ASSESSMENT OF CRITICAL MINERALS: SCREENING METHODOLOGY AND INITIAL APPLICATION

PRODUCT OF THE
Subcommittee on Critical and Strategic Mineral Supply Chains
of the Committee on Environment,
Natural Resources, and Sustainability
OF THE NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

EXECUTIVE OFFICE OF THE PRESIDENT OF THE UNITED STATES

March 2016

EXECUTIVE OFFICE OF THE PRESIDENT
NATIONAL SCIENCE AND TECHNOLOGY COUNCIL
WASHINGTON, D.C. 20502

March 11, 2016

Dear Members of Congress:

I am pleased to forward this progress report on interagency assessment of critical minerals, which describes a screening methodology based on an analysis of regularly collected data and presents the initial results of the application of that methodology. This is the first step of a two-stage process and is intended to indicate what minerals pose a potential risk of being or becoming critical based on availability and susceptibility to supply disruption. Customized, in-depth analyses of individual minerals highlighted by the screening methodology will subsequently be carried out to evaluate the circumstances that led to their identification and to assess the extent to which they are essential to some facet of the economy and/or national security, and thus to determine whether they should be considered truly critical.

This document responds to earlier House of Representatives appropriations report language that requested a report on the work of the Subcommittee on Critical and Strategic Mineral Supply Chains of the National Science and Technology Council, and is the report noted in my earlier letter to you on this subject (see report appendices). It represents a coordinated effort across the numerous agencies and Executive Office components participating in the Subcommittee, and has also been informed by responses to requests for information from, and other interactions with, industry, academia, research laboratories, and other stakeholders.

The analysis presented here covers over fifty individual elements of the periodic table and several other non-fuel mined resources, in some cases addressing multiple processes and intermediate products as separate minerals. In addition to determining the extent to which each is potentially critical based on the most recent data, the methodology has been applied over the entire span from 1996 through 2013, subject to data availability. Overarching trends are identified, and the retrospective analysis suggests that use of this screening methodology would have signaled potential concerns ahead of time for emerging supply-chain issues, such as those that involved rare earth elements around 2010.

While the approach described in this document envisions systematic reapplication of the methodology as updated data become available, based on information that is regularly collected about a wide range of minerals, more in-depth analysis will be needed to assess the specific issues and risks associated with the potentially critical minerals identified by this process. Thus, the screening methodology represents the first step in a two-stage process where a more detailed study of those minerals exhibiting a high potential for criticality would be appropriate to understand the situation better before determining whether any policy action is warranted.

A consistent approach for making assessments across a broad range of minerals and providing early warning of potential supply vulnerabilities is important to U.S. economic and national security. Critical minerals are essential to a wide range of leading technologies, ranging from aircraft and automotive components to electronics and telecommunications devices, and from displays to photovoltaics. Thank you for your interest in this important topic.

Sincerely,

John P. Holdren

John P. Holdren
Assistant to the President for Science and Technology
Director, Office of Science and Technology Policy

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The Subcommittee on Critical and Strategic Mineral Supply Chains was established by action of the NSTC Committee on Environment, Natural Resources, and Sustainability (CENRS). The purpose of the Subcommittee on Critical and Strategic Mineral Supply Chains is to advise and assist the CENRS and the NSTC on policies, procedures, and plans relating to identification and forecasting of mineral criticality, and risk mitigation in the procurement and downstream processing of minerals identified as or forecasted to become critical. Access and availability of resources, both as raw commodities and as a part of downstream supply chains, which may be sensitive to disruptions in global supply, fall within the scope of the Subcommittee.

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About this Document

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SUBCOMMITTEE ON CRITICAL AND STRATEGIC MINERAL SUPPLY CHAINS

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Executive Summary

Increasing concerns regarding the stability of U.S. access to adequate and affordable supplies of certain non-fuel mineral resources essential to the Nation's economy and/or security have prompted interest in detecting potential supply constraints before they occur. This report summarizes the results of an interagency effort to develop and apply a screening methodology for such a purpose.

Agencies are implementing a two-stage approach, with the first stage involving an indicator-based, early-warning screening that aims to identify a subset of the studied minerals as "potentially critical." The second stage will utilize the output of the early-warning screening to prioritize the potentially critical minerals for further in-depth analysis to understand the specific factors leading to their identification and determine which of them represent a significant risk to U.S. economic and national security interests. The early-warning screening, which is the focus of this report, assesses potential criticality (C) using a uniform methodology that results in a single value for each mineral resource on a common 0 to 1 scale, where increasing values signal higher potential criticality. Specifically, the assessment is based on the geometric mean of three fundamental indicators: supply risk (R), production growth (G), and market dynamics (M). These indicators were selected because they capture different aspects of availability and because of their complementary nature: R is a measure of the risk associated with geopolitical production concentration, G incorporates changes in the mineral's market size and reliance on geological resources, and M tracks the mineral's price sensitivity to changes in its market.

Terms

For the purposes of this report, the following terms will be used as described here. These definitions are derived in part from the charter of the Subcommittee on Critical and Strategic Mineral Supply Chains of the National Science and Technology Council, which is the body that produced this document.

While definitions vary, minerals are commonly considered to comprise stable, naturally-occurring inorganic substances. Here, "**minerals**" is used broadly to refer to non-fuel resources—elements or compounds—that are obtained by mining or refined from mined products, and in some cases includes such substances at various stages of processing. The subset of minerals assessed in this initial screening was determined by availability of suitable and consistent data.

"**Critical minerals**" are those that have a supply chain that is vulnerable to disruption, and that serve an essential function in the manufacture of a product, the absence of which would cause significant economic or security consequence. Indicia of criticality include low substitutability with other minerals, dependence on foreign imports for raw materials, dependence on foreign imports for refined product, and single versus multiple supplies of raw materials. The supply chain considered is from mine to the product, and includes the mining of ores, extraction, and refining of minerals and the manufacture of components, such as magnets.

"**Strategic minerals**" are regarded here as a subset of critical minerals and are those that are essential for national security applications. The initial screening methodology described in this report does not address the further determination of which critical minerals should be considered strategic.

The early-warning screening has been applied to 78 mineral resources for years 1996-2013. Results from this initial assessment reveal heterogeneity in the C indicator values across the minerals evaluated and over time. Certain minerals including bauxite, copper (Cu), and gold (Au), for example, have consistently low C values. In contrast, minerals such as germanium (Ge), the rare earths (Y, La-Lu), ruthenium (Ru), rhodium (Rh), and antimony (Sb) have some of the highest C indicator values. Most of the other minerals have moderate *C* indicator values, which, however, have mostly been increasing over the time period examined. Indeed, an overarching trend has been the overall increase in the *R* indicator, suggesting that production has become much more concentrated in countries with higher governance (geopolitical and regulatory) risk in year 2013 as compared to year 1996.

A hierarchical cluster analysis is utilized to help determine which minerals are to be considered "potentially critical." The results from the cluster analysis suggest that a *C* indicator value of 0.335 is the threshold value above which a mineral should be included in that category. For year 2013, the year for which the most recent data are available, there are 17 minerals that have *C* indicator values greater than 0.335. In descending order of potential criticality, these minerals are: ferromolybdenum (FeMo), yttrium (Y) and the rare earths (La-Lu), rhodium (Rh), ruthenium (Ru), mercury (Hg), monazite, tungsten (W), silicomanganese (SiMn), mica, iridium (Ir), magnesite, germanium (Ge), vanadium (V), bismuth mine production (Bi), antimony (Sb), and cobalt mine production (Co). Other minerals that would have met the criteria to be identified as potentially critical in prior years if the same threshold of 0.335 was used include indium (In), tantalum (Ta), niobium (Nb), rhenium (Re), and beryllium (Be). In order to provide some validation of the model and its results, the interagency group conducted a retrospective analysis to determine if one could have detected a problem with supply of the rare earths prior to 2010, the year in which China decreased its export quota for rare earths, leading to widespread concerns about shortages and dramatic increases in prices. Using the same *C* indicator threshold value of 0.335, the analysis indicates that it would have been possible to identify rare earths as potentially critical based on risk of supply disruption as early as 2001.

Overall, the results suggest that the proposed screening methodology is able to detect issues as designed. Having completed the initial early-warning screening, the first iteration of the in-depth analysis (stage 2) will be conducted over the next year. The next steps include: (1) developing a prioritized list of a subset of the current 17 potentially critical minerals for in-depth investigation; (2) developing individual project plans for those minerals for further study; and (3) carrying out the targeted studies in the next annual cycle. The in-depth analysis is not envisioned to be a "one-size-fits-all" exercise, but rather will involve different kinds of studies (e.g., geological, material flow, or sectoral analyses) that are customized for each mineral resource. A second iteration of the early-warning screening will be conducted when the next year's data are available with particular emphasis on changes that have occurred, and may identify additional potentially critical minerals for subsequent in-depth analyses.

1.0 Introduction

1.1 Background

The technological advances of the past few decades have had a profound impact on our daily lives, standard of living, and well-being. Cellular telephones have made communication and information exchange instantaneous, ubiquitous, and accessible to billions of individuals worldwide. Commercial jet aircraft have transformed intercontinental travel into one of the fastest, safest, and most efficient means of transportation. Solar-photovoltaic and wind-turbine technologies are increasingly providing renewable energy that largely avoids the environmental problems associated with fossil fuel-based energy generation. These and other advances have been made possible by the use of sophisticated materials that utilize some of the more exotic elements of the periodic table, including tantalum for capacitors in cellular telephones and other electronic devices, rhenium in superalloys for jet engines, and selenium and tellurium in certain thin-film solar-photovoltaic technologies. A consequence of these profound technological developments has been a notable increase in the diversity of materials used, such that modern technology makes use of virtually the entire periodic table of elements.[1] Indeed, as illustrated in the figure below, the ubiquitous cellular telephone alone contains several dozen metals, including many scarce and specialty metals such as europium, terbium, and yttrium, which are used in phosphors to provide the colored illumination of the phones' displays.

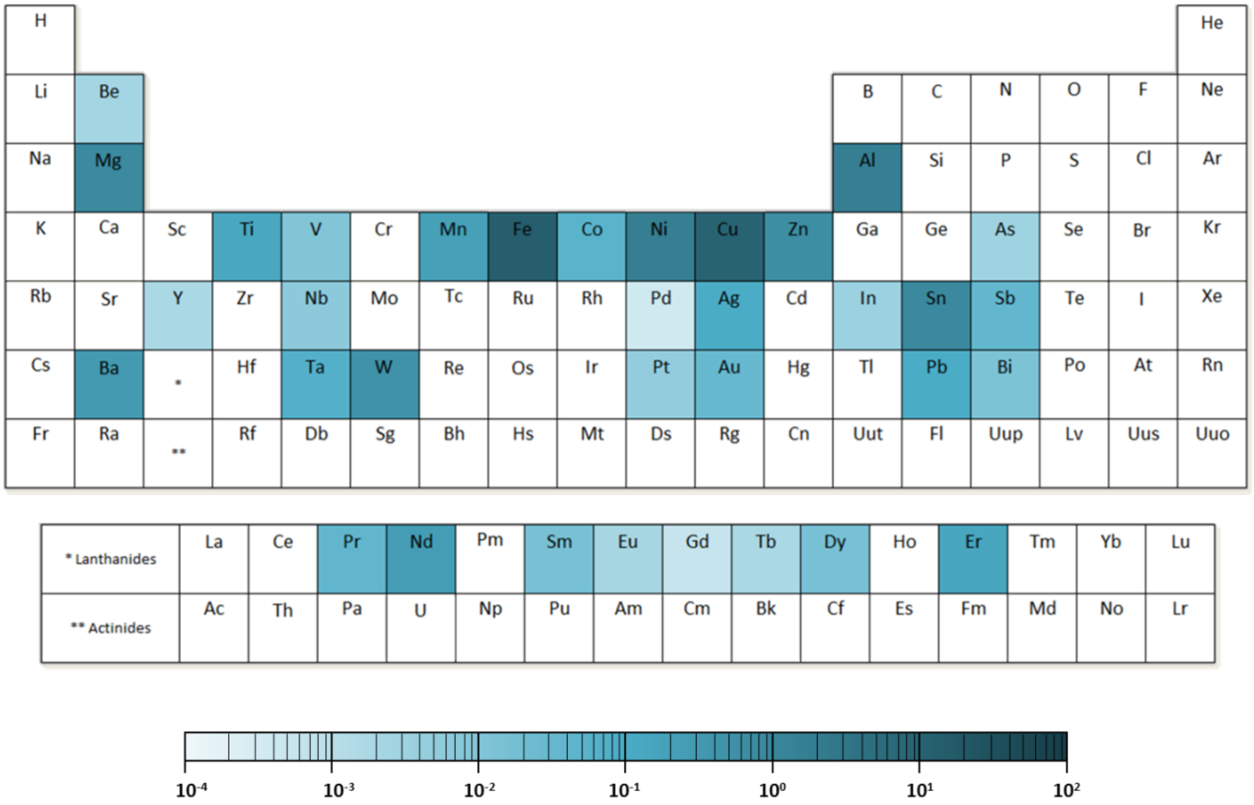

Figure 1. Average metal content of 85 cellular phones manufactured from year 1998 to 2013. Values reported in grams per phone based on an analysis conducted by Christian, et al.,[2] which did not include the phones' batteries and did not test for all elements.

In conjunction with the rapid advances in technology has been an equally unprecedented increase in the overall level of consumption of non-fuel mineral resources, including the elements mentioned above, by an increasingly affluent global population. To meet demand, production quantities have had to increase accordingly. As illustrated in Figure 2, global primary production for most non-fuel mineral resources investigated has more than doubled in the last 20 years, with production quantities increasing over 5-fold for indium, cobalt, and yttrium. This remarkable growth rate has been much greater than that of the globally aggregated gross domestic product (GDP), which grew approximately 1.7-fold over the same time period; this indicates that—far from achieving the desired decoupling of economic activity from resource use—material intensity has actually increased for the majority of these resources. For only a few resources, such as mercury and arsenic, have production quantities declined in comparison to 20 years ago, often for obvious reasons.

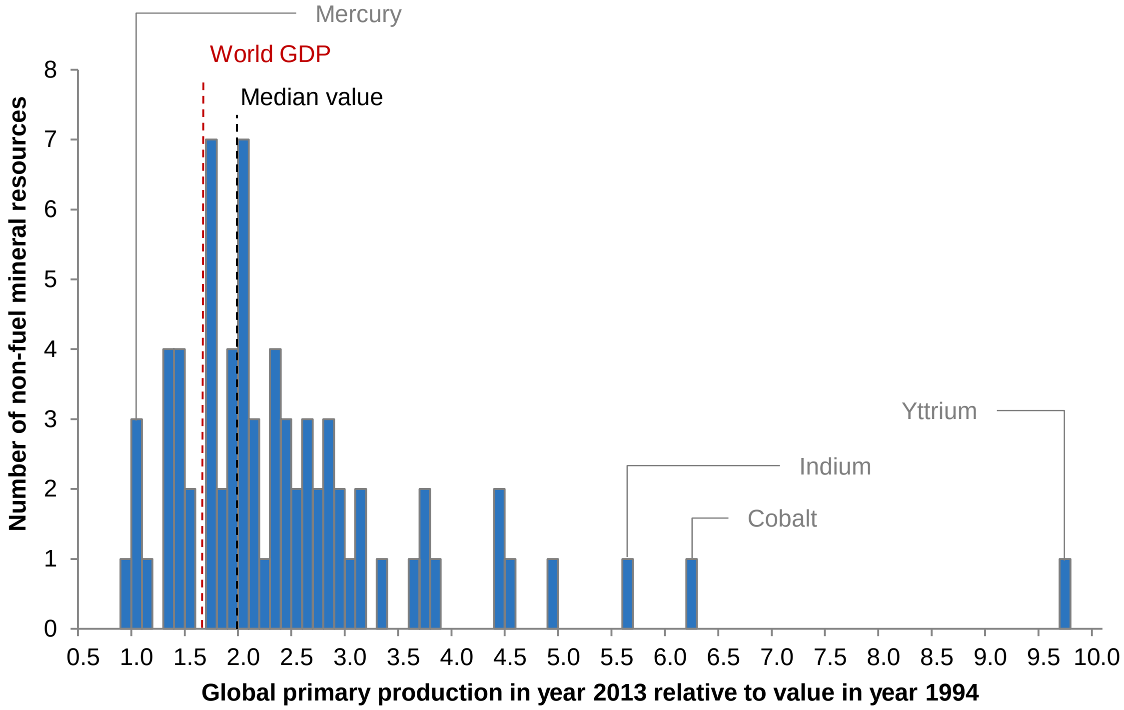

Figure 2. Histogram of global primary production growth from year 1994 to 2013 for 73 non-fuel mineral resources. A value of 1 indicates no change in production over this time period, values greater than 1 indicate increases in production, and values less than 1 indicate declines in production. For some minerals, multiple production stages (e.g., mining, smelting, and refining) are included as separate entries. GDP data are based on market exchange rates in constant 2005 U.S. dollars as reported by the World Bank.[3] Production data are from the U.S. Geological Survey.[4]

The precipitous increase in production of non-fuel mineral resources has been followed by a gradual decline in their associated ore grades.[5] Lower ore grades generally result in increased environmental burdens due to the greater quantity of waste rock and emissions generated and the greater quantity of energy and other inputs required to obtain the same quantity of the desired mineral.[6] Although declining ore grades do not necessarily imply a depletion of a resource, they do raise questions regarding its sustainability and the risks to supply associated with the reliance on primary mining to meet continuing increases in demand.

An added complexity is that many of the specialty minerals utilized in modern technology are produced only or mainly as byproducts during the processing of other minerals. Selenium, tellurium, and arsenic are produced mainly as byproducts during the processing of copper, while indium, cadmium, and germanium are produced mainly as byproducts during the processing of zinc. A recent study suggests that some 38 elements of the periodic table are produced mainly as byproducts.[7] Concerns regarding byproduct minerals stem from their dependency on the main resource for profitable recovery. Byproduct mineral supply is therefore thought to be relatively price-inelastic.[8]

In addition to being produced mainly or only as byproducts, many specialty minerals have highly concentrated production. Unlike gold, silver, and copper, whose geological resources and primary production are present throughout the globe, specialty minerals are predominately produced in only a few countries. As illustrated in the figure below, the primary production of some 52 of the 78 non-fuel mineral resources investigated can be considered highly concentrated, as indicated by a value of the Herfindahl-Hirschman Index (HHI)— a commonly utilized measure of market concentration—of 2,500 or greater.[9]

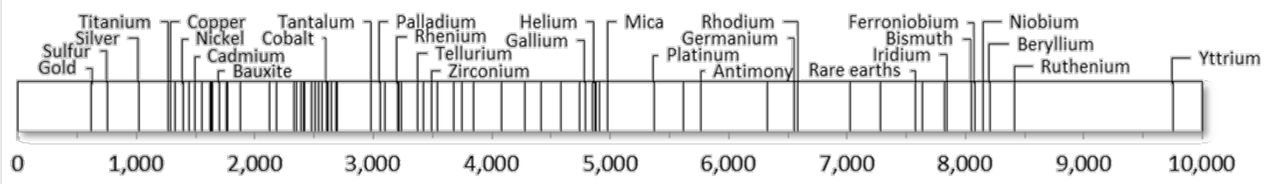

Figure 3. Distribution of geopolitical production concentration for 78 non-fuel mineral resources, as measured by the Herfindahl-Hirschman Index (HHI) at the country-level. Not all minerals are labeled in the figure. HHI values at different stages of production (e.g., mining, smelting, and refining) are included as separate entries. Labels refer to mining stage. Data source: U.S. Geological Survey[4]

Production concentration suggests that no single country has all the resources required to meet its economic and national-security needs. As illustrated in Figure 4, even countries as well-endowed with mineral resources as the United States are often partially or completely dependent on imports for some resources. Moreover, the concentration of production, especially in socially or politically unstable countries, can pose a significant risk of supply disruption, as highlighted by a number of recent events including the prolonged labor disputes in South Africa that disrupted the production of the platinum-group metals,[10] China's restriction of rare earth exports,[11] and the passage of legislation in the United States related to the restricted use of tantalum, tin, tungsten, and gold (3TG) as conflict minerals originating from the Democratic Republic of the Congo or adjoining countries.[12]

It is important to note that these issues do not indicate that access to certain minerals is becoming prohibitively restrictive; but, together, these factors do indicate trends that suggest that risk associated with the supply of certain non-fuel mineral resources is increasing.

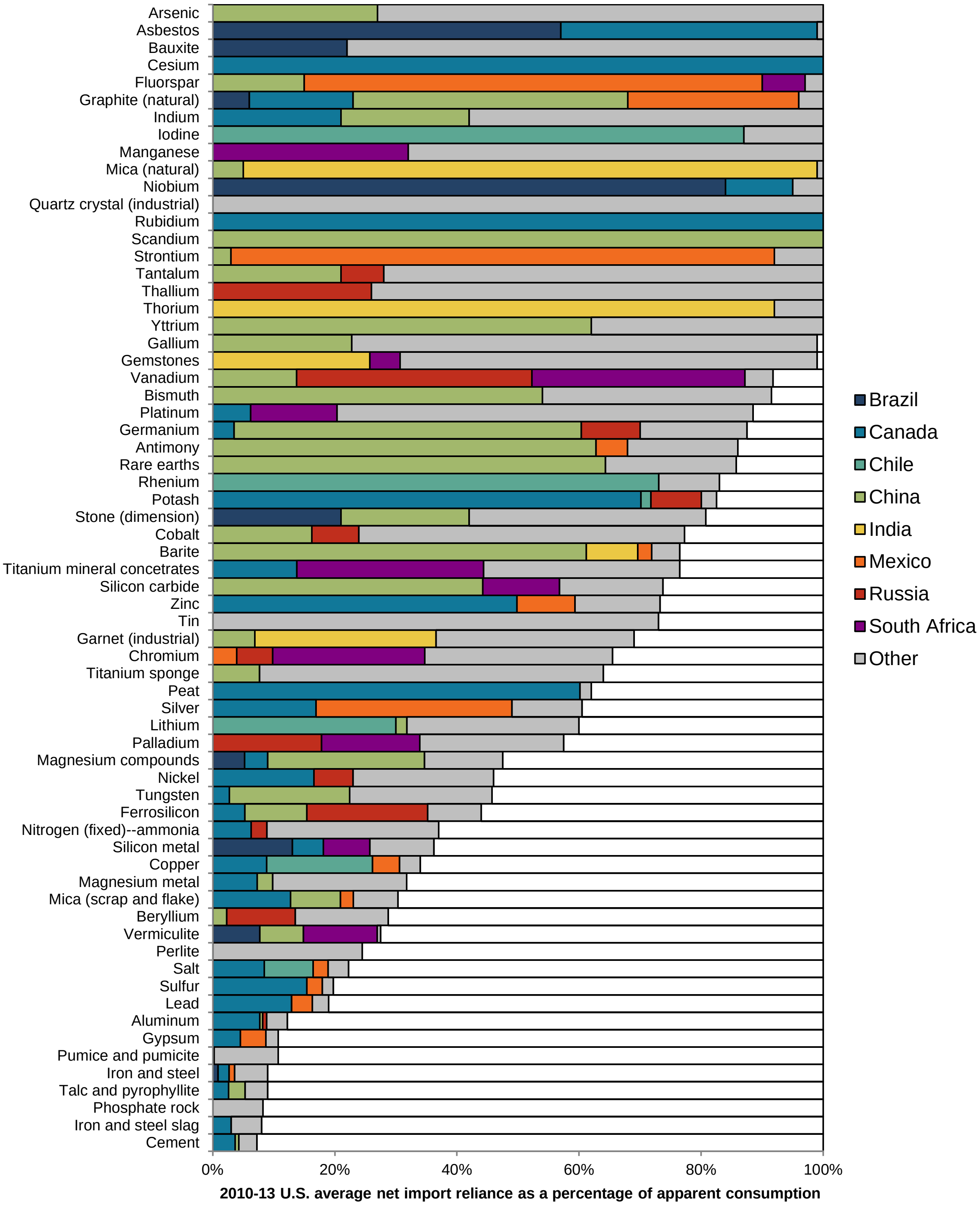

Figure 4. Average net import reliance of the United States by top 8 sourcing countries for 66 resources for years 2010-2013. Data source[i]: U.S. Geological Survey [13]

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[i] Not all resources covered in the publication are listed here: "those not shown include mineral commodities for which the United States is a net exporter (for example, molybdenum) or less than 5% import reliant (for example, lime). For some mineral commodities (for example, hafnium), not enough information is available to calculate the exact percentage of import reliance;

1.2 Motivation

The convergence of the aforementioned factors and trends has reinforced concerns regarding the reliability of supplies of non-fuel mineral resources for the United States. Each mineral resource has its own set of circumstances that define its risks and vulnerabilities: certain minerals are produced only as byproducts in a few countries and used only in niche applications, while others are produced independently throughout the world and have a myriad of applications. The potential for and the underlying causes of a supply disruption, as well as the possible impact abatement strategies, can thus vary significantly from one mineral to another.

The interagency group producing this report considers a mineral to be "critical" if it serves an essential function in the manufacture of a product, the absence of which would cause significant economic or social consequence, and if its supply chain is vulnerable to disruption. Indicia of criticality include low substitutability with other minerals, dependence on foreign imports for raw materials, dependence on foreign imports for refined product, and single versus multiple supplies of raw materials. This definition is consistent with those used in a number of other studies. "Strategic" minerals are considered here to be a subset of critical minerals and are those that are essential for national security applications. The supply chain considered is from mine to the product, and includes the mining of ores, extraction, and refining of minerals and the manufacture of components, such as magnets. The initial screening methodology described in this report focuses on supply constraints to identify potentially critical minerals, which will subsequently undergo in-depth analyses to assess which of these should be considered critical minerals (and which among those should be deemed strategic minerals).

Determining which non-fuel mineral resources are at the highest risk has been a subject of interest for many decades.[14] More recently, the National Research Council (NRC) published a report titled *Minerals, Critical Minerals, and the U.S. Economy* to begin to address some of these concerns by providing a guiding framework for determining which minerals are more "critical" than others.[15] Since the publication of the NRC report in 2008, a number of efforts aimed at assessing material criticality have been developed by (or for) different governmental agencies,[16–20] non-governmental organizations,[21,22] academic researchers,[23–25] and corporations.[26,27] As indicated in a recent review,[28] the various criticality assessments address concerns of different stakeholders and employ varying methodologies, each with a number of strengths and weaknesses. Moreover, many of these methodologies are relatively narrow in scope: some focus on a specific technological sector,[29] a certain geographic region,[17,18,30–32] or a specific technological sector within a certain geographic region.[33] Others still are limited in their application to a relatively small subset of minerals.[27,34,35]

In addition to these limitations of scope, a significant weakness common among all known efforts is that they are not updated on a regular basis, likely due to the complexity of the models employed, lack of necessary data, or lack of resources needed to perform such updates. In this interagency effort, a new methodology for assessing potential criticality has been developed with the aim of providing updated

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for others (for example, tellurium), exact percentages may have been rounded to avoid disclosing company proprietary data." Figure is displayed in descending order of import share. Data for arsenic refers to arsenic trioxide, data for rare earths include lanthanides and yttrium but exclude most scandium, data for silicon carbide refers to crude silicon carbide, data for rhenium refers to rhenium metal powder, and data for vanadium refers to vanadium pentoxide.

results on a regular basis in order to identify trends that can anticipate supply disruptions in a timely manner. By utilizing only the most pertinent of parameters, the methodology for assessing potential criticality is applicable across a wide range of minerals. Moreover, most of the data necessary for completing this analysis is systematically collected on a regular basis by the National Minerals Information Center (NMIC) within the U.S. Geological Survey (USGS), thereby enabling periodic updates.

The development of this screening methodology and the publication of its results on a regular basis also address aspects of the National Materials and Minerals Policy, Research and Development Act of 1980 as codified at 30 U.S.C. § 1601-1605, and reflect the Federal government's interagency work as requested by language in H.R. Rep. No. 113-171, at 60 (2013) and H.R. Rep. No. 113-448, at 67 (2014).

The following section describes the proposed methodology for assessing potential criticality in detail.

