TECHNICAL REPORT: IMPROVING THE ESTIMATES OF MINERAL RENT AND ASSET VALUE FOR THE CHANGING WEALTH OF NATIONS 2021

The Changing Wealth of Nations 2021

Managing Assets for the Future

WORLD BANK GROUP

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Improving the estimates of mineral rent and asset value for the *Changing Wealth of Nations 2021*

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September, 2020

[1] Acknowledgements: We are grateful for comments and advice on aspects of this work from Bernard Amaning (IFC), James Cust (AFRCE), Boubacar Boucum (IEEXI), Bram Edens (UN Statistics Division), Rocky Harris (DEFRA, UK), Luis Diego Herrera (SENGL), Carl Obst (IDEEA consulting), Pierre-Alain Pionnier (OECD), Peter van de Ven (OECD), and Robert Smith (Midsommer Analytics).

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1. Background

The World Bank is preparing a new edition of its wealth report, *The Changing Wealth of Nations 2021: Managing Assets for the Future* (P169304, CWON 2021), to be launched in 2021. CWON 2021 will apply wealth accounts to analytics for three areas of major policy concern: the linkages between natural capital and human capital, climate change, and sustainability. A key part of this effort is strengthening the measurement of wealth through expanded coverage and improved quality of all assets, notably natural capital. The wealth accounts will include five categories of assets estimated annually for 150 countries over the period 1995-2018: produced capital and urban land, nonrenewable natural capital (fossil fuels and minerals), renewable natural capital (agricultural land, forests, fisheries, mangroves and coral reefs, and protected areas), human capital, and net foreign assets. Nonrenewable natural capital includes 4 categories of fossil fuels (oil, natural gas, two qualities of coal) and ten minerals (bauxite, copper, gold, iron ore, lead, nickel, phosphate rock, silver, tin, and zinc).

The previous report, *Changing Wealth of Nations 2018: Building a Sustainable Future* (Lange et al. 2018) greatly improved estimates for fossil fuel asset values by using mine-level information from commercially available, global databases, Rystad Energy and Wood Mackenzie. The recent availability of mine-level information for key minerals from subscription-based S&P Global Market Intelligence makes it possible to introduce similar improvements to mineral accounts. The key improvement is the availability of mine-level production costs.

Estimation of asset value for each country requires annual information about price, production costs, extraction and reserves. Data for price, extraction, and reserves are updated annually from publicly available sources with good coverage and quality, but similar data for production costs are not publicly available. Under these limitations our approach in earlier CWON reports was to use average production costs from a few case studies dating from the 1980s and early 1990s, apply these costs to all producing countries in our base year, and update production cost annually by applying the Manufactures Unit Value (MUV) index.[2] The MUV is not specifically designed to capture mining costs and is not well suited to an industry where increasingly marginal resources are brought into production; however, MUV was used due to the lack of publicly available information on production costs or budget to purchase information. The resulting estimates of mineral asset value cannot be considered very accurate.

We have developed a methodology for utilizing the new data source from S&P Global Market Intelligence in a way that substantially improves our estimates of mineral rent and asset value, consulting with experts within the World Bank and from external agencies. The methodology and issues that arise from our choices are elaborated in the sections below.

We begin with an explanation of the methodology and data for asset valuation used to implement this methodology for CWON 2018 and the annual Adjusted Net Savings indicator, highlighting problem areas in the current methodology. We then describe the new data from the S&P database and revised methodology. Key results and comparisons to the current estimates are analyzed; for brevity, the analysis focuses primarily on copper and gold with comments on similarities or differences for other metals (lead, iron ore, nickel, silver, zinc). The final section sums up the new approach and highlights potential impacts this may have on wealth accounts. At the global level, in 2014 minerals comprised a small share of total wealth (1%), and only 20% of

[2] The MUV is a composite index that tracks inflation in the price of manufactured goods imported by developing countries. This index is a weighted average of export prices of manufactured goods produced by 15 major economies.

nonrenewable natural capital; fossil fuels account for 80% nonrenewable natural capital. However, minerals grew faster than any other asset, and can be a significant component of wealth for certain countries.

2. General Approach to Valuation of Mineral Assets

CWON uses the basic principles and methodology established for subsoil assets by System of National Accounts 2008 (EC et al. 2009) and the System of Environmental Economic Accounting (EC et al. 2012). As described in World Bank (2018), the value of a nation's stock of a nonrenewable resource is measured as the present value of the stream of expected total rents that may be extracted from the resource until it is exhausted. Implementing this approach requires i) estimating rents and ii) projecting the future flow of rents. Because of the high volatility of commodity prices and rents, it is customary to smooth rents over a period of 5 years or so to provide a better indication of long-term value, the aim of wealth accounting.

2.1 Current CWON Method for Estimating Mineral Asset Value

Under current CWON implementation,

Asset value, V_t, is given as

$$V_t = \sum_{i=t}^{t+T-1} \frac{\overline{R_t}}{(1+r)^{i-t}}$$

where

$\overline{R_t}$ is a lagged, five-year moving average of annual total rents, R_t, in years *t* (the current year) to *t* – 4;

r is the discount rate (assumed to be a constant 4 percent), and

T is the lifetime of the resource.

Total rents in the current year are calculated as:

$$R_t = \pi_t q_t$$

where

π_t = unit rents, and

q_t = the quantity of resource extracted.

Unit rents, π_t, in year t are calculated as:

$$\pi_t = (p_t - c_t)$$

where

p_t = equals average unit price

c_t = average unit production costs including a "normal" rate of return on fixed capital and the consumption of fixed capital

Rents, R_t, are converted into constant US dollars at market rates using country-specific GDP deflators before averaging to obtain $\overline{R_t}$. Note that $\overline{R_t}$ averages both unit rent and quantity. [3]

[3] This approach will be revised in future to smooth only the unit rents, not total rents. The lagged average unit rent will be applied to annual production, unsmoothed.

Key elements for asset valuation are the future extraction path and unit rent. The present value of rents from energy and mineral resources is estimated under the restrictive assumption that rents remain constant in future years (in accordance with guidance from the System of Environmental Economic Accounting (SEEA, UN et al. 2014), when information about extraction paths and future prices are not available, which is the case for CWON).

Time series: CWON 2021 will provide asset accounts for the period 1995 to 2018. Given the 5-year lagged average rents used for asset valuation, this requires that data for all variables are available from 1991 to 2018.

2.2 Current Data Sources

The data required to implement the methodology described in section 2.1 include: production volume, unit price, unit cost, and proved reserves. All previous editions of CWON used data sources for each of these elements listed in Table 1. United States Geological Survey (USGS), together with the British Geological Survey (BGS), provide the most comprehensive data for production and proven reserves by country for the time series, 1991 to 2018. The World Bank's Global Economic Monitor Commodities database provides a time series of mineral prices.

CWON obtains data from two annual United States Geological Survey (USGS) sources: Minerals Yearbook and the Mineral Commodity Summaries. The Minerals Yearbook provides comprehensive country coverage of production, but is not updated as quickly as the Mineral Commodity Summaries and tends to lag reporting by one or sometimes two years. CWON uses the Minerals Yearbook data for all years except the most recent; for example, 1991-2017. The Mineral Commodity Summaries data are used for the most recent year, for example, 2018 at the time of writing this note. However, its most recent year reports production and reserves by country only for the largest producers and groups the smaller producers in a category 'Other countries,' presumably in the interest of timely release of information. The Minerals Yearbook disaggregates Other countries in subsequent releases, but with a time lag. Reserves by country are only reported in the Mineral Commodity Summaries, and are subject to the same aggregation into "other countries' for the most recent year (and disaggregated in subsequent years).

CWON has a gap-filling approach for missing country coverage for the most recent year. First, we assume that countries reported as recent producers in the Minerals Yearbook are included in the broad "Other countries" category for the latest year in the Mineral Commodity Summaries. For these countries:

i) Production: production is estimated by extrapolation based on the time trend of a country's production.
ii) Reserves: CWON calculates the ratio of reserves to production for Other countries from the Mineral Commodity Summaries, and applies that ratio to production estimated for each country. This implies that the time-to-depletion used in asset valuation is the same for all these countries in the most recent year.

As mentioned in Section 1 all previous editions of CWON estimated production costs for each mineral commodity on the basis of case studies from major producing countries from the 1980s and early 1990s. Country-specific data on production costs are not readily available for all resources and all years, so regional averages were used for countries believed to have similar costs. Trends in costs over time are extrapolated for the 1980s or early 1990s by assuming that baseline production costs remain constant, adjusting for inflation according to the rate of change in the MUV index. The MUV is not specifically designed to capture mining costs and is ill-suited to an industry where increasingly marginal resources are brought into production. Details of the unit production cost estimates for each metal and mineral are described in Appendix 1.

Table 1. Data sources for mineral resources in CWON 2018 and earlier editions of CWON

Indicator	Data sources and notes
Production	• US Geological Survey (USGS), Minerals Yearbook and USGS Mineral Commodity Summaries • British Geological Survey (BGS), World Mineral Statistics
Proved reserves	• USGS, Mineral Minerals Yearbook and Commodity Summaries
Unit price	• World Bank, Global Economic Monitor Commodities database
Unit cost	• Country-specific case studies from various sources; assumed to be representative for the region • World Bank, Manufactures Unit Value Index, Global Economic Monitor Commodities database
Time coverage: CWON 2021 will provide asset accounts for the period 1995 to 2018. Given the 5-year lagged average rents used for asset valuation, this requires that data for all variables are available from 1991 to 2018.	

3. New Data Sources and Methodology for Estimating Rent at Mine Level and National Level

Four data variables are needed to estimate asset value: production, proved reserves, unit price and unit production cost. Unit rent is calculated as unit price minus unit cost, including the cost of produced capital. In this section we begin by describing the new data source, S&P Global Market Intelligence. We compare S&P's coverage of the four data variables to our current data sources and then describe the new methodology that will be used for CWON 2021.

3.1 S&P Database

S&P Global Market Intelligence[4], a division of S&P Global, is a subscription-based[5] data provider of financial and industry real-time data, research, news, and analytics to investment professionals, government agencies, corporations, and universities. Their global database includes mine-level physical and economic indicators for a number of commodities included in the CWON mineral accounts over the time series of CWON and even earlier for some minerals. S&P provides information on all four of the data variables used for CWON mineral accounts. Crucially, their database provides information on the mine-level costs of production, which can be used to address the critical weakness in the current CWON methodology.

S&P models mining and ore processing costs using a bottom up approach, modeling the process flowsheet, the equipment in place and the personnel required to operate that equipment. Input costs such as consumables are assessed. The start point is a technical report ("technical", "feasibility" or "pre-feasibility" commonly) on the asset and any other corporate disclosure on the project. This includes corporate presentations, annual, semi-annual and quarterly or monthly reporting, management discussion & analysis documents, financial statements, corporate conference calls or transcripts. S&P analysts then look to supplement this information with direct phone and email contact with the owner company, head office and site visits. Where detailed breakdowns are not available, analysts use industry benchmarks, averages or calculations, including but not limited to reagent consumption, productivity rates and electricity consumption for example.

[4] For more information, visit www.spglobal.com/marketintelligence.

[5] The CROMC unit of the World Bank holds the enterprise-wide license for the S&P Global Market Intelligence database. The CWON team (Environment GP) has contributed funds for FY19 and 20 in order to be included in this license and have access to the data for this work.

3.2 Comparing S&P and Current Data Sources for Mineral Prices, Production and Reserves

The data for prices, production and reserves from different data sources are compared in this section. The decision about which to use and how to use is described below.

Mineral Prices: continue using prices from GEM database

Although the S&P database includes information on realized price at mine level, a decision was made to use the GEM world price data after comparison confirmed consistency of prices in the two data sources. Use of GEM prices makes gap filling easier, increases transparency for data users, and eases future annual updates for the team, especially if S&P data are not accessible annually to the team. With high consistency between the two data sources, the benefits of using GEM prices outweighed any losses of information.

Mineral Production and Reserves: continue using USGS and BGS for total national figures

Table 1 provides a comparison of the coverage of production and reserves for CWON minerals by S&P to figures from USGS, the current CWON data source for mineral production[6]. While the S&P global production figures covered most of the USGS estimates in 2017, the coverage was less than half in 1991. The difference in production figures between the two data sources can occur when i) producing countries are entirely missing from S&P, or ii) coverage of production is incomplete for some (or all) countries in S&P. Appendix 2 provides a more comprehensive look at the coverage and comparisons by metal.

For the most comprehensive national coverage over the entire time series, we will continue to use the USGS and BGS data for production and reserves at the national level. However, as we discuss below, we will use S&P data for production costs, so a method to scale up production costs from S&P mine-level data to USGS/BGS national data will be required, especially in early years. This will be discussed below.

Table 1: S&P metal coverage (metric tons)

	1991			2018			Reserve and Resource Availability	
	S&P number of mines	**S&P aggregated mine production**	**USGS global production**	**S&P number of mines**	**S&P aggregated mine production**	**USGS global production**	**S&P**	**USGS**
CWON Metal								
Copper	75	6,933,982	9,090,000	393	19,134,000	20,400,000	YES	YES
Gold	60	1435	2,187	532	2620	3300	YES	YES

[6] Production data from USGS Minerals Yearbook and BGS are lagged by one year (e.g., up to 2017), while USGS Minerals Commodities Summary provides the most recent year (e.g., 2018). However, the USGS Minerals Commodities Summary is not as comprehensive in its country coverage as the Minerals Yearbook, including the major producing countries and a category "Other countries". Therefore, in the current CWON methodology, countries that are missing production data in the latest year are gap-filled with an extrapolated figure using a time trend. Reserves data are only available in the USGS Minerals Commodities Summary and also includes the "Other countries" category. Therefore, for countries that have production data but missing country-specific reserves data, the current CWON methodology uses the reserves figure for "Other countries" from the USGS Minerals Commodities Summary.

Lead	38	1,266,639	3,314,000	202	2,871,412	4,560,000	YES	YES
Nickel	1	309,840	985,361	62	1,758,142	2,400,000	YES	YES
Silver	84	4,449	15,672	529	17,721	26,900	YES	YES
Zinc	45	2752300	7,258,424	230	9,526,874	12,500,000	YES	YES
Iron ore	38	5,895,000	956,000,000	287	629,000,000	2,460,000,000	YES	YES
Non-CWON Metal								
Cobalt	3	6,184	33,300	39	108,111	148,000	YES	YES
Lithium	NA	3,897	NA	NA	422,306	95,000	YES	YES
Molybdenum	18	67,190	115,000	47	204,413	297,000	YES	YES
Palladium	1	0	134	30	173	220	YES	NO
Platinum	1	52	128	30	206	190	YES	NO
Rhodium	NA	0	NA	24	15	NA	NO	NO
U308	2	12,722	NA	18	61,796	NA	YES	NO

**Iron ore: S&P global production is the sum of mine/property's reported production of concentrates, fines, and lumps. USGS production data is reported for usable iron ore. The gap might due to different definition.*
**Palladium: S&P global production is less than 1 metric ton in 1991 and is rounded as 0. USGS world production data is not available.*
**Lithium: S&P global production data is available, yet paid metal production as well as production cost data are not available. USGS production data are incomplete for lithium; it excludes US production (US status is marked as W: Withheld to avoid disclosing company proprietary data)*
**Rhodium: S&P global production data is available from 1992 and onwards. Year 1991 is not available.*
**Platinum: USGS world production data is not available.*

3.3 Production Cost Components from S&P Data

The S&P database provides a number of options for quantifying costs. This section reviews these options and presents our proposed approach. Costs of production are affected by two important factors, i) the development stage of a mine and ii) whether a co-product or by-product approach is applied for mines with multiple mineral outputs. We explain our choices regarding these two issues then discuss the components to include in the cost of production.

Development stage of mines

The S&P database categorizes mines by three broad stages of development: (1) Early-stage and (2) Late-stage, which cover activities from establishing claims through feasibility assessment, and (3) the Mine stage, which includes all activities from preproduction to mine closing (Appendix 3 provides a full description of each stage). The costs and revenue (production x price) are very different in each stage. In the first two stages, before any production, there are only costs, no revenues yet. Using data for these early stages would result in negative rents and zero value asset. CWON intends to provide a long-term assessment of asset value, rather than year-to-year short term changes so the more appropriate information would be costs and revenues when a mine is in production. For this purpose, we limit the mines used for calculations to those already in the Mine stage, when a mine is fully operational in the sub-stages Operating (3.2.1) and Expansion (3.2.3). This approach may underestimate the value of a country's total mineral resources because the potential future value of resources still in the development stage is not included. However, the vast majority of mines in the S&P database are in

Operating and Expansion stages (see Table A2.3). For global assessments such as CWON, the data for earlier stages of development are insufficient for estimating asset value.[7]

Co-product versus by-product

Although the simple conceptual production model is one of mining a single commodity, it is sometimes the case that two or more minerals occur jointly and are extracted as joint products. In other cases, mining for a primary mineral may also produce valuable but much smaller amounts of mineral by-products. S&P provides estimates of paid metal production cost using two accounting methods: co-product and by-product[8]. Co-product accounting calculates production cost based on the share of the net revenue of each paid metal in the operation and is the proposed accounting method used for CWON. It implicitly assumes that the production costs per unit revenue is the same for each co-product. By-product accounting applies the cost of the whole operation to the one metal that is focused on and net all other metals' revenues as by-product credits. We will use the co-product approach.

