownership models. A PSC can be a form of payment to a company in lieu of cash, but with full ownership of the resource and operation staying with the state-owned enterprise, as much as it can be a sharing of ownership, joint-venture style

Government ownership would likely expand options for enhancing value in other parts of the shared-value paradigm, especially if linked with other government policies on training and local economic development. Again, however, this would be subject to environmental and economic constraints, as well as realistic appraisals of how to optimize value without putting at risk the value of the mining operation itself.

A failure of the shared-value paradigm to deliver true shared value to host countries may see a deeper investigation into these sorts of ownership and contract options by governments. The shared-value paradigm came about in part as a response to the rise of resource nationalism in the mid-2000s. The types of pressure we see on the paradigm will likely lead to further increases in resource nationalism to try and capture the full value for governments. While this may be more likely to be achieved for new investments, it is unlikely that existing investments would be fully immune.

6.0 BEYOND THIS STUDY

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6.1 Data Limitations

One clear lesson not explicit in the analysis above stems from the lack of readily available data on procurement. Despite offers from approximately a dozen companies, we ultimately found it exceedingly difficult to access data from companies on the kinds and volumes of goods and services they purchase at mine sites. In the end, all but two firms were unable to provide the information initially promised. The companies involved cited a number of difficulties that included:

- Corporate offices having little procurement data at-the-ready from their mine sites; virtually all information had to be requested "to-order" and none of this data was part of any regular internal reporting.
- Different systems of data management and reporting on procurement across the mining sites operated by the same mining corporation.
- Mining sites simply not having systems in place to be able to easily compile data on their procurement.
- Corporate office concerns over "initiative overload" and fearing they would be seeking too much information from sites if data was requested.
- Company fears, particularly from legal departments, regarding the confidentiality and commercial sensitivity of procurement information provided; even very generic data "scrubbed" of any information revealing the nature of a mining company or suppliers was considered problematic to provide in several cases.

Regrettably these data collection challenges are not unique across the global mining industry. Similar projects and research the authors have engaged with encountered similar problems.

Those problems go well beyond creating challenges for the present study. There are a number of negative implications for corporate management, partnership building and government policy-making that come out of a lack of understanding of what mining companies purchase locally. For host states, it becomes difficult to fully exploit the potential economic impact. For companies, missing this information can mean missed opportunities to target particular goods and services to purchase locally, when such purchases could lead to both costs savings and an enhanced social licence to operate.

A good starting point might be an effort by the industry to standardize the reporting in this area, if not for the sake of internal intelligence then in pursuit of ways to salvage the shared-value proposition.

6.2 The Need for More Research

The present study aims to shed some light on the question: What will trends in technology mean for host countries' ability to benefit from mining investment? We are confident that, even though they draw on a limited data set, our analysis and conclusions are robust, and constitute a valuable contribution to a vital new area of discussion.

That said, there is clearly a need for further research in this area, both in confirming our basic findings and in exploring the nuances of the relationship we have identified. Does it matter, for example, if we are looking at open-pit or underground operations? Would different minerals yield significantly different results? It would also be interesting to explore more fully the relationship between the host country income level and the impacts of technology, both confirming the distinctions we observed and considering middle-income or emerging country cases; our two cases are situated toward the ends of the country income spectrum.

We do not expect the basic message to radically change as a result of further work on the questions we examine. But we fully expect that more research will sharpen our sense of what to expect as the advent of new technologies changes the way mining investment interacts with host countries, regions and communities. The better we understand the changing realities, the better both firms and host countries can ensure the continued relevance of the promise of shared value.