2.0 Methodology

2.1 Overview of assessment

The assessment and ultimate categorization of a mineral as critical is conducted in two stages, as illustrated in Figure 5. The focus of this report is the "early-warning screening," which aims to identify a subset of minerals as "potentially critical" based on trends in fundamental indicators that raise concerns regarding their medium-term (~5-10 years) availability. Subsequent "in-depth analyses" will be conducted to ensure that the underlying factors driving indications of potential criticality in the initial screening are fully understood, to assess the extent to which availability constraints would cause significant economic or social consequence, and to determine which of these minerals constitute a

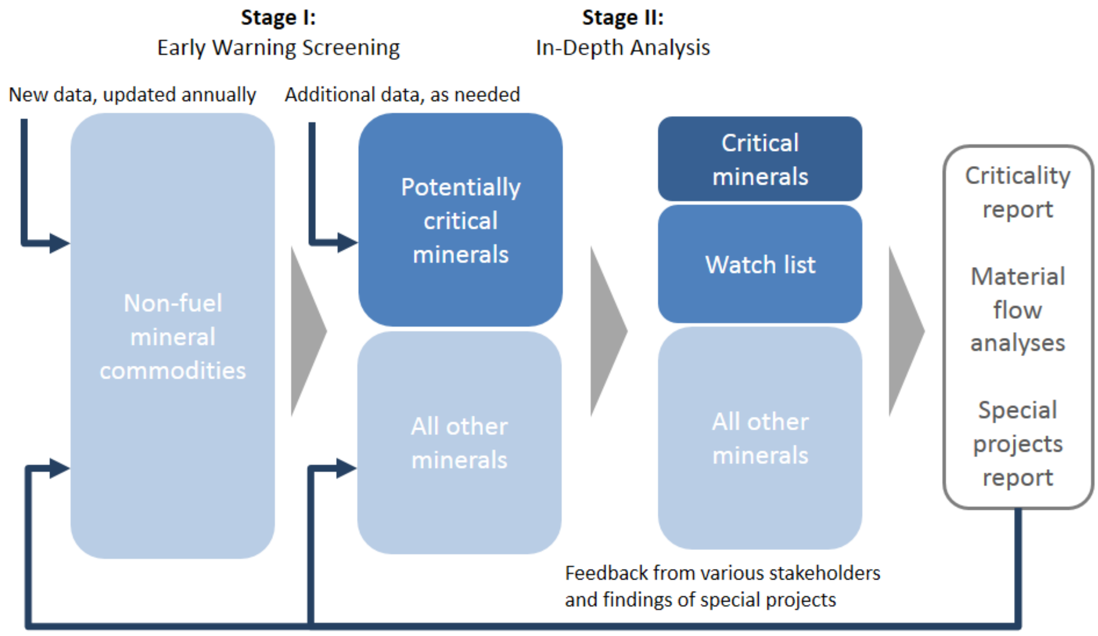

Figure 5. Overview of methodology

significant concern. The in-depth analyses of minerals identified as potentially critical will thus serve to delineate which of these should be considered critical minerals, with the remainder maintained on a watch list due to the indications of availability constraints from the initial screening. The type of study conducted in the in-depth analysis will depend on the mineral resource in question and the underlying issues that caused it to be flagged in the initial screening. It may include a material flow study to quantify the losses of the mineral during each stage of its life cycle and identify the most strategic means of reducing those losses through targeted improvements in recovery and recycling, a sector analysis to determine the mineral's most important end-use applications and to ascertain its substitution potential, a socio-geographical analysis to assess a country's vulnerability to factors that may disrupt its production capabilities such as climate change or the potential for uncontrollable disease outbreak, or some other type of analysis such as the development of supply and demand scenarios to understand the implications of certain trends and uncertainties. In all cases, the goal of the studies conducted in the in-depth analysis is to obtain a firm understanding of the fundamentals and trends in a mineral's supply and demand in order to determine whether or not the mineral should be considered critical. In turn, the results from the studies conducted in the in-depth analysis, along with feedback from various stakeholders, will be utilized to inform future assessments and, if needed, adjust the methodology.

The utilization of this two-stage approach provides several advantages over criticality assessments that rely solely on a set of preselected indicators for the classification of a mineral as critical. This is because any set of preselected indicators must be applicable across the entire suite of minerals being investigated and is thus often the set of "lowest-common" indicators due to data constraints for some of the more exotic minerals. The two-stage approach thus decreases the reliance on the early-warning screening to perfectly delineate between critical and non-critical minerals and thereby allows for a relatively streamlined methodology that utilizes only the most essential indicators, and can readily be updated periodically as subsequent-year data become available.

While the in-depth analysis will depend on the mineral in question, the methodology utilized in the early-warning screening is uniform across all minerals. This methodology is described in detail in the following section.

2.2 Methodological details of the early-warning screening

The early-warning screening aims to assess potential criticality (C) using a uniform methodology that results in a single value for each mineral on a common 0 to 1 scale, where increasing values signal higher potential criticality. Specifically, the assessment of potential criticality is based on the geometric mean of three fundamental indicators: supply risk (R), production growth (G), and market dynamics (M), as illustrated in equation 1.

$$C = \sqrt[3]{R \cdot G \cdot M} \qquad (1)$$

These indicators were selected because they capture different aspects of criticality and because of their complementary nature: R attempts to capture the risk associated with geopolitical production concentration, *G* attempts to capture changes in the mineral's market size and reliance on geological resources, and *M* attempts to capture the mineral's price sensitivity to changes in its market. Moreover, while these indicators are relatively simple, they indirectly reflect a number of different aspects related to criticality that have been incorporated in other assessments including substitutability, recycling, and byproduct dependency.[i] These indicators do not, however, account for any regional or country-specific demand or import dependencies. This is because the intent of the early-warning screening is to be as broad as possible in its ability to identify potentially critical minerals regardless of any country-specific vulnerabilities to supply restriction, which will be addressed in the in-depth analyses as necessary.

The geometric mean was selected as the method of aggregation in order to provide an appropriate measure of central tendency for the three indicators without assuming perfect substitutability across them.[36] Specifically, with the geometric mean as the method of aggregation a decrease in risk in one indicator does not necessarily linearly compensate for an increase in risk in another. Alternative aggregation methods, including several in which highly-skewed weightings were assigned to the different indicators, were compared in a sensitivity analysis and shown to produce very similar results (>80% overlap) on the basis of the minerals designated as potentially critical. (Note that with this method, a zero value for any of the three fundamental indicators would nominally result in $C = 0$ regardless of the values of the other indicators. The normalizations described below yield only one zero value across the entire dataset for each indicator, and for those three specific cases *C* values are not listed in the results below; alternative normalization or aggregation schemes may be considered in future refinements of this model.)

Details regarding each of the indicators are discussed next.

2.2.1 Supply Risk

The supply risk (*R*) indicator aims to assess the relative risk of a supply disruption by quantifying the geopolitical concentration of a mineral's production. All other things being equal, a mineral with production that is concentrated in a few socially or politically unstable countries is at a higher risk of a supply disruption than a mineral with production that is more widely dispersed in relatively stable nations. Two factors are utilized to assess geopolitical production concentration: the Herfindahl-Hirschman Index (HHI) and the Worldwide Governance Indicators (WGI). The HHI is a metric that is used to measure market concentration, while the WGI is a set of six indicators that quantify different dimensions of governance for over 200 countries and territories based on a variety of sources.[37] The HHI and WGI have both been used in combination or individually in most of the previously published criticality assessments.[38] In this analysis they are combined in the following manner to obtain a pre-normalized or "raw" (denoted with superscript *r*) *R* indicator value:

$$R^r_{m,t} = \sum S^2_{m,t,i}\,\Gamma_{t,i} \qquad (2)$$

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[i] For example, while price volatility as reflected by *M* can be caused by a number of factors, it tends to be greater if supply or demand are relatively unaffected by price variations, such as (respectively) for minerals that are produced as byproducts or for which adequate substitutes are not available. See further discussion below in Sec. 2.2.3.

where, for mineral m and year t, S is the production share of country i and Γ is the country's Composite Governance Index value. The summation across all producing countries provides a weighted-average value, with weighting being based on the square of the production shares to simulate the HHI.

The governance values are based on an aggregation of the six WGI: 1) Voice and Accountability, 2) Political Stability and Absence of Violence, 3) Government Effectiveness, 4) Regulatory Quality, 5) Rule of Law, and 6) Control of Corruption. The values of each WGI indicator are first normalized to range from a theoretical low value of 0 for high governance (low risk) to 1 for low governance (high risk) using the following equation:

$$\Gamma_{t,j,i} = 1 - \frac{\Gamma^{r}_{t,j,i} + 3.5}{7} \tag{3}$$

where for year t, WGI indicator j, and country i, Γ^{r} is the reported value and Γ (without the superscript) is the resultant normalized value. The normalized values for the six WGI indicators are then aggregated into a single value for each country based on their geometric mean:

$$\Gamma_{t,i} = \left(\prod_{j=1}^{6} \Gamma_{t,i,j} \right)^{\frac{1}{6}} \tag{4}$$

Figure 6 displays the resultant Composite Governance Index values for year 2013, with the results for all other years being presented in Appendix D.

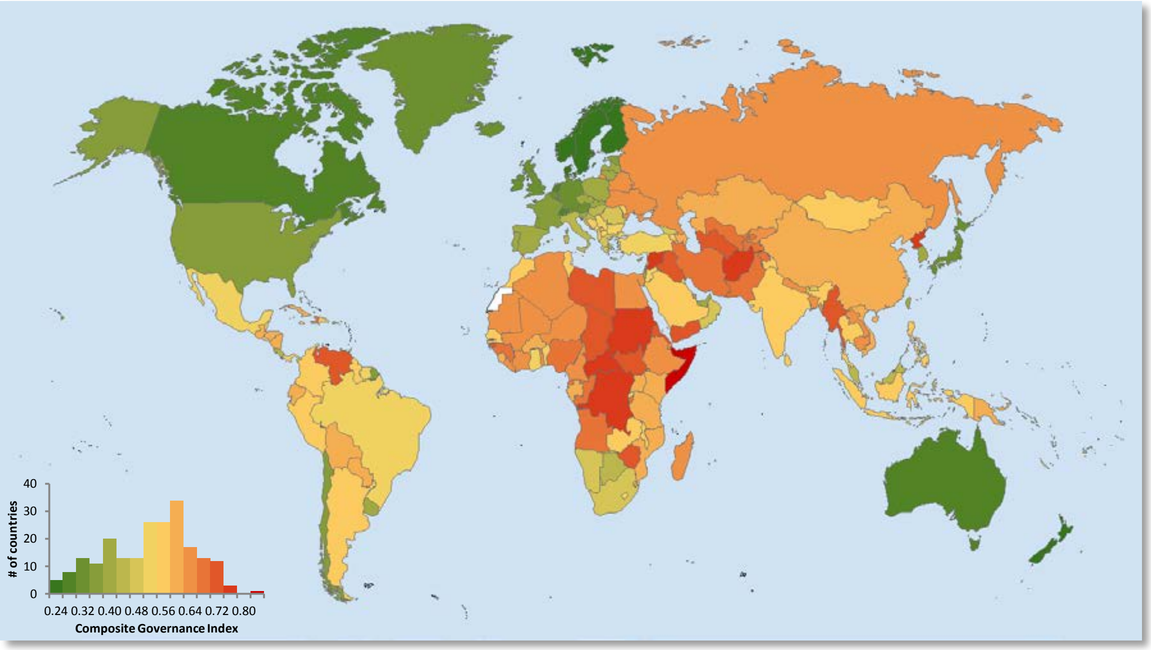

Figure 6. Composite Governance Index values for year 2013. High values (displayed in red) indicate low governance, while low values (displayed in green) indicate high governance.

To obtain *R* values that range from 0 to 1, the “raw” *R* indicator values are normalized based on the observed minimum (subscript *min*) and maximum (subscript *max*) values across all minerals and all years investigated (currently years 1996-2013) using the equation below:

$$R_{m,t} = \frac{R^r_{m,t} - R^r_{min,t}}{R^r_{max,t:t\prime} - R^r_{min,t:t\prime}} \tag{5}$$

2.2.2 Production Growth

The production growth indicator (*G*) aims to capture trends related to a mineral’s market size by quantifying recent changes in its global primary production. A mineral for which primary production is growing rapidly indicates a growth in its market size and, in turn, a growth of its importance globally. As illustrated in the equation below, the calculation of *G* is based on the compounded annual growth rate of the mineral’s global primary production:

$$G^r_{m,t} = \left(\frac{Q_{m,t}}{Q_{m,t'}}\right)^{\frac{1}{t-t'}} \tag{6}$$

where for mineral *m*, initial year *t’,* and current year *t*, *Q* is the mineral’s global primary production quantity. The time horizon (i.e., the timespan from year *t’* to *t*) is currently set at 5 years in order to reduce the “noise” associated with shorter timespans without completely diluting, and in turn overlooking, the important trends.

As with the *R* indicator, the *G* indicator is normalized to range from 0 to 1 based on the observed minimum and maximum values across all minerals and all years investigated, using the following equation:

$$G_{m,t} = \frac{G^r_{m,t} - G^r_{min,t:t\prime}}{G^r_{max,t:t\prime} - G^r_{min,t:t\prime}} \tag{7}$$

By focusing on primary production, the *G* indicator also identifies changes in the market’s reliance on geological resources. A mineral with growing primary production is becoming more reliant on geological resources and would thus receive a higher *G* value. Conversely, a mineral with decreasing primary production due to declining demand or due to increasing supply from secondary sources (i.e., recycling) is becoming less reliant on geological resources and would thus receive a lower *G* value. A decrease in primary production due to regulatory or other supply constraint will also result in a lower *G* indicator value. At first glance, this may seem undesirable given that such supply constraints should raise rather than lower the potential criticality. However, given that demand has not decreased and secondary production has not increased, prices will rise due to the decreased supply. The price increase will be captured with the *M* indicator, which quantifies price volatility. Depending on the exact changes, the overall *C* indicator value may actually increase under this scenario.

2.2.3 Market Dynamics

The market dynamics indicator (*M*) aims to capture the robustness of the mineral to sudden market changes by quantifying its price volatility. Specifically, *M* is calculated as the ratio of the standard deviation and the mean of the mineral's price (*P*) over a specified time horizon (from year *t′* to *t*)—its coefficient of variation, as illustrated in the following equation:

$$M^r_{m,t} = \frac{\sqrt{\dfrac{\sum_{t'}^{t}\left(P_{m,t} - \bar{P}_{m,t:t'}\right)^2}{t - t'}}}{\bar{P}_{m,t:t'}} \tag{8}$$

where for mineral *m* and year *t*, *P* is the mineral's annual average price and $\bar{P}$ is the mineral's annual price averaged over the specified time horizon (from year *t′* to *t*). As with the *G* indicator, the time horizon is set at 5 years. The price data utilized are adjusted to 1998 U.S. dollars to account for inflation.

The *M* indicator is similarly normalized to obtain values that range from 0 to 1 based on the observed minimum and maximum values across all minerals and all years, as illustrated in the following equation:

$$M_{m,t} = \frac{M^r_{m,t} - M^r_{min,t:t'}}{M^r_{max,t:t'} - M^r_{min,t:t'}} \tag{9}$$

Excessive price volatility can be caused by a number of different factors including unstable supply, cyclical or unpredictable demand, speculative purchases, low inventories that may otherwise buffer against sudden fluctuations, and changes in market expectations. It also suggests that supply, demand, or both may be relatively unresponsive (or at least slow to respond) to market signals. Unresponsive (i.e., inelastic) supply could be indicative of the suppliers' inability or unwillingness to alter production quantities in the face of rapid price changes. This could be due to capacity, labor, or capital constraints or simply due to the lack of economic viability. Minerals produced as byproducts may fall under this category due to their relatively low volumes and economic values when compared to the main mineral being recovered. A copper operation may, for example, not find it economical to recover selenium even if the price of selenium were to increase significantly, simply because the volumes are too low to justify the additional capital expenditure required. On the other hand, unresponsive (i.e., inelastic) demand suggests that consumers of the mineral are unwilling or unable to alter their purchasing habits despite rapid and dramatic changes in price. This could be indicative of the lack of adequate substitutes.

Sudden and dramatic price changes undoubtedly have consequences for both producers and consumers. In general, excessive price volatility is undesirable as it increases uncertainty and thus makes planning more difficult. It may also curtail investment, hamper economic development, and undermine profitability. From a criticality standpoint, a mineral with higher price volatility suggests a greater degree of sensitivity to changes or disruptions in the market and a depressed ability to adapt to those changes and disruptions.

2.3 Scope

The intent of the early-warning screening is to be as comprehensive as possible with regards to the number of minerals that are evaluated on a regular (annual) basis. As such, the analysis currently includes 50 individual elements[i] of the periodic table, as well as the rare earths (i.e., the lanthanides[ii]), which are analyzed as a single mineral resource. The analysis also includes feldspar, fluorspar, mica, and monazite as separate minerals, as well as eight ferroalloys: ferrochromium, ferromanganese, ferromolybdenum, ferronickel, ferroniobium, ferrosilicon, ferrovanadium, and silicomanganese. These mineral resources were selected mainly on the basis of data availability. For some minerals, such as hafnium and osmium, no reliable country-level production data are available. These and other minerals may be included in future analyses as the necessary data become available.

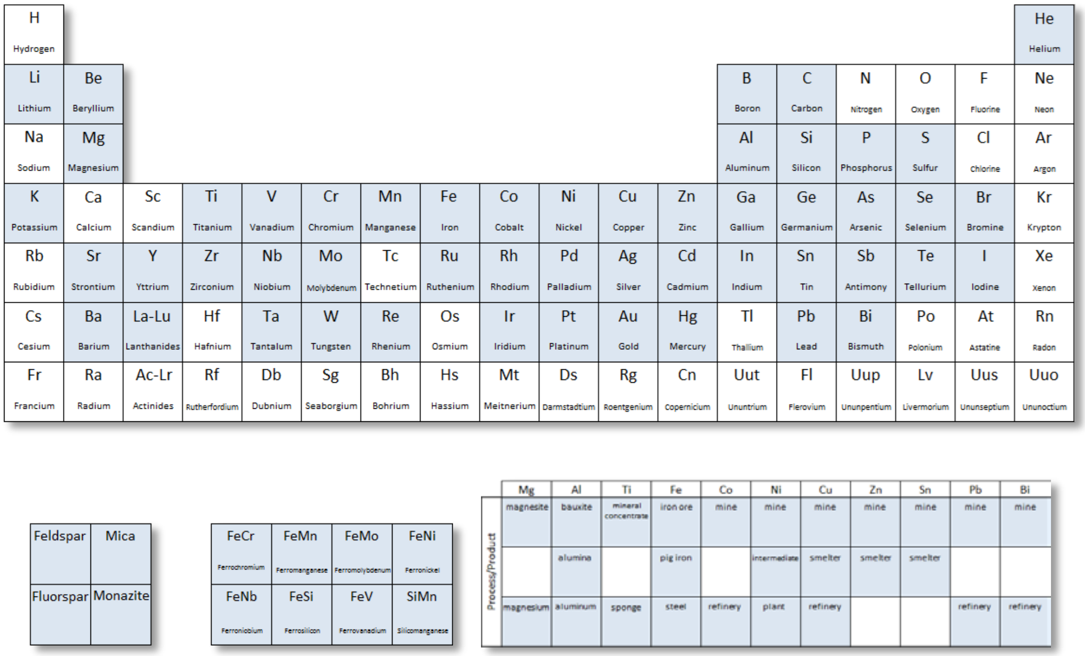

Figure 7. Scope of mineral coverage

For several minerals, namely magnesium (Mg), aluminum (Al), titanium (Ti), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), tin (Sn), lead (Pb), and bismuth (Bi), production statistics for multiple processes and intermediate products are available and are thus included in the analysis. For example, copper mining, smelting, and refining processes are all included as separate entries. By analyzing these intermediate products one is able to identify the process that is potentially at the greatest risk of disruption within the supply chain.

Including these intermediate processes and products brings the total number of mineral resources analyzed to 78. For each of these resources, production and price data have been collected for each year from 1996 to 2013. Details regarding the specific data sources for each mineral and certain assumptions are noted in Appendix E.

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[i] Graphite is listed under carbon (C) and potash is listed as potassium (K).

[ii] Yttrium is included in the analysis for the rare earths, as well as being analyzed as an individual mineral.

3.0 Results and discussion

The results for the *R*, *G*, and *M* indicators for all minerals and years investigated are displayed in the following three figures, respectively. A complete tabulation of the results for both the raw and normalized values is presented in Appendix F.

Examining the Supply Risk (*R*) indicator results (Figure 8), one is able to identify several minerals with relatively high values across most or all years examined including the rare earth elements (Y and La-Lu), niobium (Nb), ruthenium (Ru), rhodium (Rh), antimony (Sb), tungsten (W), iridium (Ir), monazite, ferromolybdenum (FeMo), and ferroniobium (FeNb). For these minerals, production is highly concentrated in countries that display relatively low governance (high risk) and thus face a greater potential of a supply disruption. In contrast, minerals such as bauxite (noted under Al), sulfur (S), potash (noted under K), titanium (Ti), manganese (Mn), iron (Fe), nickel (Ni), copper (Cu), zinc (Zn), silver (Ag), gold (Au), and feldspar have relatively low *R* indicator values across all years examined because their production is widely dispersed in many countries that typically display relatively high levels of governance (low risk). Most of the other minerals have consistently moderate values, either because their production is not extremely concentrated (as is the case for tin) or because their production is concentrated in high governance countries (as is the case for iodine). There are a few minerals, however, for which the *R* indicator values have changed significantly over the time span examined. These include graphite (noted under carbon, C), magnesium (Mg), cobalt (Co), gallium (Ga), germanium (Ge), mercury (Hg), lead (Pb), and bismuth (Bi).

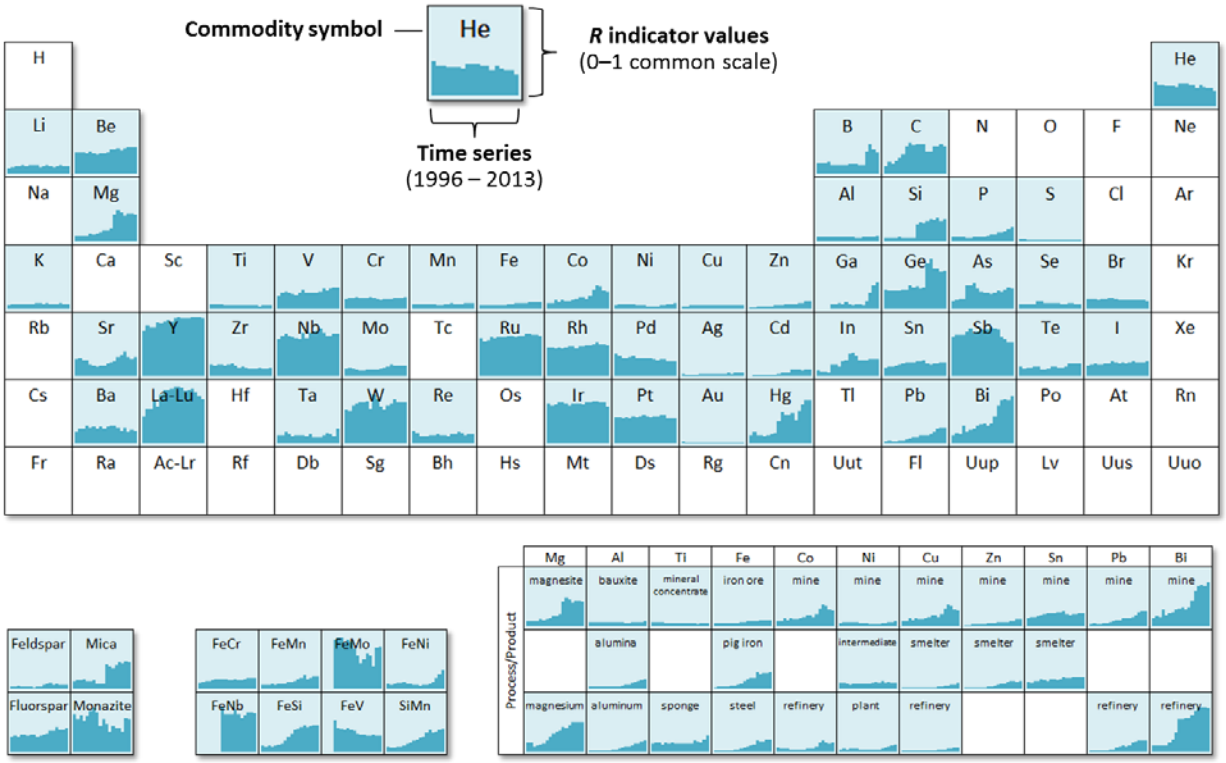


Figure 8. Normalized Supply Risk (R) indicator values for all minerals and years investigated

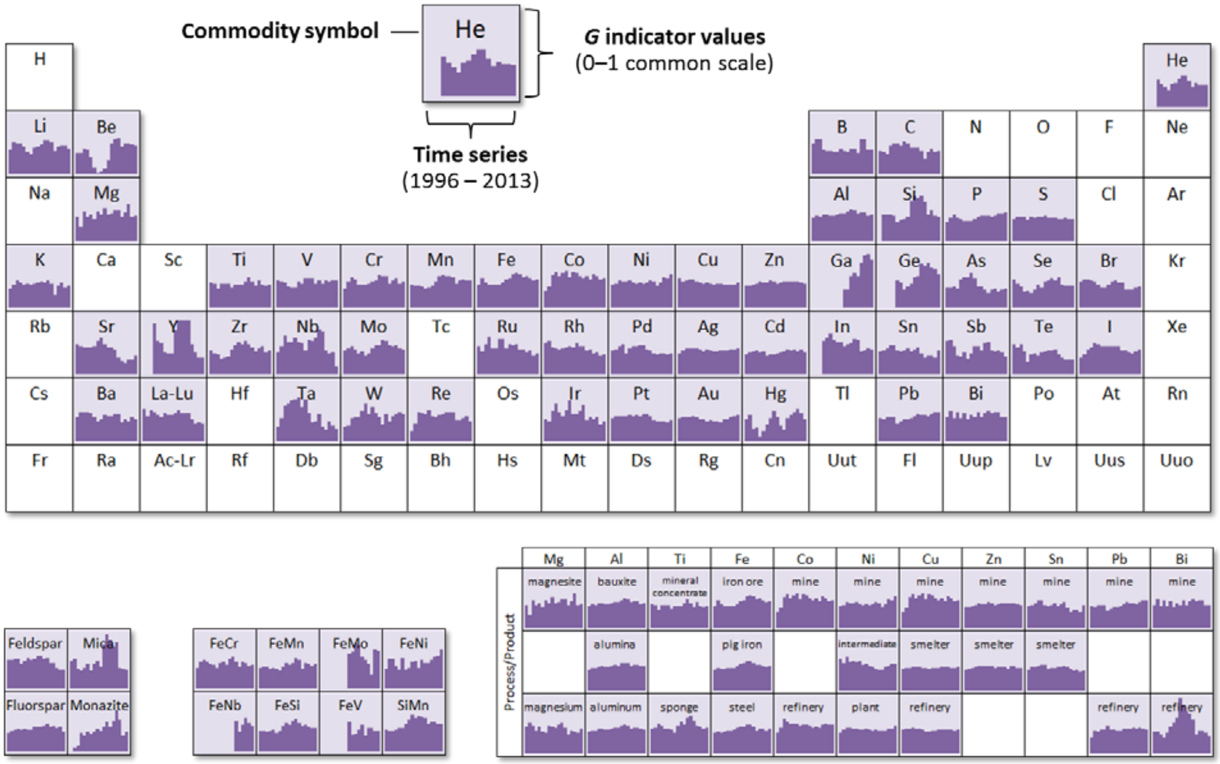


Figure 9. Normalized Production Growth (G) indicator values for all minerals and years investigated

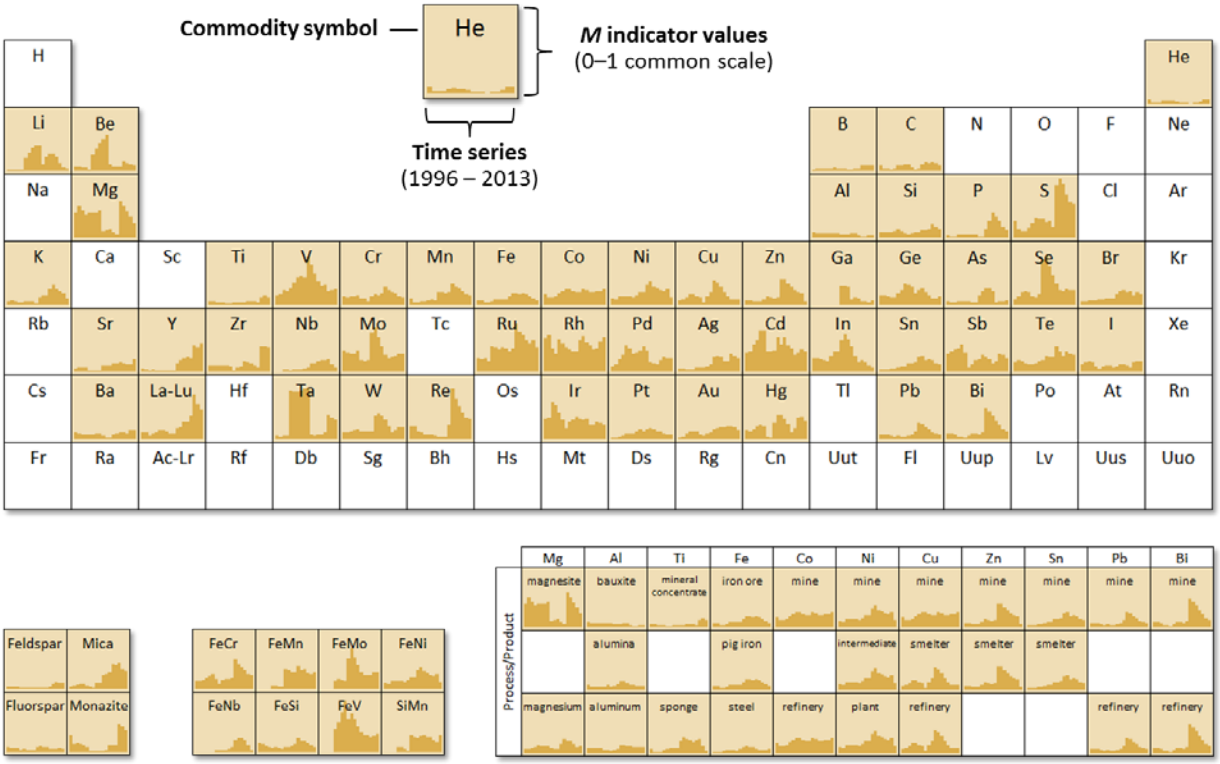


Figure 10. Normalized Market Dynamics (M) indicator values for all minerals and years investigated

In general, the increases in these minerals' *R* indicator values suggest a significant shift in production from many high-governance countries to a few countries that often exhibit low-governance. Consider the changes in the sources of production of bismuth (Figure 11).

