Preface: The COVID-19 Pandemic and Mineral Resources

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Pandemics are one of the few events that are truly global and affect all of humanity. Even World Wars I and II, as terrible and far-reaching as they were, did not affect all corners of the globe, and certainly not equally. Pandemics are different, especially in light of modern transportation and the interconnectedness of global business, education, and supply chains. One does not have to be a major participant in the global economy or even be aware of the disease at all to be affected, infected, or possibly killed.

Although the long-term effects of COVID-19 are not yet known, there are few in the minerals sector who have not been affected, whether it be by the loss of a loved one or by the economic fallout of attempts to contain the disease. Many universities and mines are closed, research and exploration budgets curtailed, and most travel halted. At the time of writing, no one knows how the pandemic will evolve—are we past the worst of it or are there new waves coming?

Following this preface are two rapid-response articles to offer a preliminary assessment of the impact of COVID-19 on the minerals industry and all of us who are connected to it. The first article, by Hitzman et al., reports the results of a survey about the pandemic's effects on the lives, education, and business of people in the minerals industry. Although necessarily limited in scope, it provides a snapshot in time that sets the stage for the second article, by Simon Jowitt, that offers a preliminary economic analysis of possible effects on prices, stocks, and supply and demand within the minerals industry.

The phrase "the new normal" has been used frequently to describe the effects and after-effects of the COVID-19 pandemic. The following two studies are complementary and provide a framework for assessing where we are today and for beginning the process of planning for the future. Although it is likely that both articles would be written differently a year or two from now, they are presented here while the pandemic is still unfolding to provide the view from July 2020.

Impact of the COVID-19 Pandemic on the Minerals Sector: A Real Time Survey

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Abstract

Through the implementation of an online survey, run at the end of April 2020, researchers at the Irish Centre for Research in Applied Geosciences (iCRAG) explored the immediate effects of the COVID-19 pandemic on the minerals sector workforce. With more than 1,000 respondents, the survey provides insights into the impact of an unprecedented global event at a crucial point in its development. Seven weeks after the World Health Organization's declaration of the pandemic, 65% of survey respondents agreed that COVID-19 had a significant impact on their work. Overall, 32% of respondents had experienced negative impacts on their employment, having either lost their jobs or been furloughed/temporarily laid off, or were working reduced hours.

Geographically, the greatest impact on employment was in Africa, where 45% of respondents suffered negative effects. More often, younger respondents (ages 18–30) reported lost jobs (14%) whereas older survey participants reported working reduced hours (21%, ages 46–60). Respondents working in mineral exploration were most affected (40% suffered negative job impacts), but the impact across base, industrial, and precious metals was broadly similar for all participants; government employees were least affected but were not immune (10% on reduced hours). The level of concern about future job security due to the COVID-19 crisis varied, with 35% of respondents being more or very concerned or having already lost their jobs, 43% had little or no concern, and 22% were moderately concerned. The survey captured the experiences and perceptions of individual workers, providing a perspective different from information available in corporate statements and official statistics.

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doi:10.5382/SEGnews.2020-122.fea-01

Introduction

The COVID-19 pandemic caused by the novel (new) coronavirus affected human activity across the planet in 2020. Early cases of COVID-19 were recorded in China in December 2019 (Huang et al., 2020) and the first cases outside China were confirmed in mid-January 2020 (World Health Organization, 2020a). The World Health Organization (WHO) set up an Incident Management Support Team on January 1, 2020. With increasing numbers of cases throughout the world, the WHO declared the COVID-19 outbreak to be a pandemic on March 11, 2020. Over 10 million cases and in excess of a half million deaths were reported worldwide to the end of June 2020 (European Centre for Disease Prevention and Control, 2020; WHO, 2020b).

Outbreaks of COVID-19 overwhelmed medical facilities in several regions, leading governments throughout the world to enforce restrictions

to prevent the spread of the illness. Wuhan, the Chinese city of 11 million people at the center of the initial outbreak, for example, entered a 76-day lockdown in response to the virus on January 23, 2020. Measures included closure of non-essential businesses, travel restrictions, border closures, quarantines, social distancing, limits on the number of people who could congregate, and cancellation of many in-person gatherings. Lockdowns to varying degrees were put in place virtually around the world by the end of March 2020 (Hale et al., 2020). Some governments deemed mining and mineral exploration to be essential businesses that could remain open. Temporary mine closures were especially common in Latin America and South Africa, but some operations in the United States, Canada, and elsewhere also reported reduced activity (S&P Global, 2020). Mineral exploration was severely affected by travel restrictions.

To better understand the impacts of COVID-19 on the minerals sector, researchers at the Irish Centre for Research in Applied Geoscience (iCRAG) launched a short online survey at the end of April 2020. The survey was designed to determine the immediate effects of the pandemic on people in the minerals sector and how the effects were distributed in terms of geographic area, sector of the minerals industry, and commodity. The survey asked about the impacts on people's employment, the nature of the impact, and the level of concern individuals had concerning job security due to COVID-19 for the remainder of 2020 (Boland et al., 2020). The survey fortuitously captured data just before many different parts of the world began to open up after a nearly global lockdown. Thus, the results capture opinion at the height of the initial response to the pandemic.

Methodology

An eight-question English-language survey was created in Google Forms in consultation with an iCRAG social scientist, followed by an ethics review at University College Dublin (Boland et al., 2020). Since Google is not accessible in Mainland China where the pandemic began, a duplicate of the questionnaire, in English, was created through a Chinese survey website. The survey was posted online on April 23, 2020, and was held open for responses until noon GMT on May 2, 2020, allowing people in other time zones to respond within the May 1 deadline.

A link to the online survey was distributed by the authors via email to their contacts in the minerals sector with a request that they fill out the survey once and pass the link on to others in the mineral exploration, mining, and minerals research sectors. Information about the survey was sent to the economic geology group of the Geological Society of Australia, International Association on the Genesis of Ore Deposits, Irish Mining and Quarrying Society, Irish Association for Economic Geology, Ore Deposits Hub, Society for Mining, Metallurgy & Exploration, and student chapters of the Society of Economic Geologists worldwide. These groups shared the information with members in various ways, including mentioning it online, in member mailings, podcasts, and webinars. iCRAG intentionally did not publicize the survey via social media such as LinkedIn in order to ensure, to the extent possible, that it would remain within the minerals sector.

A total of 1,010 English-language plus 40 Chinese responses were received by the closing date. Of the 1,050 responses, 1,007 contained sufficient information to be included in the analysis. Data from the survey and information on how the data were processed are available on the iCRAG website (Boland et al., 2020).

Choosing to distribute the survey through personal contacts and selected organizations and allowing respondents to self-select means that the survey is not based on a completely random sample and it is thus impossible to estimate the response rate. The survey was designed to be simple and rapid, with an estimated completion time of less than three minutes. In order to minimize barriers to participation and to meet the requirements of our ethical approval, respondents were not required to sign in and all responses were kept anonymous; it is possible that some people could have responded more than once.

Response Demographics

Responses were received from individuals whose most recent employment spanned 55 different countries. In terms of most recent employment location, the largest response was from those employed in North America (49% of the respondents; Fig. 1A). The second largest response group was from Europe (14%), followed by Asia (7%,) Africa and South America (6% each), and Australia (5%). However, 13% of the responses did not list a country of origin. Respondents were fairly evenly divided by age (Fig. 1B). The largest cohort of respondents (32%) were aged 31–45, whereas 28% were older than 61 years of age, 23% were age 46–60, and 17% were 18–30 years old. In relation to current employment status, 55% reported being currently employed whereas 26% listed themselves as consultants, 10% said they were students, 5% were retired, and 4% reported being unemployed (Fig. 1C).

Respondents were asked to identify the sector in which they worked: mineral exploration, mining, minerals research, or other. Some respondents selected multiple sectors, leading to many different combinations; therefore, we aggregated responses in order to simplify the analysis, as explained in Boland et al. (2020). Based on additional information provided by those who chose "other," we created a new category of "government." Following these procedures, the respondents represented 54% mineral exploration, 22% mining, 17% minerals research, 2% government, and 5% other (Fig. 1D). The other category included environment, education, law, services, policy, engineering geology, petroleum, drilling, health and safety, information technology, corporate social responsibility, and water.

For primary focus of work, respondents were asked to choose one option from the following: base metals, industrial metals, precious metals, or other. Where respondents provided details under "other" the responses were classified as "other" if they mentioned a commodity—responses included coal, critical minerals, uranium, potash, salt, construction materials, oil and gas, and helium. If the response indicated support services such as education, software, drilling, they were categorized as "no data" to indicate that they were not linked to a single commodity. Following these procedures, the respondents represented 47% precious metals, 32% base metals, 7% industrial minerals, 9% other, and 5% who were classed as none listed (Fig. 1E).

Results

The pandemic had a significant impact on people in the minerals sector by the end of April 2020, less than six months after the first cases occurred and within seven weeks of the declaration of a pandemic.