Components included in costs of production

S&P reports a variety of production cost categories. The CWON team proposes including the following in the total cost of production, listed in Table 3 below: mine site costs, transportation and offsite, smeltering and refining, reclamation and closure provision, depreciation & amortization, deferred stripping amortized, and inventory change.

Table 3. Total production cost components

	Mine Labor	Wages attributable to mining, including all salary and on-costs
+	Mine Fuel	Petrochemical fuel for heavy off-road and light vehicle uses
+	Mine Electricity	Mine power costs, including grid and own-power petrochemical generation for electrical equipment
+	Mine Other	Includes all other costs for the mining operation, with the largest portion commonly being explosives and third party site services such as geological services
+	Mill Labor	Wages attributable to processing, including salary and on-costs
+	Mill Reagents	Chemicals, including acids, leach agents, flotation and agglomeration agents, flocculants, pH balancers
+	Mill Electricity	Mill power cost, including grid and own-power petrochemical generation for electrical equipment.
+	Mill other	Includes all other costs, such as grinding media, activated carbon, third party site services
=	**Total Minesite Cost**	**Direct mining and milling cost, inc SXEW costs. For iron ore this includes pellet plant costs**
+	Transport and offsite	For bulks, broken out to inland, port loading & ocean freight. For all others, inland and ocean recorded together

[7] This information, however, could be quite useful for calculations for analytical work at the country level where additional information would be available and the timing of mining development is crucial.

[8] By-product accounting applies the cost of the whole operation to the one metal that is focused on and net all other metals' revenues as by-product credits.

+	Smeltering & Refining	Smelting, treatment, converter and refining charges. Includes toll treatment where appropriate, such as for DSO operations
=	**Cash Operating Cost**	**Direct net cash costs**
+	Reclamation & Closure Provision	Payments into an environmental fund or bond where available
+	Depreciation & amortized capital	Depreciation and amortization of previously spent capital expenditure
+	Deferred Stripping Amortized	Where broken out, amortization of deferred stripping costs
+	Inventory Change	Where present, ore, mineral or metal inventory adjustments
=	**Total product cost**	**A cost metric using depreciated spent capital as a proxy for the ongoing capital cost of mining**

Cost components available in the S&P database that we did not include in production costs:

- Royalties and production taxes: these are treated as distribution of the resource rent rather than inputs necessary for production. This information is useful for policy analysis of mineral economies and is discussed in the next section.
- Corporate overhead: S&P documentation notes that corporate overhead charges are not directly allocated on an asset level, hence may underestimate the costs of mining compared to costs reported in companies' annual reports. These charges, often paid to corporate headquarters in high-income countries where foreign operators are based, can be substantial. In some cases, these payments can be used for transfer pricing, effectively transferring income from producing countries to headquarters in other countries to reduce tax liability in the producing country.

Additional information of interest: Government share of revenues

Calculation of asset value does not require information about the distribution of mineral revenues among beneficiaries—domestic and foreign private operators, government (which in most countries is the owner of mineral resources), local communities. However, as a matter of policy, the distribution of rent is very important. Comprehensive information about rent distribution is not available globally, but some information is provided in the S&P database. Government's share is estimated as the share of royalty and production taxes in the unit rent at the mine, country, and region level. See Appendix 6 for preliminary results.

4. Calculating Rent

This section starts with a brief overview of how total rents are calculated at national level, as the product of unit rent and production, applying the equation presented in Section 2. The rest of this section describes how national unit rents are obtained from the S&P data, building up from mine-level to national, regional and global level unit rents.

For the purpose of calculating rents, minerals fall into 2 categories based on availability of data from S&P:

1. Minerals covered by USGS with coverage by S&P for at least some, but not all, countries (copper, gold, lead, zinc, iron ore, nickel, silver)
   a. Countries covered by S&P:
      - S&P mine level data used to calculate unit rent, averaged to national level

b. Countries not covered by S&P:
    - Regional average unit rent
    - If regional average not available because S&P does not cover any country in the region, global average unit rent

2. Minerals covered by USGS but with no coverage by S&P (bauxite, tin, phosphate rock)
   For these countries we use a combination of current CWON unit rent estimates for the base year, and apply a new production cost index, replacing the old index MUV. The new cost index is derived from the change in average unit costs derived from the S&P data for the 7 minerals in 1.

The derivation of unit rents is discussed in two parts, corresponding to the two categories of minerals: the seven minerals with data from S&P and the three not covered by S&P.

4.1 Calculating Total National Rents Based on USGS Production Data and S&P Unit Rent

Total rents, $R_t^{M,N}$, for each mineral, M, in each country, N, are calculated as the product of the average unit rent, $\pi_t^{M,N}$, (derived in sections 4.2 and 4.3) and national production reported by USGS. USGS data for production and reserves are used instead of S&P data because, as noted in Section 3, S&P data are often not as complete as USGS data. By using the average national unit rent calculated from S&P data, we implicitly assume that S&P's 'missing' mineral output is produced at the same average unit cost and generates the same unit rent as the average for all S&P mines. This is discussed further in Section 4.2 and 4.3.

$$R_t^{M,N} = \pi_t^{M,N} q_t^{USGS,M,N}$$

Where,

$R_t^{M,N}$ = Total rent for mineral, M, in country, N, in year t

$\pi_t^{M,N}$ = average unit rent for mineral, M, in country, N, based on S&P data in year t and GEM prices

$q_t^{USGS,M,N}$ = Total production of mineral, M, in country, N, from USGS/BGS data in year t

Annual rents calculated in this manner are then smoothed over 5 years as described in Section 2. Asset values are then calculated using the equation presented in Section 2.

4.2 Unit Rent for Minerals Covered by S&P

S&P covers 7 of the 10 minerals included in the CWON database. For each of these minerals, CWON requires national average unit rents in every year, 1991 to 2018. Unit rent calculation is carried out in two steps, first calculating unit rent at mine level, then averaging for national unit rents. Further averaging of unit rents across regions and globally is done for those countries identified by USGS as producers, but missing from the S&P database; discussed in more detail below.

Step 1. Unit rent at mine level for each mineral

Unit rent, π, is calculated at the mine level, using the S&P data for unit cost and the World Bank Global Economic Monitor (GEM) Commodities database ("The Pink Sheet") for price. [9]

[9] Price is expressed as dollars per tonne/ton/metric ton for paid copper, and dollars/troy ounce for paid gold.

$$\pi_{m,t}^{M,N} = \left(p_t^{GEM,M} - c_{m,t}^{M,N}\right)$$

where

$\pi_{m,t}^{M,N}$ = equals unit rent for mineral, M, in country, N, from mine, m, in year, t

$p_t^{GEM,M}$ = equals average global unit price in the GEM database for a mineral, M, in year t

$c_{m,t}^{M,N} = \frac{TC_{m,t}^{M,N}}{q_{m,t}^{SP,M,N}}$ unit cost is calculated from total cost and production in the S&P database

$TC_{m,t}^{M,N}$ = Total production costs for mine, m, year, t, for mineral M, in country N

$q_{m,t}^{SP,M,N}$ = Volume of production from S&P for mine, m, year, t, for mineral M, in country N

Step 2. Unit rent at national level for each mineral

Average national unit rent, $\pi_t^{M,N}$, is calculated by summing mine-level rent weighted by each mine's share of national production, as reported by S&P.

For each mineral, M = 1,…7:

$$\pi_t^{M,N} = \sum_1^n \pi_{m,t}^{M,N} \times \frac{q_{m,t}^{SP,M,N}}{q_t^{SP,M,N}}$$

where

Total S&P production at national level, $q_t^{SP,M,N}$, is the sum of production across all mines, m=1…n:

$$q_t^{SP,M,N} = \sum_1^n q_{m,t}^{SP,M,N}$$

Step 3. Unit Rent at Regional and Global Level

S&P has generally good country coverage, but it is not as complete as USGS; some countries are missing. The use of regional and global unit costs/rent for gap filling for missing data is commonly used, as discussed in Box 1. For the missing countries, we assume the unit rent for a given mineral is similar to the average unit rent for producers of that mineral in countries that are covered by S&P. We apply the regional average unit rents for that mineral in the 'missing' countries.

Regional unit rents, $\pi_t^{M,Reg}$, are calculated as the weighted average of country unit rents with USGS production is used for country weights.

$$\pi_t^{M,Reg} = \sum_1^n \pi_t^{M,N} \times \frac{q_t^{USGS,M,N}}{q_t^{USGS,M,Reg}}$$

where

Total production at regional level is the sum of USGS production across all countries in the region, N=1…n:

$$q_t^{USGS,M,Reg} = \sum_1^n q_t^{USGS,M,N}$$

For countries where there are no other producers in the region and a regional average cannot be calculated, a global average unit rent can be used. Calculating global averages is given by the following equations, noting that USGS production figures are used for weighting.

Global unit rents, $\pi_t^{M,G}$, are calculated as the weighted average of regional unit rents, with USGS production used for regional weights.

$$\pi_t^{M,G} = \sum_1^m \pi_t^{M,R} \times \frac{q_t^{USGS,M,Reg}}{q_t^{USGS,M,G}}$$

where

Total production at global level, $q_t^{USGS,M,G}$, is the sum of USGS production across all regions, R=1…m:

$$q_t^{USGS,M,G} = \sum_1^m q_t^{USGS,M,N}$$

1. National vs Regional average unit rents

National unit rent can be estimated for each country by averaging mine level information from S&P in a country. In general, when we are confident that data coverage is comprehensive or reasonably representative, we compile accounts for CWON based on national averages. But when there are significant data gaps or concern about data quality, CWON often substitutes regional averages for national averages, even when national-level information may be available for some countries. There is some concern that the S&P coverage, even where it appears reasonably comprehensive at the global level, may not be representative at the national level, e.g., data reported for only one mine when there are more. This is especially common in the early years (1990s). Ideally, we would undertake an assessment of coverage for all minerals in all countries, and then design an adjustment process for missing or unrepresentative data. But this is not possible at this time. Keeping in mind these caveats, we have chosen to use national average unit rents for countries, whenever available.

Negative rents and the calculation of national average rents

Commodity prices are notoriously volatile and, in some cases, a mine in full operation may generate negative rents if the price falls below the cost of production. A mine may continue to operate under such conditions in the expectation that prices will rise in the future. Analysis presented in Appendix 4 shows that between one-third and one-half of all mines, across a wide range of countries, report negative rents for at least one year. Following the treatment recommended in the SEEA, negative rents are set to zero for the calculation of national

unit rent. However, given the smoothing process that averages rents over five years, the rent in any given year is much less likely to be negative.

4.3 Unit Rent for Minerals Not Covered by S&P

S&P does not include information about three minerals in the CWON database: bauxite, tin, and phosphate rock. For these minerals, we propose a two-part approach:

i) *1991 base year unit cost*: continue using the 1991 base year unit cost estimated from case studies for earlier versions of CWON, but

ii) *Updating unit cost for 1992-2018*: replace MUV to update the cost estimates with a cost index, CI_t^G , based on S&P global average production costs, $c_t^{M,G}$. The index measures the change in annual production costs as a share of price, averaged over all minerals at global level. While this is far from ideal, it is an improvement over the MUV because the cost index is narrowly focused only on costs directly related to mining.

This cost index could be estimated in a manner similar to unit rents, by estimating costs at mine level and averaging across mines, countries, regions. A simpler method would take advantage of calculations already carried out to estimate global average unit costs implicit in the global average unit rent calculation. Global unit cost for each mineral could be expressed as:

$$c_t^{M,G} = \left(p_t^{GEM,M} - \pi_t^{M,G} \right)$$

Because unit prices and units of measurement are so different across the seven minerals, we look at how **cost as a share of price** changes over time for each mineral, then average this change across all minerals:

$$s_t^{M,G} = \left(c_t^{M,G} \div p_t^{GEM,M} \right)$$

where $s_t^{M,G}$ is the global average cost share of S&P mineral, M, in year t, 1991…2018

The global cost index, CI^G, is calculated in two steps: first, a global cost index is calculated for each mineral, CI^M, then a simple, unweighted average of the change is taken across all minerals.

The cost index, CI^M, for each mineral, M, would simply be the change in cost from one year to the next, using the old CWON unit cost for 1991:

$$CI_t^{M,G} = 1 + \left[\frac{(s_t^{M,G} - s_{t-1}^{M,G})}{s_{t-1}^{M,G}} \right] \text{ for t = 1992...2018}$$

The global average cost index, CI_t^G, is the simple, unweighted average of unit costs across the seven minerals in S&P:

$$CI_t^G = \sum_{1}^{7} CI_t^{M,G} \div 7$$

The unit cost for each of the three non-S&P minerals would be calculated as:

- 1991: use unit cost from older versions of CWON, $c_{1991}^{M,Old}$
- 1992 to 2018: apply the global cost index for each year to the previous year's unit cost:

$$c_t^{M,G} = c_{t-1}^{M,G} \times CI_t^G$$

for t = 1992…2018 and

M = bauxite, tin, phosphate

Unit rent for these three minerals would then be $\pi_t^{M,G} = \left(p_t^{GEM,M} - c_t^{M,G}\right)$ and total rents calculated as in section 4.1.

5. Key Results: Unit Costs and Rents Across Regions for Selected Minerals

The key results below provide some insight into the S&P data and provide analytics that the team used in deciding when to use country rental rates and when to use regional or global averages, including for non-S&P minerals. Three issues are addressed:

i) the volatility of average unit production cost/rent over time,
ii) the variability of average unit production cost/rent across countries and regions, and
iii) the expected impact on mineral rent and asset value that will result from use of S&P data for production cost .

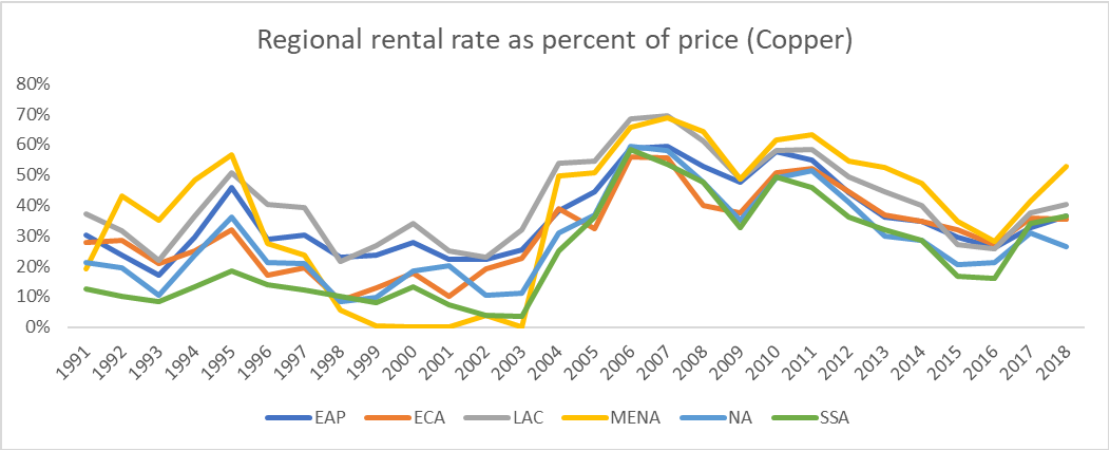
Each of these issues is illustrated by selected country/regional examples, mainly for copper and gold and mineral. More extensive coverage of regions and minerals is provided in Appendix 5.

5.1. Rental rates are volatile over time

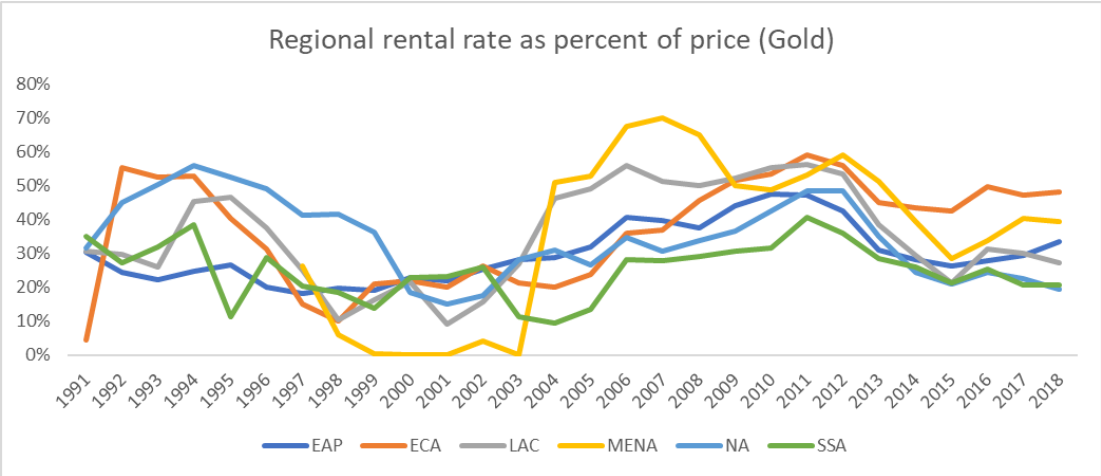
The volatility of commodity prices over time, is a well-known feature of commodities and the resulting volatility of rental rates is not unexpected. As shown in the select figures below, annual rental rates estimated using S&P data (not yet averaged over 5 years as we would do for CWON) for copper and gold show significant volatility over time and exhibit similar trends across regions. Most regions show a large dip in the rental rate in the late 1990s into the early 2000s, and then hit a peak during the rise of commodity prices in the late 2000s. Similar trends are found for the five other minerals covered by S&P.