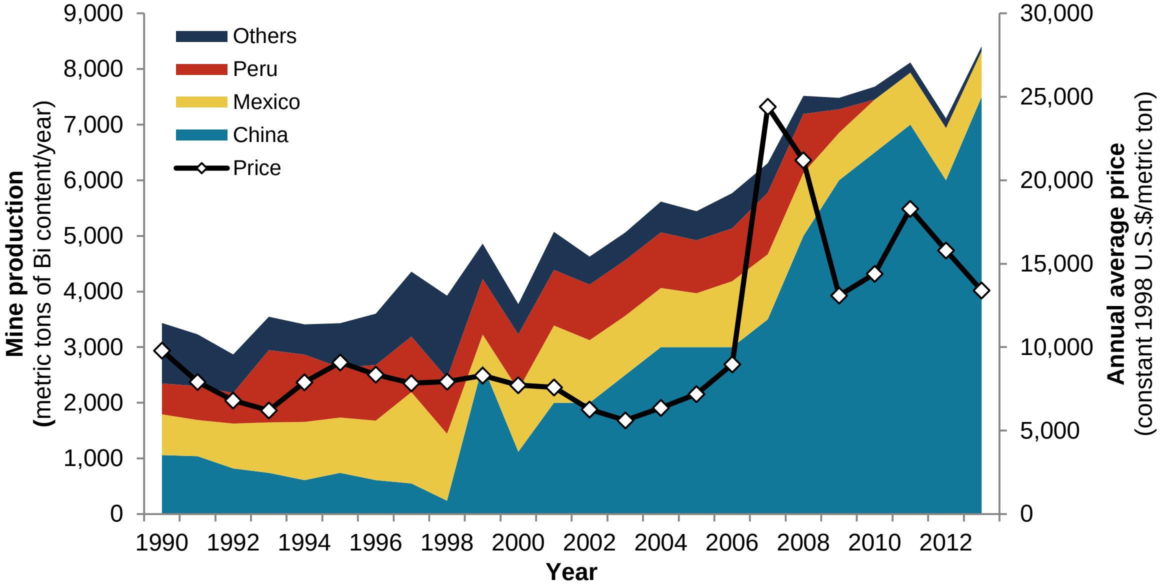


Figure 11. Mine production and price data for bismuth for years 1990-2013. Data sources: U.S. Geological Survey[4] and Kelly & Matos.[39] Price data are displayed in constant 1998 U.S. dollars.

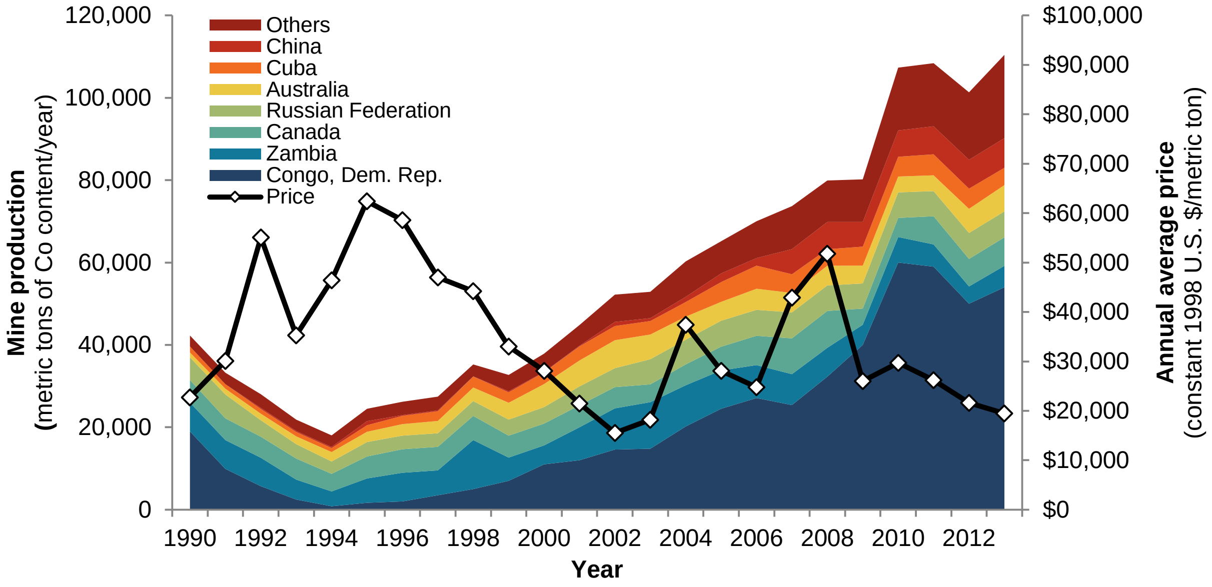


Figure 12. Mine production and price data for cobalt for years 1990-2013. Data sources: U.S. Geological Survey[4] and Kelly & Matos.[39] Price data are displayed in constant 1998 U.S. dollars.

In the 1990s, production was relatively diversified with production being equally distributed between China, Mexico, Peru, and all other countries combined. By the late-2000s, however, production shifted to be almost entirely sourced from China. A similar situation, albeit to a lesser degree, has emerged with cobalt (Figure 12), where the Democratic Republic of the Congo has (re)emerged as the dominant cobalt mine producer in the last few years.

Another important trend for both bismuth and cobalt is the notable overall increase in absolute production quantities during the same time span. These increases in primary production are captured in the *G* indicator which, as illustrated in Figure 9, is relatively high for both bismuth and cobalt. Indeed, in contrast to the *R* indicator, the *G* indicator is consistently high across most of the analyzed mineral resources for the years examined with few exceptions, namely yttrium (Y), gallium (Ga), mica, ferro-molybdenum (FeMo), mercury (Hg), beryllium (Be), bismuth refinery production, monazite, niobium (Nb), tantalum (Ta), silicon (Si), and germanium (Ge). For these minerals, production growth has not been constant: in some cases production growth is accelerating as in the case of gallium, while in other cases production is fluctuating between growth and decline as in the case of mercury. Overall, however, the *G* indicator values suggest that primary production has been steadily increasing for most minerals.

In further contrast, the *M* indicator values display significant differences among the minerals examined and across time. Several mineral resources, including helium (He), boron (B), graphite (noted as carbon, C), bauxite (noted under Al), titanium (Ti), and iron ore (Fe), show relatively low *M* indicator values that change very little over time, suggesting minimal price volatility relative to the other minerals. Others, including lithium (Li), beryllium (Be), magnesium (Mg), sulfur (S), vanadium (V), selenium (Se), indium (In), tantalum (Ta), rhenium (Re), bismuth (Bi), ferromolybdenum (FeMo), and ferrovanadium (FeV), show distinct increases in the *M* indicator values often followed by equally rapid declines. These, as illustrated in the case for bismuth, Figure 11, are often a result of temporary price increases, which may not represent a fundamental concern with the mineral's supply-demand dynamics but may hint at its susceptibility to rapid market fluctuations. There are also several minerals, including ruthenium (Ru), rhodium (Rh), and cadmium (Cd), for which *M* indicator values are high for most years examined. This may suggest systemic volatility in these mineral markets.

Comparing the overall distribution of values across all minerals and years for these three indicators, Figure 13 indicates that the *G* indicator values are notably less distributed, especially prior to normalization, than those of the other two indicators. This is due to the fact that production quantities for most minerals have increased at a similar rate over the time period examined. Another important trend can be identified when comparing the median values of the three indicators relative to their values in 1996, as shown in Figure 14. The median *G* and *M* indicator values have remained near their 1996 levels across most years, except for modest increases centered on year 2008 that may be attributed to the global financial crisis. The median *R* indicator values have, however, nearly doubled over this time period. This increase is mainly due to increases in production concentration, which is apparent when comparing the *R* indicator to the concentration index, HHI, without consideration to the governance factors. While the median HHI largely follows the *R* indicator, there are, perhaps, two important deviations. The first occurs in 1997-2000, where the median HHI has increased at a greater rate than *R*, and in 2007-2013, where the opposite has happened. Because the overall governance values have not changed significantly, these deviations may indicate a shift from concentrating production in high governance countries during the first time period from 1997-2000 to the concentration of production in low governance countries during the second time period from 2007-2013.

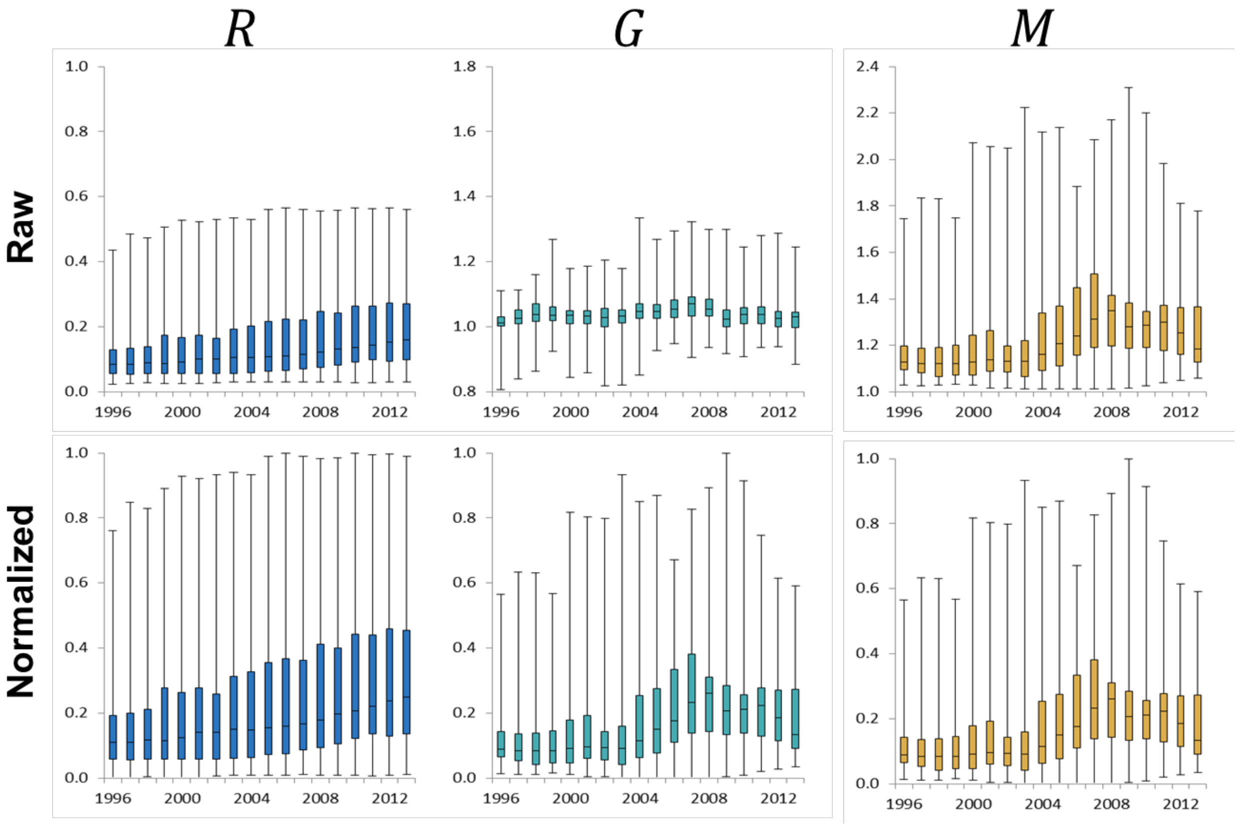


Figure 13. Distribution of the R, G, and M indicators before and after normalization. Box-and-whisker plots display annual minimums, maximums, and interquartile ranges.

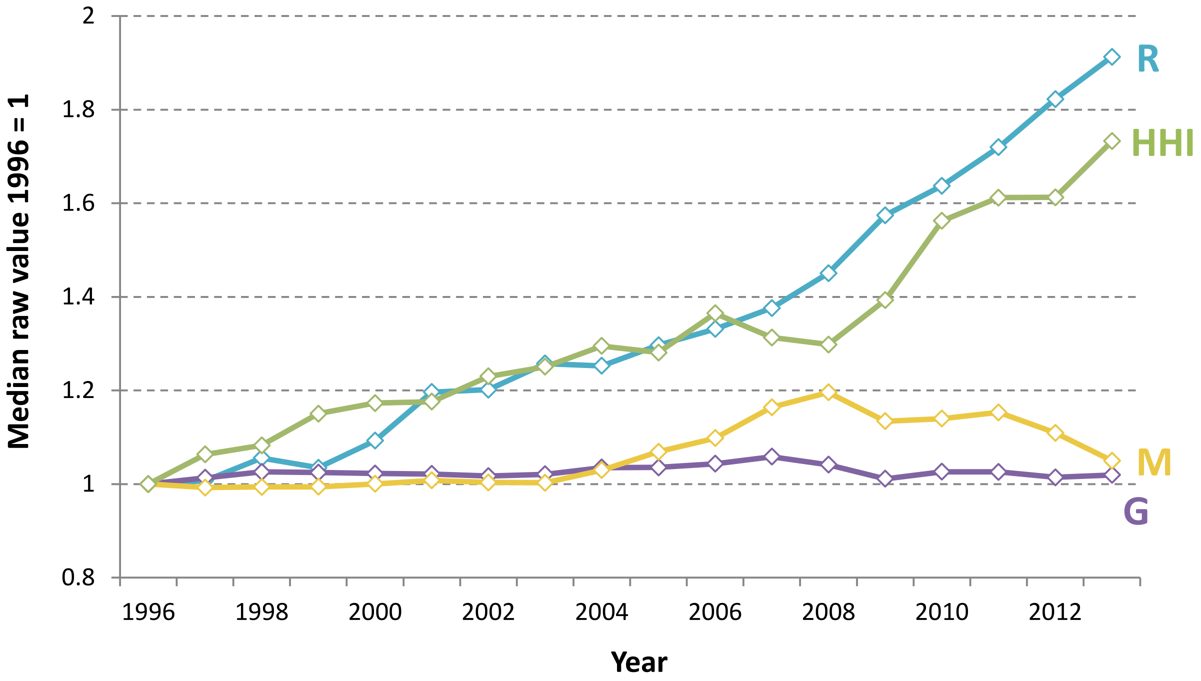


Figure 14. Relative changes to the R, G, and M indicators and the HHI from 1996-2013.

Taking into account all of the dynamics of the three indicators, via geometric weighting, yields the overall indicator of potential criticality (*C*) values, Figure 15. From this figure, one is again able to identify notable differences among the minerals. Aluminum (Al), sulfur (S), potash (noted as K), titanium (Ti), iron ore (Fe), nickel (Ni), copper (Cu), zinc (Zn), silver (Ag), gold (Au), and feldspar, for example, have consistently low *C* values. It is perhaps not surprising that most of these are the metals that are principally produced as the main product and not byproducts and have been in use for millennia. In contrast, minerals such as germanium (Ge), the rare earths (Y, La-Lu), ruthenium (Ru), rhodium (Rh), antimony (Sb), and ferromolybdenum, have among the highest *C* indicator values.

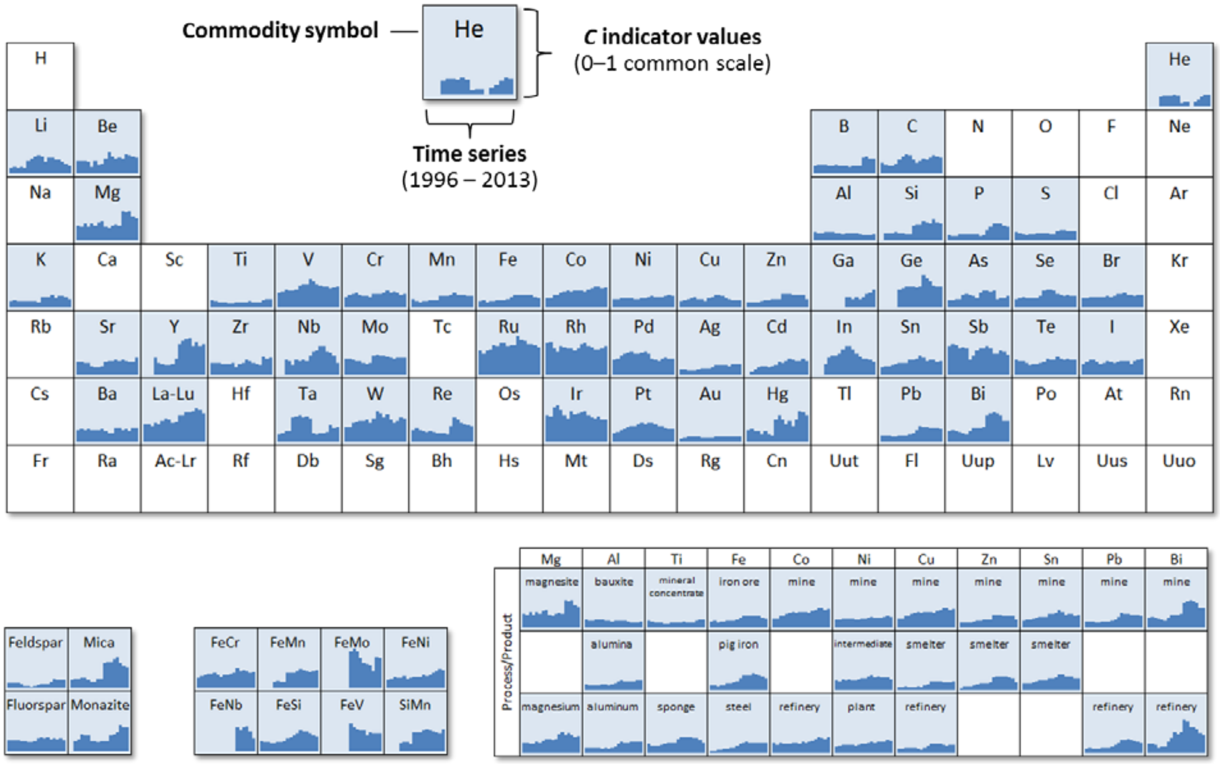
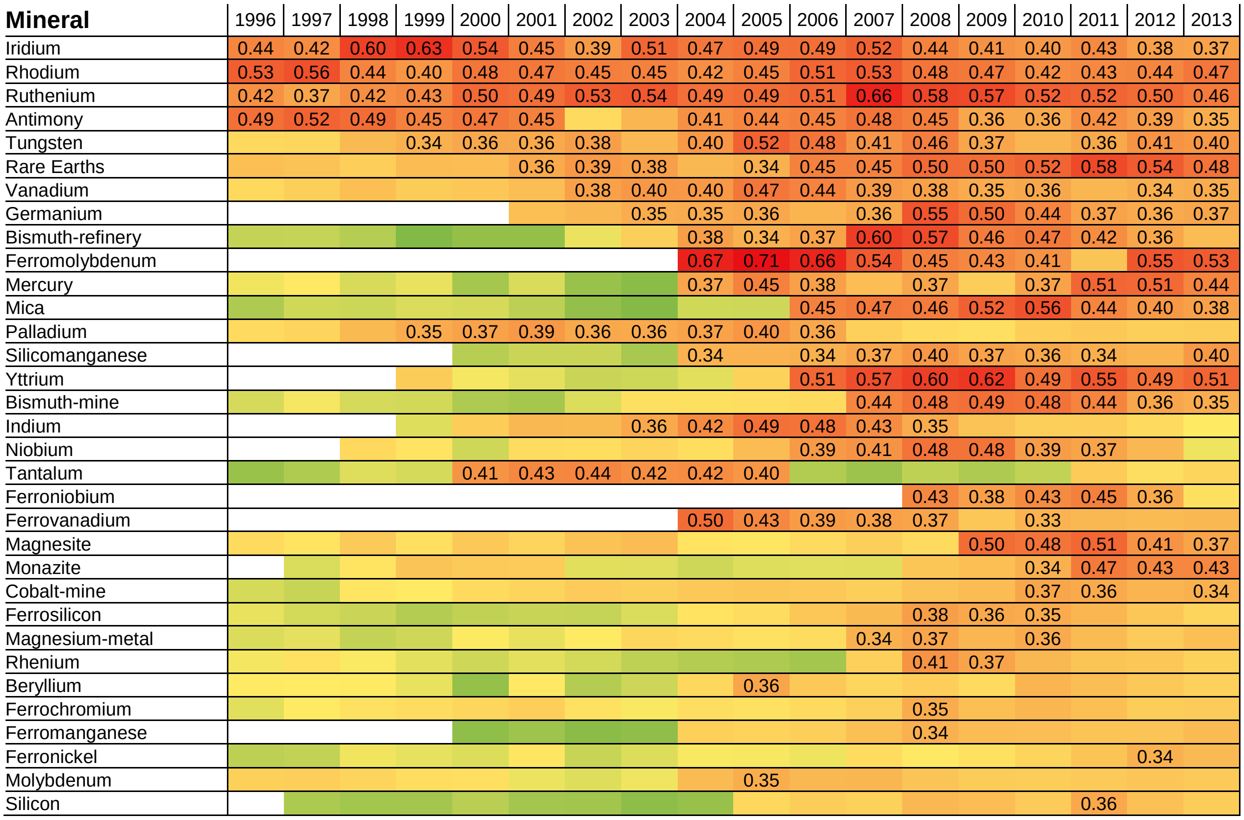


Figure 15. Potential Criticality (C) indicator values for all minerals and years investigated

A hierarchical cluster analysis was conducted to help determine which specific subset of minerals should be identified as potentially critical (Figure 5). The analysis was conducted on the *C* indicator using Ward's method[40] and the Euclidean distance across all minerals and all years to yield two clusters: one for those that would be considered potentially critical minerals and one for all others. The results from the cluster analysis suggest that a *C* indicator value of approximately 0.335 is the cut-off point between these two clusters. For year 2013, there are 17 minerals that have *C* indicator values greater than 0.335. They are (in descending order of potential criticality): ferromolybdenum (FeMo), yttrium (Y) and the rare earths (La-Lu), rhodium (Rh), ruthenium (Ru), mercury (Hg), monazite, tungsten (W), silicomanganese (SiMn), mica, iridium (Ir), magnesite, germanium (Ge), vanadium (V), bismuth mine production (Bi), antimony (Sb), and cobalt mine production (Co). This list includes some usual suspects: the rare earths and several platinum-group metals. It also includes some unexpected resources such as mercury. It is important to reiterate that inclusion on this list does not necessarily suggest that a mineral is indeed critical or represents a significant supply risk and that the in-depth analysis will help make that determination.

Other minerals that would have also been considered potentially critical if the same threshold of 0.335 was maintained for previous years include indium, tantalum, niobium, rhenium, and beryllium. The minerals that would have been included by year of analysis are noted in Table 1 in descending order of the number of times they would have been included. In general, this analysis suggests that there are only a few minerals that repeatedly appear on the list: the platinum-group metals, the rare earths, antimony, tungsten, vanadium, and germanium, all of which are on the most current list. Importantly, the selection of a somewhat different threshold is not likely to significantly alter this core list of potentially critical minerals.

Table 1. Potentially critical minerals based on a threshold C indicator value of 0.335 during at least one year. Cells are colored based on their C indicator value from low (green) to high (red). Non-colored cells indicate no result was available for that year. Only values above the threshold value of 0.335 are noted. Minerals are listed in descending order of the number of years in which values exceed 0.335, and then alphabetically.



Mineral	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Iridium	0.44	0.42	0.60	0.63	0.54	0.45	0.39	0.51	0.47	0.49	0.49	0.52	0.44	0.41	0.40	0.43	0.38	0.37
Rhodium	0.53	0.56	0.44	0.40	0.48	0.47	0.45	0.45	0.42	0.45	0.51	0.53	0.48	0.47	0.42	0.43	0.44	0.47
Ruthenium	0.42	0.37	0.42	0.43	0.50	0.49	0.53	0.54	0.49	0.49	0.51	0.66	0.58	0.57	0.52	0.52	0.50	0.46
Antimony	0.49	0.52	0.49	0.45	0.47	0.45			0.41	0.44	0.45	0.48	0.45	0.36	0.36	0.42	0.39	0.35
Tungsten				0.34	0.36	0.36	0.38		0.40	0.52	0.48	0.41	0.46	0.37		0.36	0.41	0.40
Rare Earths						0.36	0.39	0.38		0.34	0.45	0.45	0.50	0.50	0.52	0.58	0.54	0.48
Vanadium							0.38	0.40	0.40	0.47	0.44	0.39	0.38	0.35	0.36		0.34	0.35
Germanium								0.35	0.35	0.36		0.36	0.55	0.50	0.44	0.37	0.36	0.37
Bismuth-refinery									0.38	0.34	0.37	0.60	0.57	0.46	0.47	0.42	0.36	
Ferromolybdenum									0.67	0.71	0.66	0.54	0.45	0.43	0.41		0.55	0.53
Mercury									0.37	0.45	0.38		0.37		0.37	0.51	0.51	0.44
Mica											0.45	0.47	0.46	0.52	0.56	0.44	0.40	0.38
Palladium				0.35	0.37	0.39	0.36	0.36	0.37	0.40	0.36							
Silicomanganese									0.34		0.34	0.37	0.40	0.37	0.36	0.34		0.40
Yttrium											0.51	0.57	0.60	0.62	0.49	0.55	0.49	0.51
Bismuth-mine												0.44	0.48	0.49	0.48	0.44	0.36	0.35
Indium								0.36	0.42	0.49	0.48	0.43	0.35					
Niobium											0.39	0.41	0.48	0.48	0.39	0.37		
Tantalum					0.41	0.43	0.44	0.42	0.42	0.40								
Ferroniobium													0.43	0.38	0.43	0.45	0.36	
Ferrovanadium									0.50	0.43	0.39	0.38	0.37		0.33			
Magnesite														0.50	0.48	0.51	0.41	0.37
Monazite															0.34	0.47	0.43	0.43
Cobalt-mine															0.37	0.36		0.34
Ferrosilicon													0.38	0.36	0.35			
Magnesium-metal												0.34	0.37		0.36			
Rhenium													0.41	0.37				
Beryllium										0.36								
Ferrochromium													0.35					
Ferromanganese													0.34					
Ferronickel																	0.34	
Molybdenum										0.35								
Silicon																0.36		

In order to provide some validation of this model and its results, a retrospective analysis was conducted to determine whether or not one could have detected a problem with the rare earths supply prior to 2010 when China significantly decreased its rare earths export quota. As illustrated in Figure 16, rare earth oxide mine production has changed notably from being moderately diversified in the early 1990s to being dominated by China since the early 2000s. Production had not only become more concentrated but had also increased significantly during that same time period, reflecting the increased use of rare earths in modern technology. With increasing demand and highly concentrated production, China's lowering of its rare earth export quotas in 2010 caused concerns of shortages and, in turn, caused prices to increase dramatically. These dynamics are captured by the *R*, *G*, *M*, and *C* indicators (Figure 17). Reviewing Figure 17 alone does not, however, provide insights as to whether or not one would have detected a problem. Context, in terms of the identified threshold value of 0.335 (which roughly corresponds to the 82nd percentile of all *C* indicator values), must be provided. This is done for the *C* indicator values for the rare earths, bismuth, and cobalt in Figure 18.