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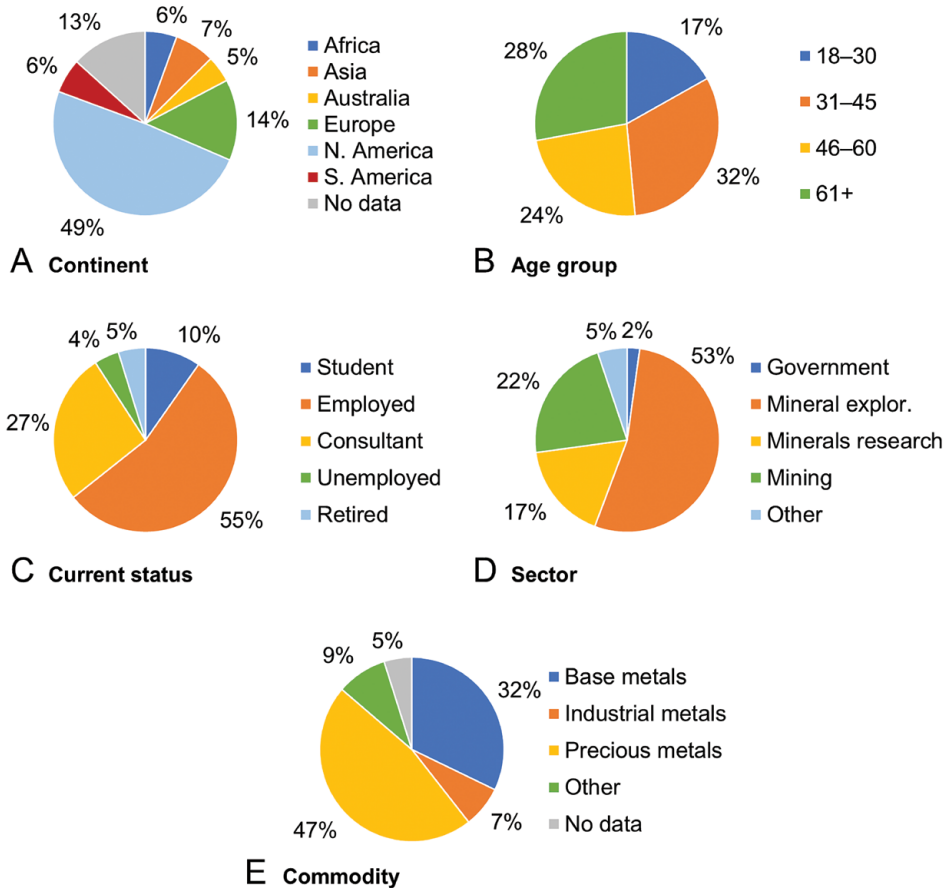

Fig. 1. iCRAG COVID-19 Survey demographic data. A. Responses by continent. B. Responses by age group. Four responses with no data (<1%) were omitted from the chart. C. Responses by employment type. One response with no data (<1%) was omitted from the chart. D. Responses by employment sector. Two responses with no data (<1%) were omitted from the chart. E. Responses by type of commodity the survey participant was involved with.

Effect on work

Survey results indicate that two-thirds of respondents had felt the effects of the pandemic on their work: 37% of respondents strongly agreed that the COVID-19 pandemic had already significantly affected their work, with another 28% agreeing that it had affected their work (Fig. 2A). Only 14% disagreed or strongly disagreed with the statement that the pandemic had affected their work.

Effect on employment status

When asked if the pandemic had had a direct impact in their employment status, 65% said there had been no change whereas 18% reported reduced hours, 4% reported being furloughed, and 9% reported having been laid off. Four percent of participants reported "no opinion" (Fig. 2B). The highest rate of change in employment status was from Africa, where 45% of respondents reported negative employment activity, defined as job loss, furlough, or reduced hours (Fig. 3A). South American respondents were next, with 34% reporting negative employment activity. Europe appeared to be the most stable, with 70% of respondents experiencing no change in employment status followed by Asia and North America, where 66% of respondents reported no change in employment status.

Currently employed (78%) and retired (83%) individuals stated they had not seen a change in employment due to the COVID-19 crisis (Fig 3B). Fifty-six percent of consultants indicated a change in employment conditions, predominantly reduced hours, due to the pandemic. Twenty-five percent of students reported either being either laid off or furloughed since the start of the pandemic. Looking at change in employment by age (Fig. 3C), the youngest cohort (ages 18–30) reported the highest percentage of lay-offs (14%) followed by the 31- to 45-year-old group (11%). The 46- to 60-year-old group fared the best with only 6% losing their jobs while those aged over 60 had 7% lay-offs. However, experiencing reduced hours was more common for the older groups, in which almost 22% of respondents aged over 45 years had their hours reduced compared to 14% of the those up to age 45.

Change in employment status was most pronounced in the mineral exploration sector, with 11% of respondents in this sector having lost employment while 23% had suffered reduced hours

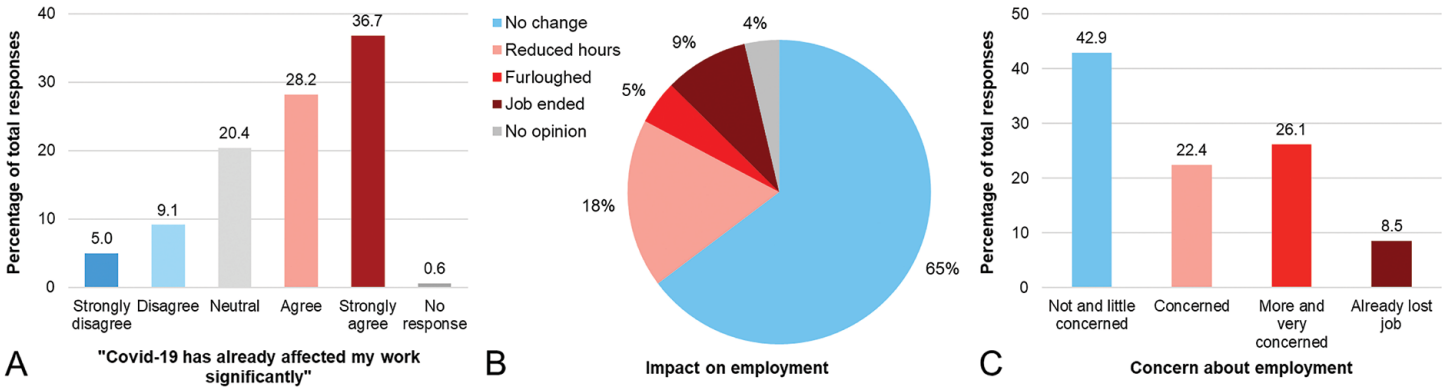

Fig. 2. iCRAG COVID-19 Survey responses concerning impact of the pandemic. A. Whether the pandemic has affected the respondent. B. The effects of the pandemic on individual respondents. C. Level of concern about employment in the future due to the pandemic by respondents.

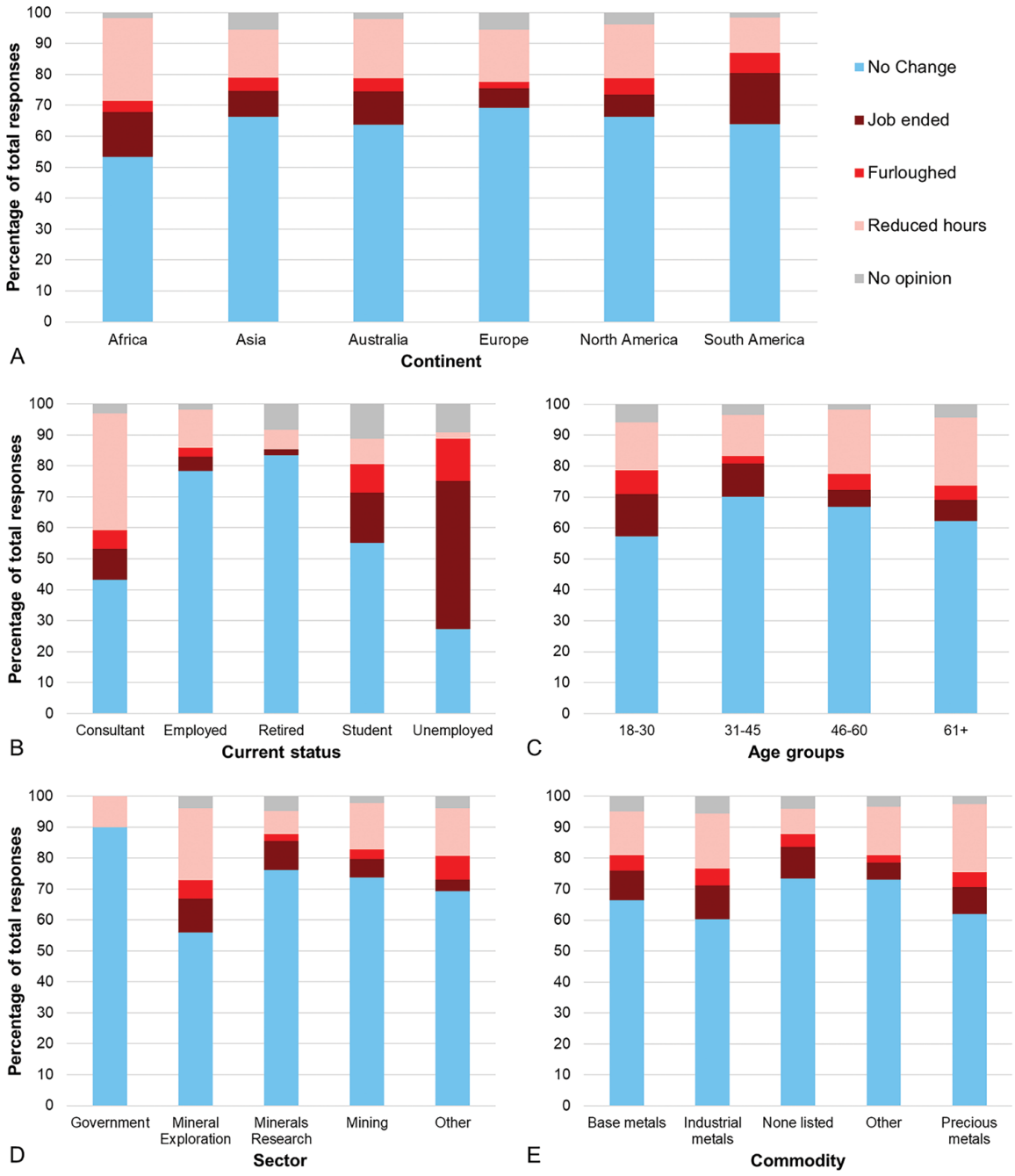

Fig. 3. iCRAG COVID-19 Survey responses on the impact of the pandemic by group. A. Impact on employment status by geographic region. B. Impact on employment status by type of current employment. C. Impact on employment status by age. D. Impact on employment status by employment sector. E. Impact on employment status by commodity the survey participant was involved with.

and 6% reported having been furloughed (Fig. 3D). Both mining and minerals research were less affected; nevertheless, 24% of respondents from the mining sector and 18% of those in the minerals research sector reported negative employment changes. The government sector reported the least change in employment though even there 10% of respondents reported reduced hours due to the COVID-19 crisis. The impact of COVID-19 on employment in the base metals, industrial metals, and precious metals sectors was broadly similar (Fig. 3E).