Figure 1. Copper and Gold regional rental rates as percent of price, 1991 to 2018

A. Copper



B. Gold



Notes: EAP is East Asia and Pacific, ECA is Europe and Central Asia, LAC is Latin America and Caribbean, NA is North America, SSA is Sub-Saharan Africa.

The figure is not subject to the 5-year lagged averaging that would be used in the CWON accounts.

Source: Authors' calculations from S&P database

5.2. The spread of country rental rates for copper and gold differ by region

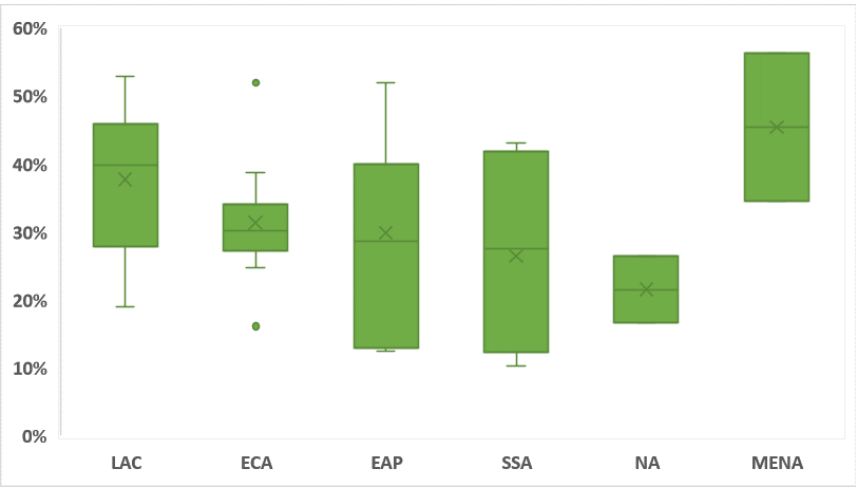
Using a global price for our calculations, rental rates will vary according to the costs of production. There are many reasons why production costs will vary across countries and mine sites. Figures 2a. and 2b. below show the spread of country rental rates within regions in 2017 for copper and gold. These box and whisker plots show the extreme ends (minimum and maximum) within a region, as well as the spread of the middle quartiles. The mean and median rental rates are fairly similar across regions, mostly between 30-40% of the global price of

copper, and a similar share of the price of gold, but the variability within regions is high. (The line is minimum, 1st quartile, median, 3rd quartile, and maximum; X is the mean)

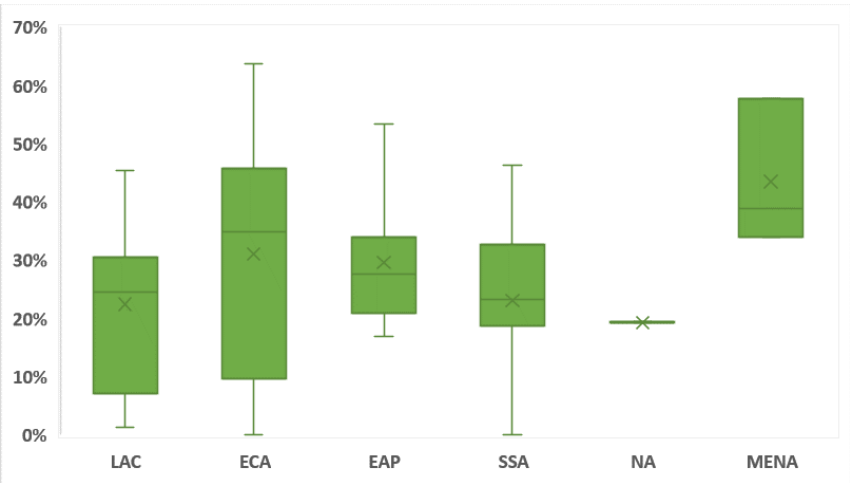
Figures are reported only for 2018, but the variability within regions is similar in other years and for other minerals (see Appendix 5)

Figure 2. Variability of country rental rates as percent of price within regions for copper and gold in 2018

A. Copper



B. Gold



Notes EAP is East Asia and Pacific, ECA is Europe and Central Asia, LAC is Latin America and Caribbean, NA is North America, SSA is Sub-Saharan Africa, MENA is Middle East and North Africa:

These box and whisker plots show the minimum and maximum within a region, as well as the spread of the middle quartiles. The "X" mark shows the mean value of the rental rate. The line is minimum, 1st quartile, median, 3rd quartile, and maximum.

Source: Authors' calculations from S&P database

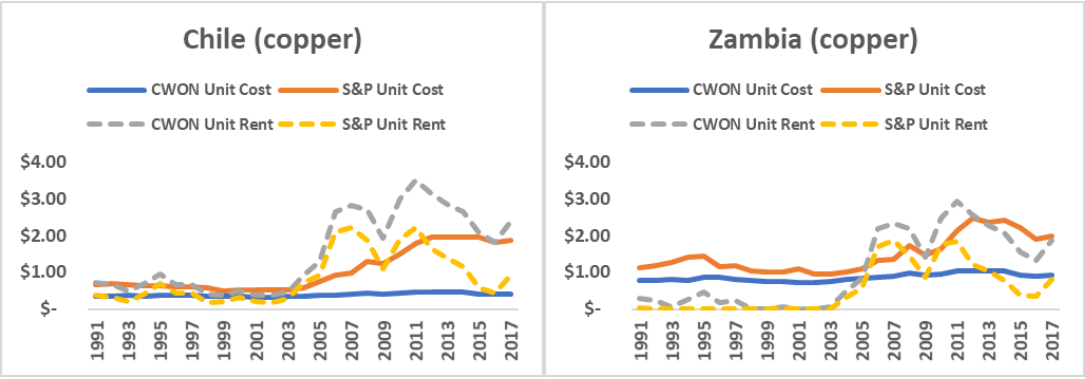
5.3. S&P cost estimates are much higher than the CWON estimates in recent years

As discussed in Section 2, the approach to estimating production costs used for previous versions of CWON is expected to underestimate costs. The previous approach used case studies that covered a small number of countries in the 1980s and 1990s to estimate costs; updates applied the MUC to those case study estimates implicitly assuming that changes in nominal costs resulted only from inflation and that the MUC was a good enough proxy to track inflation for inputs to mining. We expect both those assumptions to be incorrect (although the best that could be done for past CWON), and that the divergence between our estimated costs and actual costs would increase over time. Specifically, we expected that actual costs were much higher than we had estimated in the past 15-20 years. The S&P data allowed us to test that assumption.

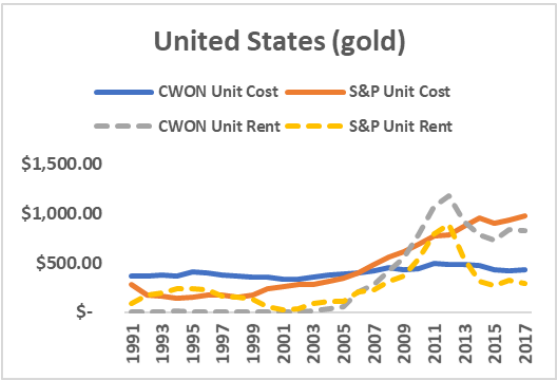
Comparisons of S&P production costs with the CWON USGS-based country estimates of production cost indicate that the MUV index is not doing a good job of picking up the fast-rising cost trends in the recent decade. This comparison was carried out across all the available countries for each mineral. Figure 3 illustrates this result using copper in Chile and Zambia, and gold in Australia and United States. The CWON and S&P estimates for most metals are fairly similar in the 1990s but start to diverge in the 20002. This would indicate that the initial case studies used for CWON estimates provided reasonable estimates of unit cost, and discrepancies arose due to updating costs with MUV, for reasons mentioned in Section 2. The results in Figure 3 are similar for the other countries producing these minerals, including 11 countries available for copper and 8 countries available for gold. (See Appendix 5 for more country comparisons of copper and gold.)

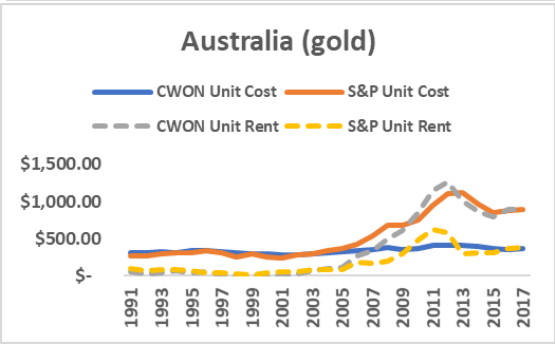
Figure 3. Unit production cost of S&P compared to CWON/USGS, copper (US dollars per pound) and gold (US dollars per troy oz)

A. Copper (US$/lb.)



B. Gold (US$/troy ounce)

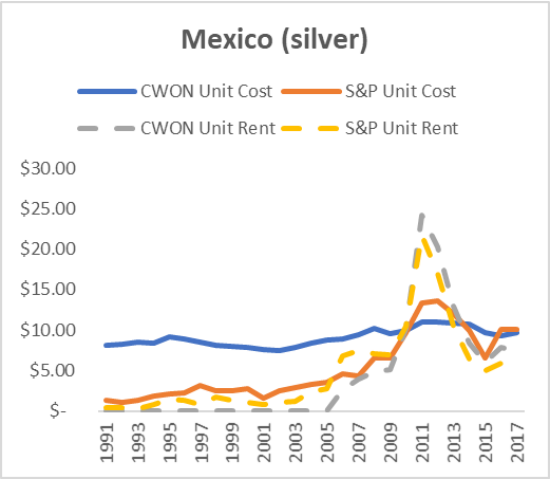


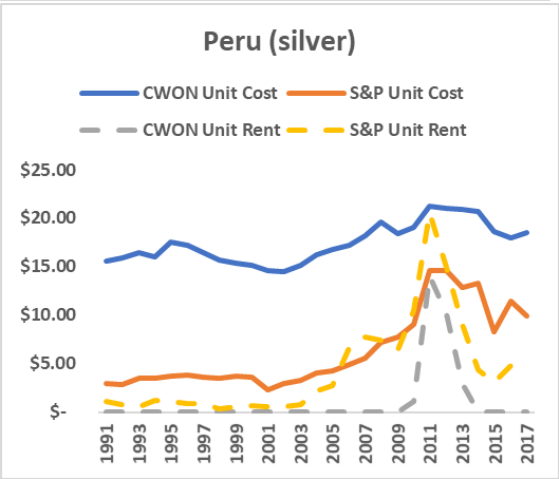


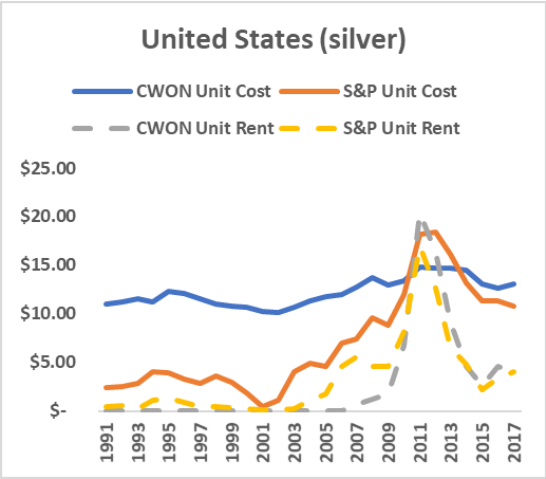
Source: Authors' calculations from S&P database

A similar check was carried out for other CWON metals that are available in the S&P database: lead, nickel, silver, and zinc. For lead, nickel, and zinc, the results are similar to copper and gold – the CWON estimates of production costs are much lower in the recent decade compared to S&P. Silver, however, is the only metal for which the CWON estimates are much higher than the S&P results especially through the 1990s and early 2000s. Figure 4 below shows the comparisons for 3 of the silver-producing countries in the S&P database. The large differences in early years, that decline over time, seem to indicate that to problem lies with the initial case studies used for CWON cost estimates rather than simply the MUV updating, as is the case for other minerals.

Figure 4. Unit production cost of S&P compared to CWON/USGS for silver (US$/oz.)


Mexico (silver)
CWON Unit Cost
S&P Unit Cost
CWON Unit Rent
S&P Unit Rent
$30.00
$25.00
$20.00
$15.00
$10.00
$5.00
$-
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017

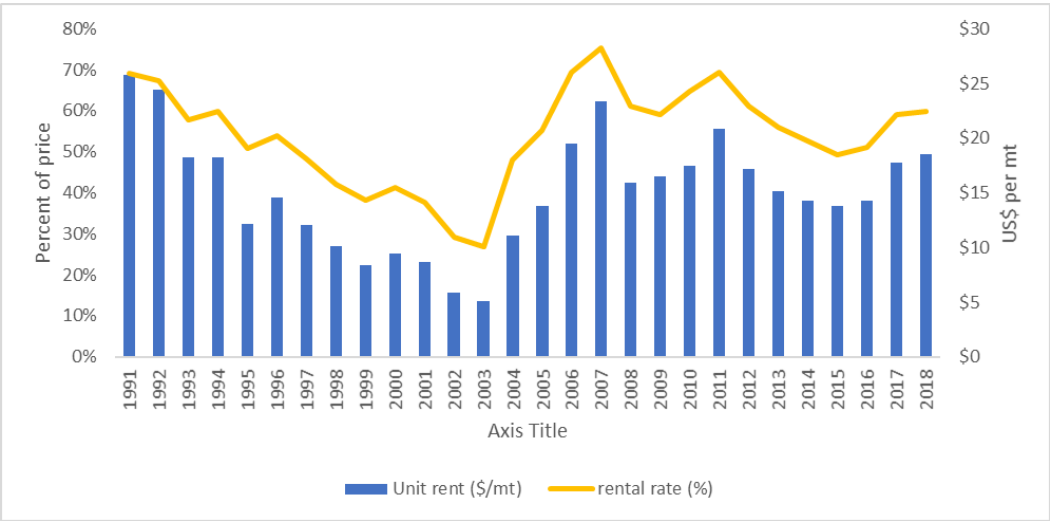

Peru (silver)
CWON Unit Cost
S&P Unit Cost
CWON Unit Rent
S&P Unit Rent
$25.00
$20.00
$15.00
$10.00
$5.00
$-
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017



5.4 Applying the Global Cost Index to estimate unit rents for Tin, Phosphate rock and Bauxite

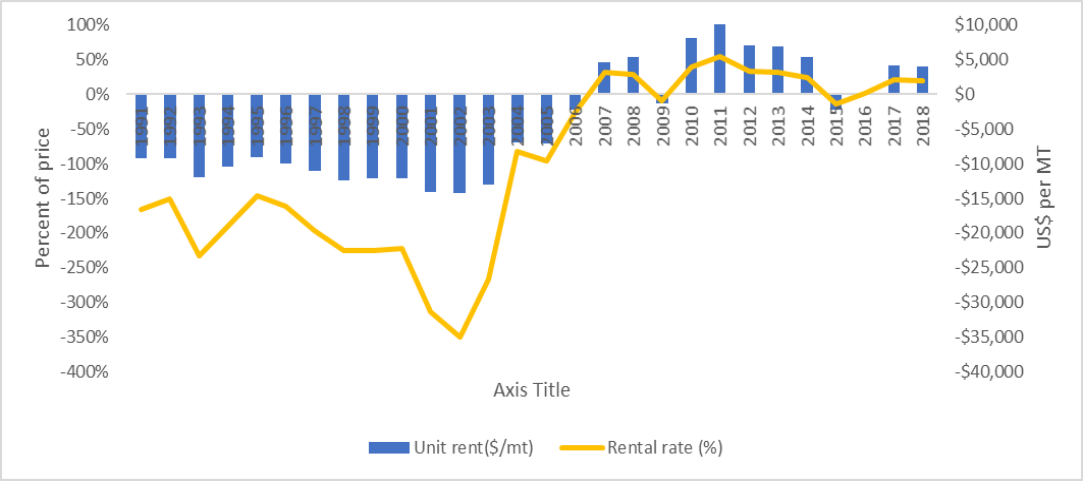
As discussed earlier, S&P does not include production costs for three CWON minerals: tin, phosphate rock and bauxite, so we apply the global cost index derived in Section 4.3. The global cost index uses the original CWON case study estimates for unit production costs 1991, the starting year, then adjusts these unit costs over time by the average annual change in costs for the seven CWON minerals covered by S&P, as shown in Figures 5-7.

Figure 5. Bauxite: unit rent and rent as a share of unit price, 1991 to 2018



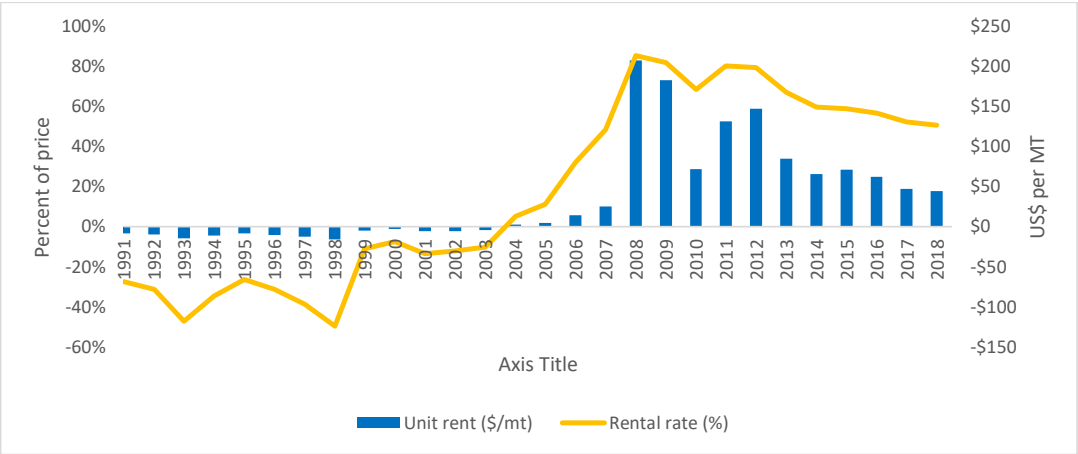
Source: Author's calculations.