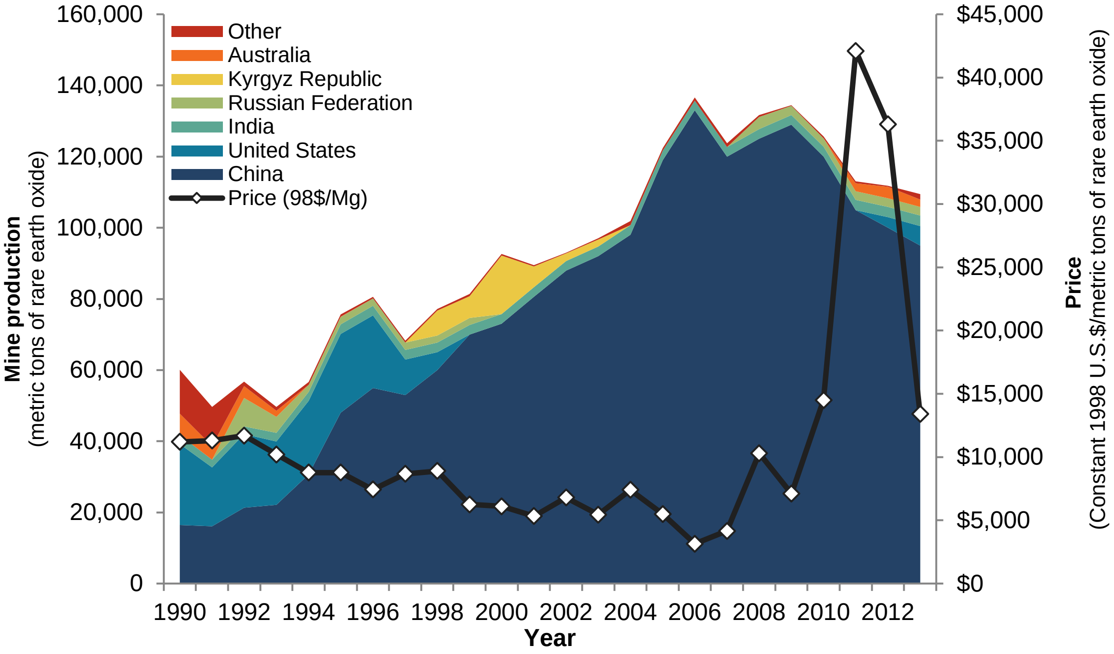


Figure 16. Mine production and price data for rare earth oxides for years 1990-2013. Price data based on weighted-average value of imports and exports of rare earths in the United States displayed in constant 1998 U.S. dollars. Data sources: U.S. Geological Survey[4] and Kelly & Matos.[39]

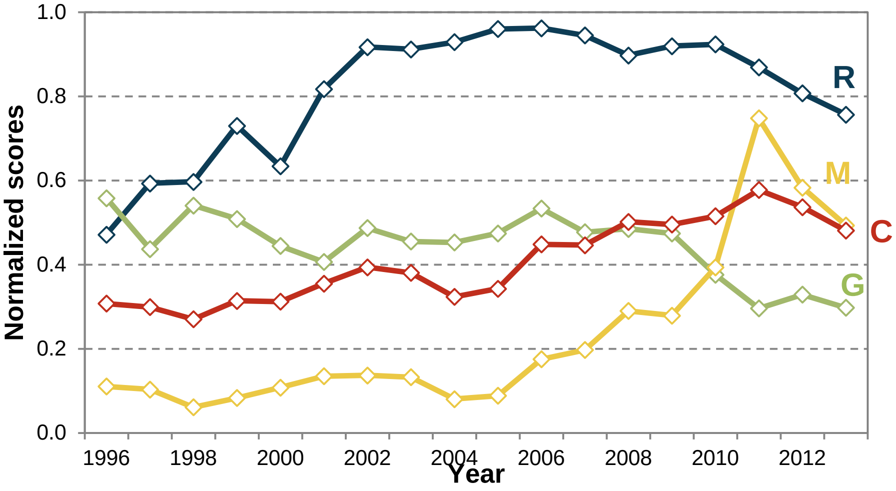


Figure 17. R, G, M, and C indicator values for rare earths for years 1996-2013.

Using the threshold value of 0.335, the methodology would have flagged the rare earths as potentially critical minerals as early as 2001[i]. Similarly, bismuth would have been so identified as early as 2007 and cobalt would have been first listed in 2010.

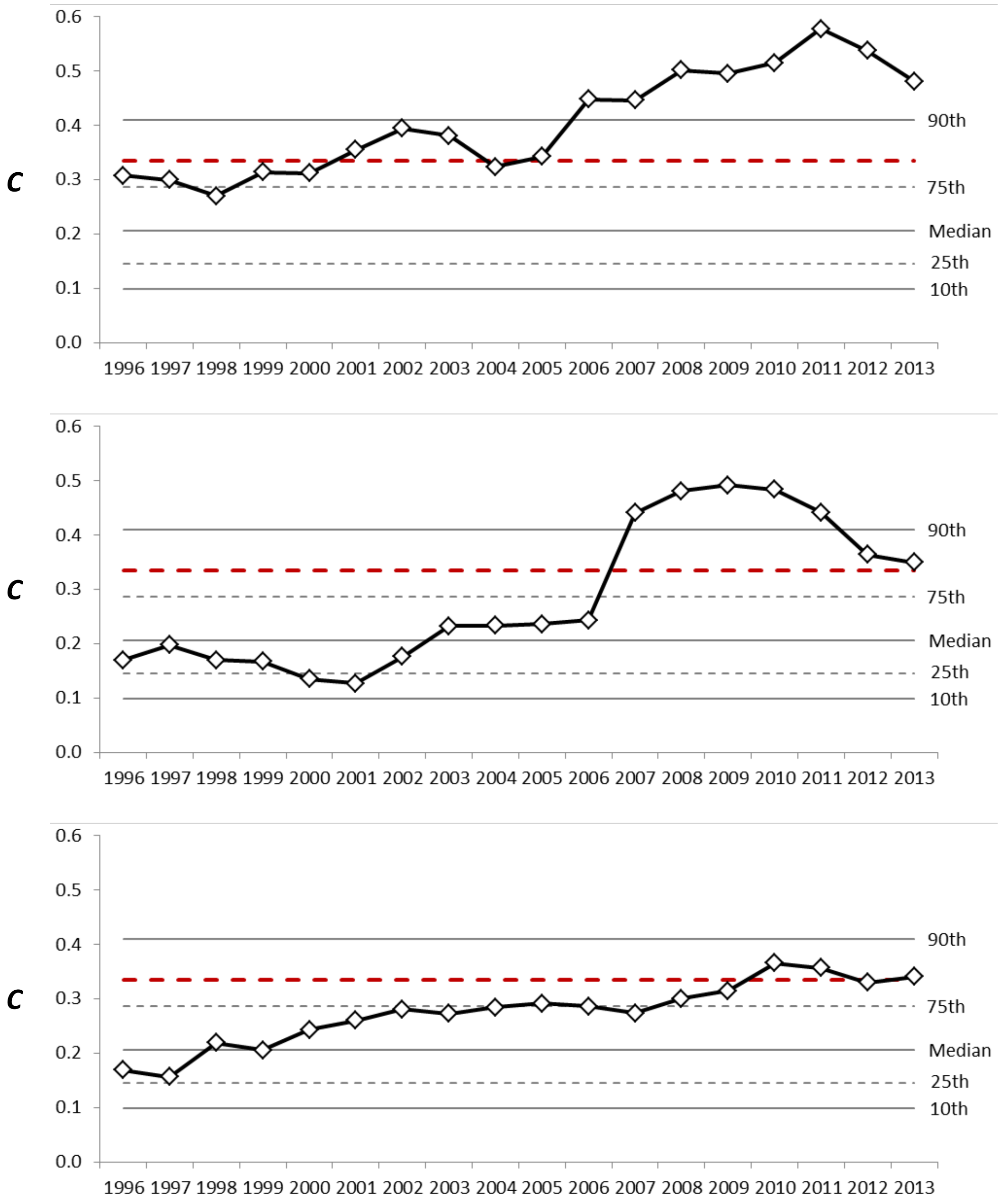


Figure 18. Potential Criticality (C) indicator values for rare earths (top), bismuth (middle), and cobalt (bottom) for 1996-2013. A threshold for identifying a mineral as potentially critical is displayed as the dashed redline at a value of 0.335 (82.5 percentile). For reference, the 10th, 25th, 50th (median), 75th, and 90th percentiles are also displayed.

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[i] Because mineral production and price data are typically delayed by a year or two, the actual year in which the rare earths would have been considered potentially critical minerals would have been delayed as well. Furthermore, the threshold value identified via the cluster analysis may have been somewhat different from the one currently selected because it would have been based only on the *C* indicator values available at the time.

4.0 Conclusions

A methodology for screening for potentially critical minerals has been developed and applied across 78 different mineral resources for years 1996-2013. The results suggest that there is a small subset of minerals including the platinum-group metals, the rare earths, antimony, vanadium, tungsten, and germanium that consistently fall into this category. This set of potentially critical minerals will be examined further in the second stage of the assessment (in-depth analyses) to ensure that the underlying factors contributing to this designation are fully understood. A determination can then be made as to which of these minerals should be deemed critical and may constitute a significant risk to U.S. interests.

It is important to note that, by design, the methodology developed for the early-warning screening is inherently focused on medium-term issues and will not “detect” short-term concerns, especially given the time delays in the production and price data, nor will it provide information regarding the long-term (>10 years) reliability of supplies for these minerals. Moreover, it may be argued that it is inherently problematic to utilize historical data to provide information regarding future events. While it is true that the future need not look like the past, it is also important to recognize that there are structural factors that can place a mineral at greater risk of a supply restriction. Capturing trends in these structural factors is the main objective of the early-warning screening which, as illustrated through the case study of the rare earths, has been shown to be capable of identifying potentially critical minerals prior to the onset of supply restrictions or other events.

Although the hierarchical cluster analysis utilized in this initial screening provides a reasonable threshold value for designating a mineral as potentially critical, it will be important to periodically validate this capability and examine alternative techniques that may be more effective at establishing said threshold. In addition to determining whether or not a mineral’s indicator of potential criticality (C) has exceeded a certain threshold it may be important to also examine trends in the value of C itself. The cobalt situation provides a prime example: cobalt’s indicator of potential criticality did not exceed the current threshold until 2010, yet the values have been trending higher since the mid-1990s. If captured, such trends may provide an enhanced means of early detection.

No methodology can, of course, perfectly screen for critical minerals. Indeed, the methodology described here (or any methodology) may be prone to mischaracterizations, both false-positives and false-negatives, regardless of the threshold limit used. The utilization of the two-stage approach will help reduce some of these issues and the proposed methodology in the first stage will be reviewed and refined as necessary to be better able to identify potentially critical minerals appropriately.

For minerals ultimately identified as critical, it is fair to wonder what can be done to decrease the associated risks and vulnerabilities. As illustrated by Ku and Hung,[41] there is a hierarchy of strategies that can be adopted to help reduce mineral supply risks. These strategies range from short-term efforts aimed at developing strategic inventories and implementing fixed-price contracts, to medium-term efforts such as improving efficiencies by reducing waste and increasing recovery rates throughout the life cycle, to longer-term efforts that include material redesign and elemental and system-level substitution. Where these efforts are best targeted can be informed by the subsequent in-depth analyses.

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Appendix A: Legislative language excerpts

Reporting on the work of the Critical and Strategic Mineral Supply Chains Subcommittee of NSTC, and in particular on activities regarding Rare Earth materials, was requested on two occasions in House of Representatives report language accompanying appropriations bills for Commerce, Justice, Science, and Related Agencies, as provided here:

H.R. Rep. No. 113-171, at 60 (appropriations for 2014):

Rare Earth materials.—The Committee understands that the NSTC Subcommittee on Critical and Strategic Mineral Supply Chains (CSMSC), which maintains a consolidated list of rare critical elements and minerals, is preparing a new effort to reassess and update the criticality of those materials based, in part, on in-depth supply chain studies. The Committee supports this work and directs OSTP to report on the results of the assessment no later than 90 days after its completion. The Committee also urges the CSMSC Subcommittee to leverage the results of its assessment into an interagency plan that will encourage domestic critical element and mineral production in order to reduce the dependence of the U.S. government and industry on foreign sources of such materials.

H.R. Rep. No. 113-148, at 67 (appropriations for 2015):

Rare Earth materials.—The Committee anticipates the submission by OSTP of a report requested for fiscal year 2014 on the work of the National Science and Technology Council's Subcommittee on Critical and Strategic Mineral Supply Chains (CSMSC). The Committee continues to urge the CSMSC Subcommittee to leverage its work into an interagency plan to encourage domestic critical element and mineral production in order to reduce the dependence of the U.S. government and industry on foreign sources of such materials.

Appendix B: March 25, 2015 OSTP letter to Members of Congress

See following pages.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20502

March 25, 2015

Dear Members of Congress:

Thank you for your continuing interest in the topic of critical materials.[1] Rapid technological progress in materials-intensive fields and industries such as clean energy, transportation, medicine, and consumer electronics and changing global patterns in consumption, production, and trade put a new group of raw materials at risk for potential vulnerabilities in supply chains. A mineral is considered critical if it serves an essential function in the manufacture of a product, the absence of which would cause significant economic or social consequence, and if its supply chain is vulnerable to disruption; strategic minerals are a subset of critical minerals and are essential for national-security applications. As both the criticality and U.S. dependency on materials shifts over time, studying early warning signs and underlying forces of material-supply disruption can inform policy development around the emerging critical materials that power economic growth and prosperity. In 2010, the Administration established the National Science and Technology Council Subcommittee on Critical and Strategic Minerals Supply Chains (CSMSC), which is responsible for coordinating critical-materials policy development across twelve Federal agencies and recommending risk-mitigation actions as needed.

Since its inception, the CSMSC has taken a number of proactive steps to mitigate the risks associated with critical and strategic minerals, including: assisting in the formation of the Department of Energy's $120 million Critical Materials Institute to research technologies that make better use of materials;[2] improving the level of our understanding of U.S. rare earths trade by initiating a U.S. International Trade Commission tariff code modification to the Harmonized Tariff Schedule;[3] and facilitating interagency analytic support to the Office of the U.S. Trade Representative, contributing to the success of a World Trade Organization dispute-settlement case filed by the United States, Japan, and the European Union addressing China's trade-distorting export restrictions on metals and minerals, including rare earths.[4]

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[1] H.R. Rep. No. 113-171, at 60 (2013); H.R. Rep. No. 113-448, at 67 (2014)

[2] http://energy.gov/eere/amo/critical-materials-hub

[3] http://hts.usitc.gov/

[4] https://ustr.gov/about-us/policy-offices/press-office/press-releases/2014/March/US-wins-victory-in-rare-earths-dispute-with-China

To enhance policymakers' ability to support stable and flexible future supply chains for key emerging technologies and provide early awareness about potentially critical materials, the CSMSC began developing, in early 2013, an approach to assess material criticality; and late that year it settled on a methodology for identifying critical materials and monitoring changes in criticality. The assessment process was initiated in 2014 and is in progress. In support of this activity, the CSMSC issued a request for information from the public in July 2014 to solicit feedback from industry, academia, research laboratories, government agencies, and other stakeholders on issues related to supply and demand, supply-chain structure, R&D, and technology transitions related to raw materials used in the U.S. economy. The CSMSC intends to deliver a report on the methodology for and initial findings of the materials assessment by the end of calendar year 2015.

Sincerely,

John P. Holdren

John P. Holdren
Assistant to the President for Science and Technology
Director, Office of Science and Technology Policy

Appendix C: Abbreviations, acronyms, and symbols

3TG	Tantalum, tin, tungsten, and gold
C	Indicator of Potential Criticality
CENRS	Committee on Environment, Natural Resources, and Sustainability
GDP	Gross domestic product
HHI	Herfindahl-Hirschman Index
G	Production Growth indicator
M	Market Dynamics indicator
NMIC	National Minerals Information Center
NRC	U.S. National Research Council
NSTC	National Science and Technology Council
OSTP	Office of Science and Technology Policy
R	Supply Risk indicator
SMPB	Strategic Materials Protection Board
STEM	Science, Technology, Engineering, and Mathematics
USGS	U.S. Geological Survey
WGI	Worldwide Governance Indicators

Appendix D: Composite Governance Index values

The following table provides the Composite Governance Index values for over 200 countries and territories across all years of investigation (1996–2013). As described in the methodology, these values are based on the geometric average of the six WGI indictors after normalization on a common 0 to 1 scale. The resultant composite scores thus also spans from a theoretical minimum of 0 to a theoretical maximum of 1, with higher values indicating lower governance. The chart is color coded from green (low) to red (high) accordingly.

No data are provided for years 1997, 1999, and 2001. Values for these years are linearly interpolated based on the values of immediately adjacent years and are displayed in italics text in the table. For other years for which no data are provided for certain countries, the value for the nearest year is utilized. These values are also displayed in italics text in the table. Mineral-producing countries for which no WGI values are available for any year (e.g., New Caledonia) are given a default median score of 0.5 across for all years. Values are left blank for countries that did not exist in certain years (e.g., South Sudan pre-2010).

Table 2. Composite Governance Index values for years 1996-2013

Country/Territory	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Afghanistan	0.79	*0.80*	0.80	*0.80*	0.80	*0.78*	0.75	0.72	0.71	0.72	0.74	0.74	0.75	0.75	0.75	0.75	0.72	0.72
Albania	0.60	*0.60*	0.60	*0.60*	0.60	*0.58*	0.57	0.57	0.56	0.57	0.56	0.54	0.53	0.52	0.52	0.53	0.54	0.53
Algeria	0.65	*0.66*	0.66	*0.66*	0.65	*0.64*	0.63	0.62	0.60	0.59	0.60	0.61	0.61	0.62	0.62	0.63	0.63	0.62
American Samoa	*0.42*	*0.42*	*0.42*	*0.42*	*0.42*	*0.42*	*0.42*	*0.42*	0.42	0.40	0.42	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Andorra	0.31	*0.31*	0.31	*0.31*	0.31	*0.31*	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30
Angola	0.71	*0.72*	0.73	*0.74*	0.74	*0.72*	0.70	0.68	0.68	0.67	0.66	0.66	0.65	0.64	0.64	0.65	0.64	0.65
Anguilla	*0.37*	*0.37*	*0.37*	*0.37*	*0.37*	*0.37*	*0.37*	*0.37*	0.37	0.32	0.31	0.31	0.31	0.32	0.31	0.30	0.31	0.30
Antigua and Barbuda	0.40	*0.40*	0.40	*0.40*	0.40	*0.40*	0.40	0.40	0.39	0.41	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Argentina	0.47	*0.48*	0.48	*0.49*	0.50	*0.54*	0.57	0.55	0.55	0.53	0.53	0.53	0.54	0.55	0.54	0.53	0.55	0.55
Armenia	0.57	*0.57*	0.57	*0.57*	0.57	*0.56*	0.55	0.53	0.54	0.54	0.55	0.54	0.54	0.53	0.54	0.54	0.52	0.52
Aruba	*0.36*	*0.36*	*0.36*	*0.36*	*0.36*	*0.36*	*0.36*	*0.36*	0.36	0.34	0.34	0.34	0.34	0.32	0.32	0.32	0.32	0.32
Australia	0.28	*0.28*	0.28	*0.27*	0.27	*0.27*	0.28	0.27	0.25	0.27	0.27	0.27	0.26	0.27	0.27	0.26	0.27	0.27
Austria	0.26	*0.26*	0.27	*0.27*	0.27	*0.26*	0.26	0.26	0.26	0.27	0.26	0.25	0.26	0.28	0.28	0.29	0.28	0.28
Azerbaijan	0.65	*0.65*	0.64	*0.64*	0.64	*0.64*	0.64	0.62	0.63	0.62	0.62	0.61	0.61	0.60	0.61	0.61	0.62	0.60
Bahamas, The	0.34	*0.34*	0.33	*0.33*	0.32	*0.32*	0.32	0.33	0.33	0.34	0.34	0.34	0.34	0.36	0.36	0.37	0.37	0.38
Bahrain	0.49	*0.49*	0.49	*0.48*	0.47	*0.46*	0.44	0.45	0.44	0.46	0.48	0.47	0.47	0.47	0.48	0.50	0.50	0.50
Bangladesh	0.60	*0.59*	0.58	*0.59*	0.60	*0.62*	0.63	0.64	0.65	0.66	0.64	0.63	0.63	0.62	0.62	0.62	0.63	0.63
Barbados	0.32	*0.32*	0.32	*0.31*	0.31	*0.32*	0.32	0.33	0.33	0.33	0.34	0.33	0.33	0.34	0.34	0.32	0.33	0.33
Belarus	0.60	*0.60*	0.61	*0.61*	0.62	*0.63*	0.63	0.61	0.64	0.64	0.64	0.63	0.61	0.61	0.63	0.64	0.62	0.62
Belgium	0.30	*0.31*	0.31	*0.31*	0.30	*0.30*	0.29	0.30	0.30	0.31	0.31	0.31	0.32	0.31	0.31	0.30	0.31	0.30
Belize	0.46	*0.46*	0.47	*0.47*	0.48	*0.48*	0.48	0.47	0.49	0.49	0.52	0.52	0.51	0.51	0.51	0.52	0.50	0.50
Benin	0.51	*0.50*	0.50	*0.50*	0.50	*0.51*	0.52	0.52	0.54	0.55	0.53	0.53	0.53	0.53	0.54	0.54	0.55	0.55
Bermuda	0.33	*0.33*	0.33	*0.33*	0.34	*0.34*	0.34	0.34	0.34	0.35	0.35	0.35	0.35	0.35	0.34	0.34	0.34	0.34
Bhutan	0.48	*0.48*	0.48	*0.48*	0.48	*0.48*	0.48	0.47	0.48	0.46	0.47	0.48	0.48	0.47	0.47	0.47	0.47	0.47
Bolivia	0.53	*0.52*	0.51	*0.52*	0.53	*0.54*	0.55	0.56	0.57	0.59	0.58	0.58	0.59	0.59	0.58	0.58	0.58	0.58
Bosnia and Herzegovina	0.58	*0.58*	0.58	*0.58*	0.58	*0.57*	0.57	0.56	0.53	0.55	0.55	0.56	0.55	0.55	0.55	0.56	0.54	0.53
Botswana	0.40	*0.40*	0.40	*0.40*	0.41	*0.41*	0.41	0.37	0.39	0.39	0.41	0.40	0.40	0.41	0.40	0.40	0.40	0.40
Brazil	0.51	*0.50*	0.50	*0.50*	0.49	*0.49*	0.48	0.48	0.50	0.51	0.51	0.51	0.50	0.49	0.48	0.49	0.49	0.50
Brunei Darussalam	0.39	*0.40*	0.42	*0.42*	0.42	*0.42*	0.42	0.43	0.42	0.43	0.43	0.42	0.42	0.38	0.39	0.39	0.40	0.40
Bulgaria	0.53	*0.51*	0.49	*0.49*	0.49	*0.48*	0.47	0.47	0.47	0.46	0.47	0.47	0.47	0.46	0.47	0.47	0.47	0.48
Burkina Faso	0.57	*0.57*	0.57	*0.56*	0.54	*0.55*	0.56	0.54	0.55	0.55	0.55	0.54	0.54	0.54	0.54	0.56	0.56	0.57
Burundi	0.75	*0.74*	0.73	*0.72*	0.71	*0.71*	0.70	0.71	0.71	0.66	0.65	0.66	0.66	0.65	0.67	0.67	0.68	0.66
Cambodia	0.62	*0.63*	0.63	*0.62*	0.61	*0.61*	0.61	0.62	0.62	0.62	0.62	0.61	0.62	0.62	0.62	0.62	0.60	0.60
Cameroon	0.66	*0.65*	0.63	*0.63*	0.62	*0.63*	0.64	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.63	0.63	0.64	0.63
Canada	0.26	*0.26*	0.26	*0.26*	0.26	*0.26*	0.26	0.26	0.27	0.27	0.27	0.27	0.27	0.26	0.26	0.27	0.27	0.27
Cape Verde	*0.44*	*0.44*	0.44	*0.43*	0.43	*0.44*	0.46	0.46	0.45	0.46	0.43	0.42	0.42	0.42	0.43	0.42	0.42	0.43
Cayman Islands	0.30	*0.30*	0.30	*0.30*	0.30	*0.30*	0.30	0.33	0.33	0.34	0.33	0.33	0.35	0.35	0.35	0.34	0.35	0.35