Concern about job security due to COVID-19 in 2020

Looking to the future, 26% of respondents were very concerned (scoring 4 or 5 on a 5-point scale) about future employment due to the pandemic, 43% stated they had little or no concern about future employment, while 22% were moderately concerned, and 9% had already lost their job (Fig. 2C). The level of concern varied by geographic area among the respondents (Fig. 4A). Some 36% of African respondents were very concerned about job security going forward due to the pandemic. Respondents from South America were next in line with 33% stating strong concern. These areas also had the highest rate of job loss due to the pandemic. Approximately 50% of respondents from Asia and Australia had little to no concerns about employment in 2020 going forward. Even though Europe showed

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the least change in employment due to the pandemic, 30% of its respondents recorded being very concerned about employment for the rest of 2020.

The survey results for job security concerns in 2020 by current employment status (Fig. 4B) showed the unemployed (32%) being the most concerned, followed by consultants (29%), then students (28%), and those employed (25%); retired respondents were the least concerned. Concerns by age (Fig. 4C) indicate that those aged 31 to 45 were most concerned, with 30% of the 31- to 45-year-old cohort being very concerned and a further 22% being concerned about job security in 2020. However, younger people were not far behind, with 27% of the 18- to 30-year-olds reporting that they were very concerned. Older people were somewhat

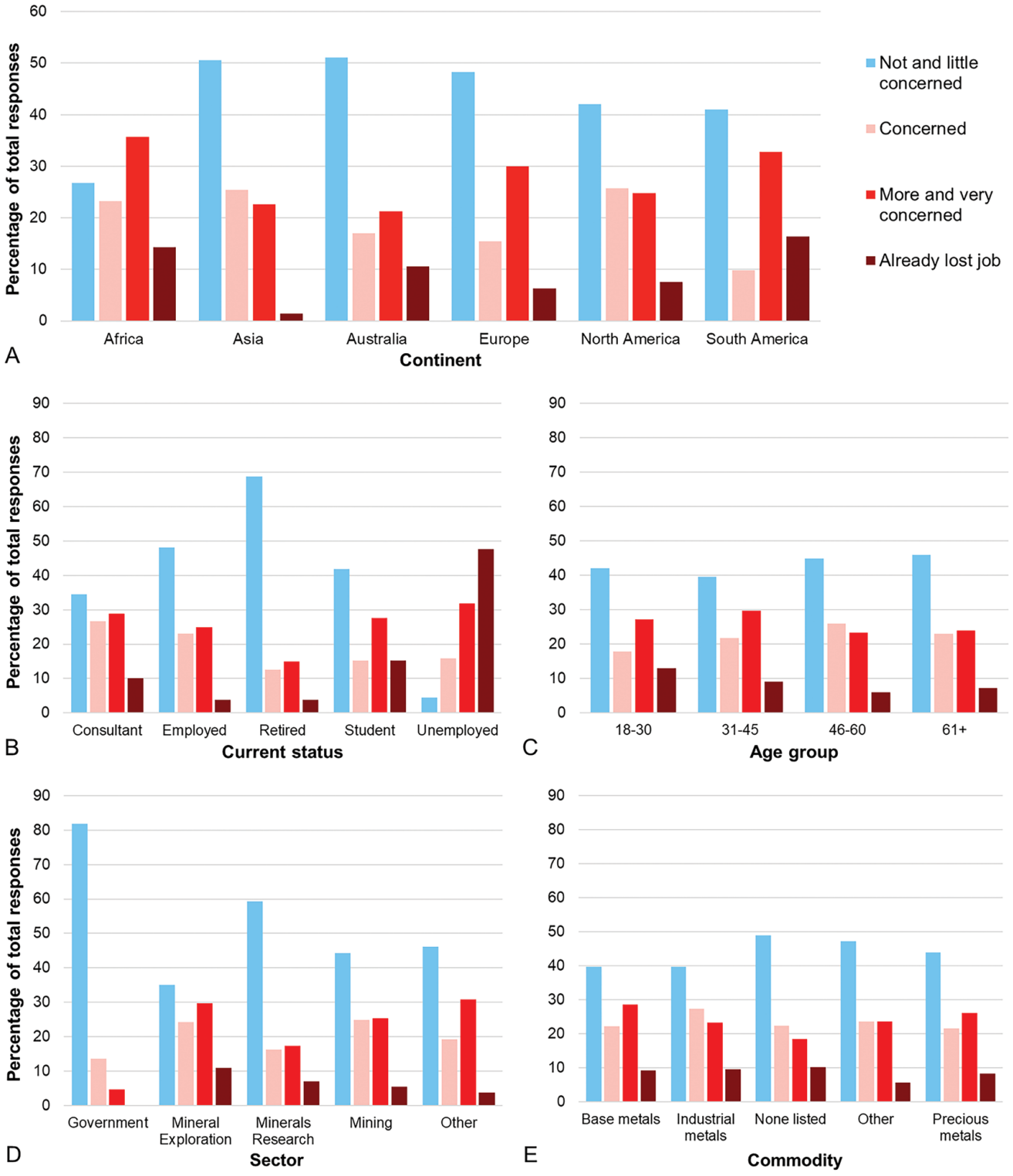

Fig. 4. iCRAG COVID-19 Survey responses on concern about the impact of the pandemic. A. Concern about employment by geographic region. B. Concern about employment by type of current employment. C. Concern about employment by age. D. Concern about employment by employment sector. E. Concern about employment by commodity the survey participant was involved with.

less concerned about the impact of the pandemic on their employment for 2020, with 23% of 46- to 60-year-olds, and 24% of the group aged over-60 reporting strong concern.

Slightly over 50% of those in both the base metals and the industrial minerals sectors were somewhat to very concerned about job security (Fig. 4D). Those in the precious metals sector fared slightly better, with 48% showing concern or significant concern. By sector, those in mineral exploration were the most concerned about job security in 2020 followed by those in mining and in the "other" job sector category (Fig 4E). Not surprisingly, government employees had the least concern though even in this group approximately 18% expressed concern or strong concern.

Discussion

This survey reflects the experiences of a self-selected section of people in the minerals industry at a particular point in time. We cannot ascertain how well the respondents represent the total workforce because there are no readily available data on the demographics of the global minerals sector workforce. There are some general indications that the survey results are credible. The age distribution matches well with the age distribution of employees in the U.S. "metal ore mining, nonmetallic mineral mining and quarrying, and not specified type of mining" employment categories for 2019, with 49% of all survey respondents being under 45 vs. 52% reported by the Bureau of Labor Statistics (2020a). The number of respondents from the United States who reported losing a job (6.6% of 303 survey responses) is very close to the reported loss of jobs in the U.S. mining (except oil and gas) workforce between January and April 2020 of 6.8% (U.S. Bureau of Labor Statistics, 2020b). Data from Australia indicate that expenditure on exploration on areas including existing deposits fell 16.0% and on areas of new deposits by 26.1%; base metals projects were impacted more than gold or iron ore projects (Australian Bureau of Statistics, 2020). Our survey results show that employment in the exploration sector was most affected but indicated less differentiation between the base and precious metals sectors.

The timing of the survey may have been fortuitous in capturing responses at the cusp between global awareness of the pandemic and the initial reopening of many economies. Although Wuhan entered quarantine on January 23, 2020, known cases outside of China did not rise significantly until March (Fig. 5A). The WHO announcement of the COVID-19 pandemic on March 11, 2020, was quickly followed by lockdowns worldwide as demonstrated by school closures (Fig. 5B). The survey at the end of April was conducted just after the first peak of COVID-19 cases in the United States, while weekly newly confirmed COVID-19 cases were still very high in Europe, but prior to a sharp rise in cases in Brazil and India (Fig. 5A).

Public interest in the pandemic, as represented by daily Google searches for the topic "Coronavirus" and related terms (Google LCC, 2020) peaked coincident with the WHO announcement and then began a slow decline throughout March and April (Fig. 5C). Daily Google searches for the topic "Unemployment" and related terms show a nearly tenfold increase in late March compared to the beginning of the year (Fig. 5D), likely reflecting global concern about job losses as a consequence of COVID-19 containment measures. Search interest in the topic "Unemployment" gradually decreased in April but, by the end of June, was still about five times higher than in the beginning of the year (Fig. 5D). The decreasing interest in both "Coronavirus" and "Unemployment" search topics corresponds to the gradual easing of COVID-19 containment measures around the world after the iCRAG survey was conducted at the end of April. As government responses became less stringent globally (Hale et al., 2020), nationwide school closures became less common (Fig. 5B), and people began to travel more in May, as indicated by the daily number of routing queries for driving and public transport in the Apple Maps application (Fig. 5E; Apple Inc, 2020). The survey was also conducted just as mine closures were beginning to wind down and some mines that closed earlier in the pandemic were beginning to reopen (S&P Global Market Intelligence, 2020).