Figure 6. Tin: unit rent and rent as a share of unit price, 1991 to 2018



Source: Author's calculations.

Figure 7. Phosphate rock: unit rent and rent as a share of unit price, 1991 to 2018



Source: Author's calculations.

6. Impact of the New Approach to Mineral Asset Valuation on Wealth Accounts

The results laid out in section 5 provide compelling evidence that the CWON methods and data significantly overestimate mineral rents in the recent decade (or underestimate for silver), and the method for estimating mineral rents has been significantly revised using the rich database available through S&P Global Mining Intelligence. In this final section we summarize the new methodology, highlight countries where wealth accounts will be most affected by the change, and discuss future work on mineral accounts.

6.1 Summary of New Methodology

The conceptual approach to asset valuation remains the same as in earlier versions of CWON, described in Section 2: asset value is calculated as the present value of the expected stream of rents generated over the lifetime of the asset. The key change is in the data sources used, how they are used, and how data gaps are filled. Of the four components—production, reserves, price and production cost—the data sources for the first three components will remain the same as in earlier versions of CWON, with information on production from S&P used as an intermediate step in the rent calculations, as described in Section 4. But the cost estimates, and hence the rent, will be derived from the new data source, S&P Global Market Intelligence. The new data sources and estimation methods are summarized in Table 3. The rest of this section comments on how the new methodology may impact wealth accounts reported in earlier years.

Table 3. Data sources and estimation methods to be used for mineral resources in CWON 2021

Indicator	Data sources and notes
Production	National level production data for computing national asset accounts • US Geological Survey (USGS), Minerals Yearbook and USGS Mineral Commodity Summaries • British Geological Survey (BGS), World Mineral Statistics Mine level production data for calculating weighted average national unit cost • S&P mine-level data used to weight mine-level production cost to calculate national-level weighted average cost
Proved reserves	• USGS, Minerals Yearbook and Mineral Commodity Summaries
Unit price	• World Bank, Global Economic Monitor Commodities database
Unit cost	• S&P Global Market Intelligence

Mineral	Estimation methodology and notes for rent calculation
7 Minerals covered by S&P	Countries with mine-level data from S&P: • National average unit rent calculated as the weighted average of mine-level unit rents, weighted by mine-level production, • National rent: calculate as the product of national unit rent and USGS reported national production. Countries lacking mine-level data from S&P • Regional average unit rent calculated as the weighted average of national unit rents, weighted by USGS reported national production • National rent: calculate as the product of regional unit rent and USGS reported national production.

Mineral	Estimation methodology and notes for rent calculation
3 Minerals not covered by S&P	Estimate global unit cost for each mineral • Use unit cost and rent from old CWON estimates for base year, 1991, for each mineral • Calculate global cost index as weighted average of change in unit costs across all 7 minerals in all countries with S&P data, weighted by value of production • Unit cost for 1992 to 2018, apply Cost Index to 1991 cost for each mineral Estimate global rent • Global unit rent calculated by subtracting unit cost from global price for each mineral • National rent: calculate as the product of global unit rent and USGS reported national production

6. 2 Minerals in countries' wealth accounts

At the global level, in 2014 minerals comprised a small share of total wealth (1%), and only 20% of nonrenewable natural capital; fossil fuels account for 80% nonrenewable natural capital. At the regional and income-group level, minerals are also quite a small share of wealth, ranging from less than 1% to 3% (Table 4). However, minerals grew faster than any other asset, and are a significant component of wealth for certain countries.

In 22 countries, mineral accounted for at least 5% of total national wealth; of these, 12 countries held at least 10% or more of their wealth in minerals Table 5). The countries span all regions and income groups, including two High-income countries, Chile and Australia. The highest shares are found in Mauritania (34%), Liberia (24%), Sierra Leone (20%), and Chile (18%). The new methodology is expected to substantially reduce the value of their mineral assets and subsequently, total national wealth.

Table 4. Minerals as share of comprehensive national wealth by income group and region, 1995 and 2014

Income Group	1995	2014
Low income	1%	3%
Lower-middle income	*	2%
Upper middle income	*	2%
High income non-OECD	*	1%
High income OECD	*	*
World	*	1%

Region	1995	2014
East Asia & Pacific	*	1%
Europe and Central Asia	*	2%
Latin America & Caribbean	1%	3%
Middle East & North Africa	*	1%
South Asia	*	2%
Sub-saharan Africa	1%	3%

*= less than 1%
Source: Authors calculations.

Table 5. Countries where minerals account for a significant share of total wealth in 2014

Country	Income group	Share of total wealth
Mauritania	Lower middle income	34%
Liberia	Low income	24%
Sierra Leone	Low income	20%
Chile	High income: OECD	18%
Mongolia	Upper middle income	15%
Papua New Guinea	Lower middle income	15%

Suriname	Upper middle income	15%
Peru	Upper middle income	12%
Guinea	Low income	11%
Congo, Democratic Republic	Low income	11%
Zambia	Lower middle income	11%
Guyana	Lower middle income	10%
Lao PDR	Lower middle income	9%
Australia	High income: OECD	9%
Togo	Low income	7%
Burkina Faso	Low income	6%
Morocco	Lower middle income	6%
Ukraine	Lower middle income	6%
Mali	Low income	6%
Kyrgyz Republic	Lower middle income	5%
Jordan	Upper middle income	5%
South Africa	Upper middle income	5%

6.3 Future Work on Mineral Accounts

The work presented here represents a great step forward in the accuracy of the mineral asset accounts. The new estimates for resource rent and asset value will be useful not only for the *Changing Wealth of Nations*, but also for analytical work at the regional and country level, where accuracy of estimates is quite important. That said, there are quite a few minerals not yet included in CWON that are economically important. With broader coverage of minerals, many more countries would be included in Table 5.

The Platinum group metals, for example, are especially important in Russia, South Africa and Zimbabwe, but only South Africa appears in Table 5. The inclusion of cobalt would greatly increase the share of minerals in wealth for the Democratic Republic of the Congo, the world's major producer. Diamonds form a large share of Botswana's national wealth and are also important in Namibia and Zimbabwe; all missing from the table. In future editions of CWON, we will work to expand mineral coverage. Global databases for production of these minerals are available; for example, USGS covers production of all of them. However, information about reserves and costs of production are not readily available.

References

EC (European Commission), IMF (International Monetary Fund), OECD (Organisation for Economic Co-operation and Development), UN (United Nations), and the World Bank. 2009. *System of National Accounts 2008*. New York: United Nations.

Lange, G., Q. Wodon and K. Carey. 2018. *Changing Wealth of Nations 2018: Building a Sustainable Future.* Washington, DC: World Bank.

UN (United Nations), EC (European Commission), Food and Agricultural Organization (FAO), IMF (International Monetary Fund), OECD (Organisation for Economic Co-operation and Development), and the World Bank. 2014. *System of Integrated Environmental and Economic Accounting 2012 Central Framework*. New York: United Nations.

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Appendix 1. Production Costs in CWON 2018

Production costs for each mineral commodity are estimated on the basis of industry data, including case studies from major producing countries. Country-specific data on production costs are not readily available for all resources and all years, so proxies are used for countries believed to have similar costs. Trends in costs over time are extrapolated by assuming that baseline production costs remain constant, adjusting for inflation according to the rate of change Manufactures Unit Value (MUV) index.[10] Details of the unit production cost estimates for each metal and mineral are described in Table A.1 below.

Table A1.1: Unit production cost estimates for metals and minerals

Minerals	Source and definition of production cost estimates
Bauxite	Unit costs in 1989 for Australia, Brazil, France, Greece, Guinea, India, and Jamaica are from Bleiwas (1996). Costs for these countries are calculated as labor + supplies + energy + overhead – byproduct credit + recovery of capital + 15% discounted cash flow rate of return (DCFROR) and expressed in USD per metric ton at market exchange rates. For all other countries, costs are assumed to be the average of the 7 countries for which data are provided by Bleiwas (1996).
Copper	Unit costs for 1988 are provided for Australia, Canada, Chile, India, Mexico, Namibia, Papua New Guinea, Indonesia, Peru, Philippines, South Africa, Spain, United States, Yugoslavia, Zaire, Zambia, and others by Bleiwas (1996). Costs equal mine cost + mill cost + smelter/refinery cost – byproduct credit and are expressed in USD per pound at market exchange rates.
Gold	Unit costs for 1992 are provided for Australia, Brazil, Canada, Chile, Indonesia, New Zealand, Papua New Guinea, South Africa, and the United States by Bleiwas (1996). Costs include operating and recovery costs plus 15% DCFROR. Exceptions are: only operating costs for New Zealand; 0% DCFROR for Australia, Indonesia, and Papua New Guinea. Data for a "World Average" are also provided by the same source. Additionally, average unit costs for market economies are estimated by World Bank (1994). Unit costs for countries for which specific cost data are not available are assumed to be equal to the world average or the average for the market economies. Costs are expressed in USD per troy ounce at market exchange rates.
Iron ore	Average unit costs for 1995 are available for the following countries/regions: Australia, Brazil, Canada, India, Mexico, United States, Africa, Europe, and South America. Data are from US Bureau of Mines (1987).
Lead	Unit costs for the following countries/regions were provided by Bleiwas (1996) for 1990: Brazil, Mexico, Morocco, Namibia, and South Africa. Average unit costs equal mine + mill + smelting/refining + transportation – byproduct + recovery of capital + 15% DCFROR and are expressed in USD per pound at market exchange rates. Unit costs for 1988-1991 are provided in World Bank (1994) for Australia, Canada, Ireland, Mexico, Peru, and United States. Data are also available for the world average. Costs are expressed in USD per pound at market exchange rates.
Nickel	Unit costs are provided by World Bank (1994) for the following countries/regions in 1990 and 1992: Australia, Botswana, Brazil, Canada, Colombia, Dominican Republic, Finland, Greece, Indonesia, Japan, New Caledonia, United States, Zimbabwe, and World. Costs are direct cash costs and include costs incurred in mining, milling, ore freight, on-site administrative expenses, smelting, refining, intermediate and final freight, marketing and byproduct credit, and depreciation. Costs are expressed in USD per metric ton at market exchange rates. Costs for all countries for which specific cost data are not available are equal to the world average

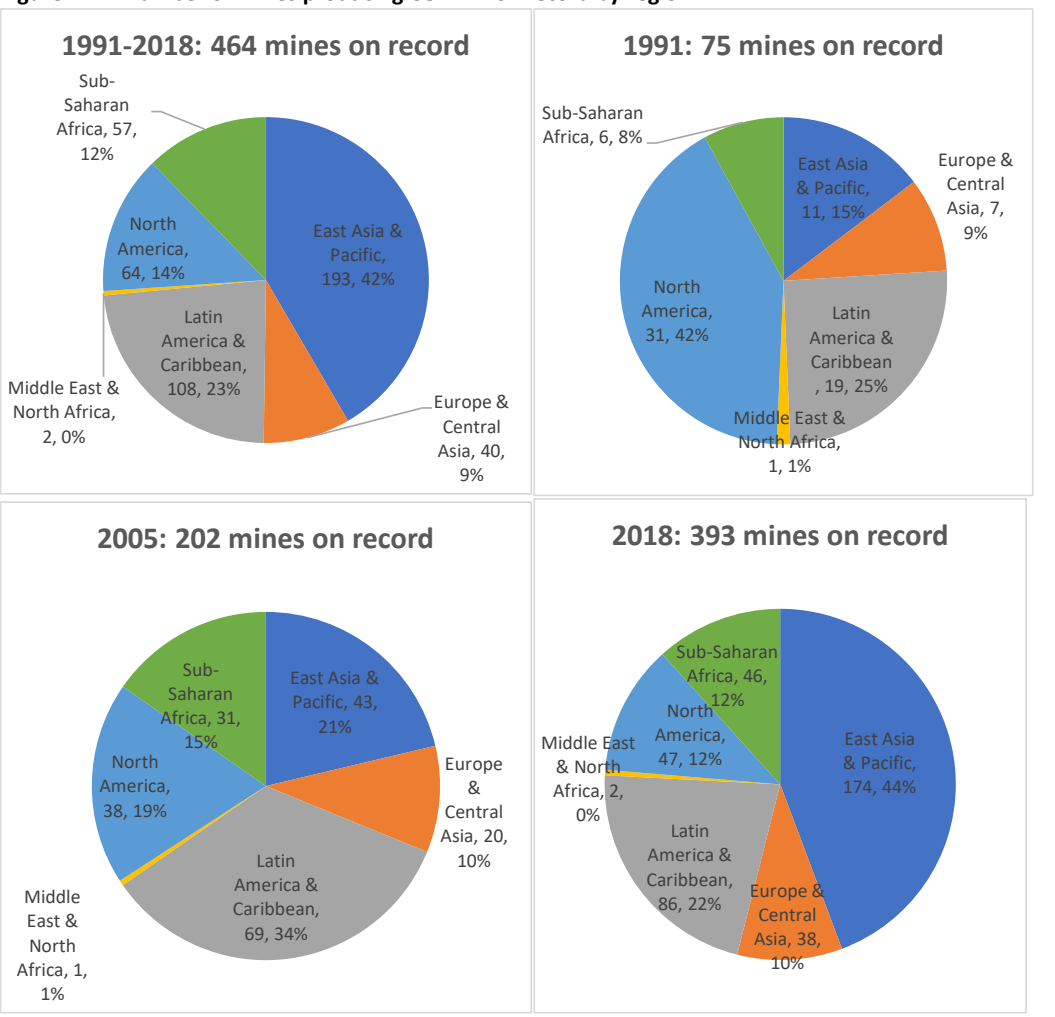
[10] The MUV is a composite index that tracks inflation in the price of manufactured goods imported by developing countries. This index is a weighted average of export prices of manufactured goods produced by 15 major economies.

Phosphate rock	Unit costs are provided by US Bureau of Mines (1987) for 1985 for the following countries/regions: United States, North Africa (Morocco), Tunisia, Algeria, Israel, Egypt, Jordan, Syria, Iraq, Christmas Island, Nauru, Australia, Brazil, Peru, Venezuela, and West Africa (Senegal and Togo). Costs include mining, milling, transportation to plant or port, recovery of capital, and 15% DCFROR. Costs are expressed in USD per metric ton at market exchange rates. Unit costs for all other countries are equal to the average of the costs for countries in US Bureau of Mines (1987), weighted by production.
Silver	Unit costs are provided by Bleiwas (1996) for 1985 for the following countries: United States, Mexico, Peru, Canada, and "Others" (average of Finland, Italy, Morocco, Spain, and Sweden). Costs include mining, milling, smelting, refining, transportation, byproduct credit, capital recovery, and 15% DCFROR. Costs are expressed in USD per troy ounce. Unit costs for all countries for which specific data are not available are assumed to be equal to the costs for Others.
Tin	Unit costs are provided by Bleiwas (1996) for 1985 for the following countries and regions: Australia, Bolivia, Brazil, Indonesia, Malaysia, South Africa, Thailand, United Kingdom, "Other African Countries" (Namibia, Nigeria, Zaire, Zimbabwe), "Others" (Argentina, Peru, Japan, Burma), and "World." Costs include mining, milling, smelting, refining, transportation, byproduct credit, capital recovery, and 15% DCFROR. Costs are expressed in USD per pound at market exchange rates. Unit costs for countries for which specific data are not available are either assumed to be equal to Others or World.
Zinc	Unit Costs are provided by Bleiwas (1996) for 1990 for the following countries and regions: Asia, Australia, Canada, Europe, Mexico, Peru, United States, and "Other." Costs include mining, milling, smelting, refining, transportation, byproduct credit, capital recovery, and 15% DCFROR. Unit Costs are provided by World Bank (1994) for 1988-1991 for the following countries and regions: Thailand, Brazil, Mexico, Canada, Australia, Peru, Spain, and "World." Costs are expressed in USD per pound at market exchange rates.