Country/Territory	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Central African Republic	0.68	*0.67*	0.66	*0.66*	0.66	*0.68*	0.69	0.70	0.70	0.69	0.69	0.69	0.69	0.68	0.68	0.68	0.69	0.72
Chad	0.65	*0.65*	0.64	*0.64*	0.63	*0.64*	0.65	0.67	0.67	0.69	0.70	0.71	0.72	0.70	0.69	0.68	0.68	0.68
Chile	0.34	*0.35*	0.36	*0.35*	0.34	*0.33*	0.32	0.33	0.33	0.32	0.33	0.34	0.34	0.33	0.32	0.33	0.33	0.33
China	0.56	*0.56*	0.56	*0.56*	0.56	*0.57*	0.58	0.58	0.57	0.58	0.58	0.57	0.57	0.57	0.57	0.57	0.58	0.57
Colombia	0.58	*0.58*	0.58	*0.58*	0.58	*0.58*	0.59	0.59	0.57	0.57	0.56	0.55	0.55	0.56	0.55	0.53	0.54	0.54
Comoros	0.61	*0.62*	0.62	*0.64*	0.65	*0.62*	0.59	0.64	0.63	0.64	0.62	0.65	0.65	0.65	0.64	0.63	0.63	0.62
Congo, Dem. Rep.	0.78	*0.80*	0.82	*0.80*	0.78	*0.76*	0.74	0.74	0.74	0.74	0.73	0.72	0.72	0.73	0.74	0.74	0.73	0.72
Congo, Rep.	0.67	*0.69*	0.70	*0.69*	0.68	*0.67*	0.67	0.65	0.65	0.67	0.67	0.66	0.66	0.65	0.65	0.65	0.65	0.65
Cook Islands	*0.54*	*0.54*	*0.54*	*0.54*	*0.54*	*0.54*	*0.54*	*0.54*	*0.54*	*0.54*	*0.54*	*0.54*	*0.54*	0.54	0.53	*0.53*	*0.53*	*0.53*
Costa Rica	0.41	*0.40*	0.39	*0.40*	0.40	*0.40*	0.40	0.41	0.42	0.42	0.43	0.43	0.43	0.41	0.41	0.42	0.41	0.41
Côte D'ivoire	0.54	*0.55*	0.56	*0.60*	0.64	*0.65*	0.66	0.67	0.70	0.70	0.69	0.68	0.68	0.66	0.67	0.66	0.64	0.63
Croatia	0.54	*0.54*	0.53	*0.51*	0.48	*0.47*	0.46	0.45	0.44	0.45	0.45	0.45	0.45	0.45	0.44	0.44	0.44	0.44
Cuba	0.58	*0.58*	0.58	*0.58*	0.57	*0.58*	0.58	0.59	0.59	0.59	0.58	0.58	0.57	0.57	0.57	0.57	0.57	0.58
Cyprus	0.34	*0.35*	0.36	*0.36*	0.36	*0.36*	0.35	0.36	0.37	0.36	0.35	0.34	0.33	0.34	0.34	0.35	0.35	0.36
Czech Republic	0.38	*0.38*	0.39	*0.41*	0.43	*0.40*	0.37	0.38	0.39	0.38	0.37	0.38	0.37	0.37	0.37	0.37	0.37	0.37
Denmark	0.24	*0.24*	0.24	*0.23*	0.23	*0.23*	0.23	0.23	0.22	0.23	0.22	0.22	0.22	0.23	0.23	0.23	0.24	0.24
Djibouti	0.61	*0.62*	0.64	*0.63*	0.62	*0.61*	0.60	0.61	0.59	0.62	0.60	0.59	0.57	0.57	0.58	0.59	0.59	0.60
Dominica	0.38	*0.40*	0.42	*0.42*	0.42	*0.41*	0.41	0.40	0.40	0.40	0.39	0.39	0.39	0.40	0.39	0.39	0.40	0.39
Dominican Republic	0.53	*0.55*	0.56	*0.55*	0.54	*0.53*	0.53	0.56	0.56	0.56	0.54	0.55	0.55	0.55	0.56	0.55	0.54	0.54
Ecuador	0.58	*0.57*	0.56	*0.58*	0.60	*0.60*	0.60	0.60	0.60	0.61	0.62	0.62	0.62	0.62	0.61	0.61	0.60	0.58
Egypt, Arab Rep.	0.54	*0.54*	0.54	*0.54*	0.54	*0.55*	0.56	0.57	0.57	0.57	0.59	0.58	0.57	0.56	0.57	0.60	0.61	0.63
El Salvador	0.57	*0.55*	0.54	*0.54*	0.53	*0.53*	0.53	0.53	0.52	0.53	0.52	0.52	0.52	0.51	0.51	0.51	0.52	0.52
Equatorial Guinea	0.66	*0.67*	0.68	*0.68*	0.68	*0.68*	0.68	0.67	0.68	0.69	0.67	0.67	0.67	0.66	0.67	0.67	0.67	0.68
Eritrea	0.60	*0.58*	0.56	*0.58*	0.59	*0.60*	0.60	0.63	0.64	0.65	0.68	0.69	0.68	0.69	0.69	0.70	0.70	0.71
Estonia	0.40	*0.40*	0.39	*0.39*	0.38	*0.37*	0.37	0.36	0.36	0.36	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.34
Ethiopia	0.66	*0.64*	0.63	*0.63*	0.63	*0.64*	0.65	0.64	0.63	0.65	0.63	0.63	0.63	0.64	0.63	0.63	0.63	0.63
Fiji	0.47	*0.48*	0.48	*0.51*	0.54	*0.52*	0.50	0.51	0.52	0.51	0.53	0.55	0.57	0.60	0.60	0.58	0.59	0.58
Finland	0.25	*0.24*	0.23	*0.22*	0.21	*0.22*	0.22	0.21	0.21	0.22	0.22	0.23	0.23	0.23	0.23	0.23	0.23	0.23
France	0.33	*0.33*	0.33	*0.33*	0.32	*0.33*	0.33	0.33	0.31	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.33	0.33
French Guiana	0.40	*0.40*	0.40	*0.40*	0.40	*0.40*	0.40	0.40	0.43	0.41	0.41	0.42	0.41	0.35	0.35	0.35	0.35	0.35
Gabon	0.55	*0.55*	0.54	*0.54*	0.53	*0.53*	0.53	0.54	0.57	0.56	0.59	0.59	0.59	0.59	0.57	0.57	0.57	0.57
Gambia, The	0.56	*0.55*	0.54	*0.54*	0.54	*0.54*	0.54	0.53	0.55	0.57	0.57	0.56	0.57	0.57	0.57	0.57	0.57	0.59
Georgia	0.65	*0.64*	0.63	*0.62*	0.60	*0.62*	0.64	0.60	0.58	0.57	0.54	0.52	0.52	0.52	0.50	0.49	0.48	0.47
Germany	0.27	*0.27*	0.27	*0.27*	0.27	*0.27*	0.27	0.29	0.29	0.29	0.28	0.28	0.29	0.29	0.29	0.29	0.29	0.29
Ghana	0.54	*0.54*	0.54	*0.53*	0.51	*0.52*	0.53	0.51	0.52	0.51	0.49	0.49	0.49	0.49	0.48	0.48	0.49	0.49
Greece	0.40	*0.39*	0.38	*0.38*	0.39	*0.39*	0.39	0.39	0.39	0.40	0.40	0.40	0.41	0.43	0.44	0.45	0.46	0.45
Greenland	*0.31*	*0.31*	*0.31*	*0.31*	*0.31*	*0.31*	*0.31*	*0.31*	*0.31*	*0.31*	*0.31*	*0.31*	*0.31*	0.31	0.30	0.29	0.30	0.30
Grenada	0.41	*0.42*	0.42	*0.42*	0.42	*0.42*	0.42	0.42	0.43	0.44	0.44	0.44	0.44	0.45	0.44	0.45	0.44	0.44
Guam	*0.41*	*0.41*	*0.41*	*0.41*	*0.41*	*0.41*	*0.41*	*0.41*	0.41	0.40	0.40	0.40	0.39	0.40	0.41	0.40	0.40	0.40
Guatemala	0.59	*0.59*	0.58	*0.58*	0.58	*0.58*	0.58	0.59	0.58	0.59	0.58	0.58	0.58	0.58	0.58	0.58	0.59	0.59
Guinea	0.65	*0.64*	0.62	*0.64*	0.66	*0.65*	0.65	0.63	0.65	0.66	0.69	0.71	0.70	0.69	0.68	0.67	0.67	0.67
Guinea-Bissau	0.69	*0.70*	0.71	*0.68*	0.64	*0.64*	0.64	0.64	0.64	0.64	0.63	0.64	0.65	0.65	0.65	0.65	0.68	0.69
Guyana	0.53	*0.52*	0.51	*0.52*	0.53	*0.53*	0.54	0.53	0.55	0.57	0.56	0.55	0.56	0.56	0.55	0.55	0.56	0.56
Haiti	0.66	*0.66*	0.66	*0.66*	0.66	*0.69*	0.72	0.71	0.73	0.71	0.67	0.66	0.66	0.65	0.66	0.67	0.66	0.65
Honduras	0.60	*0.58*	0.56	*0.57*	0.57	*0.58*	0.58	0.58	0.58	0.59	0.59	0.57	0.59	0.58	0.59	0.58	0.59	0.60
Hong Kong SAR, China	0.34	*0.35*	0.35	*0.35*	0.34	*0.33*	0.32	0.29	0.28	0.29	0.28	0.28	0.28	0.29	0.29	0.29	0.29	0.29
Hungary	0.38	*0.37*	0.37	*0.37*	0.37	*0.36*	0.35	0.36	0.37	0.37	0.37	0.38	0.38	0.40	0.40	0.40	0.41	0.41
Iceland	0.29	*0.28*	0.27	*0.25*	0.24	*0.24*	0.24	0.23	0.23	0.24	0.25	0.25	0.25	0.28	0.29	0.29	0.29	0.29
India	0.52	*0.53*	0.53	*0.53*	0.52	*0.53*	0.54	0.54	0.54	0.52	0.52	0.52	0.53	0.53	0.54	0.54	0.55	0.55
Indonesia	0.57	*0.60*	0.63	*0.62*	0.60	*0.61*	0.62	0.63	0.61	0.60	0.59	0.57	0.57	0.57	0.57	0.56	0.55	0.55
Iran, Islamic Rep.	0.61	*0.62*	0.62	*0.62*	0.61	*0.61*	0.61	0.61	0.61	0.62	0.64	0.64	0.65	0.67	0.67	0.66	0.65	0.66
Iraq	0.76	*0.75*	0.74	*0.75*	0.75	*0.75*	0.74	0.73	0.77	0.75	0.75	0.75	0.72	0.70	0.70	0.69	0.69	0.69
Ireland	0.28	*0.28*	0.27	*0.28*	0.28	*0.28*	0.28	0.29	0.29	0.28	0.27	0.27	0.27	0.28	0.29	0.29	0.30	0.30
Israel	0.38	*0.39*	0.39	*0.40*	0.40	*0.40*	0.40	0.41	0.41	0.42	0.40	0.40	0.40	0.41	0.40	0.39	0.40	0.40
Italy	0.38	*0.38*	0.38	*0.38*	0.38	*0.38*	0.39	0.39	0.40	0.41	0.41	0.42	0.42	0.42	0.42	0.43	0.43	0.43
Jamaica	0.49	*0.49*	0.48	*0.49*	0.49	*0.50*	0.51	0.51	0.51	0.51	0.50	0.49	0.50	0.50	0.51	0.49	0.50	0.49
Japan	0.35	*0.35*	0.36	*0.35*	0.34	*0.35*	0.36	0.34	0.33	0.33	0.32	0.33	0.33	0.33	0.32	0.32	0.32	0.31
Jersey, Channel Islands	*0.30*	*0.30*	*0.30*	*0.30*	*0.30*	*0.30*	*0.30*	*0.30*	*0.30*	*0.30*	*0.30*	*0.30*	*0.30*	*0.30*	*0.30*	0.30	0.30	0.30
Jordan	0.50	*0.49*	0.49	*0.49*	0.49	*0.51*	0.52	0.49	0.49	0.49	0.50	0.49	0.49	0.50	0.51	0.51	0.51	0.52
Kazakhstan	0.62	*0.61*	0.59	*0.60*	0.60	*0.60*	0.61	0.59	0.60	0.58	0.58	0.57	0.56	0.55	0.57	0.59	0.59	0.60
Kenya	0.60	*0.61*	0.62	*0.61*	0.61	*0.61*	0.61	0.60	0.59	0.60	0.59	0.60	0.60	0.61	0.59	0.60	0.60	0.59
Kiribati	*0.46*	*0.46*	*0.46*	*0.46*	*0.46*	*0.46*	*0.46*	0.46	0.46	0.46	0.45	0.46	0.47	0.48	0.48	0.48	0.48	0.48
Korea, Dem. Rep.	0.72	*0.72*	0.72	*0.71*	0.70	*0.69*	0.68	0.70	0.69	0.70	0.71	0.70	0.70	0.71	0.72	0.72	0.71	0.73
Korea, Rep.	0.42	*0.43*	0.44	*0.43*	0.42	*0.41*	0.40	0.41	0.40	0.39	0.40	0.38	0.40	0.39	0.39	0.38	0.39	0.39
Kosovo													0.52	0.52	0.58	0.57	0.57	0.57
Kuwait	0.46	*0.47*	0.47	*0.46*	0.46	*0.46*	0.45	0.45	0.45	0.46	0.46	0.46	0.47	0.47	0.47	0.48	0.51	0.51

Country/Territory	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Kyrgyz Republic	0.57	*0.57*	0.56	*0.57*	0.59	*0.59*	0.60	0.62	0.62	0.64	0.64	0.63	0.62	0.63	0.62	0.62	0.61	0.61
Lao PDR	0.59	*0.60*	0.60	*0.62*	0.64	*0.64*	0.65	0.69	0.66	0.67	0.65	0.64	0.63	0.64	0.64	0.63	0.62	0.61
Latvia	0.46	*0.46*	0.45	*0.45*	0.45	*0.44*	0.42	0.40	0.41	0.40	0.40	0.41	0.41	0.41	0.41	0.41	0.40	0.40
Lebanon	0.55	*0.55*	0.55	*0.55*	0.54	*0.55*	0.56	0.56	0.56	0.56	0.60	0.61	0.60	0.59	0.58	0.59	0.60	0.60
Lesotho	0.53	*0.53*	0.53	*0.53*	0.52	*0.52*	0.52	0.52	0.52	0.53	0.53	0.55	0.54	0.52	0.51	0.52	0.52	0.51
Liberia	0.78	*0.77*	0.76	*0.75*	0.74	*0.74*	0.74	0.73	0.72	0.66	0.63	0.62	0.64	0.63	0.61	0.61	0.61	0.61
Libya	0.66	*0.67*	0.67	*0.66*	0.65	*0.65*	0.65	0.63	0.62	0.63	0.64	0.61	0.60	0.61	0.65	0.70	0.69	0.71
Liechtenstein	0.29	*0.29*	0.29	*0.29*	0.29	*0.29*	0.29	0.30	0.30	0.30	0.30	0.30	0.29	0.27	0.26	0.27	0.27	0.27
Lithuania	0.42	*0.43*	0.43	*0.44*	0.44	*0.43*	0.41	0.39	0.39	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.39	0.38
Luxembourg	0.25	*0.25*	0.26	*0.25*	0.24	*0.24*	0.24	0.26	0.25	0.27	0.27	0.26	0.26	0.26	0.25	0.25	0.25	0.25
Macao SAR, China	0.45	*0.45*	0.45	*0.45*	0.44	*0.44*	0.43	0.35	0.33	0.37	0.39	0.42	0.41	0.39	0.38	0.38	0.40	0.40
Macedonia, FYR	0.58	*0.58*	0.57	*0.58*	0.58	*0.58*	0.58	0.56	0.55	0.56	0.54	0.52	0.51	0.51	0.51	0.52	0.51	0.51
Madagascar	0.55	*0.55*	0.56	*0.54*	0.53	*0.53*	0.53	0.50	0.52	0.52	0.53	0.53	0.56	0.59	0.61	0.60	0.61	0.62
Malawi	0.55	*0.54*	0.53	*0.54*	0.55	*0.56*	0.58	0.56	0.56	0.56	0.55	0.55	0.54	0.54	0.54	0.55	0.55	0.56
Malaysia	0.43	*0.44*	0.45	*0.45*	0.45	*0.45*	0.44	0.43	0.43	0.43	0.44	0.44	0.46	0.47	0.45	0.45	0.45	0.44
Maldives	0.42	*0.43*	0.43	*0.44*	0.45	*0.46*	0.46	0.47	0.52	0.48	0.50	0.54	0.55	0.55	0.54	0.55	0.55	0.55
Mali	0.56	*0.55*	0.55	*0.55*	0.55	*0.54*	0.53	0.52	0.52	0.53	0.52	0.53	0.54	0.55	0.56	0.56	0.63	0.61
Malta	0.36	*0.35*	0.35	*0.34*	0.33	*0.33*	0.33	0.32	0.33	0.34	0.33	0.32	0.32	0.33	0.33	0.34	0.33	0.33
Marshall Islands	*0.48*	*0.48*	*0.48*	*0.48*	*0.48*	*0.48*	*0.48*	0.48	0.49	0.48	0.49	0.49	0.48	0.48	0.49	0.49	0.49	0.49
Martinique	0.38	*0.38*	0.38	*0.38*	0.38	*0.38*	0.38	0.38	0.37	0.38	0.38	0.38	0.39	0.39	0.39	0.39	0.39	0.39
Mauritania	0.53	*0.54*	0.54	*0.54*	0.54	*0.53*	0.51	0.53	0.57	0.57	0.57	0.58	0.62	0.61	0.63	0.62	0.62	0.62
Mauritius	0.41	*0.40*	0.39	*0.40*	0.40	*0.40*	0.39	0.39	0.40	0.40	0.40	0.40	0.38	0.39	0.39	0.38	0.38	0.38
Mexico	0.54	*0.53*	0.52	*0.51*	0.50	*0.50*	0.49	0.49	0.50	0.51	0.51	0.52	0.52	0.52	0.52	0.52	0.51	0.52
Micronesia, Fed. Sts.	*0.49*	*0.49*	*0.49*	*0.49*	*0.49*	*0.49*	*0.49*	0.49	0.45	0.43	0.43	0.45	0.46	0.46	0.48	0.48	0.48	0.47
Moldova	0.52	*0.52*	0.52	*0.54*	0.57	*0.57*	0.58	0.58	0.58	0.58	0.57	0.56	0.56	0.56	0.55	0.54	0.54	0.54
Monaco[i]	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*
Mongolia	0.49	*0.49*	0.50	*0.49*	0.49	*0.48*	0.47	0.48	0.50	0.51	0.51	0.52	0.52	0.53	0.53	0.52	0.53	0.52
Montenegro	*0.52*	*0.52*	*0.52*	*0.52*	*0.52*	*0.52*	*0.52*	*0.52*	*0.52*	*0.52*	0.52	0.51	0.48	0.48	0.49	0.48	0.48	0.48
Morocco	0.51	*0.49*	0.48	*0.50*	0.51	*0.52*	0.53	0.54	0.53	0.56	0.55	0.55	0.56	0.54	0.54	0.55	0.54	0.55
Mozambique	0.55	*0.55*	0.55	*0.55*	0.55	*0.55*	0.54	0.55	0.55	0.55	0.54	0.54	0.54	0.53	0.54	0.55	0.55	0.57
Myanmar	0.72	*0.72*	0.72	*0.72*	0.73	*0.73*	0.73	0.73	0.75	0.74	0.74	0.73	0.74	0.75	0.75	0.73	0.70	0.69
Namibia	0.43	*0.44*	0.46	*0.47*	0.47	*0.47*	0.47	0.46	0.47	0.47	0.45	0.45	0.43	0.45	0.45	0.45	0.45	0.45
Nauru	*0.46*	*0.46*	*0.46*	*0.46*	*0.46*	*0.46*	*0.46*	*0.46*	*0.46*	*0.46*	*0.46*	0.46	0.47	0.45	0.45	0.46	0.46	0.48
Nepal	0.53	*0.55*	0.57	*0.57*	0.58	*0.59*	0.60	0.61	0.64	0.64	0.62	0.62	0.62	0.62	0.63	0.62	0.63	0.62
Netherlands	0.24	*0.24*	0.23	*0.23*	0.22	*0.24*	0.25	0.25	0.25	0.26	0.26	0.26	0.26	0.26	0.26	0.25	0.25	0.26
Netherlands Antilles (Former)	*0.39*	*0.39*	*0.39*	*0.39*	*0.39*	*0.39*	*0.39*	*0.39*	0.39	0.37	0.37	0.37	0.37	0.39	0.38	0.38	0.38	0.39
New Caledonia[i]	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*	*0.50*
New Zealand	0.24	*0.24*	0.24	*0.24*	0.25	*0.25*	0.25	0.24	0.23	0.25	0.25	0.25	0.25	0.24	0.24	0.23	0.24	0.24
Nicaragua	0.57	*0.57*	0.56	*0.57*	0.57	*0.57*	0.56	0.56	0.56	0.57	0.58	0.58	0.58	0.59	0.59	0.58	0.59	0.58
Niger	0.65	*0.64*	0.63	*0.61*	0.59	*0.59*	0.59	0.57	0.58	0.58	0.58	0.59	0.59	0.60	0.60	0.58	0.60	0.60
Nigeria	0.67	*0.66*	0.65	*0.65*	0.64	*0.66*	0.68	0.67	0.68	0.66	0.66	0.66	0.65	0.66	0.66	0.66	0.66	0.66
Niue	*0.54*	*0.54*	*0.54*	*0.54*	*0.54*	*0.54*	*0.54*	*0.54*	*0.54*	*0.54*	*0.54*	*0.54*	*0.54*	0.54	0.53	*0.53*	*0.53*	*0.53*
Norway	0.24	*0.24*	0.24	*0.25*	0.25	*0.25*	0.25	0.26	0.25	0.26	0.26	0.26	0.26	0.26	0.25	0.25	0.24	0.24
Oman	0.46	*0.46*	0.45	*0.45*	0.44	*0.44*	0.43	0.44	0.43	0.46	0.47	0.45	0.44	0.45	0.46	0.48	0.47	0.48
Pakistan	0.61	*0.61*	0.61	*0.62*	0.63	*0.63*	0.64	0.63	0.64	0.63	0.62	0.64	0.65	0.65	0.65	0.66	0.66	0.65
Palau	*0.45*	*0.45*	*0.45*	*0.45*	*0.45*	*0.45*	*0.45*	*0.45*	*0.45*	*0.45*	*0.45*	0.45	0.45	0.44	0.45	0.45	0.45	0.46
Panama	0.50	*0.48*	0.46	*0.47*	0.47	*0.48*	0.48	0.49	0.49	0.50	0.49	0.49	0.48	0.48	0.49	0.48	0.49	0.49
Papua New Guinea	0.56	*0.56*	0.57	*0.57*	0.57	*0.58*	0.59	0.60	0.60	0.63	0.61	0.60	0.60	0.60	0.60	0.59	0.59	0.59
Paraguay	0.59	*0.61*	0.62	*0.64*	0.65	*0.64*	0.64	0.63	0.62	0.62	0.61	0.61	0.60	0.60	0.59	0.58	0.59	0.59
Peru	0.54	*0.53*	0.52	*0.54*	0.55	*0.55*	0.55	0.55	0.55	0.56	0.55	0.54	0.54	0.55	0.53	0.52	0.53	0.53
Philippines	0.51	*0.50*	0.49	*0.52*	0.55	*0.54*	0.54	0.56	0.57	0.55	0.57	0.56	0.57	0.57	0.57	0.56	0.55	0.54
Poland	0.40	*0.39*	0.39	*0.40*	0.41	*0.41*	0.41	0.41	0.43	0.42	0.43	0.42	0.41	0.39	0.39	0.38	0.38	0.38
Portugal	0.31	*0.31*	0.32	*0.32*	0.33	*0.32*	0.32	0.32	0.33	0.33	0.36	0.36	0.35	0.35	0.37	0.37	0.37	0.36
Puerto Rico	0.38	*0.37*	0.37	*0.37*	0.37	*0.36*	0.36	0.37	0.37	0.37	0.39	0.40	0.40	0.41	0.41	0.41	0.40	0.42
Qatar	0.50	*0.48*	0.45	*0.45*	0.44	*0.44*	0.44	0.44	0.44	0.43	0.42	0.44	0.41	0.37	0.39	0.41	0.39	0.38
Réunion	*0.36*	*0.36*	*0.36*	*0.36*	*0.36*	*0.36*	*0.36*	*0.36*	0.36	0.36	0.36	0.36	0.37	0.37	0.37	0.37	0.37	0.37
Romania	0.50	*0.50*	0.51	*0.52*	0.53	*0.51*	0.50	0.51	0.50	0.50	0.48	0.48	0.48	0.48	0.48	0.48	0.49	0.48
Russian Federation	0.60	*0.61*	0.61	*0.62*	0.62	*0.60*	0.59	0.59	0.60	0.60	0.61	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Rwanda	0.71	*0.70*	0.68	*0.67*	0.66	*0.66*	0.65	0.63	0.62	0.63	0.58	0.57	0.56	0.56	0.53	0.53	0.52	0.51
Samoa	0.42	*0.42*	0.43	*0.43*	0.42	*0.42*	0.42	0.41	0.43	0.41	0.42	0.43	0.43	0.45	0.46	0.45	0.45	0.44
São Tomé And Principe	0.49	*0.50*	0.52	*0.51*	0.49	*0.51*	0.52	0.54	0.53	0.55	0.54	0.54	0.54	0.55	0.56	0.55	0.56	0.56
Saudi Arabia	0.55	*0.55*	0.55	*0.55*	0.55	*0.54*	0.54	0.54	0.56	0.54	0.56	0.55	0.54	0.54	0.53	0.56	0.54	0.54

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[i] A composite score cannot be calculated for this country because one or more of the individual WGI values is missing for all years

Country/Territory	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Senegal	0.53	*0.54*	0.54	*0.53*	0.52	*0.51*	0.49	0.52	0.51	0.52	0.54	0.55	0.54	0.55	0.56	0.55	0.53	0.53
Serbia[i]	0.65	*0.66*	0.67	*0.66*	0.66	*0.62*	0.59	0.58	0.56	0.57	0.54	0.54	0.54	0.52	0.52	0.52	0.52	0.51
Seychelles	0.41	*0.43*	0.46	*0.46*	0.46	*0.46*	0.47	0.48	0.49	0.47	0.48	0.48	0.48	0.48	0.47	0.47	0.47	0.47
Sierra Leone	0.68	*0.69*	0.70	*0.70*	0.71	*0.68*	0.65	0.64	0.62	0.63	0.62	0.60	0.60	0.60	0.60	0.59	0.60	0.60
Singapore	0.27	*0.27*	0.27	*0.27*	0.26	*0.27*	0.27	0.28	0.26	0.27	0.27	0.26	0.26	0.27	0.27	0.27	0.26	0.27
Slovak Republic	0.43	*0.42*	0.42	*0.43*	0.43	*0.42*	0.41	0.40	0.39	0.38	0.39	0.39	0.38	0.39	0.39	0.39	0.39	0.40
Slovenia	0.34	*0.34*	0.34	*0.36*	0.38	*0.37*	0.36	0.36	0.36	0.37	0.36	0.36	0.36	0.35	0.37	0.37	0.37	0.38
Solomon Islands	*0.49*	*0.49*	0.49	*0.55*	0.60	*0.62*	0.64	0.64	0.60	0.56	0.57	0.58	0.57	0.57	0.56	0.56	0.56	0.56
Somalia	0.82	*0.81*	0.81	*0.81*	0.80	*0.78*	0.76	0.80	0.81	0.80	0.83	0.85	0.85	0.84	0.83	0.82	0.82	0.82
South Africa	0.44	*0.44*	0.45	*0.45*	0.44	*0.45*	0.45	0.44	0.44	0.44	0.44	0.45	0.46	0.46	0.46	0.46	0.47	0.47
South Sudan																0.71	0.70	0.71
Spain	0.33	*0.33*	0.33	*0.32*	0.32	*0.32*	0.32	0.32	0.34	0.34	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.38
Sri Lanka	0.55	*0.55*	0.54	*0.55*	0.55	*0.53*	0.52	0.52	0.54	0.55	0.55	0.55	0.56	0.56	0.55	0.54	0.55	0.55
St. Kitts And Nevis	*0.43*	*0.43*	*0.43*	*0.43*	*0.43*	*0.43*	*0.43*	0.43	0.43	0.35	0.36	0.38	0.38	0.37	0.38	0.38	0.38	0.38
St. Lucia	*0.44*	*0.44*	0.45	*0.43*	0.41	*0.43*	0.44	0.42	0.42	0.35	0.36	0.37	0.38	0.37	0.37	0.37	0.39	0.37
St. Vincent And The Grenadines	*0.43*	*0.43*	0.43	*0.42*	0.42	*0.43*	0.44	0.43	0.42	0.36	0.36	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Sudan	0.73	*0.72*	0.72	*0.71*	0.71	*0.70*	0.69	0.72	0.70	0.73	0.70	0.71	0.73	0.72	0.73	0.72	0.73	0.73
Suriname	0.54	*0.53*	0.52	*0.51*	0.50	*0.50*	0.50	0.50	0.51	0.51	0.52	0.52	0.51	0.51	0.52	0.51	0.51	0.51
Swaziland	0.57	*0.57*	0.57	*0.57*	0.58	*0.58*	0.57	0.59	0.60	0.61	0.59	0.59	0.58	0.58	0.57	0.59	0.58	0.57
Sweden	0.25	*0.25*	0.25	*0.25*	0.24	*0.24*	0.24	0.24	0.23	0.26	0.26	0.25	0.25	0.24	0.24	0.24	0.23	0.24
Switzerland	0.25	*0.25*	0.24	*0.24*	0.24	*0.24*	0.24	0.25	0.24	0.26	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Syrian Arab Republic	0.61	*0.62*	0.62	*0.62*	0.62	*0.61*	0.59	0.61	0.62	0.63	0.64	0.63	0.63	0.62	0.63	0.66	0.72	0.74
Taiwan, China	0.39	*0.38*	0.38	*0.38*	0.39	*0.38*	0.38	0.37	0.36	0.37	0.39	0.39	0.38	0.38	0.36	0.36	0.36	0.36
Tajikistan	0.74	*0.73*	0.72	*0.70*	0.69	*0.68*	0.67	0.66	0.66	0.66	0.66	0.65	0.66	0.66	0.66	0.66	0.66	0.67
Tanzania	0.59	*0.58*	0.57	*0.58*	0.58	*0.58*	0.57	0.57	0.57	0.56	0.55	0.55	0.55	0.55	0.55	0.56	0.56	0.56
Thailand	0.46	*0.46*	0.46	*0.46*	0.45	*0.46*	0.47	0.48	0.50	0.50	0.53	0.53	0.54	0.54	0.54	0.54	0.53	0.54
Timor-Leste	*0.57*	*0.57*	*0.57*	*0.57*	*0.57*	*0.57*	0.59	0.58	0.58	0.60	0.63	0.64	0.62	0.62	0.61	0.61	0.61	0.61
Togo	0.60	*0.61*	0.61	*0.61*	0.62	*0.62*	0.62	0.63	0.64	0.66	0.65	0.64	0.62	0.63	0.63	0.62	0.63	0.64
Tonga	*0.54*	*0.54*	*0.54*	*0.54*	*0.54*	*0.54*	*0.54*	0.54	0.52	0.52	0.53	0.53	0.53	0.53	0.50	0.49	0.48	0.48
Trinidad And Tobago	0.43	*0.43*	0.43	*0.44*	0.45	*0.45*	0.46	0.46	0.46	0.47	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
Tunisia	0.51	*0.50*	0.50	*0.50*	0.50	*0.50*	0.49	0.49	0.50	0.51	0.50	0.51	0.51	0.51	0.52	0.53	0.53	0.54
Turkey	0.54	*0.55*	0.56	*0.54*	0.53	*0.53*	0.54	0.52	0.52	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.51
Turkmenistan	0.63	*0.64*	0.66	*0.66*	0.66	*0.67*	0.68	0.68	0.70	0.70	0.71	0.69	0.67	0.68	0.69	0.69	0.68	0.68
Tuvalu	*0.44*	*0.44*	*0.44*	*0.44*	*0.44*	*0.44*	*0.44*	0.44	0.43	0.42	0.44	0.45	0.45	0.44	0.45	0.48	0.48	0.48
Uganda	0.60	*0.59*	0.59	*0.59*	0.60	*0.60*	0.60	0.59	0.58	0.59	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
Ukraine	0.59	*0.60*	0.60	*0.61*	0.61	*0.60*	0.60	0.59	0.59	0.57	0.56	0.55	0.56	0.58	0.57	0.58	0.58	0.60
United Arab Emirates	0.44	*0.44*	0.44	*0.44*	0.43	*0.41*	0.40	0.43	0.42	0.42	0.42	0.42	0.42	0.42	0.43	0.42	0.41	0.40
United Kingdom	0.26	*0.26*	0.25	*0.26*	0.26	*0.26*	0.27	0.28	0.28	0.29	0.28	0.28	0.29	0.31	0.30	0.30	0.30	0.29
United States	0.29	*0.29*	0.29	*0.28*	0.28	*0.29*	0.29	0.30	0.30	0.31	0.31	0.32	0.31	0.32	0.32	0.32	0.32	0.32
Uruguay	0.41	*0.40*	0.40	*0.40*	0.40	*0.40*	0.40	0.40	0.42	0.40	0.40	0.40	0.39	0.39	0.38	0.38	0.39	0.39
Uzbekistan	0.67	*0.68*	0.69	*0.69*	0.69	*0.69*	0.69	0.69	0.69	0.72	0.71	0.69	0.68	0.68	0.68	0.68	0.68	0.68
Vanuatu	*0.49*	*0.49*	0.49	*0.48*	0.48	*0.49*	0.50	0.52	0.51	0.44	0.44	0.45	0.45	0.45	0.46	0.46	0.46	0.46
Venezuela, RB	0.58	*0.58*	0.58	*0.58*	0.59	*0.61*	0.64	0.64	0.65	0.65	0.65	0.67	0.67	0.68	0.68	0.68	0.68	0.69
Vietnam	0.56	*0.56*	0.57	*0.57*	0.57	*0.57*	0.58	0.58	0.58	0.56	0.57	0.57	0.57	0.57	0.58	0.57	0.57	0.57
Virgin Islands (U.S.)	*0.37*	*0.37*	*0.37*	*0.37*	*0.37*	*0.37*	*0.37*	*0.37*	0.37	0.36	0.38	0.38	0.38	0.39	0.38	0.37	0.38	0.37
West Bank And Gaza	0.64	*0.64*	0.64	*0.64*	0.64	*0.65*	0.65	0.64	0.60	0.63	0.64	0.66	0.67	0.60	0.57	0.60	0.61	0.60
Yemen, Rep.	0.61	*0.62*	0.63	*0.63*	0.64	*0.65*	0.66	0.64	0.65	0.65	0.64	0.64	0.65	0.67	0.68	0.69	0.69	0.69
Zambia	0.59	*0.58*	0.57	*0.57*	0.57	*0.58*	0.58	0.56	0.56	0.58	0.56	0.55	0.54	0.55	0.55	0.54	0.53	0.53
Zimbabwe	0.58	*0.59*	0.60	*0.63*	0.67	*0.69*	0.70	0.70	0.71	0.72	0.71	0.72	0.72	0.72	0.72	0.71	0.69	0.69

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[i] Applies to Serbia & Montenegro prior to 2006

Appendix E: Mineral resource coverage and data sources

The following table outlines the various processes/products and their respective prices as utilized in the analysis and specifies the data sources. Data obtained from the various USGS references are often updated retrospectively. Data from the latest publication are, therefore, utilized in the analysis. In certain cases, only one U.S. producer is known to have produced a certain mineral in a specific year (e.g., selenium production in the United States since 1997). Although these values are reported to the NMIC, they are withheld to avoid disclosing proprietary company information. In these cases, the production values have been approximated. Additional notes and assumptions are typically reported by the references.