Company press releases are a key source of corporate information on the minerals sector and were examined to provide additional context for our survey results. Based on an analysis of 1,234 press releases from publicly traded junior resource companies collated by the Junior Mining Network (2020) between January and mid-June 2020, the overall number of press releases began to drop in mid-February 2020, perhaps reflecting a decrease in corporate activity. COVID-19 was first mentioned in these mining company press releases in mid-February in connection with delayed shipments of mine construction components from China. COVID-19 was mentioned frequently in press releases during April and May 2020. Some press releases provided information on mine closures or suspension of activities. Several press releases highlighted corporate efforts to mitigate the impact of the pandemic on workers and local communities, including improved health and safety measures, donations of personal protective equipment, water, and food, as well as providing education about COVID-19. However, it proved very difficult to derive a comprehensive picture of the impacts of the pandemic on the minerals sector from press releases, reflecting the selective nature of the information provided.

Perhaps the most surprising result from the survey is that while 65% of respondents felt that COVID-19 had significantly impacted their work, only about a third of the respondents reported a significant change in employment status. At the time of the survey the globe was largely in lockdown (Fig. 5B), people in most non-essential sectors were working from home, and some had been furloughed or laid off. The fact that nearly two-thirds of respondents did not report significant impact on their employment status illustrates how the mining and mineral exploration industry differs from many other industries and sectors of employment. This may reflect the fact that some countries considered mining to be an essential activity, meaning that mines remained in operation. Some companies quarantined workers at mine and exploration sites to enable them to keep working without contact outside the workplace. In mineral exploration it appears many were transferred from fieldwork to work on desk studies that did not entail travel, especially international air travel which was largely interrupted (Fig. 5E). Though details were not requested in the survey, the high percentage of students (25%) reporting either being laid off or furloughed since the start of the pandemic may represent loss of research project or internship funding and/or inability to complete research due to closure of

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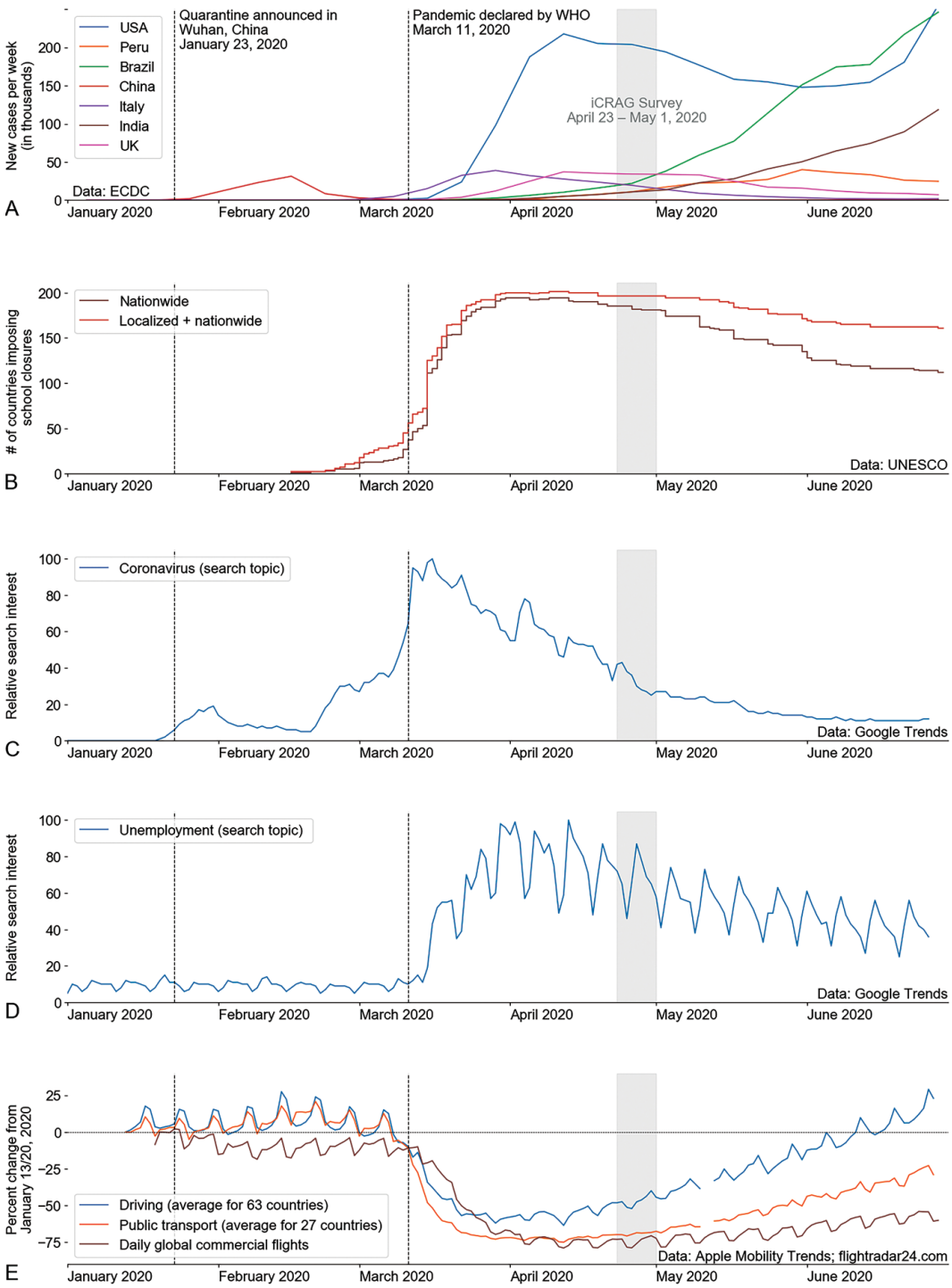

Fig. 5. Comparison of time series relating to the COVID-19 pandemic from January to June 2020. Vertical lines indicate the announcement of the quarantine in Wuhan, China (23.01.2020), and declaration of the COVID-10 pandemic by the World Health Organization (11.03.2020); the shaded area highlights the time of the iCRAG survey (23.04.–01.05.2020). A. Weekly number of newly confirmed COVID-19 cases for a selection of countries (European Centre for Disease Prevention and Control, 2020). B. Number of countries declaring country-wide or local school closures (UNESCO, 2020) as part of their COVID-19 containment measures. C. Google Trends data for daily relative global interest in the topic "Coronavirus" (Google LCC, 2020). The Google Trends data for topics include Google searches in different languages and for related terms. D. Google Trends data for daily relative global interest in the topic "Unemployment" (Google LCC, 2020). The periodicity of the data reflects variation between weekdays and weekends. E. Relative change in driving, public transport (Apple Mobility Trends, Apple Inc, 2020) and commercial flights (Flightradar24, 2020). The daily Apple Mobility Trends data show relative change from January 13, 2020, for routing queries in Apple Maps. Data for driving are the daily averages for 63 countries; data for public transport are the daily averages for 27 countries. Data for daily global commercial flights show relative change from January 20, 2020. The periodicity of the data reflects variation between weekdays and weekends.

labs or restrictions on fieldwork (Gonzales and Keane, 2020).

The survey demonstrates that while there were significant similarities in response to the pandemic by individuals in the mineral industry worldwide, differences can be discerned geographically. The pandemic was severe in Europe and North America at the end of April and there was widespread appreciation of its potential long-term effects, but many people were beginning to move (Fig. 5E) indicating a weakening of the lockdowns. The survey results reflect this with large majorities stating that the pandemic had affected their work to some degree and with widespread worry about the future in terms of employment. The very high levels of concern in Africa and South America are notable because at the time of the survey the pandemic had not led to the dramatic number of reported cases and deaths in these areas compared to those then observed in Europe and North America. However, according to our analysis of mining company press releases and data collected by S&P Global (2020), minerals sector operations in Latin America and South Africa were most affected by COVID-19 containment measures.

Most of the survey results are what would be expected in terms of response by age and by employment status with younger employees and consultants most affected. Results by type of employment were predictable with those in the mineral exploration sector both most affected and also most concerned, reflecting the typical response to a downturn in the minerals industry when exploration spending is commonly an early causality followed by changes of employment for temporary or contract employees.

Conclusion

The survey provides insights into the effects of COVID-19 on the minerals sector workforce

at a distinctive point in time during an unprecedented global event. It captures the experiences and perceptions of individual workers, providing a perspective that is different from the information in corporate statements and official statistics. Surveys such as this can supplement other approaches such as economic analyses and data-mining studies (e.g., Stephany et al., 2020) as we strive to understand the full implications of the COVID-19 pandemic.

Acknowledgments

We wish to thank all those that took part in the survey as well as those who helped spread awareness of its existence.

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COVID-19 and the Global Mining Industry

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Abstract

The world is currently experiencing a rapid and deep economic slowdown as a result of COVID-19 mitigation efforts. The depth and global nature of this recession, which could turn into a depression, suggests that this pandemic will significantly affect the demand for metals and the global mining sector. The majority of governments consider mining to be essential, meaning that the effect of mitigation on the mining industry and on metal production has been minimal to date. However, increases in metal stocks and decreases in metal prices suggest that the mining industry will be negatively affected by the COVID-19 crisis, at least in the short term.

This paper presents an overview of the effects of COVID-19 mitigation on the mining sector to date. That includes variations in metal and commodity prices and stocks during the crisis and the outlining of two possible scenarios for COVID-19 related impacts. The first involves persistent supply-chain disruptions, where metal supply is restricted by logistical or COVID-19–related mitigation impacts on intermediates such as smelters and refiners. This restriction of supply could cause higher metal

doi:10.5382/SEGnews.2020-122.fea-02

COVID-19 and the Global Mining Industry (*continued*)

prices but also could cause issues with demand for ores and concentrates that negatively affect individual mining operations. More likely is a second slower demand growth scenario in which a global decrease in demand for metals causes further lowering of metal prices with associated negative economic impacts on mining operations. However, further research into global metal supply chains and the impact of the COVID-19 crisis on individual metals is needed. Key remaining unknowns include the influence of mitigation efforts on global metal supply and demand, the effect of these efforts on metal prices, and the geography of supply chains.