Appendix 2. S&P Global Market Intelligence Data Summary

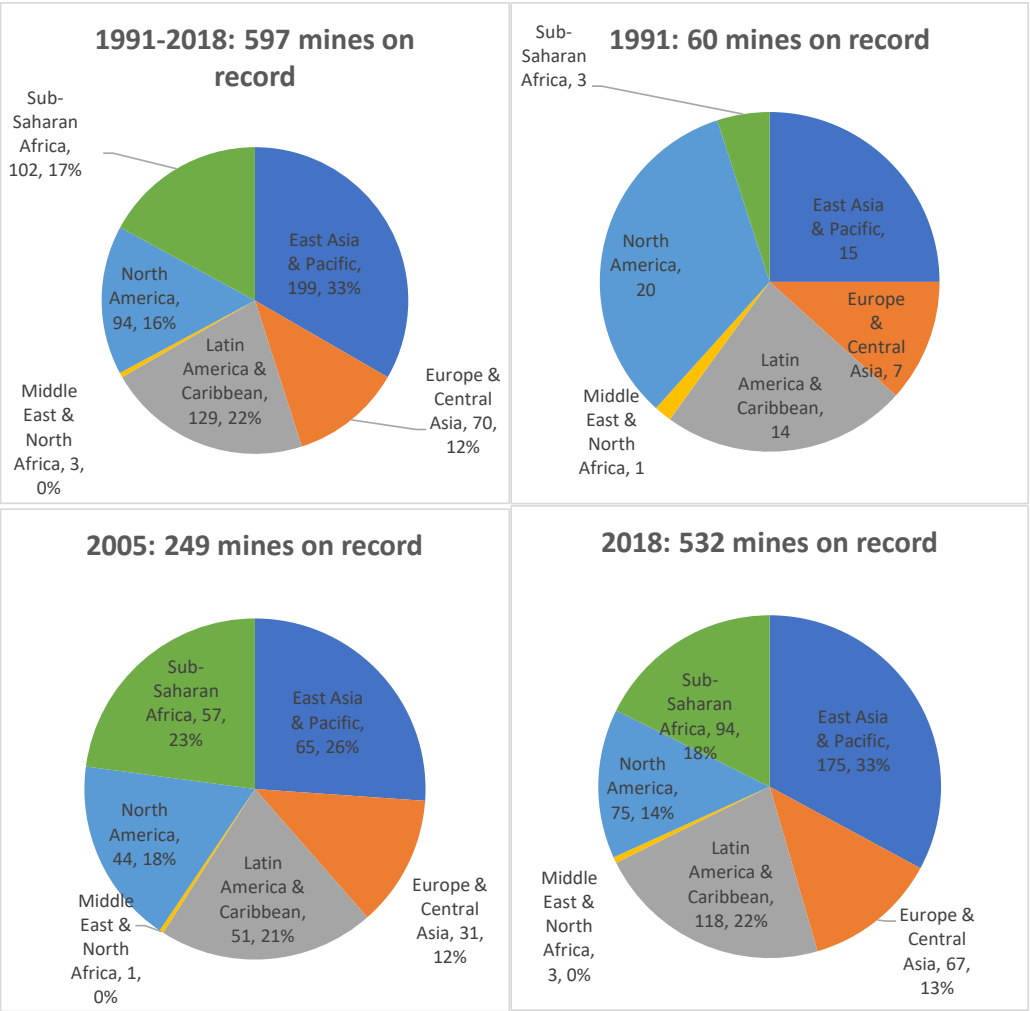
A2.1 Distribution of Mines by Region and Development Stage

Figure A2.1: number of mines producing COPPER on record by region



Source: Authors' calculations.

Figure A2.2: number of mines producing GOLD on record by region



Source: Authors' calculations.

Figure A2.3: Number of copper mines by development stage (see Appendix 3, Table 2 for development stage definitions)

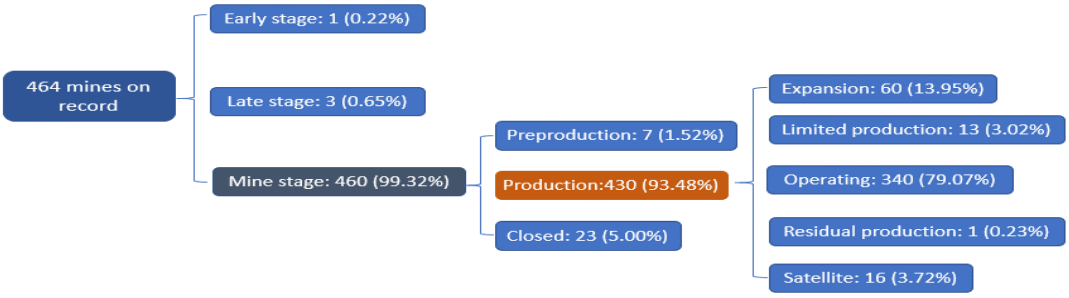
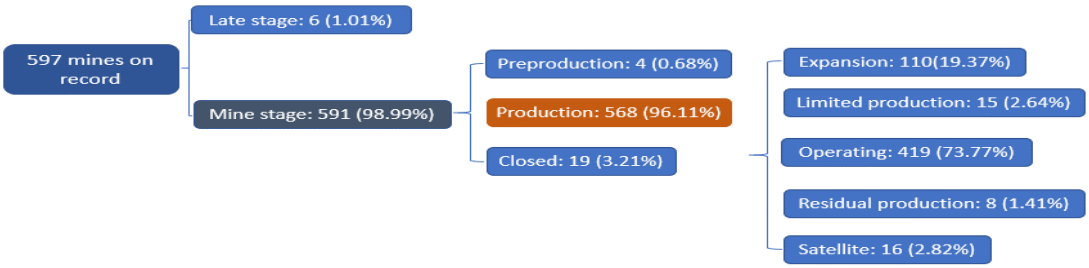


Figure A2.4: Number of gold mines by development stage



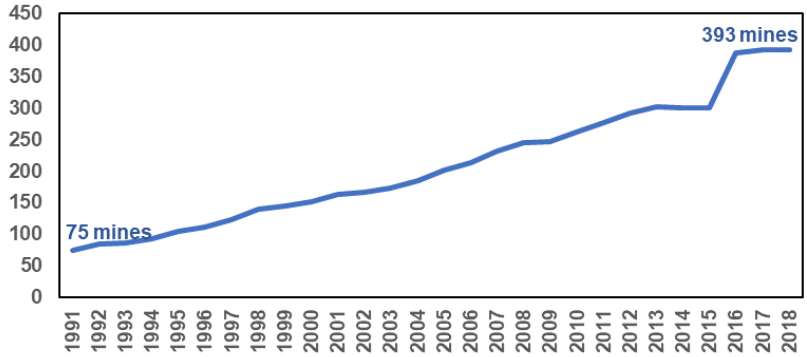
Source: Authors' calculations.

A2.2. Time dimension of mines

The world's number of copper/gold mines has steadily increased over the past years.[11] Metal production of mines is of various year duration.

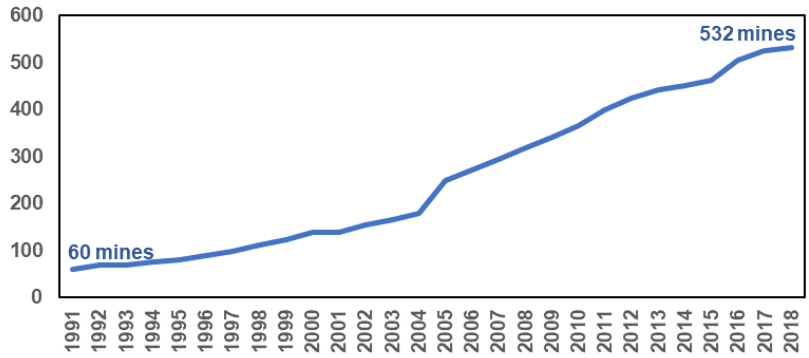
Figure A2.5. Number of mines producing copper by year

[11] For copper there is minor discrepancy in exports results between S&P screener data (screener tab) and mine economics cost curve (commodity tab). Despite the S&P team said they've fixed it and 9 mines have been added to the screener report, spotting checks find gaps. For instance, 2016 still has a gap of 6 mines. (Similar issues for gold).



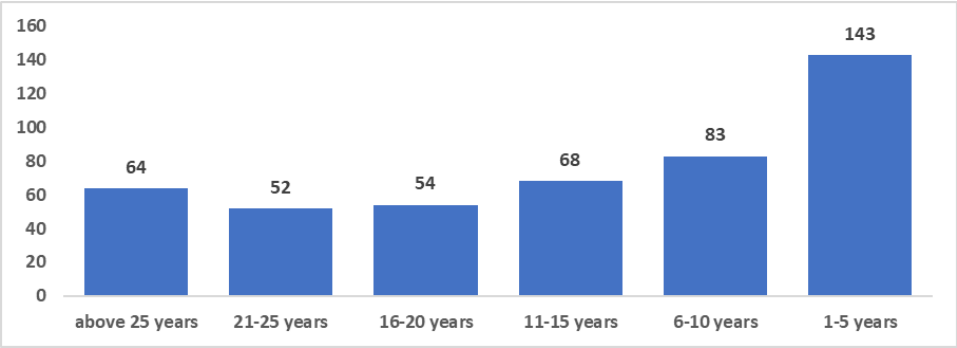
Source: Authors' calculations.

Figure A2.6. Number of mines producing gold by year



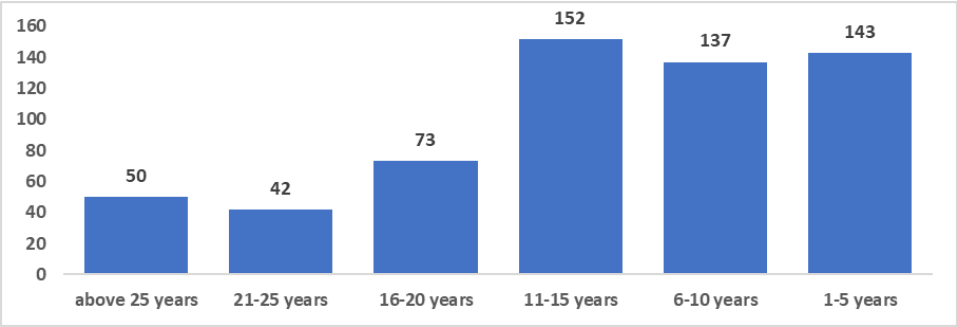
Source: Authors' calculations.

Figure A2.7. Number of copper mines by years of production in S&P database



Source: Authors' calculations.

Figure A2.8. Number of gold mines by years of production on S&P

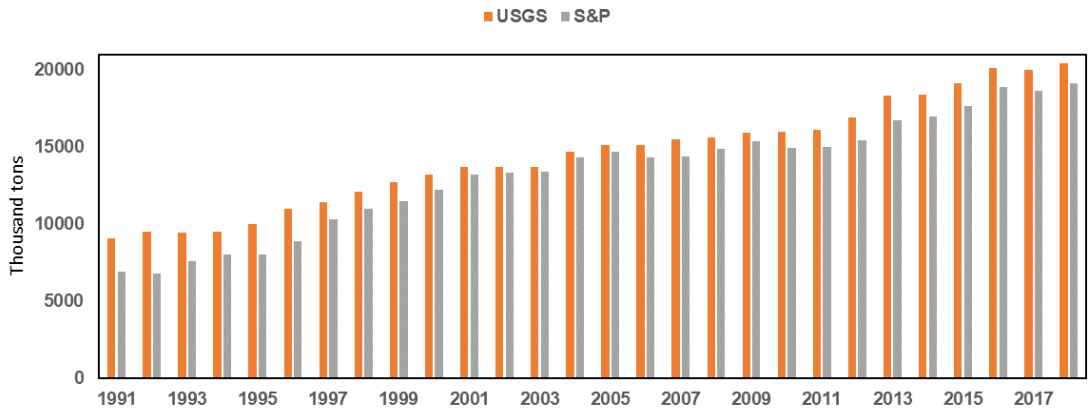


Source: Authors' calculations.

A2.3 Representativeness of S&P production data

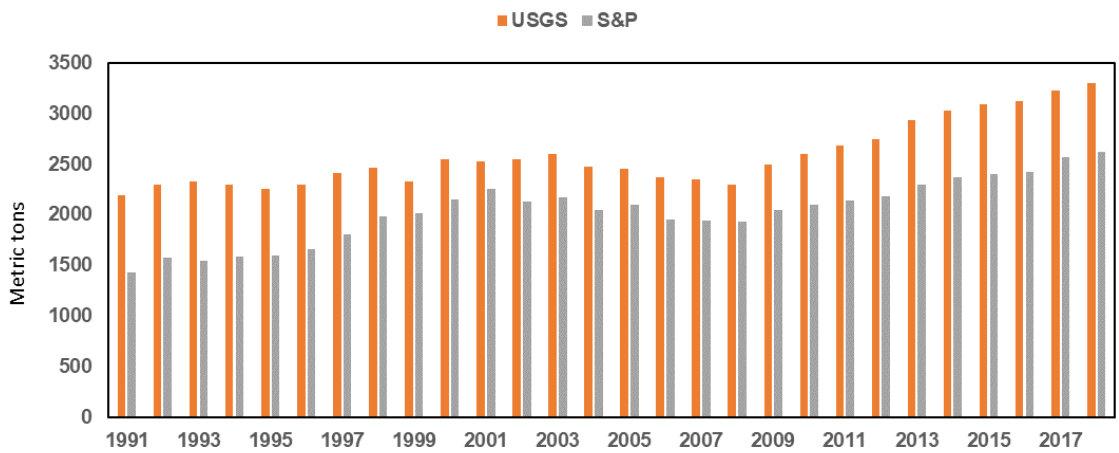
S&P publishes mine production for each property annually, which is aggregated to see the gap with USGS global mine production estimates.

Figure A2.9. World Copper production: comparison of S&P and USGS, 1991 to 2018



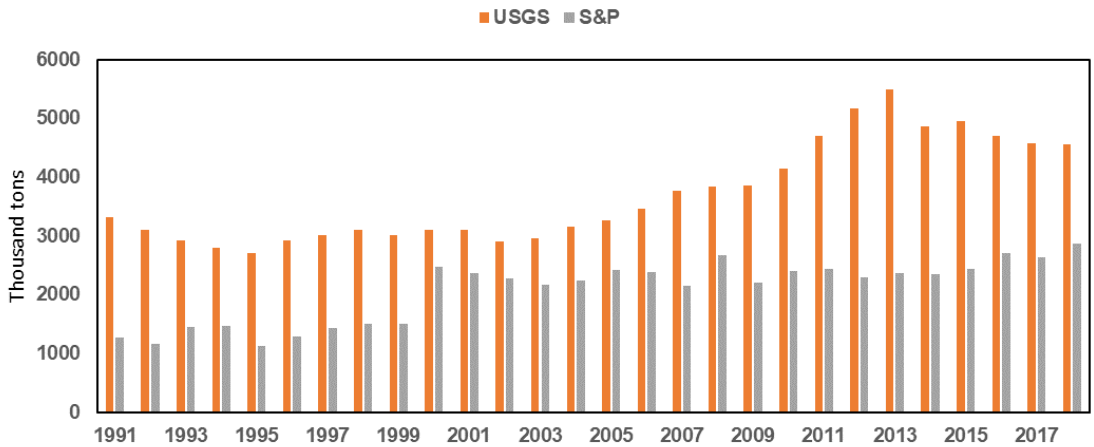
Source: Authors' calculations.

Figure A2.10. World Gold production: comparison of S&P and USGS, 1991 to 2018



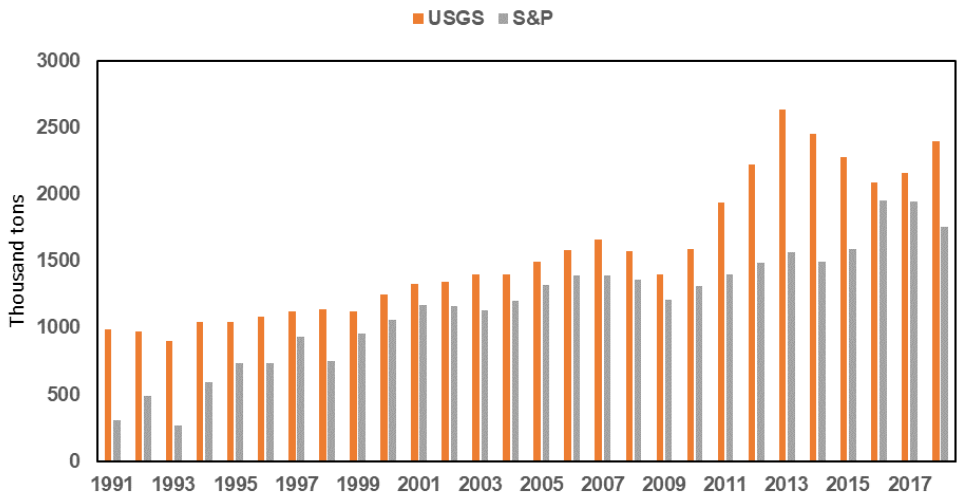
Source: Authors' calculations.

Figure A2.11. World Lead production: comparison of S&P and USGS, 1991 to 2018



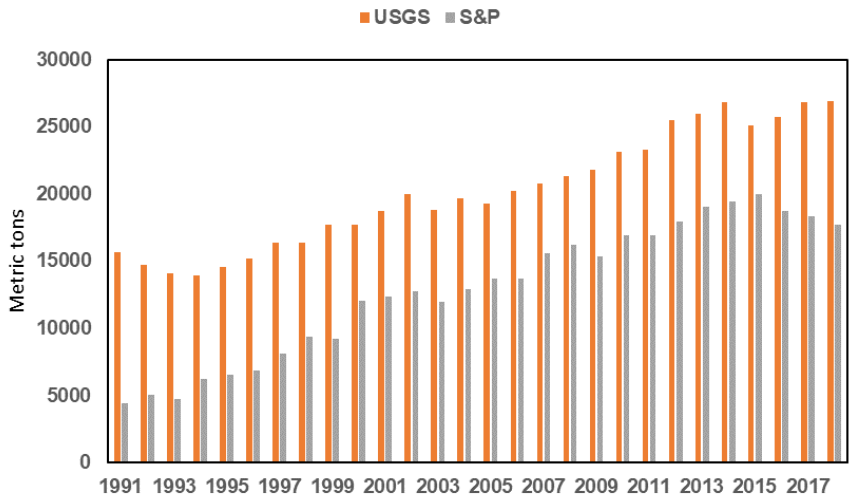
Source: Authors' calculations.