Table 3. Scope of mineral resource coverage and data sources

Mineral	**Production**		**Price**[i]	
	Process(es)/product(s)	**References**	**Description**	**References**
Aluminum	a) Bauxite mine production b) Alumina refinery production c) Aluminum smelter production	4	a) Values are based on the average U.S. import price of bauxite, port of shipment, free alongside ship b) Values are based on the average U.S. import price of calcined alumina, port of shipment, free alongside ship c) Values are based on the annual average primary aluminum price	39
Antimony	Antimony mine production	4	Values are based on the average market price of antimony metal.	39
Arsenic	Arsenic trioxide production	4	Values are based on the average market price of arsenic trioxide, which is converted to the value for the contained arsenic by dividing the arsenic trioxide price by the percentage of arsenic contained in arsenic trioxide (75.7 percent).	39
Barium	Barite production	4	Values are estimated based on the sales and trade value of barite in the United States.	39
Beryllium	Beryl production	4	Up to year 2000, values are estimated based on the yearend beryllium metal market price. For more recent years, values are estimated based on the monetary value of imports of beryllium-copper master alloys.	39
Bismuth	a) Bismuth mine production b) Bismuth refinery	4	Up to year 1998, values are estimated based on the average bismuth metal market price. Data for year 1999 to the most recent year are based on the average domestic dealer price for bismuth.	39
Boron	Boron minerals production	4	Values are estimated based on the sum of production and import values less export values divided by the sum of production and import quantity less export quantity of B_2O_3 content.	39
Bromine	Bromine production	4	Up to year 2006, values are estimated using the market price of purified bulk bromine. Data for years 2007 to the most	4,39

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[i] All prices are based on annual averages in constant 1998 U.S. dollars

Mineral	Production		Price[i]	
	Process(es)/product(s)	References	Description	References
			recent year are obtained from the U.S. Geological Survey[4] and are based on export values.	
Cadmium	Cadmium refinery production	4	Values are based on the New York Dealer cadmium metal price.	39
Chromium	Chromite production	4	Values are estimated based on the mass-weighted value and chromium content of reported U.S. exports, imports, and production.	39
Cobalt	a) Cobalt mine production b) Cobalt refinery production	4	Values are estimated based on the monetary value of U.S. cobalt imports.	39
Copper	a) Copper mine production b) Copper smelter production c) Copper refinery production	4	Values are based on the annual average U.S. producer copper price.	39
Feldspar	Feldspar production	4	Values are based on the production and trade value of feldspar and nepheline syenite in the United States.	39
Ferrochromium	Ferrochromium production	4	Values are based on the average price for ferrochromium (low-carbon/.1%) per Platts Metals Week and Ryan's Notes.	4
Ferromanganese	Ferromanganese production	4	Values are based on the average price for standard high-carbon ferromanganese per Platts Metals Week and Ryan's Notes	4
Ferromolybdenum	Ferromolybdenum production	4	Values are based on the average price of ferromolybdenum per Platts Metals Week and Ryan's Notes.	4
Ferronickel	Ferronickel production	4	Values are based on the London Metal Exchange cash annual mean price per Platts Metals Week and Ryan's Notes.	4
Ferroniobium	Ferroniobium production	4	Values are based on the weighted average value of imports and exported ferroniobium alloys in the United States	4
Ferrosilicon	Ferrosilicon production	4	Values are based on the 50% ferrosilicon price per Platts Metals Week and Ryan's Notes.	4
Ferrovanadium	Ferrovanadium production	4	Values are based on the average ferrovanadium price per Platts Metals Week and Ryan's Notes.	4
Fluorspar	Fluorspar production (all grades)	4	Values are based on the U.S. average import value of fluorspar.	4
Gallium	Gallium production	Unofficial estimates	Values are based on the average momentary value of U.S. imports of 99.99%-pure gallium metal.	4
Germanium	Germanium refinery production	42	Up to year 1998, values are based on the annual average germanium price. For years 1999 to the most recent year, values are based on the zone-refined prices.	39
Gold	Gold mine production	4	Values are based on Englehard's average price quotation for refined gold.	39
Graphite	Natural graphite production	4	Values are based on the monetary value of natural graphite imports in the United States.	39
Helium	Grade-A and crude Helium production	13	Up to year 1999, values are based on the average monetary value of Grade-A helium as produced and sold in the United States. Grade-A helium price data are not available for year 2000 to the most recent year. Values for years 2000 to the most recent year are based on the average fiscal	39

Mineral	Production		Price[i]	
	Process(es)/product(s)	References	Description	References
			year price of crude helium sold by the U.S. Government. Crude helium contains approximately 80 percent helium and has less value than Grade-A helium.	
Indium	Indium refinery production	4	Values are based on the U.S. producer price per Platts Metals Week as reported by the U.S. Geological Survey[13,43]	39
Iodine	Crude iodine production	4	Values are based on the average import value as reported by the U.S. Geological Survey.[4]	39
Iridium	Iridium mine production	4 and unofficial estimates	Values are based on monthly average Johnson Matthey base prices for 99.9%-pure iridium averaged for the year.	44
Iron	a) Iron ore production b) Pig iron and direct reduced iron	4	Values are based on a weighted average value of iron ore as shipped from mines, which includes exports and domestic sales.	39
Lead	a) Lead mine production b) Lead refinery production	4	Values are based on domestic refined lead as reported by the U.S. Geological Survey.[13]	39
Lithium	Lithium minerals and brine (converted into Li content)	4	Values are based on the price of lithium carbonate.	39
Magnesium	a) Magnesite production b) Magnesium primary production	4	a) Values are based on import values of magnesite as reported by the U.S. Geological Survey[4] b) Up to year 1992, values are based on U.S. transaction prices for 99.8%-pure magnesium ingot noted in Metals Week as reported by the U.S. Geological Survey.[43] For years 1993-1998, values are based on U.S. spot Western price for 99.8%-pure magnesium ingot per Platts Metals Week as reported by the U.S. Geological Survey[43]. Since 1998, values are based on yearend prices per Platts Metal Week as reported in U.S. Geological Survey.[4]	4,39
Manganese	Manganese ore production	4	Values are based on the monetary value of manganese ores and ferroalloys imports.	39
Mercury	Mercury mine production	4	Values are based on the average market price of mercury per flask as reported in by the U.S. Geological Survey.[43] For years1999 to the most recent year, values are estimated from the average market price of mercury per flask as reported by the U.S. Geological Survey[13]. All mercury prices are based on the 76-pound mercury flask.	39
Mica	Mica production	4	Values are estimated by averaging the price for block, film, and split mica, as reported by the U.S. Geological Survey.[13]	39
Molybdenum	Molybdenum mine production	4	Up to year 2007, values are estimated by the molybdenum oxide price series from Platts Metals Week. For years 2008 to the most recent year, the values are based on	39

Mineral	Production		Price[i]	
	Process(es)/product(s)	References	Description	References
			by the molybdenum oxide price series from Ryan's Notes.	
Monazite	Monazite concentrate production	4	Values are based on the yearend price of monazite concentrate on the basis of its rare earth oxide content.	4
Nickel	a) Nickel mine production b) Nickel intermediate c) Nickel plant production	4	Values are based on the London Metal Exchange nickel price.	39
Niobium	Niobium mineral concentrate production	4	Values based on the Brazilian export price of niobium oxides.	45
Palladium	Palladium mine production	4	Values are based on monthly average Johnson Matthey base prices for 99.95%-pure palladium averaged for the year.	44
Phosphate	Phosphate rock production	4	Values are based on domestic sales and trade values of phosphate rock in the United States.	39
Platinum	Platinum mine production	4	Values are based on monthly average Johnson Matthey base prices for 99.95%-pure platinum averaged for the year.	44
Potash	Marketable potash production	4	Values are based on domestic sales and trade values of potash (K_2O equivalents) in the United States.	39
Rare Earths	Rare earth oxide mine production	4	Values are based on a weighted average of the monetary value of imports and exports of rare earth oxides in the United States.	39
Rhenium	Rhenium production	4	Up to year 2007, values are estimated by weighted averaging of the import value of rhenium metal and ammonium perrhenate in metal content. For years 2008 to the most recent year, values are based on the rhenium metal price series from Metal Bulletin.	39
Rhodium	Rhodium mine production	[4,46] and unofficial estimates	Values are based on monthly average Johnson Matthey base prices for 99.9%-pure rhodium averaged for the year.	44
Ruthenium	Ruthenium mine production	[4] and unofficial estimates	Values are based on monthly average Johnson Matthey base prices for 99.9%-pure ruthenium averaged for the year.	44
Selenium	Selenium refinery production	4	Values are based on the annual average commercial-grade selenium price as reported by the U.S. Geological Survey.[43]	39
Silicomanganese	Silicomanganese production	4	Values are based on average silicomanganese prices as reported by Platts Metals Week and Ryan's Notes.	4
Silicon	Silicon metal production	4	Up to year 2005 and from year 2011 to the most recent year, values are based on weight averaging the value of production and imports of all silicon-containing materials. For years 2006–2010, values reflect the weighted average value of ferrosilicon production and imports; silicon metal is excluded to avoid disclosing company proprietary production data.	39
Silver	Silver mine production	4	Values are based on the price of silver of a minimum purity of 99.9 percent as reported by the U.S. Geological Survey[4,43].	39

Mineral	Production		Price[i]	
	Process(es)/product(s)	References	Description	References
Steel	Raw steel production	4	Values are based on the annual average composite steel price.	39
Strontium	Celestite production	4	Values are based on the total monetary value of strontium imports including, strontium carbonate, chromate, metal, minerals, nitrate, salts, sulfate, and other unspecified compounds.	39
Sulfur	Sulfur production (all forms)	4	Values are estimated using the value of sulfur shipments.	39
Tantalum	Tantalum mineral concentrate production	4	Values are based on the yearend average price of tantalite ore reported by trade journals in units of tantalum pentoxide content as reported by the U.S. Geological Survey.[4,43]	39
Tellurium	Tellurium refinery production	4	Up to year 1998, values are based on the U.S. producer price quotes for 99.7%-pure tellurium reported by the U.S. Geological Survey[43]. For years 1999–2004, values are estimated using the monetary value of imports. For years 2005–2009, values are based on the published price from Mining Journal for the United Kingdom lump and powder 99.95% minimum tellurium. From year 2010 to the most recent year, values are based on the average price published by Metal-Pages for 99.95% minimum tellurium.	39
Tin	a) Tin mine production b) Tin smelter production	4	Up to year 2003, values are based on the price for domestic refined tin as reported by the U.S. Geological Survey[43]. Since 2004, values are based on the Platts Metals Week composite price.	39
Titanium	a) Titanium mineral concentrate b) Titanium sponge production	4,13	a) Values are based on TiO_2 pigment shipment values as reported by the U.S. Geological Survey[4] b) Values are based on the value of scrap imports.	39
Tungsten	Tungsten concentrate production	4	Value are based on the annual average U.S. free market price of ammonium paratungstate based as reported by the U.S. Geological Survey.[4,43]	39
Vanadium	Vanadium production (vanadium content of ores, concentrates, slags, petroleum residues, ash, and spent catalyst)	4	Values are based on the price of vanadium pentoxide as reported by the U.S. Geological Survey,[13] but converted to vanadium content by dividing by 0.5602.	39
Yttrium	Yttrium oxide mine production	13	Values are based on the price of yttrium oxide, 99.99% purity, as reported by Metal-Pages, Ltd and Rhodia.	4
Zinc	a) Zinc mine production b) Zinc smelter production	4	a) and b) Values are based on U.S. prices for high-grade zinc for years 1991–2001 and Platts Metals Week North American prices for special high grade zinc for years 2002 to the most recent year.	39
Zirconium	Zirconium mineral concentrates production	4	Values are based on the monetary value of the apparent consumption of zirconium	39

Mineral	Production		Price[i]	
	Process(es)/product(s)	References	Description	References
			mineral ores and concentrates as reported by the U.S. Geological Survey.[4]	

Appendix F: Raw and normalized indicator values

Table 4. Raw Supply Risk (R^r) indicator values for years 1996-2013

Mineral	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Alumina	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12
Aluminum	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.08	0.08	0.08	0.10	0.11	0.12	0.13
Antimony	0.38	0.41	0.40	0.40	0.43	0.46	0.42	0.43	0.45	0.45	0.45	0.47	0.46	0.45	0.38	0.36	0.33	0.33
Arsenic	0.10	0.10	0.11	0.11	0.24	0.24	0.25	0.21	0.18	0.17	0.17	0.16	0.17	0.19	0.18	0.20	0.22	0.21
Barite	0.13	0.16	0.16	0.19	0.17	0.17	0.16	0.18	0.16	0.18	0.19	0.19	0.17	0.14	0.17	0.13	0.15	0.14
Bauxite	0.06	0.06	0.06	0.06	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.06	0.07	0.07	0.07
Beryllium	0.21	0.22	0.22	0.21	0.23	0.21	0.20	0.21	0.21	0.22	0.25	0.25	0.25	0.24	0.25	0.26	0.26	0.27
Bismuth-mine	0.10	0.12	0.11	0.19	0.13	0.15	0.16	0.18	0.20	0.21	0.19	0.21	0.27	0.37	0.42	0.43	0.42	0.46
Bismuth-refinery	0.08	0.08	0.08	0.08	0.08	0.11	0.14	0.21	0.34	0.34	0.35	0.35	0.38	0.42	0.46	0.46	0.46	0.45
Boron	0.12	0.12	0.12	0.13	0.10	0.11	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.10	0.23	0.29	0.24	0.22
Bromine	0.11	0.11	0.11	0.10	0.11	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Cadmium	0.02	0.02	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.05	0.05	0.08	0.08	0.08	0.08	0.08	0.08
Chromite	0.11	0.12	0.12	0.13	0.12	0.12	0.12	0.14	0.12	0.11	0.10	0.11	0.11	0.11	0.12	0.12	0.12	0.13
Cobalt-mine	0.08	0.07	0.10	0.08	0.10	0.09	0.10	0.10	0.11	0.13	0.13	0.11	0.14	0.20	0.24	0.23	0.19	0.18
Cobalt-refinery	0.07	0.06	0.06	0.06	0.04	0.04	0.04	0.04	0.04	0.06	0.06	0.06	0.07	0.11	0.13	0.12	0.10	0.11
Copper-mine	0.04	0.05	0.05	0.06	0.05	0.05	0.05	0.06	0.06	0.05	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05
Copper-refinery	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.05	0.05	0.06	0.07
Copper-smelter	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.05	0.06	0.07	0.08
Feldspar	0.05	0.04	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.05	0.07	0.07	0.08	0.06	0.07	0.06	0.06	0.07
Ferrochromium	0.08	0.09	0.10	0.11	0.11	0.12	0.12	0.12	0.12	0.11	0.11	0.12	0.12	0.12	0.13	0.13	0.13	0.13
Ferromanganese	0.06	0.07	0.06	0.07	0.06	0.07	0.07	0.07	0.09	0.09	0.10	0.12	0.13	0.16	0.12	0.13	0.15	0.15
Ferromolybdenum				0.51	0.53	0.52	0.48	0.51	0.49	0.42	0.35	0.28	0.32	0.37	0.36	0.25	0.43	0.44
Ferronickel	0.07	0.07	0.08	0.08	0.08	0.10	0.07	0.07	0.07	0.06	0.05	0.06	0.06	0.07	0.10	0.13	0.17	0.21
Ferroniobium								0.46	0.39	0.39	0.39	0.44	0.40	0.35	0.38	0.41	0.41	0.40
Ferrosilicon	0.08	0.07	0.08	0.07	0.09	0.09	0.10	0.13	0.17	0.20	0.24	0.25	0.26	0.28	0.27	0.27	0.28	0.28
Ferrovanadium				0.33	0.26	0.25	0.24	0.25	0.24	0.23	0.20	0.19	0.19	0.18	0.18	0.18	0.18	0.18
Fluorspar	0.17	0.18	0.17	0.19	0.19	0.18	0.19	0.19	0.17	0.18	0.19	0.20	0.22	0.22	0.27	0.24	0.24	0.26
Gallium					0.06	0.06	0.07	0.06	0.08	0.06	0.06	0.06	0.07	0.05	0.09	0.16	0.24	0.27
Germanium	0.19	0.19	0.19	0.19	0.19	0.19	0.20	0.24	0.22	0.23	0.21	0.22	0.44	0.48	0.39	0.40	0.37	0.37
Gold	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Graphite	0.10	0.13	0.11	0.14	0.17	0.20	0.28	0.30	0.28	0.29	0.30	0.30	0.23	0.23	0.28	0.28	0.30	0.28
Helium	0.25	0.22	0.21	0.21	0.21	0.21	0.20	0.23	0.22	0.22	0.22	0.21	0.18	0.22	0.20	0.19	0.19	0.16
Indium	0.07	0.06	0.07	0.05	0.13	0.13	0.11	0.16	0.17	0.22	0.23	0.21	0.17	0.17	0.17	0.18	0.18	0.17
Iodine	0.12	0.13	0.14	0.13	0.13	0.14	0.14	0.16	0.15	0.14	0.15	0.14	0.15	0.16	0.15	0.15	0.15	0.16
Iridium	0.39	0.37	0.38	0.40	0.40	0.39	0.37	0.39	0.40	0.39	0.38	0.40	0.40	0.41	0.41	0.40	0.40	0.37
Iron ore	0.05	0.05	0.05	0.06	0.05	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.08	0.08	0.09	0.08	0.09
Lead-mine	0.04	0.05	0.05	0.05	0.05	0.06	0.06	0.08	0.08	0.09	0.10	0.10	0.10	0.11	0.13	0.16	0.17	0.17
Lead-refinery	0.04	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.06	0.07	0.08	0.08	0.09	0.11	0.12	0.13	0.13	0.13
Lithium	0.08	0.08	0.09	0.09	0.10	0.09	0.10	0.10	0.10	0.09	0.09	0.10	0.09	0.08	0.09	0.10	0.10	0.09
Magnesite	0.07	0.07	0.08	0.07	0.09	0.08	0.09	0.11	0.12	0.12	0.14	0.26	0.31	0.28	0.25	0.28	0.28	0.27
Magnesium-metal	0.11	0.11	0.07	0.08	0.09	0.10	0.13	0.17	0.20	0.22	0.22	0.26	0.25	0.28	0.31	0.31	0.32	0.32
Manganese-mine	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.06	0.07	0.07	0.07
Mercury	0.10	0.13	0.10	0.10	0.09	0.10	0.11	0.12	0.23	0.32	0.28	0.28	0.31	0.24	0.33	0.38	0.42	0.42
Mica	0.11	0.11	0.11	0.12	0.10	0.10	0.11	0.07	0.07	0.08	0.26	0.24	0.23	0.25	0.28	0.28	0.29	0.28
Molybdenum	0.10	0.10	0.09	0.08	0.08	0.07	0.08	0.08	0.08	0.08	0.09	0.10	0.11	0.13	0.12	0.12	0.12	0.12
Monazite	0.39	0.34	0.38	0.32	0.37	0.42	0.46	0.41	0.27	0.35	0.29	0.22	0.27	0.26	0.25	0.22	0.35	0.34
Nickel-intermediate	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.09	0.09	0.10	0.08	0.09	0.08	0.08
Nickel-mine	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.07	0.08
Nickel-plant	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.06	0.06	0.07	0.08	0.10
Niobium	0.37	0.39	0.41	0.40	0.38	0.38	0.37	0.42	0.38	0.42	0.43	0.44	0.46	0.42	0.40	0.39	0.42	0.41
Palladium	0.23	0.21	0.19	0.19	0.20	0.21	0.19	0.19	0.19	0.19	0.19	0.18	0.17	0.18	0.18	0.16	0.16	0.16
Phosphate	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.08	0.08	0.10	0.10	0.11	0.13	0.15
Pig iron and direct reduced iron	0.04	0.04	0.04	0.04	0.04	0.05	0.06	0.06	0.07	0.10	0.12	0.13	0.13	0.19	0.17	0.18	0.18	0.19
Platinum	0.27	0.27	0.26	0.27	0.25	0.27	0.26	0.27	0.29	0.28	0.27	0.28	0.27	0.28	0.28	0.26	0.25	0.25
Potash	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.06	0.07	0.07	0.06	0.07
Rare Earths	0.28	0.35	0.35	0.42	0.37	0.47	0.52	0.52	0.53	0.54	0.55	0.54	0.51	0.52	0.52	0.49	0.46	0.43
Rhenium	0.14	0.12	0.10	0.09	0.09	0.10	0.10	0.11	0.10	0.10	0.09	0.11	0.11	0.13	0.12	0.11	0.11	0.11
Rhodium	0.28	0.28	0.28	0.29	0.27	0.28	0.29	0.29	0.28	0.30	0.30	0.31	0.31	0.32	0.33	0.32	0.31	0.31
Ruthenium	0.37	0.35	0.36	0.38	0.37	0.38	0.38	0.38	0.39	0.39	0.38	0.39	0.39	0.41	0.41	0.40	0.40	0.39
Selenium	0.06	0.06	0.06	0.06	0.07	0.09	0.09	0.08	0.07	0.07	0.07	0.07	0.07	0.06	0.07	0.07	0.07	0.07
Silicomanganese	0.07	0.06	0.06	0.07	0.07	0.08	0.10	0.11	0.13	0.14	0.16	0.17	0.20	0.24	0.21	0.21	0.23	0.24
Silicon	0.06	0.05	0.05	0.05	0.06	0.05	0.05	0.05	0.06	0.18	0.20	0.19	0.20	0.23	0.22	0.24	0.21	0.23
Silver	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Steel	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.07	0.08	0.08	0.09	0.13	0.12	0.12	0.14	0.14
Strontium	0.18	0.19	0.17	0.16	0.14	0.12	0.11	0.12	0.12	0.14	0.15	0.16	0.20	0.22	0.25	0.19	0.18	0.20
Sulfur	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Tantalum	0.10	0.10	0.14	0.11	0.09	0.10	0.10	0.11	0.09	0.11	0.08	0.09	0.08	0.11	0.12	0.11	0.10	0.16
Tellurium	0.12	0.09	0.10	0.10	0.11	0.11	0.08	0.09	0.09	0.11	0.11	0.11	0.10	0.11	0.14	0.14	0.14	0.14
Tin-mine	0.10	0.11	0.11	0.12	0.13	0.14	0.15	0.15	0.15	0.16	0.16	0.17	0.14	0.13	0.14	0.14	0.15	0.15
Tin-smelter	0.09	0.08	0.10	0.10	0.12	0.11	0.10	0.12	0.12	0.11	0.12	0.14	0.13	0.13	0.14	0.14	0.14	0.14
Titanium	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Titanium-sponge	0.11	0.11	0.11	0.09	0.11	0.10	0.11	0.10	0.10	0.10	0.10	0.11	0.11	0.13	0.12	0.12	0.14	0.18
Tungsten	0.33	0.32	0.37	0.39	0.40	0.40	0.41	0.34	0.47	0.43	0.37	0.34	0.37	0.40	0.43	0.40	0.41	0.40
Vanadium	0.14	0.17	0.17	0.17	0.16	0.15	0.16	0.20	0.17	0.17	0.17	0.17	0.18	0.20	0.19	0.21	0.22	0.21
Yttrium	0.44	0.48	0.47	0.47	0.52	0.51	0.53	0.53	0.53	0.56	0.57	0.56	0.56	0.56	0.56	0.56	0.56	0.56
Zinc-mine	0.04	0.04	0.04	0.04	0.05	0.05	0.04	0.05	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.08	0.09	0.09
Zinc-smelter	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.05	0.06	0.07	0.07	0.09	0.10	0.10	0.09	0.10
Zirconium	0.13	0.12	0.13	0.13	0.12	0.13	0.14	0.12	0.10	0.11	0.11	0.09	0.09	0.10	0.10	0.09	0.09	0.10