Introduction

The rapidly evolving and global COVID-19 crisis has impacted all aspects of human life, including metal and mineral production and the industries that the mining sector supplies. This has led to a slowdown in the global economy as a result of efforts to reduce the spread of COVID-19. However, the effect of the crisis on the mining industry remains unclear, partly because of the different approaches to mitigation adopted by various governments. Most countries consider mining essential (albeit with a couple of major exceptions in South Africa and Mexico) although mitigation approaches have also varied over time as COVID-19 outbreaks are managed. These variations are a function of the swift development of the crisis, the relative importance of mining to different regions of the world, and economic and political pressures acting on governments at all levels. The often essential nature of mining means that the direct impact on the global mining sector may not be as significant as the impact on other economic sectors, such as transportation and leisure travel, which have been greatly curtailed. However, the fact that mining operations have remained open during the COVID-19 crisis is not the end of the story. The economic impact of COVID-19 may be sharp and deep but a return to economic normality may not be equally as rapid (i.e., is not likely to be V-shaped). A slow return to economic normality is even more likely given the current lack of vaccine or effective treatment for COVID-19 and the need to prolong mitigating measures.

The continuing supply of metals provided by a continuation of mining also contrasts with an apparent decrease in global metal demand as a result of the COVID-19 crisis. This potential oversupply suggests we may enter a period of relatively low metal prices until either demand recovers or some mines close as a result of the prevailing economic conditions. This paper discusses the data underlying these scenarios and highlights the variables involved in the current situation. It also outlines the impact of this crisis on mining to date and areas for future research to more fully determine the likely effects of COVID-19 on the global mining sector as well as possible mitigation approaches.

Mining continues in most countries; challenges are not governmental; they are logistical and related to the outbreak itself and economics

Most governments have allowed mining to continue during the COVID-19 pandemic, if not as per normal then with somewhat limited restrictions relating to COVID-19 mitigation (Table 1), despite the suspension by some companies of individual operations for their own economic or other reasons. The continuation of mining is not directly related to the dependency of the economy of a given country on mining or the value of mining to a country (i.e., gross domestic product, GDP), as is shown in Table 1.

There are some notable exceptions to the continuation of mining where the crisis has resulted in the temporary closure of individual mines, the cessation of mining in certain regions, or in rare cases the closure of the entire mining industry of a country. This most likely reflects the nature of mining in the countries that enacted these measures, as COVID-19 mitigation approaches are naturally much harder to enact in underground labor-intensive mining situations relative to large and more mechanized or automated open-pit environments. A complete shutdown occurred in Mexico, where the mining industry was forced to cease operations on March 31, 2020, but was allowed to reopen on May 18, 2020. The South African government also initially approached their underground-dominated and often labor-intensive mining industry the same way, closing operations in March 2020 (Ramaphosa, 2020) but later changing this to only reduce mining capacity by 50%.

This is not to say that mining activities that are currently continuing couldn't be suspended if a second wave of COVID-19 infection (e.g., Anderson et al., 2020) eventuates or if outbreaks develop at individual mine sites. The remote nature of (most) mine sites may be advantageous in terms of keeping operations running as this physical distance from the general population may act to prevent COVID-19 outbreaks. Mining operations that have gone through recent epidemics are also particularly well equipped to continue operating during this crisis. This is exemplified by West Africa, where knowledge of screening and isolation practices developed during the Ebola epidemic means that individual mine sites and other businesses in this part of the world are better equipped to continue operations during the COVID-19 pandemic (Ihekweazu, 2020).

Mining companies are also making decisions based on their own situations, including local COVID-19 outbreaks at individual operations, logistical challenges, and changes in metal prices and demand (both positive and negative). This undoubtedly has the potential to create clashes between mining companies, intermediates, and governments if legislation is enacted that suspends operations against the will of the operator. Other clashes may occur if countries with high mining contribution index (MCI) values, an indication of the mining dependency of a country's economy, want production to continue and individual companies do not—as a result of low metal prices or other factors. One example of this is Zambia, where the government appeared to be encouraging mining operations to remain open even where operators were considering shutting down for economic reasons (e.g., the Mopani Copper Mines; Biesheuvel et al., 2020). It is also important to note that the dependency of a country on mining does not just incorporate the contribution of mining to that country's GDP. For example, the MCI values shown in Table 1 are a composite of four indicators that capture different aspects of the contribution of mining to a country's economy. These are the value of mineral and metal exports

and how they have varied over time, indicating whether the importance is increasing or decreasing (International Council on Mining & Metals, 2018) of mining as an economic activity to a given country. The MCI values shown in Table 1 also incorporate mineral production and mineral rents as a percentage of GDP, providing a sense of the value of mining to an economy for the former and the contribution of mining-related taxes and profits to the economy of a country for the latter (International Council on Mining & Metals, 2018). The incorporation of these variables gives a more accurate overview of the true contribution of mining to an economy, rather than just comparing the value of mineral production to the overall GDP of a country; this also explains the contrasting high MCI but low contribution to GDP values for some of the countries listed in Table 1.

The closure of mining operations could also have additional negative effects beyond the global economic slowdown in countries with economies that are heavily reliant on mining for the reasons discussed immediately above (Table 1). Even if mining operations can remain open, COVID-19 containment measures such as enforcing physical distancing and reducing numbers of personnel gathered in one place might reduce metal production capacity. International and domestic travel restrictions may also impact the ability of mines to continue to operate, given the significant numbers of mine site employees that work on a fly-in, fly-out (FIFO) basis in some countries (e.g., Australia). These potential personnel shortages could mean that some mines may not be able to sustain operations in the short term, especially given the lead-in time needed to move a mining operation from production to care and maintenance. This lead-in time is essential to allow mines to efficiently reopen and to prevent environmental issues arising during the cessation of mining activity. Mines in countries such as the United States, Canada, Australia, and elsewhere that employ significant numbers of indigenous employees may also be forced to reduce operations or close, given the risk of these workers passing infections on to often remote communities with limited medical infrastructure. These mitigation measures have led individual mines such as Red Dog in Alaska to institute their own travel restrictions to prevent the spread of COVID-19 (DeMarban, 2020). The pandemic may also drive companies more rapidly towards automation of mining operations, a trend that is already well established. However, the prevailing lack of certainty on the duration of the crisis and the fact it may be difficult to accelerate beyond current uptake in the short timescales typically associated with modern epidemics and pandemics means it remains unclear whether increased automation is a viable approach to mitigation against COVID-19. All of this suggests that although mining operations may be allowed to continue, a wide variety of other (non-economic) factors could mean mines operate at lower capacity or have to transition to care and maintenance.

The crisis is also posing logistical challenges relating to the transport of supplies and the products of mining such as metal concentrates. It is unclear whether there has been any major impact or interruption on the supplying of mining operations with key materials such as fuel, explosives, or even the personal protective equipment needed to operate. However, the shipping of ores and concentrates from mines has certainly been affected. For instance, cobalt and copper concentrates produced within the Democratic Republic of the Congo (DRC), a country with only limited closures of mining operations, are generally shipped to China for further processing via the South African port of Durban (e.g., Luk, 2020). However, the widespread closures and transport restrictions in South Africa are causing most shipments to be diverted to Mozambique or Tanzania, resulting in a decrease in concentrate exports as a result of customs delays. These logistical challenges are present despite the South African Maritime Safety Authority's stating that all cargoes can be loaded and unloaded at South African ports. This directly contrasts with information from another government agency, the Transnet National Ports Authority, which maintained that metal exports from Durban were banned at the time of the statement by the South African Maritime Safety Authority indicating ports were open, creating a clearly confusing situation (Luk, 2020). These conflicting statements and positions are typical of the challenges and unknowns affecting all industries, not just mining.

In addition, smelters and refiners that process ores and concentrates from mining operations face both possible COVID-19 mitigation-related restrictions as well as potential decreases in the demand for their own products. All of these uncertainties relating to the transport of ores and concentrates and the operation of smelters and refiners mean that although mining is likely to be able to continue, the possibility remains of a reduction in demand as a result of logistical disruptions to producers or the closure or lowering of production at smelters and refiners.

In summary, the major challenges facing the mining industry are not from governments closing operations to mitigate the spread of COVID-19. Instead, the logistical challenges of supplying operations with the essential workforce and transporting products such as concentrates represent more significant difficulties on the production side of mining. This in turn suggests that metal supply may not be significantly affected by the direct impact of COVID-19 mitigation or outbreaks although, as discussed above, indirect impacts are certainly possible. Instead, it is more likely that the demand for metals and minerals and the economics of mining operations may be negatively affected by this crisis, as discussed in the following section.