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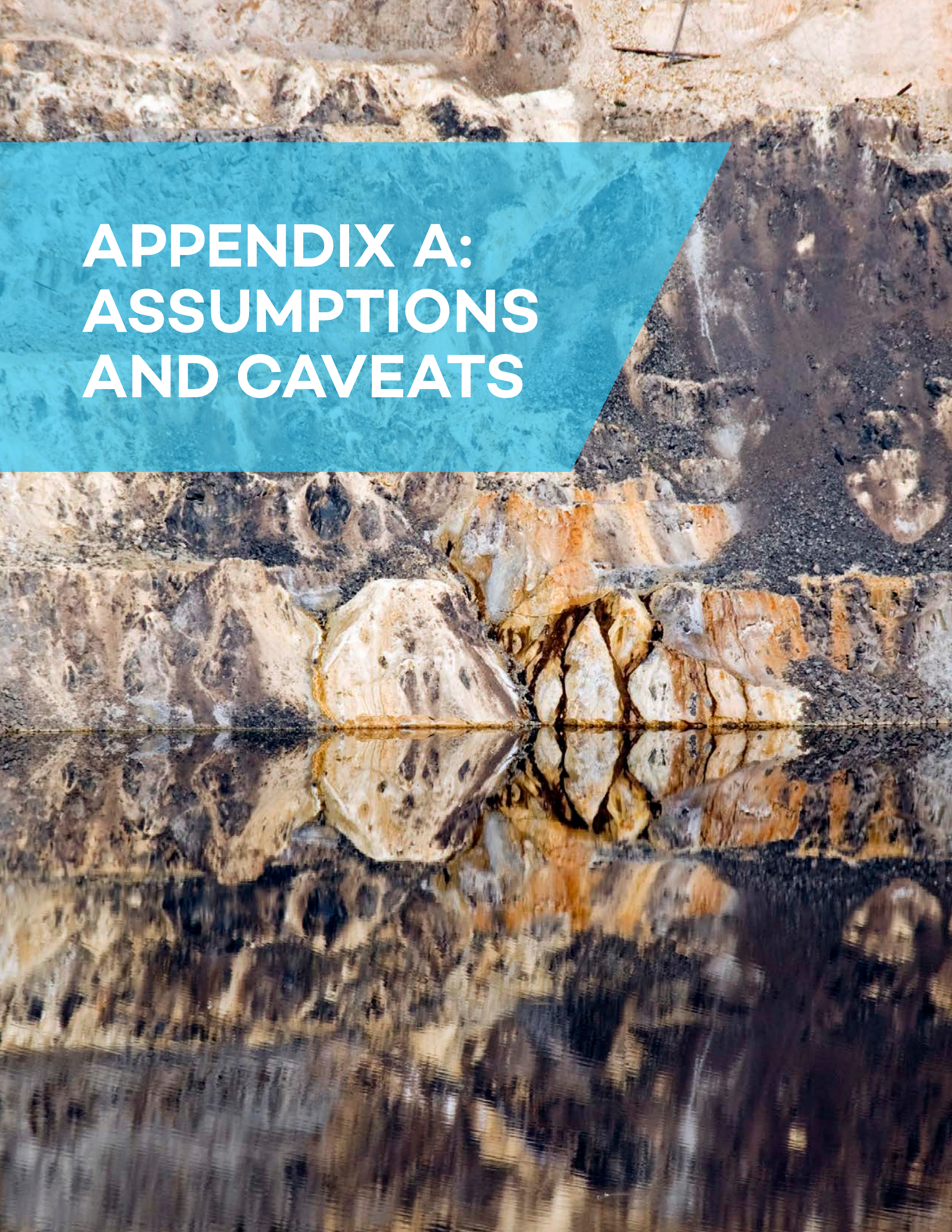
APPENDIX A: ASSUMPTIONS AND CAVEATS



APPENDIX A: ASSUMPTIONS AND CAVEATS

We drew the data used in this analysis from two mining firms, one operating in a lower-middle-income country and one in a high-income OECD country (World Bank classifications). The firms themselves supplied all data on procurement, based on 2014 figures, to the research team. We drew all other data from the firms' respective public corporate reports from 2014 unless otherwise specified. All figures in this report are quoted in U.S. dollars. Exchange rates used are averages from the year of expenditure.

For both operations, data on wages and benefits, and spending on finance and transfers to government are average figures from the operating years 2012, 2013 and 2014. Averages are used to help smooth over some of the variability inherent in these figures.

The high-income OECD country operation reported payments to providers of capital that would presumably be split among several operations, not just those in our case. Given that the operations in our case are by far the major elements of the firm, we have assumed dividends and interest paid are all attributable to the case study operations.

We grouped suppliers for the high-income OECD country into community-level, regional and national by means of their addresses in procurement records. This is not a foolproof method—firms might have local postal addresses or branch offices quite apart from their real central offices.

The number of full-time equivalent employees for the high-income OECD country included all full-time staff and all contract (term) employees. It considered all co-op, summer and part-time staff as half time. We included head office staff (non-local, but national) as employees, but only counted a third of those staff, to account for time spent on purely corporate strategy and on other sites owned by the company.[19] We adjusted reported payments of wages and benefits to account for payment only to those we have assumed are site-specific staff. We did not include contractors as employees for either operation. Excluding contractors from the analysis may understate the impacts of automation, since the expected workforce reductions are only applied to employees when in fact they may also affect contractors.

We calculated personal income tax payable for both countries assuming that all employees are earning the average wage/benefits package. We then applied the respective countries' tax regimes to those earning levels. We assumed no tax deductions, and applied taxes to benefits as well as wages, which means we are probably overstating the estimates of lost government revenues.

The multipliers used are national. In the case of the high-income OECD country, the multipliers are from the national statistical agency's input-output model. They are average figures, a blend of the multipliers for gold and silver ore mining and copper, silver, lead and zinc ore mining. The lower-middle-income country multipliers are World Bank country study estimates for gold mining.

The multiplier analysis is imperfect in two ways. Multipliers are designed to tell us what happens to each incremental dollar of investment in a mining operation. In looking at GDP impacts, we are applying them to incremental dollars spent on salaries and local procurement, but these are only part of the total investment. The multiplier for this type of spending would almost certainly be different. For salaries, the true type II multiplier would undoubtedly be larger. The type I multiplier would probably be lower.

As well, the employment multiplier is based on empirical observations of how many workers are needed to produce a given amount of output. The scenario we are examining fundamentally changes that ratio. So the employment multiplier is not an ideal way to estimate how many jobs would be lost via indirect and induced impacts. In our three scenarios the multiplier should be smaller, as should the final job-related impacts of automation.

[19] The one third ratio is based on estimates provided by the mining company.

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