Table 5. Normalized Supply Risk (R) indicator values for years 1996-2013

Mineral	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Alumina	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.03	0.03	0.03	0.05	0.07	0.08	0.11	0.12	0.14	0.16	0.18
Aluminum	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.04	0.05	0.07	0.10	0.10	0.11	0.14	0.15	0.18	0.20
Antimony	0.67	0.71	0.69	0.69	0.75	0.80	0.73	0.75	0.78	0.79	0.78	0.82	0.80	0.78	0.66	0.62	0.57	0.57
Arsenic	0.13	0.14	0.16	0.17	0.39	0.40	0.42	0.34	0.28	0.27	0.27	0.25	0.27	0.31	0.29	0.32	0.35	0.34
Barite	0.19	0.25	0.25	0.30	0.27	0.28	0.25	0.28	0.26	0.29	0.31	0.30	0.28	0.22	0.26	0.19	0.24	0.22
Bauxite	0.07	0.07	0.07	0.07	0.08	0.08	0.07	0.07	0.06	0.07	0.07	0.06	0.06	0.08	0.07	0.08	0.08	0.09
Beryllium	0.35	0.35	0.36	0.34	0.38	0.35	0.32	0.34	0.34	0.36	0.41	0.41	0.42	0.40	0.42	0.44	0.44	0.45
Bismuth-mine	0.14	0.17	0.17	0.31	0.19	0.23	0.26	0.30	0.32	0.34	0.31	0.34	0.46	0.64	0.73	0.75	0.73	0.81
Bismuth-refinery	0.11	0.11	0.11	0.10	0.11	0.16	0.22	0.34	0.59	0.58	0.60	0.60	0.66	0.73	0.80	0.81	0.80	0.79
Boron	0.17	0.17	0.18	0.19	0.15	0.15	0.14	0.14	0.14	0.16	0.15	0.16	0.15	0.14	0.38	0.50	0.41	0.36
Bromine	0.16	0.16	0.16	0.15	0.17	0.17	0.17	0.18	0.16	0.15	0.14	0.14	0.14	0.14	0.15	0.15	0.14	0.13
Cadmium	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.03	0.03	0.05	0.05	0.05	0.10	0.11	0.10	0.10	0.11	0.10
Chromite	0.16	0.17	0.18	0.19	0.18	0.18	0.19	0.21	0.17	0.15	0.14	0.17	0.15	0.16	0.18	0.17	0.18	0.19
Cobalt-mine	0.10	0.08	0.14	0.10	0.13	0.13	0.13	0.14	0.16	0.20	0.20	0.16	0.21	0.32	0.40	0.38	0.30	0.29
Cobalt-refinery	0.08	0.06	0.06	0.06	0.04	0.03	0.04	0.04	0.04	0.06	0.06	0.06	0.09	0.15	0.19	0.17	0.13	0.16
Copper-mine	0.04	0.04	0.05	0.06	0.06	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05
Copper-refinery	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.03	0.04	0.04	0.05	0.06	0.07	0.08
Copper-smelter	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.05	0.07	0.08	0.10
Feldspar	0.04	0.04	0.05	0.04	0.03	0.03	0.04	0.03	0.03	0.04	0.08	0.09	0.10	0.07	0.09	0.07	0.07	0.08
Ferrochromium	0.10	0.13	0.14	0.15	0.16	0.17	0.18	0.18	0.17	0.15	0.16	0.17	0.17	0.17	0.19	0.19	0.20	0.20
Ferromanganese	0.07	0.08	0.07	0.08	0.07	0.08	0.08	0.09	0.12	0.13	0.14	0.17	0.19	0.26	0.18	0.20	0.24	0.23
Ferromolybdenum				0.89	0.93	0.92	0.84	0.89	0.86	0.73	0.60	0.47	0.54	0.64	0.61	0.41	0.75	0.76
Ferronickel	0.08	0.08	0.10	0.11	0.11	0.13	0.09	0.09	0.08	0.07	0.06	0.07	0.07	0.09	0.13	0.20	0.26	0.35
Ferroniobium								0.80	0.67	0.68	0.68	0.76	0.69	0.60	0.66	0.71	0.71	0.70
Ferrosilicon	0.11	0.09	0.11	0.09	0.11	0.12	0.14	0.20	0.28	0.32	0.40	0.41	0.44	0.48	0.45	0.46	0.47	0.48
Ferrovanadium				0.56	0.43	0.42	0.40	0.42	0.40	0.37	0.32	0.30	0.30	0.29	0.29	0.30	0.29	0.28
Fluorspar	0.27	0.29	0.27	0.30	0.30	0.28	0.31	0.30	0.27	0.28	0.31	0.32	0.37	0.37	0.45	0.39	0.39	0.44
Gallium					0.07	0.07	0.08	0.07	0.10	0.06	0.06	0.07	0.08	0.05	0.13	0.26	0.39	0.45
Germanium	0.31	0.31	0.31	0.30	0.30	0.31	0.32	0.39	0.36	0.37	0.35	0.36	0.77	0.84	0.68	0.68	0.63	0.63
Gold	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Graphite	0.13	0.20	0.17	0.21	0.26	0.32	0.47	0.51	0.48	0.49	0.51	0.51	0.38	0.38	0.47	0.47	0.50	0.47
Helium	0.41	0.36	0.35	0.35	0.34	0.33	0.33	0.37	0.37	0.37	0.36	0.35	0.30	0.37	0.33	0.31	0.31	0.25
Indium	0.08	0.07	0.08	0.05	0.19	0.19	0.17	0.24	0.26	0.37	0.39	0.34	0.26	0.28	0.26	0.29	0.28	0.28
Iodine	0.18	0.19	0.21	0.20	0.20	0.21	0.21	0.25	0.23	0.21	0.23	0.22	0.23	0.25	0.23	0.22	0.23	0.25
Iridium	0.67	0.64	0.65	0.69	0.69	0.68	0.64	0.68	0.68	0.67	0.66	0.70	0.70	0.71	0.71	0.70	0.69	0.63
Iron ore	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.08	0.09	0.09	0.10	0.10	0.11	0.11	0.11
Lead-mine	0.04	0.05	0.04	0.04	0.05	0.06	0.07	0.10	0.11	0.12	0.13	0.14	0.14	0.16	0.19	0.24	0.27	0.27
Lead-refinery	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.06	0.08	0.10	0.10	0.12	0.16	0.18	0.19	0.19	0.19
Lithium	0.10	0.10	0.12	0.12	0.14	0.13	0.14	0.14	0.14	0.12	0.13	0.14	0.13	0.11	0.12	0.13	0.13	0.12
Magnesite	0.08	0.09	0.10	0.08	0.12	0.11	0.13	0.15	0.18	0.18	0.22	0.44	0.52	0.48	0.42	0.47	0.46	0.46
Magnesium-metal	0.15	0.15	0.09	0.11	0.12	0.14	0.20	0.27	0.33	0.35	0.37	0.44	0.42	0.48	0.53	0.53	0.54	0.54
Manganese-mine	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.06	0.06	0.07	0.07	0.08	0.08	0.08	0.07	0.08	0.09	0.09
Mercury	0.15	0.19	0.14	0.14	0.13	0.14	0.16	0.19	0.37	0.54	0.48	0.48	0.52	0.40	0.56	0.66	0.73	0.73
Mica	0.15	0.16	0.16	0.17	0.14	0.14	0.15	0.09	0.09	0.09	0.44	0.40	0.38	0.42	0.48	0.47	0.49	0.48
Molybdenum	0.13	0.14	0.12	0.10	0.10	0.09	0.10	0.10	0.11	0.11	0.12	0.14	0.16	0.19	0.18	0.17	0.18	0.17
Monazite	0.68	0.59	0.66	0.55	0.64	0.74	0.80	0.71	0.46	0.59	0.50	0.36	0.46	0.43	0.42	0.36	0.61	0.59
Nickel-intermediate	0.10	0.10	0.08	0.08	0.09	0.09	0.08	0.09	0.09	0.10	0.10	0.13	0.11	0.14	0.11	0.12	0.11	0.10
Nickel-mine	0.06	0.07	0.07	0.07	0.07	0.06	0.06	0.05	0.05	0.04	0.04	0.04	0.04	0.05	0.05	0.07	0.08	0.09
Nickel-plant	0.04	0.05	0.04	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.06	0.07	0.08	0.10	0.13
Niobium	0.63	0.68	0.72	0.69	0.66	0.65	0.63	0.73	0.65	0.74	0.75	0.76	0.80	0.74	0.68	0.68	0.72	0.71
Palladium	0.37	0.34	0.31	0.31	0.32	0.35	0.31	0.30	0.30	0.30	0.30	0.28	0.28	0.29	0.28	0.26	0.25	0.25
Phosphate	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.07	0.07	0.08	0.09	0.11	0.10	0.14	0.14	0.16	0.19	0.22
Pig iron and direct reduced iron	0.03	0.03	0.03	0.03	0.03	0.05	0.06	0.07	0.09	0.14	0.18	0.20	0.20	0.30	0.27	0.28	0.29	0.31
Platinum	0.45	0.45	0.44	0.45	0.43	0.46	0.44	0.46	0.48	0.47	0.45	0.47	0.46	0.48	0.48	0.44	0.42	0.42
Potash	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.09	0.08	0.08	0.08	0.07	0.08	0.08	0.07	0.08
Rare Earths	0.47	0.59	0.60	0.73	0.63	0.82	0.92	0.91	0.93	0.96	0.96	0.94	0.90	0.92	0.92	0.87	0.81	0.76
Rhenium	0.21	0.18	0.13	0.13	0.12	0.15	0.15	0.15	0.15	0.14	0.13	0.16	0.16	0.20	0.17	0.15	0.16	0.16
Rhodium	0.48	0.48	0.47	0.49	0.46	0.48	0.49	0.49	0.46	0.51	0.50	0.52	0.52	0.54	0.57	0.54	0.53	0.53
Ruthenium	0.64	0.59	0.61	0.66	0.65	0.66	0.66	0.66	0.67	0.67	0.66	0.68	0.68	0.71	0.71	0.69	0.70	0.68
Selenium	0.07	0.07	0.07	0.07	0.08	0.12	0.13	0.09	0.09	0.08	0.08	0.09	0.08	0.07	0.09	0.09	0.08	0.08
Silicomanganese	0.09	0.07	0.06	0.09	0.08	0.11	0.14	0.16	0.19	0.22	0.24	0.27	0.33	0.39	0.34	0.35	0.39	0.41
Silicon	0.06	0.06	0.05	0.05	0.06	0.05	0.05	0.05	0.06	0.29	0.32	0.31	0.33	0.38	0.37	0.40	0.35	0.38
Silver	0.03	0.03	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.04	0.05	0.05	0.05
Steel	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.04	0.05	0.08	0.09	0.11	0.12	0.20	0.18	0.18	0.21	0.21
Strontium	0.29	0.30	0.27	0.26	0.20	0.18	0.16	0.17	0.17	0.22	0.22	0.24	0.32	0.35	0.41	0.31	0.29	0.32
Sulfur	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.02
Tantalum	0.14	0.15	0.20	0.17	0.12	0.14	0.14	0.15	0.12	0.15	0.11	0.11	0.11	0.15	0.18	0.16	0.13	0.25
Tellurium	0.17	0.13	0.14	0.15	0.15	0.16	0.11	0.11	0.12	0.16	0.16	0.15	0.14	0.16	0.21	0.22	0.22	0.21
Tin-mine	0.15	0.16	0.17	0.17	0.20	0.21	0.23	0.24	0.23	0.25	0.26	0.28	0.22	0.19	0.21	0.22	0.23	0.23
Tin-smelter	0.13	0.11	0.15	0.15	0.17	0.16	0.15	0.18	0.17	0.16	0.18	0.21	0.20	0.20	0.21	0.22	0.21	0.22
Titanium	0.06	0.07	0.07	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.05	0.05	0.05
Titanium-sponge	0.15	0.15	0.16	0.13	0.15	0.14	0.16	0.14	0.14	0.14	0.14	0.15	0.15	0.20	0.18	0.17	0.22	0.28
Tungsten	0.57	0.55	0.65	0.67	0.70	0.69	0.71	0.59	0.82	0.75	0.63	0.58	0.64	0.69	0.75	0.70	0.71	0.70
Vanadium	0.21	0.26	0.28	0.27	0.25	0.24	0.26	0.32	0.27	0.26	0.26	0.27	0.29	0.33	0.30	0.34	0.35	0.35
Yttrium	0.76	0.85	0.83	0.83	0.91	0.90	0.93	0.94	0.93	0.99	1.00	0.99	0.98	0.99	1.00	1.00	1.00	0.99
Zinc-mine	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.06	0.06	0.07	0.07	0.08	0.08	0.09	0.10	0.12	0.13
Zinc-smelter	0.00	0.01	0.01	0.02	0.03	0.03	0.02	0.03	0.04	0.05	0.07	0.08	0.09	0.12	0.14	0.14	0.13	0.15
Zirconium	0.19	0.18	0.20	0.19	0.19	0.19	0.21	0.18	0.15	0.16	0.15	0.13	0.13	0.13	0.14	0.13	0.12	0.15

Table 6. Raw Production Growth (G^r) indicator values for years 1996-2013

Mineral	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Alumina	1.01	1.02	1.03	1.04	1.04	1.03	1.04	1.04	1.05	1.05	1.07	1.07	1.07	1.05	1.06	1.05	1.05	1.04
Aluminum	1.01	1.02	1.03	1.04	1.04	1.03	1.04	1.04	1.05	1.06	1.07	1.08	1.07	1.04	1.05	1.06	1.04	1.04
Antimony	1.11	1.11	1.06	0.98	0.96	1.00	0.95	1.00	1.06	1.06	1.02	1.09	1.10	1.02	1.01	1.02	1.00	0.97
Arsenic	0.99	0.98	0.99	0.98	1.06	1.08	1.08	1.12	1.07	0.99	0.99	0.97	0.94	0.96	0.97	0.95	0.97	0.98
Barite	1.03	1.07	1.07	1.07	1.06	1.02	0.98	1.01	1.04	1.04	1.03	1.05	1.05	0.97	1.00	0.99	1.03	1.01
Bauxite	1.01	1.03	1.02	1.04	1.04	1.03	1.03	1.05	1.05	1.06	1.07	1.09	1.08	1.05	1.06	1.06	1.03	1.05
Beryllium	0.99	1.00	1.04	1.03	0.96	0.86	0.82	0.82	0.85	0.93	1.08	1.11	1.13	1.05	1.08	1.08	1.07	1.06
Bismuth-mine	1.02	1.08	1.01	1.07	1.01	1.06	1.01	1.05	1.02	1.07	1.03	1.06	1.08	1.06	1.07	1.07	1.02	1.02
Bismuth-refinery	1.02	1.01	0.99	0.96	1.01	1.06	1.10	1.15	1.34	1.27	1.21	1.18	1.13	0.99	1.03	1.02	1.00	0.97
Boron	1.08	1.11	1.12	1.02	1.02	1.02	1.00	1.01	1.03	1.02	1.00	1.03	1.03	0.99	1.12	1.12	1.03	1.02
Bromine	1.04	1.06	1.06	1.05	1.05	1.01	0.99	0.99	1.01	1.04	1.06	1.03	1.04	0.96	0.97	0.97	0.98	1.00
Cadmium	0.98	1.01	1.02	1.02	1.00	1.01	0.97	0.98	0.99	1.00	1.00	1.01	1.03	1.02	1.03	1.01	1.04	1.01
Chromite	0.97	1.04	1.08	1.06	1.01	1.01	1.01	1.03	1.05	1.05	1.10	1.09	1.09	1.02	1.05	1.07	1.03	1.04
Cobalt-mine	0.95	1.00	1.10	1.13	1.09	1.11	1.14	1.08	1.13	1.11	1.09	1.07	1.09	1.06	1.10	1.09	1.07	1.07
Cobalt-refinery	1.00	1.05	1.14	1.11	1.09	1.09	1.09	1.07	1.08	1.08	1.07	1.06	1.06	1.05	1.08	1.09	1.08	1.08
Copper-mine	1.07	1.04	1.05	1.06	1.06	1.05	1.04	1.03	1.03	1.03	1.02	1.03	1.02	1.02	1.01	1.01	1.02	1.03
Copper-refinery	1.04	1.04	1.05	1.06	1.05	1.04	1.03	1.02	1.02	1.02	1.02	1.03	1.04	1.03	1.03	1.03	1.02	1.03
Copper-smelter	1.02	1.02	1.03	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.02	1.03	1.03
Feldspar	1.08	1.08	1.09	1.09	1.04	1.07	1.10	1.08	1.09	1.12	1.12	1.09	1.09	1.05	1.05	1.00	0.98	0.98
Ferrochromium	1.00	1.06	1.08	1.06	1.04	1.03	1.01	1.05	1.06	1.04	1.09	1.11	1.06	1.01	1.06	1.05	1.02	1.04
Ferromanganese	1.00	1.02	1.02	1.00	1.00	1.00	0.98	1.01	1.05	1.03	1.05	1.10	1.08	0.99	1.05	1.04	1.02	1.04
Ferromolybdenum									1.13	1.16	1.24	1.22	1.11	1.08	1.04	0.94	1.19	1.16
Ferronickel	0.99	1.09	1.09	1.02	0.99	1.10	0.98	1.00	1.06	1.07	1.01	1.08	1.05	1.05	1.08	1.11	1.11	1.18
Ferroniobium													1.10	0.99	1.06	1.13	1.08	1.05
Ferrosilicon	1.00	1.00	0.99	1.00	1.01	0.99	1.00	1.05	1.08	1.06	1.10	1.12	1.08	1.05	1.06	1.05	1.03	1.04
Ferrovanadium									1.09	0.97	0.97	1.01	1.06	0.95	1.03	1.03	1.00	1.00
Fluorspar	0.99	1.00	1.01	1.03	1.01	1.03	1.01	1.02	1.04	1.04	1.04	1.05	1.07	1.04	1.05	1.04	1.05	1.00
Gallium										0.96	0.97	1.09	1.11	1.09	1.21	1.28	1.29	1.24
Germanium						1.05	1.03	0.97	0.99	1.02	1.08	1.09	1.20	1.19	1.21	1.16	1.15	1.10
Gold	1.01	1.02	1.02	1.03	1.03	1.02	1.01	1.00	0.99	0.99	0.98	0.98	0.98	1.01	1.01	1.02	1.03	1.04
Graphite	1.02	1.00	0.99	1.06	1.08	1.08	1.06	1.10	1.08	1.04	1.05	1.04	1.01	0.94	1.00	1.03	1.01	1.01
Helium				1.05	1.01	0.99	0.95	1.02	1.03	1.06	1.09	1.09	1.04	0.99	1.02	1.01	1.00	1.00
Indium				1.11	1.13	1.17	1.12	1.10	1.10	1.06	1.08	1.09	1.13	1.11	1.02	1.03	1.04	1.03
Iodine	0.96	0.99	1.03	1.05	1.09	1.08	1.06	1.06	1.06	1.06	1.06	1.06	1.02	1.02	1.01	1.00	1.01	1.04
Iridium	1.00	0.98	1.08	1.15	1.08	1.03	1.09	1.18	1.05	1.05	1.08	1.13	1.00	1.02	1.01	1.02	0.96	0.99
Iron ore	1.01	1.08	1.03	1.02	1.02	1.01	1.01	1.03	1.06	1.07	1.11	1.12	1.11	1.08	1.09	1.07	1.05	1.06
Lead-mine	1.02	1.00	1.03	1.02	1.02	0.97	0.99	1.01	1.01	1.02	1.04	1.05	1.04	1.04	1.04	1.05	1.07	1.07
Lead-refinery	0.96	1.02	1.02	1.03	1.04	1.07	1.03	1.03	1.02	1.03	1.04	1.04	1.05	1.05	1.05	1.05	1.05	1.04
Lithium	1.03	1.09	1.08	1.08	1.05	1.00	0.99	1.04	1.05	1.07	1.11	1.11	1.09	1.01	1.05	1.06	1.06	1.03
Magnesite	1.02	0.93	1.07	1.02	1.04	1.00	1.07	1.04	1.10	1.04	1.05	1.08	1.08	1.02	1.06	1.14	1.02	1.03
Magnesium-metal	1.06	1.09	1.07	1.02	1.07	1.01	1.01	1.08	1.06	1.05	1.08	1.10	1.05	0.98	1.02	1.01	1.00	1.04
Manganese-mine	1.01	1.01	1.01	1.00	0.98	0.99	1.00	1.04	1.09	1.10	1.09	1.09	1.08	1.02	1.06	1.06	1.05	1.05
Mercury	1.00	1.04	0.92	0.92	0.84	0.90	0.96	1.02	1.08	1.02	0.95	0.91	1.01	1.05	1.07	1.10	1.06	1.01
Mica	1.07	1.09	0.99	0.98	1.00	1.04	0.98	1.05	1.08	1.02	1.23	1.32	1.27	1.22	1.25	1.01	0.99	0.99
Molybdenum	1.02	1.04	1.06	1.04	1.00	1.01	0.97	0.99	1.04	1.07	1.07	1.12	1.11	1.07	1.06	1.07	1.04	1.03
Monazite	0.81	0.84	0.86	0.98	0.95	0.99	0.97	1.00	1.03	1.01	1.04	1.09	1.05	1.10	1.20	1.11	0.96	0.99
Nickel-intermediate	1.10	1.07	1.13	1.08	1.09	1.08	1.09	1.05	1.06	1.04	1.03	1.01	1.01	1.01	1.03	1.04	1.07	1.06
Nickel-mine	1.01	1.02	1.05	1.05	1.04	1.05	1.04	1.02	1.03	1.03	1.03	1.05	1.04	1.01	1.03	1.08	1.07	1.10
Nickel-plant	1.01	1.03	1.06	1.05	1.04	1.04	1.03	1.03	1.04	1.03	1.03	1.04	1.03	1.02	1.02	1.04	1.05	1.07
Niobium	1.01	1.06	1.16	1.09	1.10	1.14	1.10	1.09	1.02	1.12	1.11	1.13	1.21	1.19	1.03	0.99	1.00	0.88
Palladium	1.02	1.03	1.06	1.08	1.00	1.05	1.06	1.06	1.07	1.07	1.04	1.03	1.00	0.98	0.99	0.99	0.98	1.00
Phosphate	0.98	1.01	1.05	1.01	1.00	0.99	0.99	0.99	1.01	1.02	1.03	1.04	1.04	1.02	1.04	1.05	1.05	1.06
Pig iron and direct reduced iron	1.01	1.02	1.02	1.01	1.02	1.03	1.03	1.05	1.06	1.07	1.09	1.09	1.07	1.05	1.05	1.05	1.03	1.05
Platinum	1.02	1.03	1.03	1.03	1.03	1.04	1.03	1.04	1.03	1.06	1.05	1.03	1.00	0.99	0.98	0.98	0.97	1.00
Potash	0.98	1.01	1.05	1.03	1.02	1.02	1.01	1.03	1.03	1.05	1.03	1.05	1.02	0.92	1.00	1.03	0.99	1.00
Rare Earths	1.10	1.04	1.09	1.08	1.04	1.02	1.06	1.05	1.05	1.06	1.09	1.06	1.06	1.06	1.01	0.96	0.98	0.96
Rhenium	0.90	0.96	1.07	1.06	1.05	1.09	1.03	1.02	1.04	1.06	1.07	1.07	1.07	1.00	0.99	1.01	1.03	0.98
Rhodium	1.09	1.11	1.05	1.04	1.03	1.04	1.05	1.07	1.05	1.09	1.07	1.06	1.02	1.03	0.99	1.00	0.97	0.99
Ruthenium	1.07	1.01	1.08	1.15	1.05	1.04	1.13	1.13	1.04	1.08	1.07	1.08	1.04	1.03	1.01	1.03	0.98	1.00
Selenium	1.07	1.02	0.99	0.94	0.96	0.94	0.97	1.01	0.98	1.04	1.06	1.07	1.05	1.08	1.01	1.01	1.00	1.00
Silicomanganese	1.02	1.01	1.01	1.02	1.03	1.03	1.07	1.10	1.15	1.13	1.15	1.14	1.13	1.07	1.09	1.09	1.07	1.07
Silicon		1.04	1.04	1.04	1.03	0.97	1.00	1.00	1.02	1.17	1.21	1.20	1.22	1.16	1.04	1.08	1.04	1.02
Silver	0.99	1.02	1.04	1.04	1.04	1.04	1.03	1.02	1.03	1.03	1.01	1.01	1.03	1.02	1.02	1.03	1.03	1.04
Steel	1.00	1.02	1.01	1.02	1.02	1.03	1.03	1.05	1.06	1.06	1.08	1.08	1.06	1.03	1.05	1.04	1.02	1.04
Strontium	1.08	1.06	1.06	1.05	1.05	1.06	1.11	1.13	1.08	1.05	1.06	1.03	0.95	0.93	0.91	0.94	0.94	0.98
Sulfur	1.00	1.02	1.02	1.02	0.99	1.02	1.02	1.02	1.03	1.03	1.02	1.02	1.01	1.01	1.00	1.01	1.01	1.01
Tantalum	0.94	1.01	1.13	1.15	1.18	1.19	1.21	1.12	1.19	1.06	0.98	0.98	1.05	0.94	0.91	0.99	0.95	0.92
Tellurium	1.08	1.06	1.08	1.01	0.92	0.99	0.99	0.98	1.01	1.02	1.03	1.02	1.04	0.99	0.96	0.94	0.94	0.94
Tin-mine	1.02	1.03	1.04	1.07	1.07	1.02	1.02	1.02	1.04	1.01	1.04	1.05	1.00	0.96	0.98	0.98	0.96	1.02
Tin-smelter	1.01	1.03	1.03	1.04	1.05	1.05	1.02	1.03	1.03	1.04	1.03	1.04	1.03	1.02	1.00	1.00	0.99	0.99
Titanium	1.03	1.03	0.98	1.02	1.02	1.02	0.99	1.01	1.01	1.02	1.04	1.08	1.04	1.00	1.05	1.02	1.01	1.01
Titanium-sponge	1.04	1.05	1.09	1.07	1.04	1.04	1.04	1.00	1.07	1.11	1.08	1.15	1.16	1.12	1.07	1.06	1.04	1.05
Tungsten	0.94	0.95	1.02	1.02	1.03	1.08	1.15	1.05	1.12	1.06	1.02	0.96	1.06	0.98	1.03	1.05	1.07	1.06
Vanadium	1.05	1.05	1.03	0.99	0.98	0.99	1.04	1.02	1.07	1.07	1.07	1.03	1.05	1.02	1.05	1.04	1.05	1.05
Yttrium				1.27	1.11	1.09	1.00	1.00	1.00	1.20	1.30	1.30	1.30	1.30	1.08	1.00	0.96	0.96
Zinc-mine	1.01	1.01	1.02	1.02	1.04	1.04	1.03	1.05	1.04	1.03	1.03	1.05	1.05	1.04	1.04	1.04	1.04	1.02
Zinc-smelter	1.01	1.02	1.02	1.03	1.04	1.04	1.04	1.04	1.04	1.03	1.03	1.03	1.03	1.01	1.04	1.04	1.02	1.02
Zirconium	1.02	0.99	0.98	0.94	0.96	0.96	1.03	1.07	1.10	1.08	1.11	1.08	1.06	1.01	1.04	1.06	1.00	1.02