Changes in metal demand and price; metal stocks higher, metal prices lower with the exception of gold

Global production and manufacturing have declined as a result of economic slowdowns caused by efforts to prevent the spread of COVID-19. This led the United Nations to predict that this slowdown would result in global GDP dropping by at least 1% (UNDESA, 2020) and the International Monetary Fund to predict a change in global economic growth of –4.9% during 2020 (International Monetary Fund, 2020). These impacts are further demonstrated by a decrease in U.S. industrial production (indexed where 2012 = 100) from 109.1 in January 2020 to 92.6 in April 2020, a contraction of ~15% (Board of Governors of the Federal Reserve System, 2020). This decrease was coincident with an increase in U.S. unemployment from 3.6% in January 2020 to 14.7% in April 2020 (U.S. Bureau of Labor Statistics, 2020). Although some of these statistics are U.S. specific, similar

Table 1. Summary of the Mitigation Approaches to COVID-19 and Their Impacts on the Mining Industry in Selected Countries Listed by Value of Metallic Mineral and Coal Production

Country or state	Metallic mineral and coal production value 2016 (in billions of USD)	2018 MCI score	Production value as % of GDP	Major metals produced	Business operations restricted?	Mining allowed to continue?	Country-wide or state/province-wide mitigation?	Notes
China	626.3	53.1	5.6	Antimony, arsenic, bauxite, coal, cobalt, copper, diamonds, gold, iron ore, lead, lithium, manganese, molybdenum, nickel, REE, silver, tin, titanium, vanadium, zinc	Yes	Yes	State/province	Some reduction of production in significantly affected provinces
Australia	123.1	69.8	10.2	Bauxite, coal, cobalt, copper, diamonds, gold, iron ore, lead, lithium, manganese, nickel, REE, silver, tin, titanium, zinc	Yes	Yes	State/province	Internal travel restrictions restricting some FIFO operations
Russian Federation	91.5	77.9	7.1	Antimony, arsenic, bauxite, coal, cobalt, copper, diamonds, gold, iron ore, lead, molybdenum, nickel, platinum group elements (PGE), rare earth elements (REE), silver, tin, tungsten, vanadium, zinc	Yes	Yes	Country	
United States	89.7	41	0.5	Bauxite, coal, cobalt, copper, gold, iron ore, lead, lithium, molybdenum, nickel, PGE, REE, Silver, Titanium, Zinc	Yes	Yes	State/province although mineworkers are deemed essential	
India	77.0	56.9	3.4	Bauxite, coal, chromium, iron ore, lead, manganese, REE, titanium, zinc	Yes	Yes	Country	Mines allowed to remain open but downstream facilities suspending or lessening operations
South Africa	48.9	65.1	16.5	Coal, chromium, cobalt, diamonds, gold, iron ore, manganese, PGE, titanium, vanadium	Yes	Yes	Country	Initial countrywide closure of mining industry followed by change to allow mining at 50% capacity
Indonesia	47.5	58.8	5.1	Coal, Copper, Gold, Nickel, Tin	Yes	Yes	Country	
Canada	39.4	55.1	2.6	Bauxite, cobalt, diamonds, gold, iron ore, lithium, molybdenum, nickel, PGE, titanium, zinc	Yes	Yes	State/province	Designation of mining as an essential business varies from province to province; some mining operations closed as a precaution
Brazil	36.6	55.3	2.0	Bauxite, diamonds, gold, iron ore, lithium, manganese, nickel, REE, tin, titanium, vanadium	Yes	Yes	Country	
Chile	33.5	69.1	13.4	Copper, iron ore, lithium, molybdenum, silver	Yes	Yes	Country	Mining companies requested to reduce workforce
Mexico	28.9	53.2	2.7	Antimony, copper, gold, iron ore, lead, manganese, molybdenum, silver, zinc	Yes	No	Country	Mining industry closed March 31, allowed to reopen May 18
Peru	27.1	80.1	14.1	Copper, gold, iron ore, lead, molybdenum, silver, tin, zinc	Yes	Partially	Country	Mine operators given partial exemption from closure orders, allowing necessary operations to proceed; 75% of mining workforce evacuated
Kazakhstan	18.6	76.7	13.6	Antimony, coal, chromium, copper, gold, iron ore, lead, manganese, zinc	Yes	Yes	State/Province	
Turkey	17.2	67.5	2.0	Antimony, chromium, lead, molybdenum	Yes	Yes	State/Province	
Germany	15.8	36.5	0.5	Coal	Yes	Yes	Country	
Poland	14.6	49.1	3.1	Coal, silver	Yes	Yes	Country	
Colombia	10.1	72	3.6	*Coal, copper, gold, iron ore, nickel, PGE, silver*	Yes	Yes	Country	Mining allowed to continue with restrictions
Ukraine	9.9	61.4	10.6	Iron ore, manganese, titanium	Yes	Yes	Country	
Finland	8.5	57.3	3.6	Chromium	Yes	Yes	Country	
DRC	7.9	96.4	2.2	Cobalt, copper	Yes	Yes	State/province	Limited shutdowns of operations have taken place in some provinces, e.g., 48-hour closures in Haut Katanga
Mongolia	6.0	84.9	53.6	Molybdenum, tungsten	Yes	Yes	Country	
Ghana	5.5	90.9	12.8	Gold, manganese	Yes	Yes	Country	
Botswana	5.0	86.1	31.8	*Coal, cobalt, copper,* diamonds, *gold, nickel, PGE, silver*	Yes	Yes	Country	
Uzbekistan	4.4	89.1	6.6	Gold, molybdenum	Yes	Yes	State/province	
Zambia	4.4	78.4	21.1	*Cobalt*, copper, *gold, manganese, silver*	Yes	Yes	Country	Import duties on metal concentrates and export duties on metals suspended, and government encouraging some mines to remain open
Madagascar	4.2	87.1	41.6	Cobalt, REE, titanium	Yes	Yes	Country	Curfews have restricted activities at certain mines, causing closures

Table 1 (*Cont.*)

Country or state	Metallic mineral and coal production value 2016 (in billions of USD)	2018 MCI score	Production value as % of GDP	Major metals produced	Business operations restricted?	Mining allowed to continue?	Country-wide or state/province-wide mitigation?	Notes
Bolivia	2.9	84.5	8.5	Arsenic, lead, silver, tin, tungsten, zinc	Yes	Yes	Country	Curfews have restricted activities at certain mines, causing closures
Zimbabwe	2.8	84.2	16.8	*Chromite, cobalt*, diamonds, gold, lithium, *nickel, PGE*	Yes	Yes	Country	
Kyrgyz Republic	2.5	93.3	36.3	Antimony, *copper, gold, silver*	Yes	Yes	Country	Government supporting the continued opening of some mining operations
Senegal	2.5	84.4	16.9	*Gold, lead, silver*, titanium	Yes	Yes	Country	
Sudan	2.5	79.9	2.6	*Chromite, gold, iron ore, manganese, silver, zinc*	Yes	Yes	Country	
Mali	1.9	93.2	13.6	*Coal, gold, silver*	Yes	Yes	Country	
Guinea	1.8	94.3	19.0	Bauxite, diamonds	Yes	Yes	Country	
Burkina Faso	1.8	93.4	15.2	*Gold, lead, manganese, silver, zinc*	Yes	Yes	Country	
Tajikistan	1.7	84.9	24.9	Antimony	No	No	N/A	No officially reported COVID-19 cases
Dominican Republic	1.7	78.3	2.4	*Bauxite, copper, gold, nickel, silver*	Yes	Yes	Country	
Sierra Leone	1.2	92.6	34.4	Diamonds, titanium	Yes	Yes	Country	
Mauritania	1.2	78.6	24.7	*Copper, gold, iron ore*	Yes	Yes	Country	Mauritania reported to be COVID-19 free on 21st April
Suriname	1.0	96.4	33.0	*Bauxite, gold*	Yes	Yes	Country	
Namibia	1.0	87.6	8.8	Arsenic, *copper*, diamonds, *gold, lead, silver, zinc*	Yes	No	Country	Mining operations suspended
Guyana	0.9	80.4	27.8	*Bauxite, gold*	Yes	Yes	Country	
Armenia	0.7	84.9	7.0	Molybdenum	Yes	Yes	Country	
Liberia	0.3	92.1	14.3	*Diamond, gold, iron ore*	Yes	Yes	Country	

Countries shown are the top 20 countries by 2016 production value of metallic minerals and coal and the 25 countries with the highest 2018 Mining Contribution Index values (MCI; data from International Council on Mining & Metals, 2018, for which increasing MCI values are indicative of the increasing dependency of a given country on mining and mineral production); major metals are identified using the USGS production statistics (U.S. Geological Survey, 2020) and italics indicate high MCI countries with production of the indicated commodities that are nationally but not internationally important; also given are production values as a percentage (%) of the total GDP to indicate the relative importance of mining and metal production to an individual country's economy; COVID-19–related closures and cessations of business are current at the time of submission but the rapidity of developments means that this information may change on a daily or weekly basis; note that business restrictions can mean full or partial shut-downs, curfews, distancing restrictions, and more; the rapid variations in these restrictions mean that tracking individual efforts to determine specific restrictions on a province/state or country basis is difficult and is beyond the remit of this paper; also note that even if mining is generally allowed to continue, individual mines may still close as a result of COVID-19 cases, logistical issues, or the deleterious effect of COVID-19 mitigation approaches on production and the economics of a given mine (e.g. curfews)

impacts are occurring around the world. This global economic slowdown and the resulting decrease in production of manufactured goods will undoubtedly have a negative impact on the demand for metals. This decrease in demand has the potential to create an oversupply in metals given the continuation of production, which in turn will drive metal prices down.

The recent price history for metals and oil confirms this. Figure 1 shows prices for a number of metals and Brent Crude oil between January 2 and May 18, 2020. The majority of metal prices started to decrease around March 10, 2020, to between 10 and 20% of early January 2020 prices, whereas oil prices started to decline before this (but not as a result of the COVID-19 crisis, as discussed below). Metal prices then rallied around March 23, 2020, coincident with the onset of possible production restrictions related to the temporary closure of the South African mining industry (Ramaphosa, 2020). This rally was also influenced by the increasing likelihood of demand stimulated by the signing of the Coronavirus Aid, Relief, and Economic Security (CARES) Act by the U.S. federal government. Most metal prices shown in Figure 1 have generally similar trends and positively correlate with each other (Table 2), independent of whether they are base (e.g., Cu, Ni; Fig. 1B) or minor or bulk (e.g., Co, Sn, Al; Fig. 1C) commodities. These data suggest that the majority of metal prices (barring the precious metals Au and Pd; Fig. 1A) have been uniformly affected by this crisis with changes reflecting the global economic slowdown rather than any specific changes on a commodity-by-commodity basis. The uniformity of the response of the metal market to COVID-19 is reflected by the temporal consistency (Fig. 1) and positive correlation (Table 2) of metal price changes.