Figure A2.12. World Nickel production: comparison of S&P and USGS, 1991 to 2018



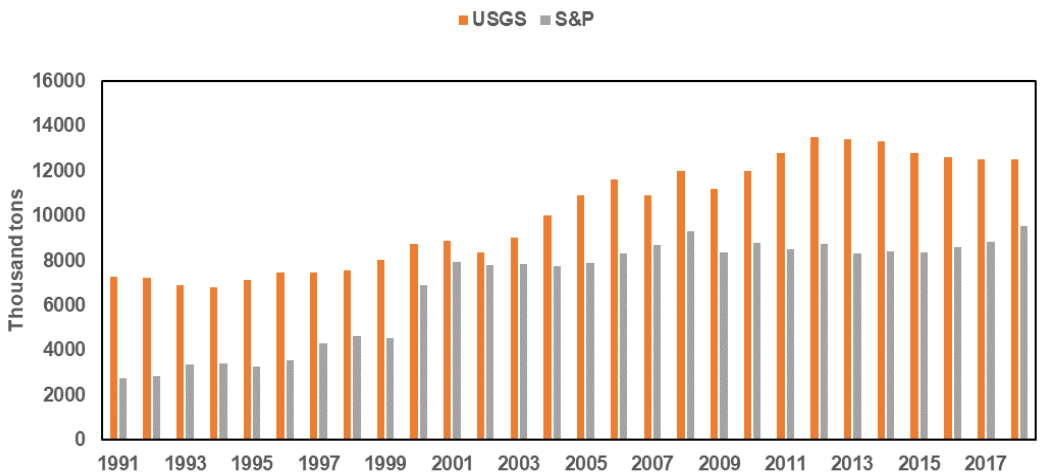
Source: Authors' calculations.

Figure A2.13. World Silver production: comparison of S&P and USGS, 1991 to 2018



Source: Authors' calculations.

Figure A2.14. World Zinc production: comparison of S&P and USGS, 1991 to 2018



Source: Authors' calculations.

Appendix 3. S&P Global Market Intelligence Database Definitions

Table A3.1. Total production cost components

	Mine Labor	Wages attributable to mining, including all salary and on-costs
+	Mine Fuel	Petrochemical fuel for heavy off-road and light vehicle uses
+	Mine Electricity	Mine power costs, including grid and own-power petrochemical generation for electrical equipment
+	Mine Other	Includes all other costs for the mining operation, with the largest portion commonly being explosives and third party site services such as geological services
+	Mill Labor	Wages attributable to processing, including salary and on-costs
+	Mill Reagents	Chemicals, including acids, leach agents, flotation and agglomeration agents, flocculants, pH balancers
+	Mill Electricity	Mill power cost, including grid and own-power petrochemical generation for electrical equipment.
+	Mill other	Includes all other costs, such as grinding media, activated carbon, third party site services
=	Total Minesite Cost	Direct mining and milling cost, inc SXEW costs. For iron ore this includes pellet plant costs
+	Transport and offsite	For bulks, broken out to inland, port loading & ocean freight. For all others, inland and ocean recorded together
+	Smeltering & Refining	Smelting, treatment, converter and refining charges. Includes toll treatment where appropriate, such as for DSO operations
=	Cash Operating Cost	Direct net cash costs
+	Reclamation & Closure Provision	Payments into an environmental fund or bond where available
+	Depreciation	Depreciation and amortization of previously spent capital expenditure
+	Deferred Stripping Amortized	Where broken out, amortization of deferred stripping costs
+	Inventory Change	Where present, ore, mineral or metal inventory adjustments
=	Total product cost	A cost metric using depreciated spent capital as a proxy for the ongoing capital cost of mining

Table A3.2: development stage categories

Development stage	Sub-stage	Activity	Description
1.Early-stage			A project without a defined Resource estimate.
	1.1. Grass Roots		Claims have been staked on prospects, occurrences and other areas where no work has been done beyond reconnaissance.
	1.2. Exploration		Preliminary testing is underway, which may include mapping and sampling, geophysical and geochemical work and reconnaissance drilling.
	1.3. Target Outline		Targets have been identified and more detailed surface and/or underground exploration and drilling is being undertaken to determine if the project will proceed.
2.Late Stage			A project with a defined resource that has not yet reached a production decision.
	2.1. Reserves Development		An initial reserve/resource has been calculated and work is oriented toward quantifying and detailing the ore potential.
		2.1.1. Advanced Exploration	Drilling is being completed to add additional reserves/resources. It may include diamond properties undergoing bulk sampling
		2.1.2. Prefeasibility/Scoping	Usually an in-house assessment that includes any preliminary assessment to determine

			mining and processing methods, capital costs, net present value (NPV), internal rate of return (IRR), marketing of produced materials and logistics such as transport.
	2.2. Feasibility		A bankable feasibility study is underway to determine economic viability. It will include an examination of broader issues such as environmental impact, native title and community agreements, legal and permitting requirements. Activities may include trial mining, exploration adit or decline for bulk sampling or an optimization study to better define the economic parameters of the project.
		2.2.1. Feasibility Started	A feasibility report has commenced.
		2.2.2. Feasibility Complete	A feasibility report is complete.
3. Mine-Stage			A project that has made a decision to move forward with production, is actively producing, or has recently stopped production.
	3.1. Preproduction		A go-ahead decision has been made and the project is being readied for production. Activities may include pre-stripping, shaft sinking or decline development

		3.1.1. Construction Planned	Construction is planned for the property
		3.1.2. Construction Started	Construction has begun at the property
		3.1.3. Commissioning	The mine is commissioned, and production has started.
	3.2. Production		Commercial production has been achieved.
		3.2.1. Operating	The mine is in fully operational
		3.2.2. Satellite	A satellite of a central processing complex; its production and/or reserves are included in the central entity's.
		3.2.3. Expansion	Operator is engaged in an active capital expansion of the facilities that will increase production and/or extend mine life.
		3.2.4. Limited Production	Some ore and/or commodity is being produced. This stage may include test production, preliminary production at noncommercial rates, and production from the processing of development ore or a decrease in production that sometimes occurs as a mine nears closure.
		3.2.5. Residual Production	The operator has stopped mining ore and is leaching the residual ore.
	3.3. Closed		Operation has stopped, in many cases because the ore has been exhausted.

Appendix 4. Robustness Checks for Treatment of mines with negative unit rents

For some mines in a given year, the unit rent is estimated to be negative. The standard CWON method (following the SEEA recommended methodology) is to replace the negative unit rent with zero. The team carried out the following analysis and robustness checks to see:

a) Is there a pattern/trend in the incidence and distribution of negative rents?
b) Does dropping a mine with unit rent, rather than replacing the value with zero, have a significant effect on the regional rental rate?

The team found that 232 (35%) of 438 copper mines and 295 of 526 (56%) gold mines on S&P record have some years with negative rents. Figures A4.1 and A4.2. show the number of copper and gold mines that have negative rent, with the most common being a mine with just one year of negative rent. Negative rent mines are spread across countries (31 for copper and 41 for gold) and have similar density as total number of mines. Distribution of negative unit rent mines across years see fluctuations but no clear concentration in particular years (see Figure A4.3 and Figure A4.4 below). As expected, dropping mines with negative unit rent did not significantly affect the general trend of the regional rental rate (see Figures A4.5 and A4.6 below).

Figure A4.1. Number of copper mines by number of years with negative rent

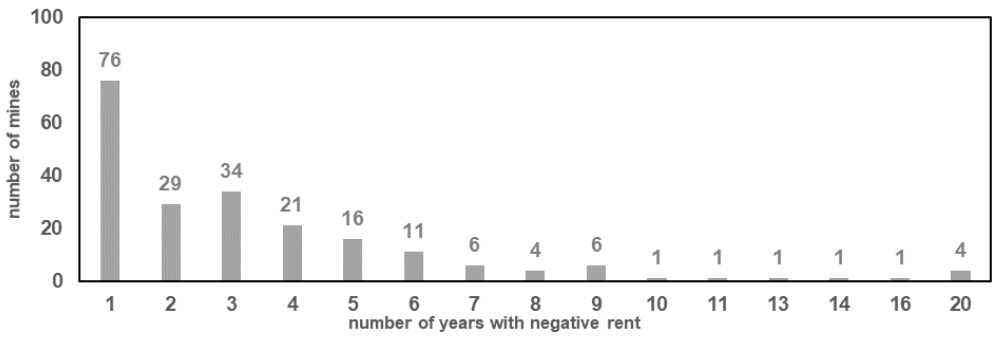


Figure A4.2. Number of gold mines by number of years with negative rent

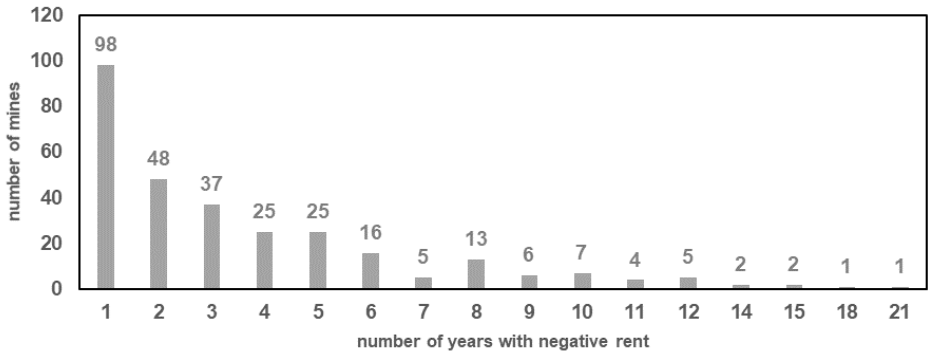


Figure A4.3. number/percent of copper mines with negative unit rents over years

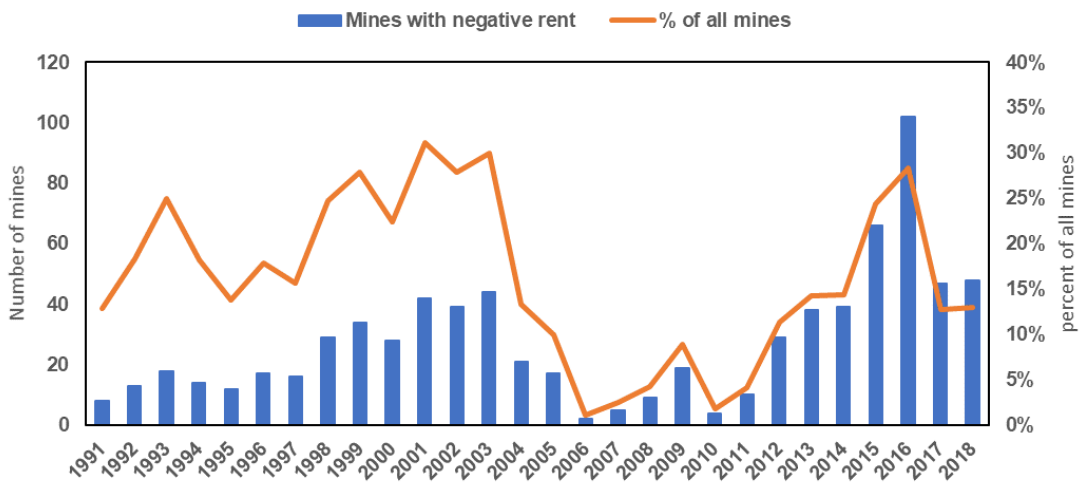


Figure A4.4. number/percent of gold mines with negative unit rents over years

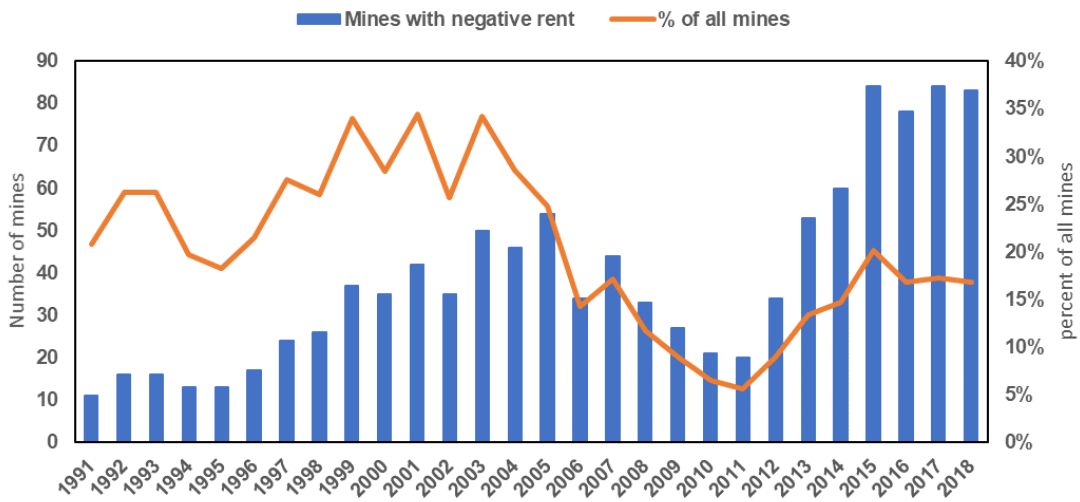
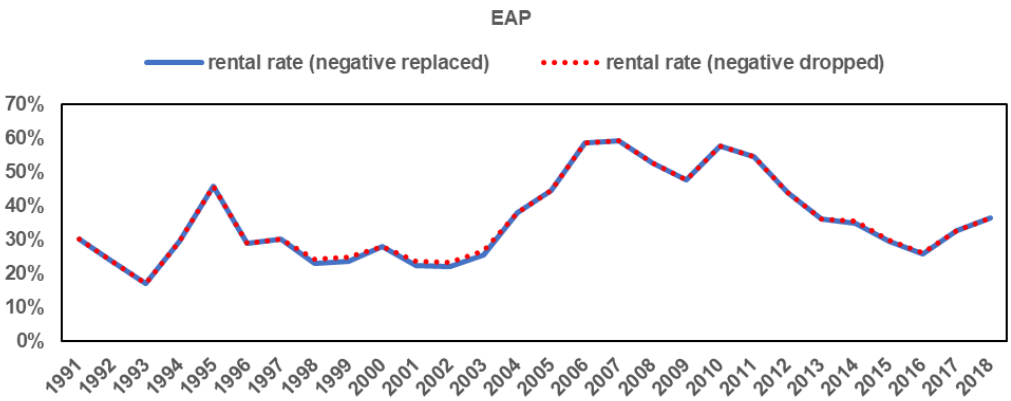
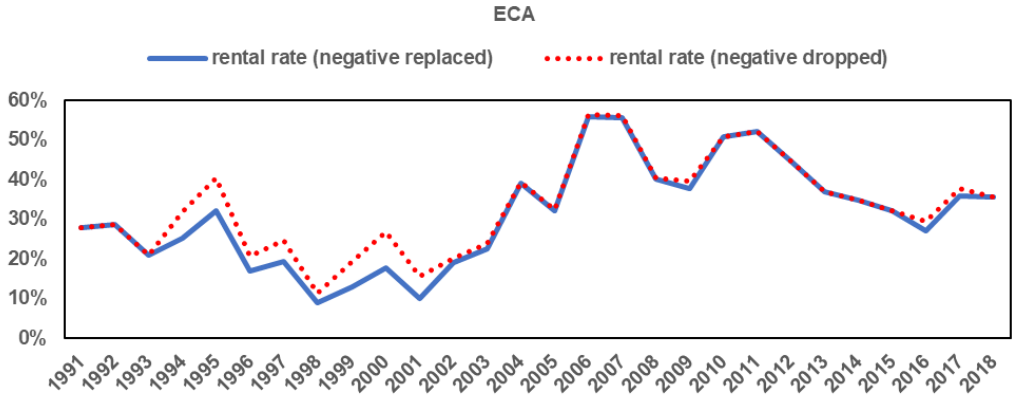
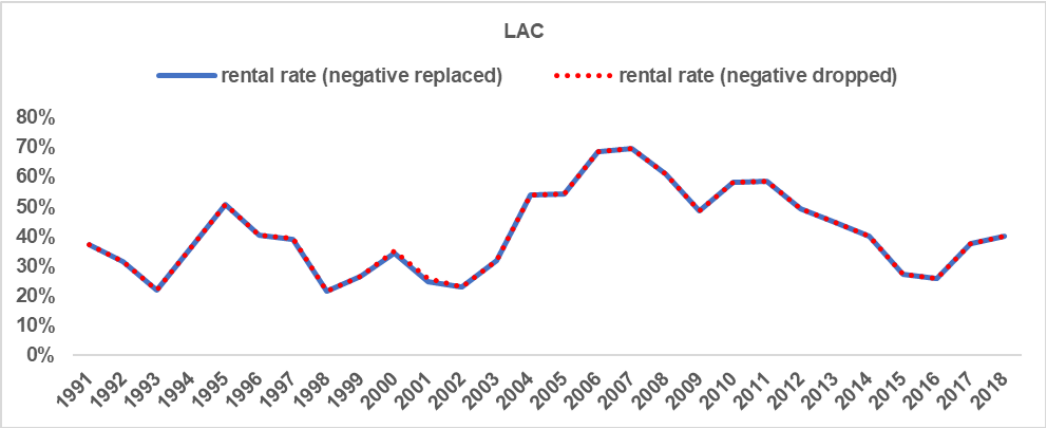
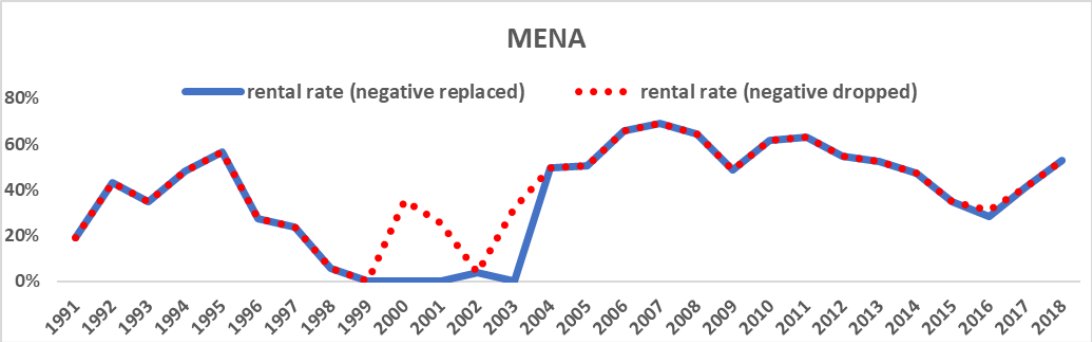