The change in metal prices as a result of decreased demand without a change in supply is consistent with metal stock data (i.e., metals available for sale) for copper, nickel, and zinc (Fig. 2). The stocks of all three of these base metals have steadily increased since January 2020. This trend probably reflects a decrease in demand for these metals without a significant decrease in supply. This was the case for copper concentrates during the January-February 2020 COVID-19 slowdown in China (Davy, 2020), although this decrease

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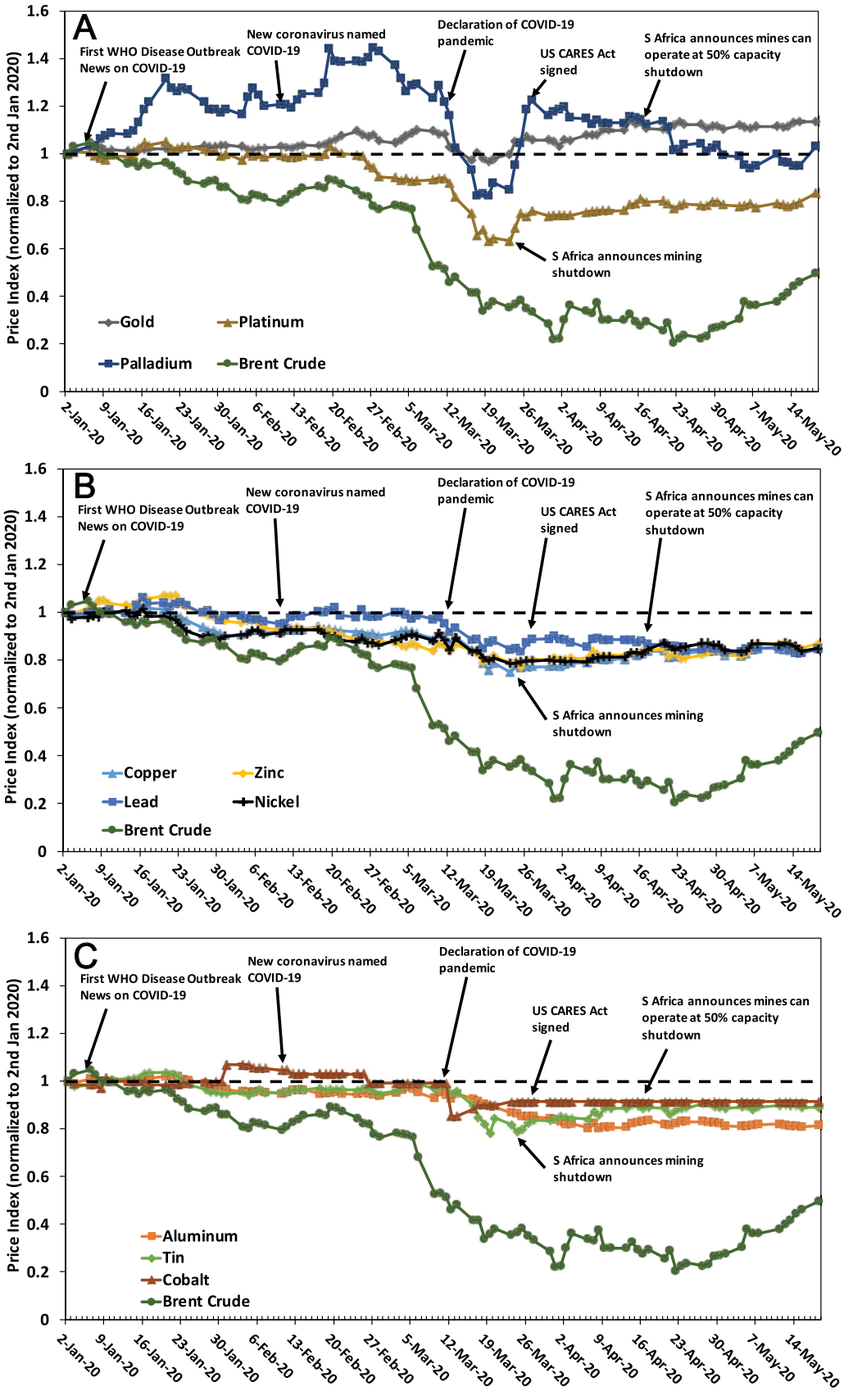

Fig. 1. Recent changes in precious (A), base (B), and bulk (aluminum) and minor (tin and cobalt; C) metals and Brent Crude oil prices indexed to January 2, 2020, compared to select COVID-19–related events. Base metal price data are from the London Metal Exchange, palladium and platinum data are from Johnson Matthey, and gold and Brent Crude oil prices are from the Federal Reserve Bank of St. Louis, USA. Dashed line indicates metal and oil values as of January 2, 2020.

in demand was earlier than the major decrease in copper (and other metal) prices in March 2020 (Fig. 1). This suggests that although the effects of mitigation in China influenced metal stocks during very early 2020, the slump in most metal prices evident in Figure 1 was more related to later decreases in demand for these commodities caused by COVID-19 mitigation in Europe and North America (Fig. 2).

Not all metals have been negatively affected by the COVID-19 crisis. Gold and palladium are the only metals in Figure 1 with prices in April and May 2020 above their respective prices on January 2, 2020. Increases in gold and palladium price (Fig. 1) may reflect two factors that potentially overprint or enhance the existing pre-COVID-19 trend of increasing prices for these metals. These are (1) the temporary shutdown of mining in South Africa, an important producer of both metals, and (2) increased demand for these precious metals as safe investment havens. The fact that platinum has not had a price increase similar to that of palladium may reflect a lack of confidence in future demand that primarily relates to a decrease in the use of platinum in catalytic converters (e.g., Mudd et al., 2018). The generally negative correlation between gold prices and the majority of the other commodities shown in Figure 1 and Table 2 also suggests that gold is once again being considered a safe haven during economically turbulent times.

Oil prices have also declined more significantly than metal prices during the COVID-19 crisis, reflecting two factors. The first of these is a decline in demand resulting from COVID-19–related economic slowdowns (i.e., the same as metal prices). The second is that oil prices have also been negatively affected by a decision taken by Saudi Arabia and Russia to not cut back on oil production, thus creating excess supply. Similar controversies may develop with metals if stocks continue to accumulate (e.g., Fig. 2) as a result of production continuing to be

Table 2. Correlation Coefficients for the Metal and Oil Prices Shown in Figure 1

	Copper	Aluminum	Zinc	Lead	Tin	Nickel	Cobalt	Gold	Platinum	Palladium	Brent crude
Copper	**1.00**										
Aluminum	0.91	**1.00**									
Zinc	0.93	0.86	**1.00**								
Lead	0.93	0.90	0.85	**1.00**							
Tin	0.96	0.86	0.84	0.93	**1.00**						
Nickel	0.97	0.88	0.93	0.87	0.91	**1.00**					
Cobalt	0.69	0.68	0.64	0.76	0.69	0.66	**1.00**				
Gold	–0.32	–0.54	–0.45	–0.28	0.16	–0.36	–0.16	**1.00**			
Platinum	0.92	0.83	0.87	0.92	0.90	0.86	0.84	–0.19	**1.00**		
Palladium	0.34	0.23	0.19	0.53	0.48	0.21	0.55	0.42	0.56	**1.00**	
Brent crude	0.94	0.93	0.89	0.93	0.87	0.90	0.80	–0.41	0.92	0.36	**1.00**

unaffected by COVID-19, leading to a corresponding decrease in prices. This may create clashes between countries with economies that are heavily dependent on the production of the same metal and which therefore will want mining of this metal to continue despite potentially low prices (e.g. the DRC, Zambia, and Chile in the case of copper).

Future impacts on metal mining are uncertain

It is difficult to quantify the long-term negative impacts on the metal mining industry as a result of COVID-19 because the future path of the pandemic and the resulting global recession remain unknown. It is inappropriate to make long-term predictions based on historical events such as the Great Depression or the 2008 Global Financial Crisis (GFC) because these events were caused by economic issues rather than pandemic-related events. Perhaps a better analogy is to compare the COVID-19 pandemic to a world war. For example, both wars and pandemics result in the global removal of the human workforce from "daily duties" and a corresponding reduction in the ability of the general populace to spend on non-essential goods. These impacts, combined with the fact that a rapid V-shaped economic recovery without a vaccine or treatment is unlikely, will mean that COVID-19 is very likely to have a continuing and severe influence on the global economy for some time, as was the case for both world wars. One possible but smaller analogue is the 2014–2015 Ebola epidemic in West Africa, when the negative economic impact of this event far outlasted the epidemiological impact of the outbreak (World Bank, 2016). The same may well apply to COVID-19.

However, it is also possible that COVID-19 may have some positive longer-term effects on the mining industry. If the COVID-19 crisis is analogous to global conflicts such as World War II, then longer-term outcomes may be similar, with World War II followed by three decades of above-average GDP growth and increased metal demand associated with reconstruction in Europe and Japan. A similar situation is possible in which COVID-19 postpones investment spending for several years but is followed by a surge in investment spending on infrastructure, capital and transportation equipment, and consumer durables, all of which would cause higher metal demand and associated increases in metal prices. Ongoing efforts to stimulate domestic manufacturing in countries like the United States and Europe as a result of supply security issues may also contribute to increasing domestic mining in these areas. However, any longer-term positive effect of COVID-19 on the mining industry needs to be considered in light of possible shorter-term negative impacts that may mean that some parts of the industry do not survive long enough to reap any possible longer-term benefits.

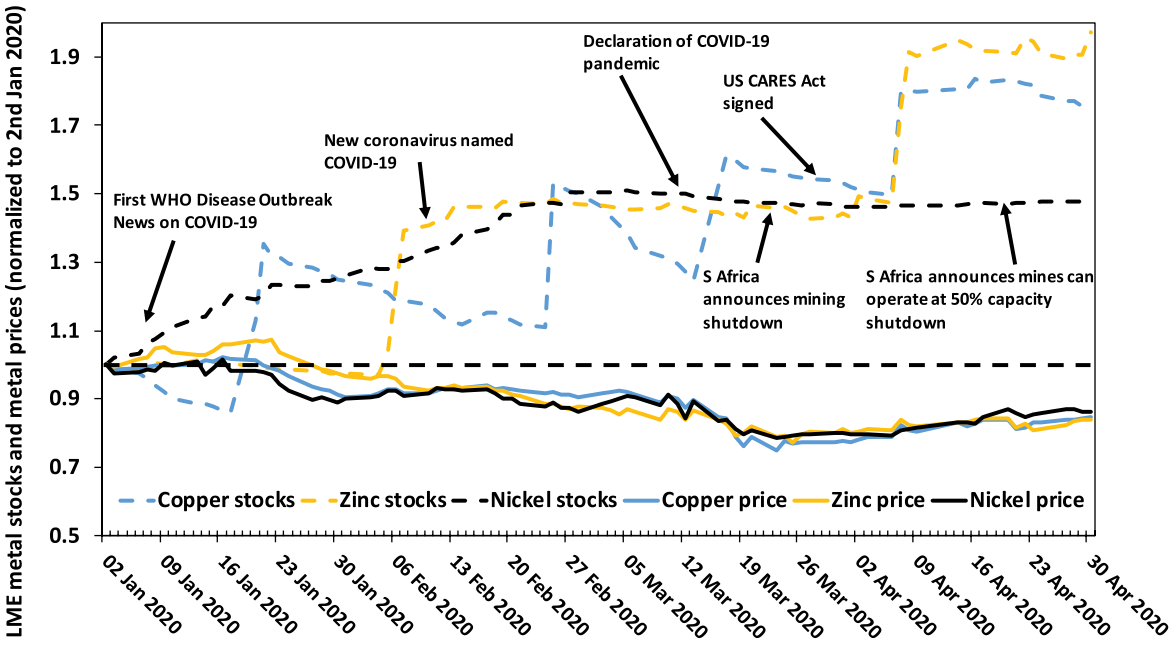

Fig. 2. London Metal Exchange (LME) copper, zinc, and nickel stocks (i.e., quantities of metal within the LME warehouse system, shown as dashed lines) and prices (shown as solid lines) compared to key COVID-19 events. Note the different timescale from Figure 1 as a result of data availability. Data are indexed to LME metal stocks as of January 2, 2020, and the dashed line indicates metal and oil values as of this date.

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One thing that is clear is that it is likely that this pandemic will not be resolved quickly. Modeling (e.g., Anderson et al., 2020) of the epidemiology of this crisis suggests that slow reopening and removal of restrictions will be needed to ensure second waves of outbreaks are either prevented or mitigated (e.g., Lipsitch et al., 2020). The impact of this slow reopening is apparent; whether this causes further economic losses or can be managed in a way to ensure that economies recover as soon as possible is key. Equally, later outbreaks and potential peaks need to be managed effectively and quickly to prevent a resurgence of the major economic slowdown seen from March 2020 onward. Evidence from China suggests that even if quarantine-style regulations are imposed on the general population, smelting, refining, and manufacturing operations can still reopen (if closed) relatively rapidly (e.g., Daly, 2020). Different parts of the world are also likely to be affected in different ways (e.g., Chaudhry, 2020). This reflects variations in government financial support packages, different COVID-19 caseloads, and variations in the ability of healthcare systems to cope, and differences in approaches to mitigating the spread of COVID-19 and their relative efficacy (Table 1). All of this means that the long-term economic picture is just as complex as the public health picture.

The longer-term effect of the COVID-19 crisis on demands for different individual metals is also unclear. This uncertainty reflects the fact that these metals and their associated end uses will be affected in variable ways by the closure and the contraction or expansion of various parts of the economy. For example, the demand for certain medical equipment such as ventilators is likely to significantly increase (e.g., Wells et al., 2020). However, it is unclear how this and other increases in demand might affect different metals and how long the situation will last. Equally, the contraction of the travel industry may cause a decrease in demand for metals such as aluminum, molybdenum, and rhenium, all of which are used in jet engines.

Understanding the impact of COVID-19 on the metal mining sector and the wider economy requires a comprehensive analysis of three main things. These are (1) how metals are currently used and (2) what sectors and end-products are likely to increase or decrease in size and production as a result of COVID-19. It is also important to understand (3) the interplay between different parts of the metal mining sector and consequent feedback. Point (3) is especially true given that some metals are predominantly or entirely by- or coproducts of other metals (e.g., Nasser et al., 2015; Jowitt et al., 2018). All these linkages and their feedback make the current picture very complex, although at least two short- to medium-term scenarios can be envisaged, as outlined immediately below.

Supply-chain disruptions or slow demand growth; resolving the uncertainties

It is likely that one of two potential scenarios might play out over the next few years: either a persistent supply-chain disruption or a slower demand growth. The persistent supply-chain disruption scenario reflects a situation in which mining is similar to farming and is not significantly impacted by COVID-19. Rather, intermediate industries like smelters or refiners in the mining sector—or meat-processing plants in the farming sector—are impacted either as a direct result of COVID-19 mitigation or as a result of indirect challenges to transport and logistics (as described for the DRC, above). This would create bottlenecks in which demand for metals cannot be met, potentially leading to an increase in metal prices. In comparison, the slower demand growth scenario is somewhat akin to that currently facing the retail industry, where production can continue and stock is on hand but demand has fallen sharply as a result of both a lack of consumer access and limits in consumer spending. This drop in demand would most likely lead to a decrease in metal prices.

To avoid the persistent supply-chain disruptions scenario, the temporary suspension of mining operations should ideally be contemporaneous with the closure of smelters and processing facilities and other downstream users of metals. This would generate a rolling blackout-type scenario where a balance of supply and demand is maintained. This possible scenario warrants further investigation to determine the likelihood of decreasing supply matching decreasing demand as the pandemic progresses.

Recent metal price decreases and metal stock increases (Figs. 1, 2) associated with the COVID-19 crisis are indicative of a lowering of demand by end-users. These changes suggest that the mining industry may be facing the second slower demand growth scenario. Applying this scenario to the mining sector means that mines as well as intermediates like smelters and refiners would generally remain open at previous or slightly lowered capacity than before COVID-19. However, demand in this scenario drops as a result of the ongoing economic slowdown. That would lead to a reduction in metal prices (e.g., Fig. 1) and a significantly negative impact on the metal mining industry. Decreasing demand could also lead to an excess of supply, especially if governments put pressure on mining operations to remain open despite poor economics and challenging COVID-19 issues. This would compound the issue of decreasing demand and would increase the negative economic impact on the mining industry. Metal prices would then decrease, causing some mines to become uneconomic, with shutting down or moving onto care and maintenance as a result, decreasing supply to maintain parity with decreased demand. Such actions would put significant stress on at least high MCI countries (Table 1), potentially leading to economic assistance from governments to ensure mines remain open, legislation to try to force mines to stay open despite challenging economics, or even to nationalization in the most extreme cases.

Predicting the impact of the COVID-19 crisis on the mining sector and the balance between metal demand and supply requires further research. Firstly, it is clear that not all metals and parts of the mining industry will be affected in the same way by the COVID-19 crisis. For example, will certain metals like copper or gold see pre-COVID-19 or higher demand as a result of uses on antiviral surfaces or as safe investments? Will other metals—such as aluminum, molybdenum, and rhenium that are used in the airline industry—see a greater decrease in demand as a result of the decrease in air travel? This is especially true given this sector was already affected by issues surrounding the Boeing 737-Max (e.g., Frasch, 2019). Will governments enact policies such as vehicle buy-backs that would stimulate parts of the economy but would also potentially increase the amount of metal recycling, reducing primary demand? Understanding the relationships between main, co-, and by-products will also be crucial as poor economics for a given metal may well

lead to a reduction in production and shortages in other linked metals such as the critical elements (e.g., Nasser et al., 2015; Jowitt et al., 2018).

Conclusions

The rapidity and depth of the COVID-19-related economic slowdown is unprecedented. Although mines are being considered essential and are generally staying open during the crisis, production is likely to be less than prior to the onset of the COVID-19 pandemic. Mines also face logistical challenges such as the transportation of concentrates to smelters. Metal prices, barring gold and palladium, have also generally decreased during the crisis independent of whether they are base, bulk, or minor metals. Stocks of metals have also generally increased, suggesting a global decrease in demand for most metals. However, not all metal prices have been negatively affected by the COVID-19, with increases in the price of gold and palladium to levels above that of January 2020 and the subsequent onset of the pandemic. The question then is which of two scenarios the mining industry will face. Will we see a supply chain disruption, where an inability to meet demand is not the result of mine closures; rather, it results from supply bottlenecks and/or the closure of intermediates such as smelters and refineries? Or are we likely to see a slower demand growth scenario in which mines and intermediates remain open and operating at near capacity but are affected by a continued decrease in demand, creating excess supply and lowering metal prices with associated negative economic impacts on mining operations. Currently available data suggest we are facing the second scenario and that mining companies and governments will need to plan for these impacts so as to recover from the crisis as rapidly as possible.

Acknowledgments

This paper has been written as the COVID-19 crisis is unfolding and the situation continues to change rapidly. I thank Brian McNulty and Cassady Harraden for reviewing a pre-resubmission version of this manuscript and Larry Meinert for excellent and patient editorial handling. Numerous constructive comments on previous versions of this manuscript by Steve Kesler and Rod Eggert significantly improved this paper although any omissions or errors present are certainly the fault of the author rather than the reviewers.

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