Figure A4.5. Copper regional rental rate as percent of price (dropping vs replacing) by region, 1991 to 2018




ECA
rental rate (negative replaced)
rental rate (negative dropped)
60%
50%
40%
30%
20%
10%
0%
1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018


LAC
rental rate (negative replaced)
rental rate (negative dropped)
80%
70%
60%
50%
40%
30%
20%
10%
0%
1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018


MENA
rental rate (negative replaced)
rental rate (negative dropped)
80%
60%
40%
20%
0%
1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018

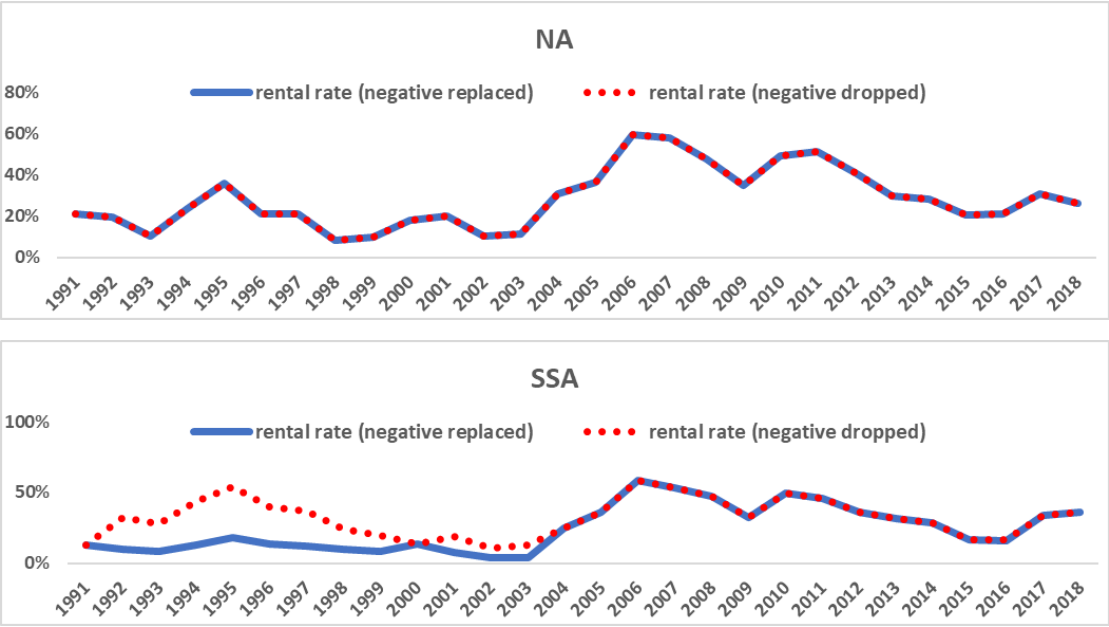
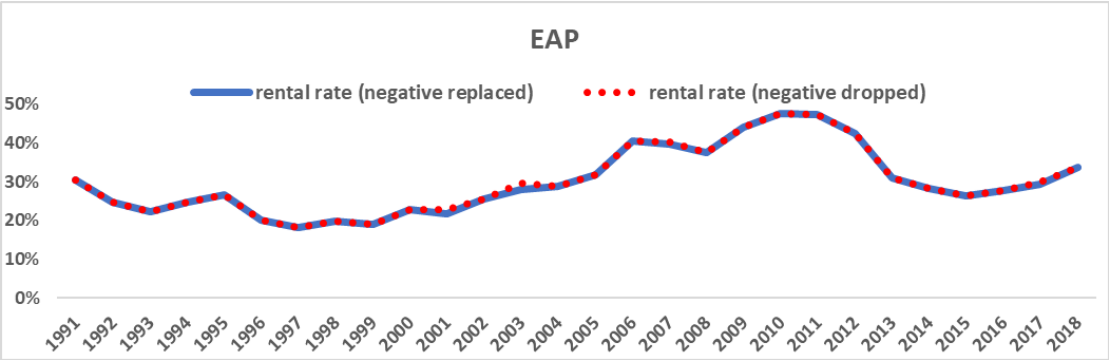
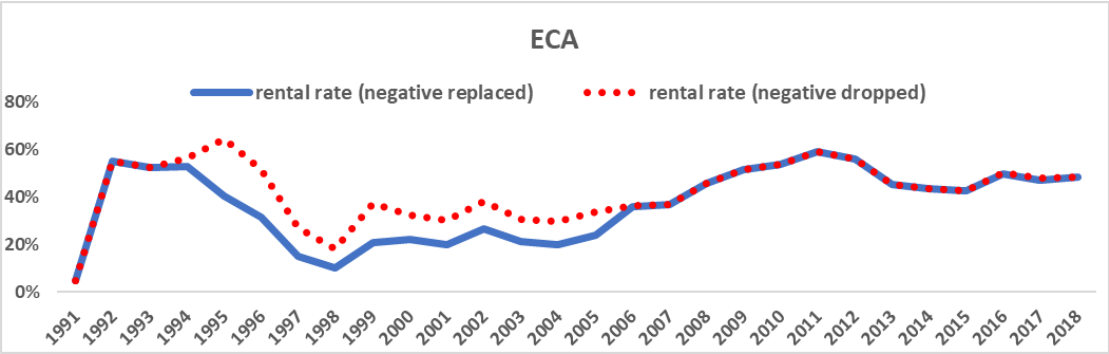
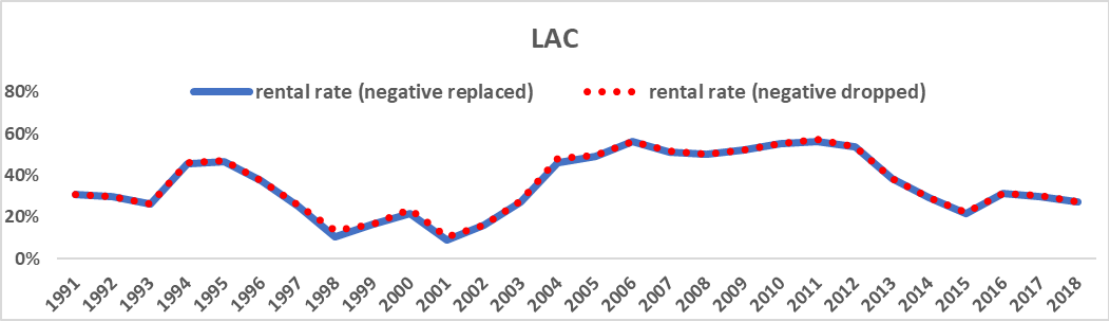
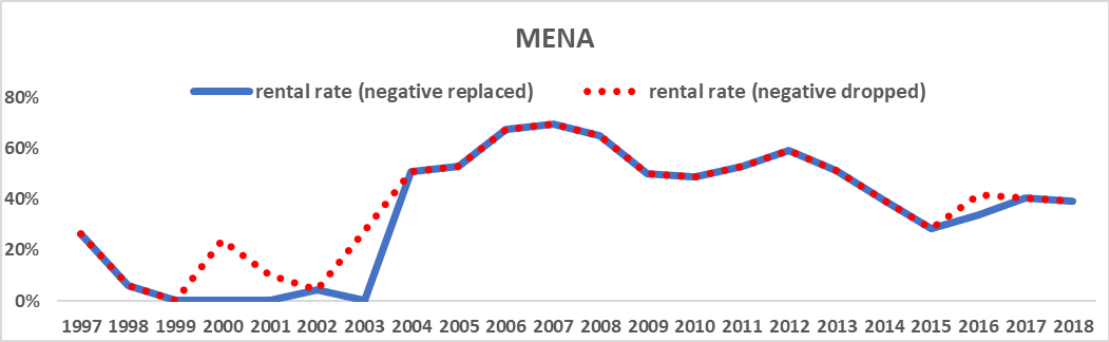


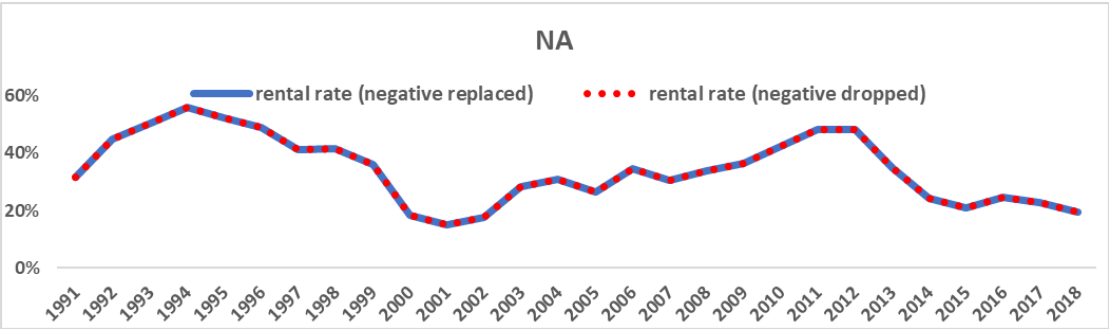
Figure A4.6. Gold regional rental rate as percent of price (dropping vs replacing) by region, 1991 to 2018

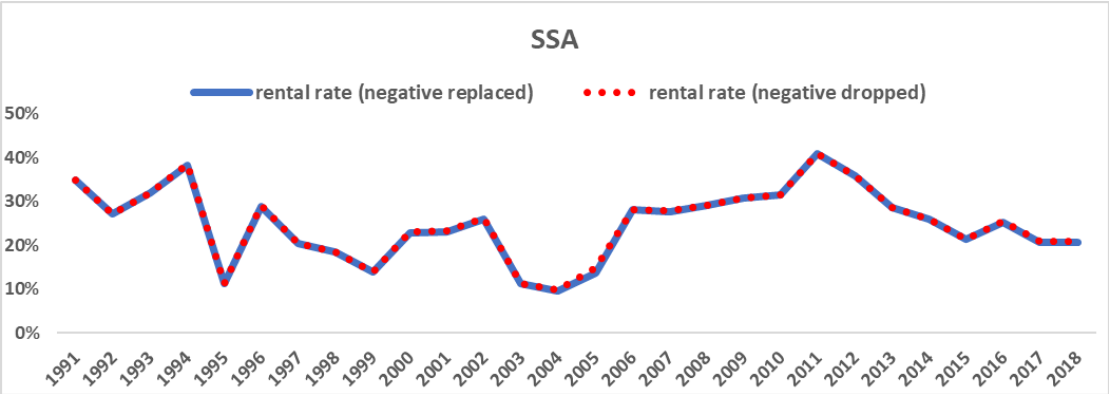



ECA
rental rate (negative replaced)
rental rate (negative dropped)
80%
60%
40%
20%
0%
1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018


LAC
rental rate (negative replaced)
rental rate (negative dropped)
80%
60%
40%
20%
0%
1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018


MENA
rental rate (negative replaced)
rental rate (negative dropped)
80%
60%
40%
20%
0%
1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018


NA
rental rate (negative replaced)
rental rate (negative dropped)
60%
40%
20%
0%
1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018

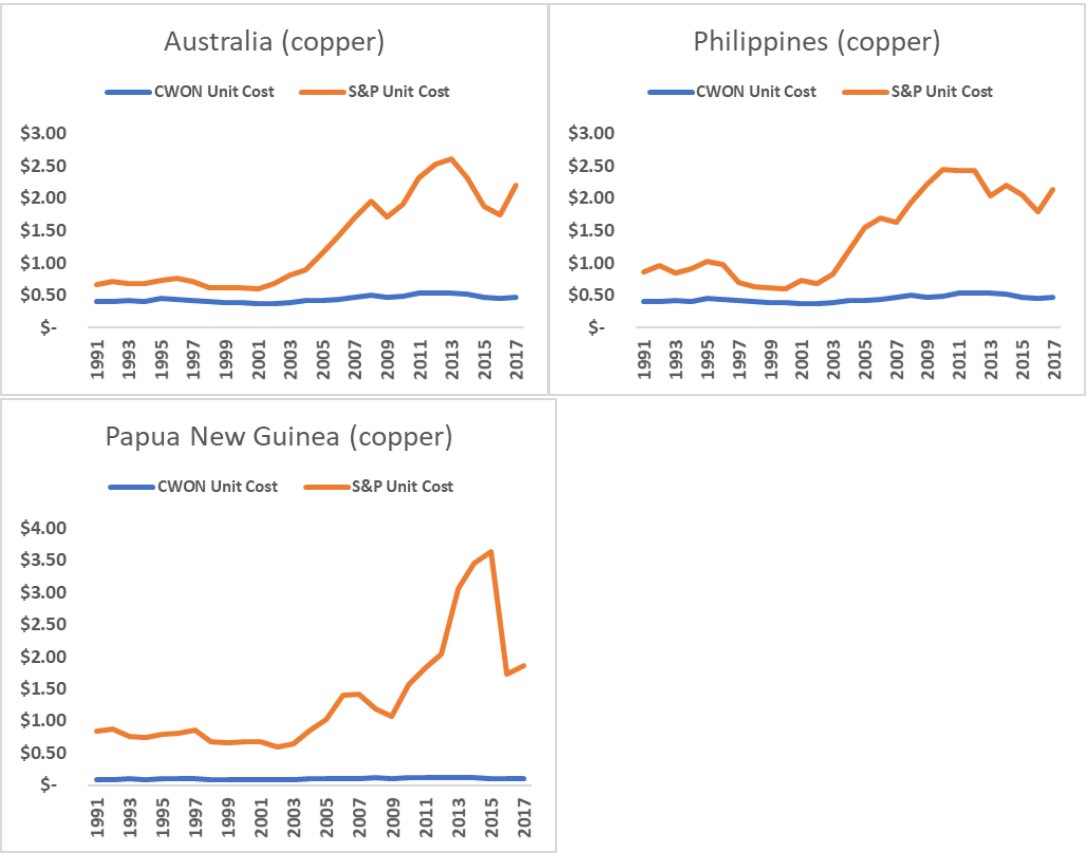

SSA
rental rate (negative replaced)
rental rate (negative dropped)
50%
40%
30%
20%
10%
0%
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018

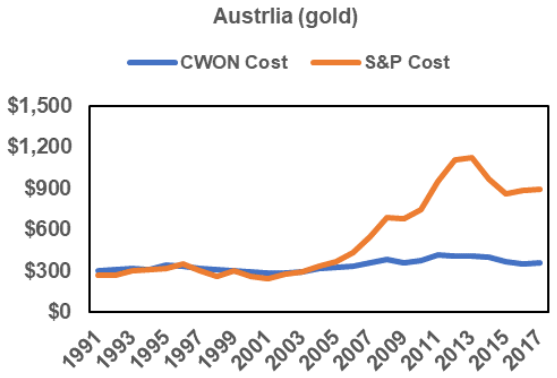
Appendix 5. Comparison of S&P and CWON unit production costs for copper and gold in major producing countries

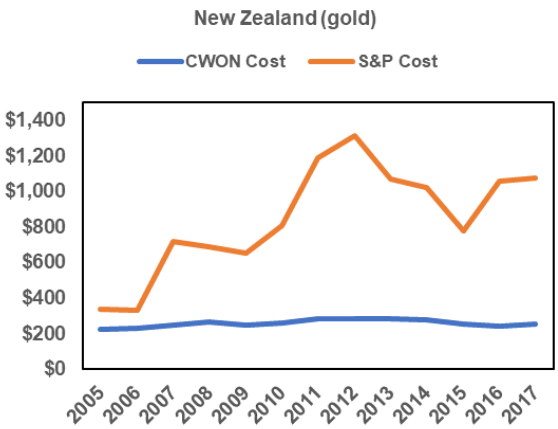
Note: unit costs for copper are measured in $/lb. Unit costs for gold are measured in $/troy ounce

Figure A5.1. Production cost comparison in East Asia & Pacific

East Asia & Pacific




Austrlia (gold)
CWON Cost
S&P Cost
$1,500
$1,200
$900
$600
$300
$0
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017


New Zealand (gold)
CWON Cost
S&P Cost
$1,400
$1,200
$1,000
$800
$600
$400
$200
$0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017

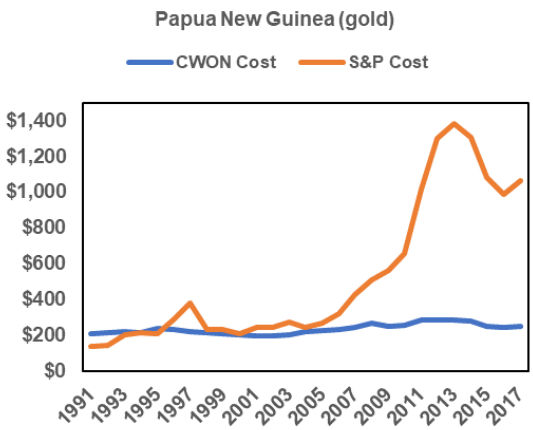

Papua New Guinea (gold)
CWON Cost
S&P Cost
$1,400
$1,200
$1,000
$800
$600
$400
$200
$0
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017

Figure A5.2. Production cost comparison in Europe & Central Asia

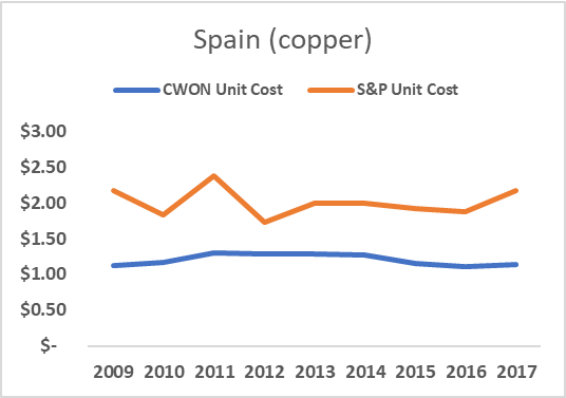
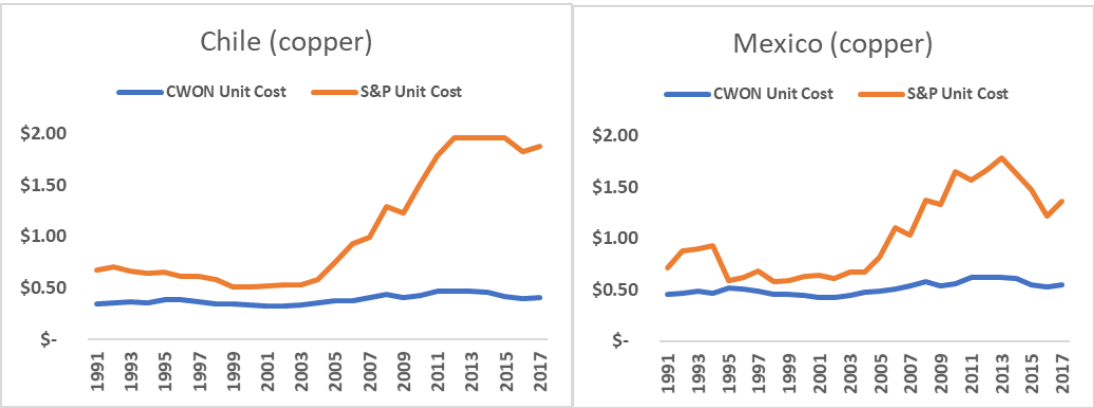


Figure A5.3. Production cost comparison in Latin America & Caribbean



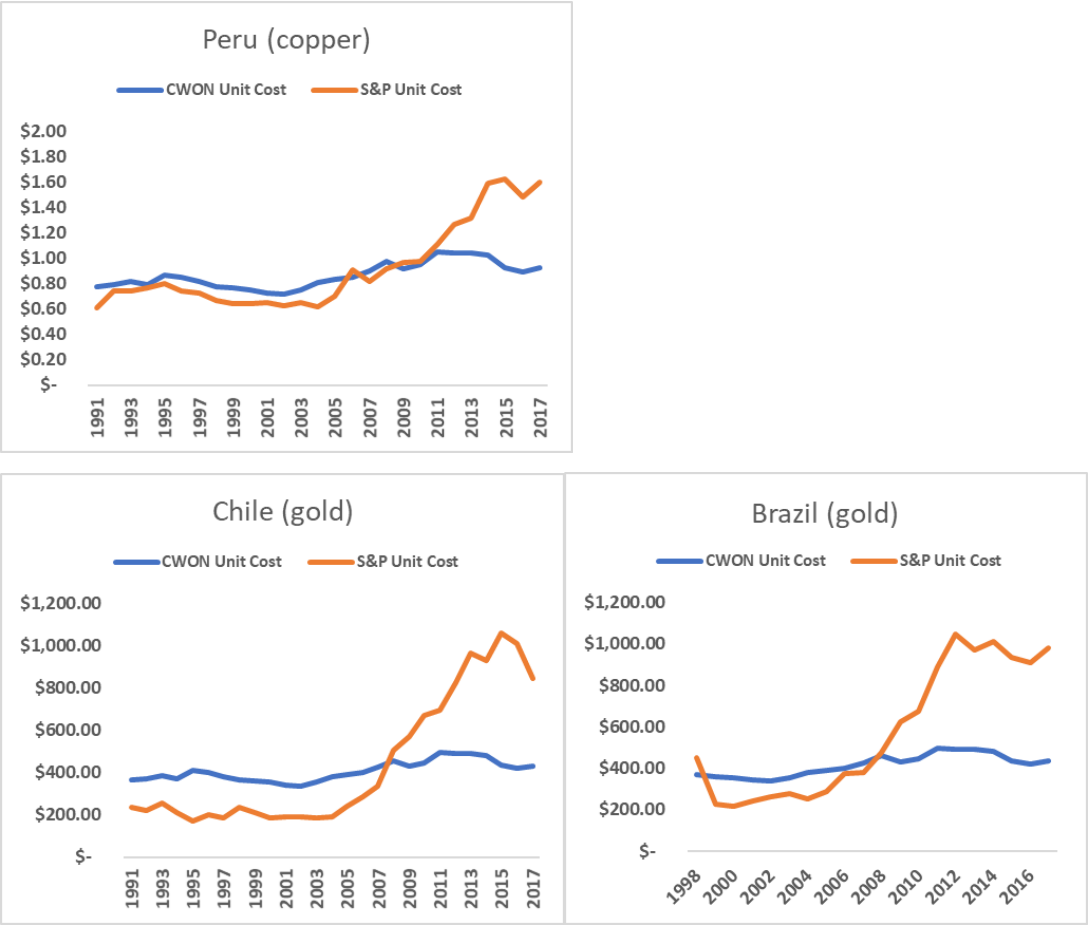
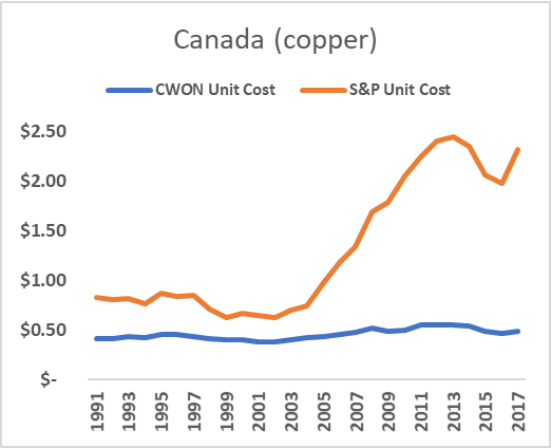
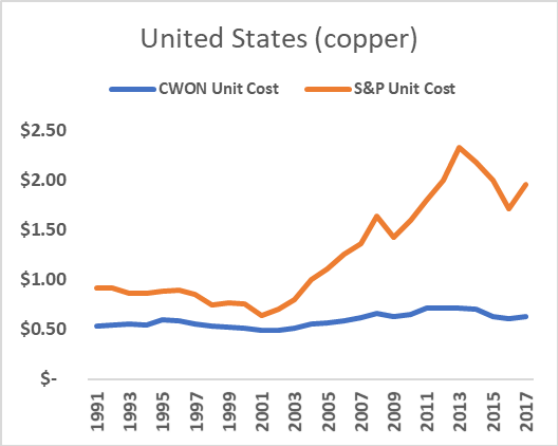


Figure 5.4. Production cost comparison in North America


Canada (copper)
CWON Unit Cost
S&P Unit Cost
$2.50
$2.00
$1.50
$1.00
$0.50
$-
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017


United States (copper)
CWON Unit Cost
S&P Unit Cost
$2.50
$2.00
$1.50
$1.00
$0.50
$-
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017

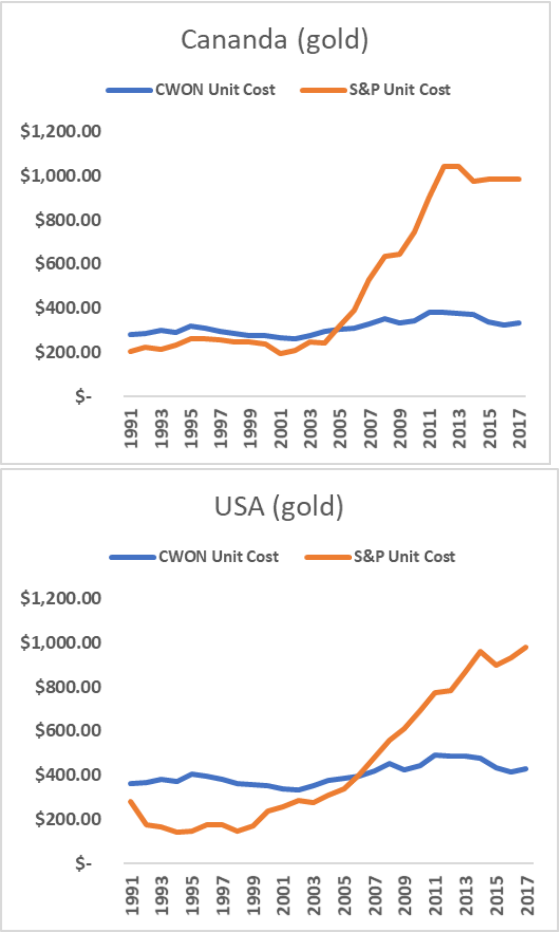
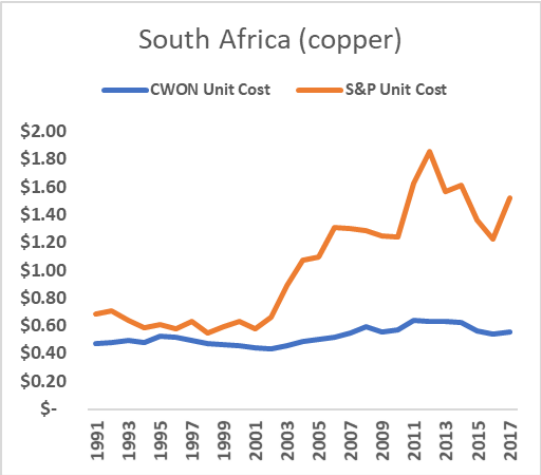
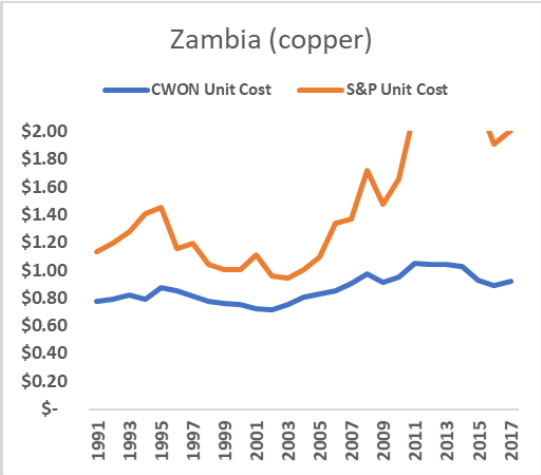
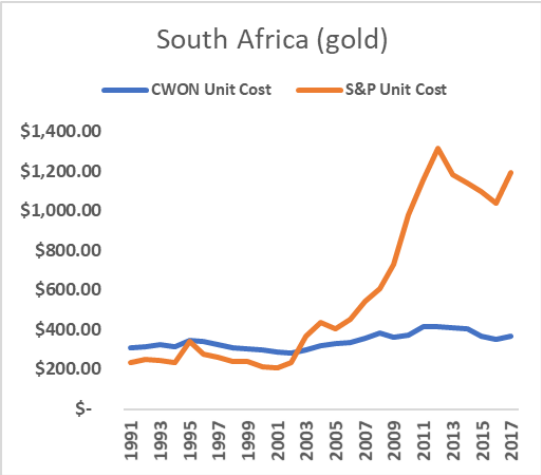


Figure A5.5. Production cost comparison in Sub-Saharan Africa


South Africa (copper)
CWON Unit Cost
S&P Unit Cost
$2.00
$1.80
$1.60
$1.40
$1.20
$1.00
$0.80
$0.60
$0.40
$0.20
$-
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017


Zambia (copper)
CWON Unit Cost
S&P Unit Cost
$2.00
$1.80
$1.60
$1.40
$1.20
$1.00
$0.80
$0.60
$0.40
$0.20
$-
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017


South Africa (gold)
CWON Unit Cost
S&P Unit Cost
$1,400.00
$1,200.00
$1,000.00
$800.00
$600.00
$400.00
$200.00
$-
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017

Appendix 6. Government Share of Rent for Copper and Gold

The CWON team did a quick analysis of government take (royalties and production taxes) as a share of total rent for the top producing countries, hinting at the additional analysis that can be carried out using the S&P data.

The team calculated a given country's share of government take as the production-weighted average of government take (reported as dollars per unit) divided by the production-weighted average of unit rent (also reported as dollars per unit). Note that there is an alternative approach to calculating a country's share of government take, by calculating this share at the mine-level and then estimating a production-weighted average for the country. The results are different and therefore guidance on the correct approach is needed.

Figure A6.1. Government share of rent in the top five world Copper producers[12]

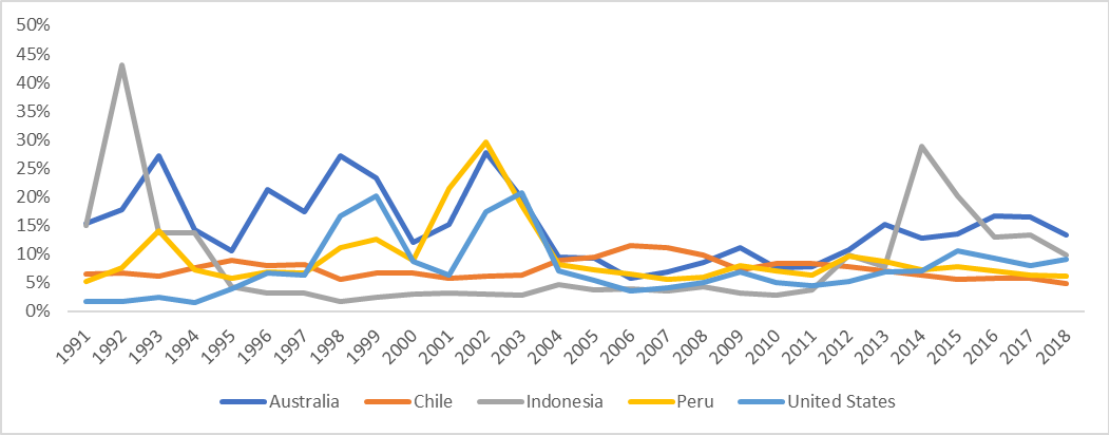
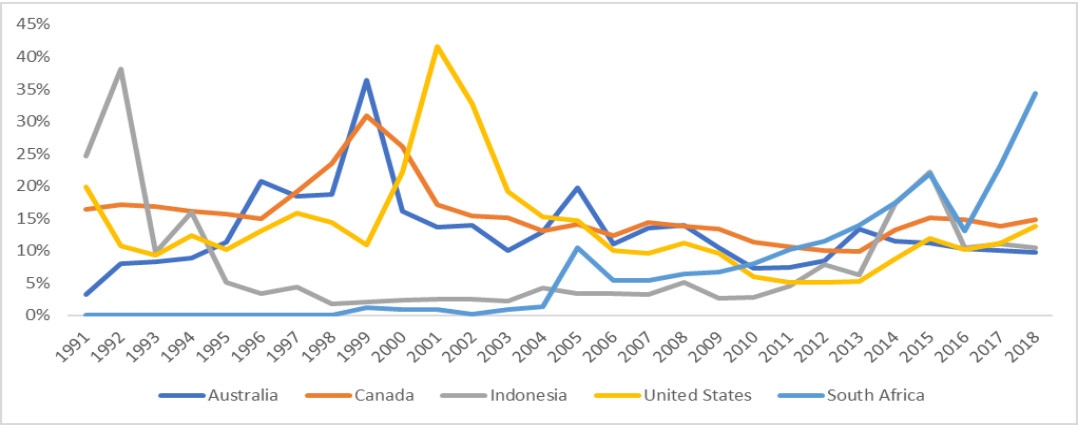


Figure A6.2. Government share of rent in the top five world Gold producers



[12] Top producers are identified by the aggregated paid metal production since 1991.