Table 7. Normalized Production Growth (G) indicator values for years 1996-2013

Mineral	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Alumina	0.38	0.41	0.42	0.44	0.44	0.43	0.44	0.44	0.46	0.45	0.50	0.50	0.51	0.45	0.47	0.46	0.45	0.45
Aluminum	0.39	0.41	0.42	0.45	0.45	0.43	0.44	0.45	0.46	0.47	0.50	0.51	0.50	0.45	0.47	0.47	0.44	0.44
Antimony	0.57	0.58	0.48	0.33	0.30	0.37	0.27	0.37	0.48	0.49	0.41	0.53	0.55	0.41	0.39	0.40	0.37	0.31
Arsenic	0.34	0.34	0.35	0.32	0.48	0.52	0.52	0.58	0.49	0.35	0.35	0.31	0.25	0.29	0.32	0.27	0.30	0.33
Barite	0.42	0.51	0.50	0.49	0.48	0.41	0.33	0.38	0.45	0.44	0.43	0.47	0.47	0.31	0.37	0.34	0.42	0.38
Bauxite	0.39	0.43	0.41	0.44	0.44	0.43	0.43	0.45	0.46	0.47	0.50	0.54	0.52	0.46	0.48	0.48	0.43	0.45
Beryllium	0.36	0.36	0.43	0.42	0.29	0.10	0.02	0.03	0.09	0.23	0.51	0.58	0.61	0.47	0.52	0.53	0.50	0.48
Bismuth-mine	0.41	0.52	0.39	0.49	0.39	0.48	0.38	0.45	0.41	0.50	0.42	0.49	0.52	0.48	0.50	0.50	0.41	0.41
Bismuth-refinery	0.40	0.39	0.34	0.29	0.38	0.47	0.56	0.65	1.00	0.87	0.77	0.71	0.61	0.34	0.41	0.40	0.37	0.31
Boron	0.52	0.58	0.58	0.41	0.40	0.40	0.37	0.38	0.43	0.40	0.37	0.43	0.43	0.35	0.60	0.59	0.42	0.41
Bromine	0.45	0.49	0.48	0.47	0.45	0.39	0.34	0.35	0.39	0.44	0.47	0.43	0.44	0.30	0.30	0.30	0.34	0.36
Cadmium	0.33	0.38	0.40	0.40	0.37	0.39	0.32	0.33	0.34	0.36	0.37	0.38	0.43	0.41	0.43	0.39	0.44	0.38
Chromite	0.31	0.44	0.52	0.49	0.38	0.39	0.39	0.41	0.45	0.47	0.56	0.54	0.54	0.40	0.46	0.50	0.42	0.44
Cobalt-mine	0.28	0.36	0.56	0.61	0.54	0.58	0.63	0.53	0.61	0.58	0.54	0.50	0.53	0.48	0.56	0.54	0.49	0.49
Cobalt-refinery	0.37	0.46	0.62	0.57	0.54	0.53	0.53	0.49	0.52	0.53	0.49	0.47	0.48	0.46	0.52	0.53	0.52	0.52
Copper-mine	0.49	0.45	0.46	0.48	0.48	0.45	0.43	0.42	0.42	0.41	0.40	0.42	0.41	0.40	0.39	0.39	0.40	0.43
Copper-refinery	0.43	0.44	0.45	0.47	0.45	0.45	0.42	0.40	0.40	0.41	0.40	0.43	0.43	0.42	0.42	0.42	0.41	0.42
Copper-smelter	0.40	0.41	0.42	0.43	0.43	0.43	0.41	0.41	0.40	0.40	0.41	0.41	0.42	0.42	0.42	0.41	0.42	0.43
Feldspar	0.52	0.51	0.53	0.54	0.44	0.50	0.56	0.51	0.53	0.59	0.59	0.53	0.55	0.46	0.46	0.37	0.33	0.33
Ferrochromium	0.37	0.48	0.52	0.48	0.44	0.43	0.38	0.46	0.47	0.44	0.54	0.57	0.48	0.39	0.48	0.46	0.40	0.43
Ferromanganese	0.37	0.40	0.39	0.36	0.38	0.37	0.33	0.39	0.46	0.43	0.46	0.56	0.51	0.35	0.47	0.44	0.41	0.44
Ferromolybdenum									0.62	0.66	0.82	0.78	0.58	0.52	0.44	0.25	0.72	0.67
Ferronickel	0.35	0.53	0.54	0.41	0.34	0.55	0.33	0.37	0.48	0.49	0.38	0.52	0.47	0.47	0.52	0.57	0.58	0.71
Ferroniobium													0.56	0.35	0.48	0.61	0.52	0.47
Ferrosilicon	0.37	0.37	0.36	0.38	0.39	0.35	0.38	0.46	0.51	0.49	0.55	0.59	0.52	0.47	0.49	0.45	0.42	0.43
Ferrovanadium									0.53	0.31	0.32	0.38	0.47	0.28	0.42	0.43	0.37	0.37
Fluorspar	0.35	0.37	0.39	0.42	0.39	0.42	0.39	0.40	0.44	0.44	0.45	0.46	0.51	0.44	0.47	0.44	0.45	0.36
Gallium										0.30	0.31	0.54	0.58	0.53	0.77	0.90	0.91	0.83
Germanium						0.46	0.43	0.30	0.35	0.41	0.52	0.53	0.75	0.72	0.77	0.67	0.66	0.56
Gold	0.39	0.40	0.40	0.42	0.42	0.41	0.38	0.37	0.34	0.35	0.34	0.34	0.33	0.38	0.38	0.41	0.42	0.44
Graphite	0.40	0.38	0.35	0.47	0.51	0.52	0.49	0.56	0.52	0.44	0.45	0.44	0.38	0.26	0.37	0.42	0.38	0.39
Helium				0.47	0.39	0.34	0.28	0.40	0.42	0.49	0.54	0.54	0.44	0.35	0.41	0.38	0.37	0.37
Indium				0.58	0.62	0.69	0.59	0.56	0.55	0.48	0.51	0.54	0.61	0.58	0.40	0.41	0.45	0.43
Iodine	0.29	0.35	0.42	0.47	0.53	0.52	0.48	0.48	0.48	0.49	0.49	0.47	0.41	0.41	0.38	0.36	0.39	0.43
Iridium	0.37	0.33	0.52	0.65	0.51	0.43	0.53	0.70	0.47	0.46	0.52	0.62	0.37	0.41	0.38	0.40	0.29	0.34
Iron ore	0.39	0.51	0.42	0.40	0.40	0.39	0.39	0.43	0.48	0.50	0.57	0.58	0.57	0.51	0.53	0.51	0.47	0.48
Lead-mine	0.40	0.37	0.42	0.40	0.40	0.31	0.34	0.38	0.38	0.40	0.43	0.47	0.44	0.45	0.44	0.47	0.50	0.50
Lead-refinery	0.29	0.41	0.40	0.43	0.43	0.50	0.42	0.43	0.41	0.42	0.44	0.44	0.45	0.46	0.45	0.46	0.45	0.44
Lithium	0.42	0.54	0.52	0.51	0.46	0.37	0.34	0.44	0.47	0.50	0.58	0.58	0.54	0.39	0.47	0.49	0.48	0.43
Magnesite	0.41	0.24	0.49	0.40	0.44	0.38	0.50	0.45	0.56	0.44	0.46	0.51	0.53	0.41	0.48	0.62	0.41	0.43
Magnesium-metal	0.48	0.55	0.51	0.41	0.49	0.39	0.38	0.51	0.49	0.46	0.52	0.55	0.46	0.34	0.41	0.39	0.37	0.44
Manganese-mine	0.39	0.38	0.38	0.36	0.32	0.34	0.37	0.44	0.54	0.55	0.53	0.53	0.52	0.40	0.47	0.48	0.46	0.46
Mercury	0.37	0.45	0.22	0.22	0.07	0.17	0.29	0.40	0.51	0.41	0.27	0.19	0.39	0.45	0.50	0.55	0.47	0.38
Mica	0.50	0.53	0.35	0.32	0.37	0.45	0.33	0.45	0.51	0.40	0.81	0.97	0.88	0.77	0.83	0.38	0.36	0.34
Molybdenum	0.40	0.44	0.49	0.44	0.36	0.38	0.32	0.35	0.45	0.49	0.50	0.59	0.58	0.50	0.47	0.50	0.44	0.43
Monazite	0.00	0.06	0.11	0.34	0.28	0.36	0.31	0.36	0.41	0.38	0.44	0.53	0.46	0.56	0.75	0.57	0.29	0.35
Nickel-intermediate	0.56	0.49	0.61	0.51	0.53	0.52	0.54	0.46	0.48	0.44	0.43	0.39	0.38	0.38	0.43	0.45	0.49	0.49
Nickel-mine	0.39	0.41	0.46	0.45	0.45	0.46	0.43	0.41	0.43	0.41	0.42	0.46	0.44	0.38	0.43	0.52	0.49	0.56
Nickel-plant	0.38	0.42	0.47	0.46	0.44	0.45	0.43	0.43	0.44	0.43	0.42	0.44	0.42	0.41	0.41	0.44	0.45	0.51
Niobium	0.38	0.48	0.67	0.54	0.55	0.63	0.56	0.54	0.41	0.59	0.58	0.62	0.76	0.73	0.42	0.35	0.37	0.15
Palladium	0.41	0.43	0.49	0.52	0.37	0.45	0.49	0.48	0.50	0.50	0.43	0.42	0.37	0.34	0.35	0.36	0.34	0.36
Phosphate	0.33	0.39	0.45	0.39	0.37	0.35	0.34	0.34	0.38	0.41	0.43	0.44	0.43	0.40	0.43	0.47	0.47	0.47
Pig iron and direct reduced iron	0.38	0.40	0.40	0.39	0.40	0.42	0.41	0.45	0.48	0.50	0.53	0.54	0.49	0.46	0.47	0.45	0.43	0.45
Platinum	0.40	0.43	0.42	0.43	0.42	0.45	0.42	0.44	0.43	0.47	0.46	0.43	0.36	0.35	0.33	0.34	0.31	0.36
Potash	0.32	0.39	0.46	0.43	0.40	0.41	0.39	0.42	0.43	0.45	0.42	0.46	0.41	0.21	0.37	0.43	0.35	0.38
Rare Earths	0.56	0.44	0.54	0.51	0.44	0.41	0.49	0.46	0.45	0.47	0.53	0.48	0.49	0.47	0.38	0.30	0.33	0.30
Rhenium	0.17	0.30	0.50	0.47	0.46	0.54	0.43	0.41	0.44	0.47	0.51	0.50	0.49	0.36	0.35	0.38	0.43	0.34
Rhodium	0.54	0.57	0.47	0.45	0.43	0.44	0.46	0.49	0.46	0.54	0.49	0.48	0.41	0.42	0.35	0.38	0.31	0.35
Ruthenium	0.49	0.39	0.52	0.65	0.45	0.44	0.61	0.61	0.44	0.52	0.50	0.51	0.44	0.43	0.38	0.41	0.32	0.36
Selenium	0.49	0.40	0.35	0.26	0.29	0.25	0.31	0.39	0.33	0.45	0.47	0.50	0.47	0.52	0.39	0.38	0.37	0.37
Silicomanganese	0.40	0.38	0.38	0.40	0.43	0.43	0.49	0.56	0.66	0.61	0.64	0.63	0.61	0.51	0.54	0.53	0.50	0.50
Silicon		0.44	0.44	0.44	0.42	0.32	0.36	0.37	0.41	0.69	0.76	0.74	0.77	0.67	0.44	0.51	0.44	0.41
Silver	0.35	0.41	0.44	0.45	0.44	0.45	0.43	0.40	0.42	0.42	0.39	0.39	0.42	0.41	0.41	0.42	0.43	0.44
Steel	0.37	0.40	0.38	0.40	0.41	0.42	0.42	0.46	0.48	0.48	0.52	0.52	0.49	0.42	0.45	0.44	0.41	0.44
Strontium	0.52	0.48	0.47	0.47	0.46	0.48	0.57	0.62	0.52	0.46	0.47	0.43	0.28	0.24	0.20	0.25	0.25	0.33
Sulfur	0.37	0.41	0.41	0.41	0.35	0.41	0.40	0.41	0.42	0.42	0.40	0.40	0.39	0.38	0.37	0.38	0.38	0.38
Tantalum	0.25	0.39	0.61	0.64	0.70	0.72	0.76	0.60	0.72	0.49	0.32	0.34	0.47	0.26	0.19	0.34	0.27	0.22
Tellurium	0.52	0.47	0.52	0.39	0.21	0.34	0.35	0.33	0.38	0.40	0.42	0.41	0.43	0.34	0.29	0.25	0.25	0.25
Tin-mine	0.40	0.42	0.44	0.49	0.49	0.41	0.40	0.41	0.45	0.39	0.43	0.46	0.37	0.29	0.33	0.33	0.29	0.41
Tin-smelter	0.38	0.43	0.42	0.45	0.47	0.46	0.40	0.42	0.42	0.44	0.43	0.45	0.43	0.40	0.36	0.37	0.35	0.36
Titanium	0.43	0.41	0.32	0.41	0.41	0.41	0.34	0.39	0.39	0.40	0.45	0.51	0.44	0.37	0.46	0.40	0.38	0.39
Titanium-sponge	0.45	0.47	0.54	0.49	0.44	0.44	0.43	0.37	0.50	0.57	0.52	0.65	0.67	0.59	0.50	0.48	0.45	0.47
Tungsten	0.25	0.27	0.39	0.41	0.42	0.52	0.65	0.46	0.59	0.48	0.41	0.29	0.47	0.34	0.42	0.47	0.51	0.47
Vanadium	0.47	0.45	0.43	0.36	0.33	0.34	0.45	0.41	0.50	0.50	0.49	0.42	0.47	0.41	0.46	0.45	0.46	0.46
Yttrium				0.87	0.57	0.53	0.37	0.36	0.36	0.75	0.92	0.93	0.93	0.93	0.51	0.37	0.28	0.28
Zinc-mine	0.38	0.38	0.40	0.41	0.44	0.43	0.43	0.46	0.44	0.42	0.42	0.45	0.45	0.44	0.44	0.44	0.44	0.41
Zinc-smelter	0.38	0.40	0.40	0.43	0.44	0.44	0.45	0.45	0.45	0.42	0.42	0.42	0.43	0.39	0.45	0.44	0.40	0.41
Zirconium	0.41	0.35	0.34	0.26	0.28	0.30	0.43	0.50	0.55	0.51	0.57	0.52	0.47	0.39	0.44	0.48	0.37	0.41

Table 8. Raw Market Dynamics (M^r) indicator values for years 1996-2013

Mineral	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Alumina	1.12	1.08	1.08	1.08	1.07	1.09	1.12	1.08	1.11	1.14	1.22	1.22	1.17	1.13	1.12	1.11	1.11	1.11
Aluminum	1.13	1.13	1.14	1.12	1.12	1.08	1.09	1.06	1.08	1.09	1.19	1.20	1.17	1.17	1.16	1.15	1.15	1.14
Antimony	1.41	1.45	1.49	1.53	1.62	1.42	1.11	1.18	1.26	1.30	1.38	1.34	1.29	1.21	1.25	1.40	1.37	1.32
Arsenic	1.07	1.07	1.07	1.08	1.07	1.09	1.07	1.07	1.06	1.22	1.31	1.37	1.39	1.32	1.06	1.07	1.07	1.09
Barite	1.15	1.12	1.10	1.10	1.10	1.11	1.12	1.13	1.08	1.04	1.05	1.12	1.14	1.15	1.14	1.14	1.19	1.20
Bauxite	1.12	1.11	1.11	1.11	1.11	1.12	1.10	1.09	1.08	1.08	1.08	1.10	1.10	1.06	1.04	1.04	1.05	1.06
Beryllium	1.10	1.10	1.09	1.07	1.03	1.36	1.49	1.61	1.71	1.79	1.16	1.10	1.11	1.12	1.22	1.18	1.15	1.13
Bismuth-mine	1.12	1.12	1.11	1.05	1.06	1.04	1.08	1.13	1.14	1.11	1.16	1.67	1.61	1.51	1.41	1.31	1.22	1.18
Bismuth-refinery	1.12	1.12	1.11	1.05	1.06	1.04	1.08	1.13	1.14	1.11	1.16	1.67	1.61	1.51	1.41	1.31	1.22	1.18
Boron	1.05	1.05	1.05	1.06	1.06	1.06	1.07	1.07	1.06	1.05	1.04	1.04	1.05	1.06	1.13	1.12	1.13	1.14
Bromine	1.09	1.09	1.10	1.11	1.10	1.12	1.12	1.15	1.14	1.16	1.24	1.31	1.33	1.29	1.32	1.21	1.28	1.25
Cadmium	1.44	1.45	1.60	1.70	1.92	1.91	1.46	1.46	1.49	1.77	1.62	1.78	1.59	1.52	1.39	1.43	1.50	1.45
Chromite	1.19	1.18	1.19	1.21	1.22	1.15	1.15	1.09	1.21	1.25	1.22	1.26	1.41	1.33	1.30	1.26	1.19	1.18
Cobalt-mine	1.25	1.18	1.19	1.20	1.27	1.32	1.36	1.37	1.31	1.30	1.30	1.35	1.34	1.28	1.29	1.30	1.32	1.37
Cobalt-refinery	1.25	1.18	1.19	1.20	1.27	1.32	1.36	1.37	1.31	1.30	1.30	1.35	1.34	1.28	1.29	1.30	1.32	1.37
Copper-mine	1.11	1.12	1.19	1.23	1.25	1.19	1.17	1.07	1.20	1.30	1.54	1.51	1.40	1.28	1.20	1.13	1.13	1.14
Copper-refinery	1.11	1.12	1.19	1.23	1.25	1.19	1.17	1.07	1.20	1.30	1.54	1.51	1.40	1.28	1.20	1.13	1.13	1.14
Copper-smelter	1.11	1.12	1.19	1.23	1.25	1.19	1.17	1.07	1.20	1.30	1.54	1.51	1.40	1.28	1.20	1.13	1.13	1.14
Feldspar	1.06	1.06	1.06	1.05	1.04	1.02	1.02	1.01	1.01	1.02	1.02	1.02	1.02	1.05	1.13	1.18	1.16	1.15
Ferrochromium	1.21	1.21	1.23	1.27	1.31	1.36	1.24	1.14	1.22	1.25	1.23	1.27	1.71	1.59	1.52	1.44	1.36	1.34
Ferromanganese					1.07	1.09	1.06	1.06	1.46	1.45	1.42	1.41	1.55	1.46	1.46	1.39	1.36	1.41
Ferromolybdenum					1.19	1.23	1.21	1.20	1.74	1.97	1.76	1.57	1.40	1.33	1.34	1.35	1.41	1.40
Ferronickel	1.15	1.12	1.19	1.19	1.20	1.20	1.18	1.22	1.29	1.29	1.45	1.53	1.42	1.38	1.35	1.31	1.35	1.18
Ferroniobium							1.05	1.06	1.06	1.06	1.09	1.12	1.29	1.35	1.33	1.29	1.17	1.06
Ferrosilicon	1.22	1.20	1.15	1.12	1.11	1.14	1.11	1.09	1.12	1.13	1.16	1.19	1.33	1.28	1.27	1.23	1.17	1.12
Ferrovanadium					1.56	1.71	1.94	2.22	1.77	1.93	1.78	1.62	1.47	1.41	1.40	1.36	1.39	1.43
Fluorspar	1.13	1.11	1.12	1.10	1.07	1.07	1.06	1.05	1.07	1.13	1.14	1.13	1.12	1.08	1.08	1.08	1.10	1.08
Gallium									1.42	1.42	1.42	1.13	1.17	1.16	1.09	1.07	1.07	1.11
Germanium	1.23	1.22	1.20	1.18	1.18	1.27	1.33	1.47	1.46	1.41	1.27	1.33	1.38	1.28	1.22	1.16	1.15	1.19
Gold	1.03	1.07	1.12	1.16	1.18	1.17	1.10	1.08	1.12	1.15	1.22	1.24	1.26	1.27	1.28	1.30	1.27	1.20
Graphite	1.14	1.06	1.06	1.04	1.06	1.12	1.13	1.15	1.16	1.08	1.04	1.07	1.16	1.20	1.16	1.20	1.18	1.14
Helium	1.11	1.05	1.04	1.04	1.07	1.08	1.08	1.07	1.05	1.01	1.01	1.01	1.01	1.02	1.02	1.06	1.10	1.10
Indium	1.32	1.30	1.29	1.27	1.24	1.36	1.44	1.45	1.70	1.85	1.74	1.56	1.37	1.23	1.26	1.23	1.16	1.11
Iodine	1.16	1.21	1.25	1.22	1.14	1.09	1.12	1.16	1.14	1.11	1.14	1.17	1.17	1.16	1.11	1.22	1.25	1.24
Iridium	1.46	1.47	1.83	1.75	1.60	1.42	1.24	1.37	1.44	1.50	1.46	1.44	1.46	1.32	1.32	1.37	1.37	1.32
Iron ore	1.12	1.10	1.05	1.07	1.09	1.13	1.13	1.12	1.14	1.21	1.26	1.26	1.24	1.26	1.25	1.21	1.16	1.10
Lead-mine	1.11	1.11	1.11	1.07	1.07	1.08	1.07	1.05	1.07	1.11	1.18	1.36	1.34	1.27	1.22	1.16	1.12	1.10
Lead-refinery	1.11	1.11	1.11	1.07	1.07	1.08	1.07	1.05	1.07	1.11	1.18	1.36	1.34	1.27	1.22	1.16	1.12	1.10
Lithium	1.04	1.04	1.03	1.03	1.03	1.29	1.42	1.52	1.57	1.58	1.14	1.31	1.39	1.37	1.31	1.18	1.08	1.07
Magnesite	1.57	1.70	1.63	1.52	1.56	1.57	1.57	1.61	1.16	1.18	1.20	1.13	1.08	1.81	1.71	1.59	1.47	1.35
Magnesium-metal	1.11	1.11	1.12	1.14	1.20	1.16	1.17	1.17	1.13	1.11	1.11	1.22	1.34	1.29	1.28	1.21	1.16	1.17
Manganese-mine	1.15	1.06	1.05	1.08	1.09	1.11	1.13	1.10	1.29	1.28	1.28	1.29	1.47	1.40	1.39	1.32	1.25	1.23
Mercury	1.19	1.16	1.23	1.28	1.31	1.29	1.06	1.03	1.35	1.54	1.56	1.45	1.33	1.16	1.25	1.49	1.49	1.41
Mica	1.05	1.08	1.11	1.13	1.13	1.08	1.05	1.04	1.14	1.16	1.34	1.35	1.40	1.58	1.58	1.62	1.47	1.43
Molybdenum	1.49	1.44	1.40	1.40	1.48	1.26	1.24	1.27	1.87	2.00	1.77	1.57	1.39	1.31	1.34	1.35	1.42	1.41
Monazite	1.40	1.19	1.21	1.20	1.18	1.12	1.04	1.04	1.04	1.04	1.05	1.05	1.17	1.17	1.17	1.65	1.61	1.53
Nickel-intermediate	1.15	1.12	1.19	1.19	1.20	1.20	1.18	1.22	1.29	1.30	1.45	1.53	1.42	1.38	1.34	1.31	1.35	1.18
Nickel-mine	1.15	1.12	1.19	1.19	1.20	1.20	1.18	1.22	1.29	1.30	1.45	1.53	1.42	1.38	1.34	1.31	1.35	1.18
Nickel-plant	1.15	1.12	1.19	1.19	1.20	1.20	1.18	1.22	1.29	1.30	1.45	1.53	1.42	1.38	1.34	1.31	1.35	1.18
Niobium			1.05	1.05	1.03	1.06	1.06	1.07	1.08	1.10	1.19	1.20	1.25	1.27	1.27	1.29	1.18	1.10
Palladium	1.14	1.17	1.30	1.37	1.60	1.52	1.41	1.42	1.47	1.56	1.48	1.23	1.20	1.18	1.27	1.34	1.32	1.31
Phosphate	1.05	1.03	1.03	1.08	1.08	1.08	1.07	1.07	1.08	1.03	1.03	1.19	1.39	1.57	1.47	1.38	1.25	1.17
Pig iron and direct reduced iron	1.12	1.10	1.05	1.07	1.09	1.13	1.13	1.12	1.14	1.21	1.26	1.26	1.24	1.26	1.25	1.21	1.16	1.10
Platinum	1.04	1.04	1.06	1.08	1.12	1.13	1.14	1.18	1.21	1.18	1.23	1.24	1.23	1.18	1.16	1.12	1.10	1.10
Potash	1.09	1.10	1.07	1.06	1.06	1.07	1.07	1.07	1.04	1.18	1.23	1.22	1.36	1.45	1.36	1.31	1.26	1.15
Rare Earths	1.16	1.15	1.09	1.12	1.15	1.19	1.19	1.18	1.12	1.13	1.24	1.27	1.39	1.37	1.52	1.98	1.77	1.65
Rhenium	1.28	1.30	1.17	1.14	1.12	1.11	1.11	1.08	1.07	1.06	1.05	1.32	2.12	1.90	1.74	1.59	1.48	1.46
Rhodium	1.75	1.83	1.52	1.40	1.72	1.64	1.54	1.49	1.45	1.44	1.72	1.80	1.67	1.59	1.50	1.52	1.67	1.78
Ruthenium	1.31	1.28	1.31	1.25	1.58	1.54	1.51	1.54	1.52	1.46	1.53	2.08	1.89	1.82	1.71	1.63	1.72	1.54
Selenium	1.13	1.21	1.28	1.32	1.28	1.19	1.18	1.25	2.00	2.09	1.87	1.66	1.48	1.33	1.31	1.36	1.33	1.33
Silicomanganese					1.12	1.12	1.09	1.04	1.40	1.37	1.34	1.39	1.41	1.35	1.35	1.30	1.25	1.41
Silicon	1.14	1.14	1.12	1.13	1.16	1.19	1.16	1.10	1.09	1.12	1.12	1.12	1.18	1.17	1.19	1.30	1.25	1.19
Silver	1.08	1.08	1.06	1.05	1.06	1.10	1.11	1.11	1.13	1.16	1.33	1.36	1.33	1.25	1.25	1.40	1.36	1.31
Steel	1.03	1.03	1.04	1.07	1.08	1.09	1.09	1.07	1.11	1.15	1.17	1.16	1.16	1.10	1.09	1.09	1.09	1.09
Strontium	1.09	1.10	1.09	1.09	1.05	1.04	1.04	1.04	1.15	1.16	1.16	1.19	1.20	1.23	1.19	1.17	1.18	1.29
Sulfur	1.37	1.20	1.16	1.15	1.21	1.35	1.46	1.44	1.44	1.37	1.37	1.25	2.17	2.31	2.20	1.97	1.81	1.74
Tantalum	1.07	1.07	1.07	1.07	2.07	2.05	2.05	2.08	2.12	2.14	1.11	1.07	1.10	1.10	1.15	1.53	1.49	1.42
Tellurium	1.22	1.27	1.25	1.19	1.17	1.16	1.20	1.25	1.26	1.37	1.33	1.33	1.58	1.45	1.37	1.46	1.41	1.38
Tin-mine	1.06	1.07	1.06	1.08	1.09	1.11	1.13	1.12	1.20	1.21	1.23	1.33	1.36	1.27	1.29	1.28	1.19	1.18
Tin-smelter	1.06	1.07	1.06	1.08	1.09	1.11	1.13	1.12	1.20	1.21	1.23	1.33	1.36	1.27	1.29	1.28	1.19	1.18
Titanium	1.09	1.08	1.07	1.05	1.05	1.04	1.04	1.05	1.06	1.06	1.06	1.07	1.07	1.07	1.06	1.16	1.22	1.18
Titanium-sponge	1.10	1.04	1.04	1.05	1.07	1.11	1.12	1.14	1.13	1.30	1.38	1.33	1.31	1.27	1.31	1.33	1.17	1.07
Tungsten	1.15	1.16	1.18	1.20	1.22	1.18	1.17	1.17	1.18	1.52	1.57	1.53	1.42	1.29	1.16	1.19	1.26	1.26
Vanadium	1.21	1.24	1.33	1.31	1.39	1.50	1.61	1.65	1.61	2.07	1.88	1.71	1.52	1.44	1.44	1.31	1.34	1.37
Yttrium	1.08	1.06	1.04	1.05	1.03	1.03	1.03	1.03	1.03	1.04	1.20	1.27	1.32	1.35	1.31	1.59	1.55	1.64
Zinc-mine	1.10	1.10	1.09	1.09	1.09	1.14	1.20	1.17	1.16	1.18	1.58	1.56	1.48	1.41	1.34	1.30	1.26	1.09
Zinc-smelter	1.10	1.10	1.09	1.09	1.09	1.14	1.20	1.17	1.16	1.18	1.58	1.56	1.48	1.41	1.34	1.30	1.26	1.09
Zirconium	1.15	1.16	1.16	1.16	1.15	1.16	1.13	1.03	1.09	1.13	1.24	1.23	1.19	1.14	1.10	1.58	1.58	1.55

Table 9. Normalized Market Dynamics (M) indicator values for years 1996-2013

Mineral	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Alumina	0.08	0.05	0.05	0.05	0.05	0.06	0.09	0.05	0.08	0.10	0.16	0.16	0.12	0.09	0.08	0.08	0.07	0.07
Aluminum	0.09	0.09	0.09	0.08	0.09	0.05	0.06	0.04	0.05	0.06	0.13	0.15	0.12	0.12	0.11	0.11	0.11	0.10
Antimony	0.30	0.34	0.37	0.40	0.47	0.31	0.07	0.13	0.19	0.22	0.28	0.25	0.21	0.15	0.18	0.30	0.28	0.24
Arsenic	0.05	0.04	0.04	0.05	0.05	0.06	0.05	0.04	0.03	0.16	0.23	0.28	0.29	0.24	0.04	0.05	0.05	0.06
Barite	0.10	0.08	0.07	0.07	0.07	0.08	0.08	0.09	0.05	0.02	0.03	0.08	0.10	0.11	0.10	0.10	0.14	0.15
Bauxite	0.09	0.07	0.08	0.08	0.07	0.08	0.06	0.06	0.05	0.05	0.06	0.07	0.07	0.04	0.02	0.02	0.03	0.04
Beryllium	0.07	0.07	0.06	0.05	0.01	0.27	0.37	0.46	0.54	0.60	0.11	0.07	0.08	0.08	0.16	0.13	0.11	0.09
Bismuth-mine	0.09	0.09	0.07	0.03	0.03	0.02	0.06	0.09	0.10	0.08	0.11	0.51	0.46	0.39	0.31	0.23	0.16	0.13
Bismuth-refinery	0.09	0.09	0.07	0.03	0.03	0.02	0.06	0.09	0.10	0.08	0.11	0.51	0.46	0.39	0.31	0.23	0.16	0.13
Boron	0.03	0.03	0.03	0.03	0.04	0.03	0.05	0.04	0.04	0.03	0.02	0.02	0.03	0.04	0.09	0.09	0.09	0.10
Bromine	0.06	0.06	0.07	0.07	0.07	0.08	0.09	0.10	0.10	0.11	0.18	0.23	0.24	0.21	0.24	0.16	0.21	0.18
Cadmium	0.33	0.34	0.46	0.53	0.70	0.69	0.34	0.35	0.36	0.58	0.47	0.59	0.45	0.39	0.29	0.32	0.38	0.33
Chromite	0.13	0.13	0.14	0.15	0.16	0.11	0.11	0.06	0.15	0.18	0.16	0.19	0.31	0.24	0.22	0.19	0.14	0.13
Cobalt-mine	0.18	0.13	0.13	0.14	0.20	0.24	0.27	0.27	0.23	0.22	0.22	0.26	0.25	0.21	0.22	0.22	0.24	0.27
Cobalt-refinery	0.18	0.13	0.13	0.14	0.20	0.24	0.27	0.27	0.23	0.22	0.22	0.26	0.25	0.21	0.22	0.22	0.24	0.27
Copper-mine	0.08	0.08	0.13	0.17	0.19	0.14	0.12	0.04	0.14	0.22	0.41	0.38	0.30	0.21	0.14	0.09	0.09	0.10
Copper-refinery	0.08	0.08	0.13	0.17	0.19	0.14	0.12	0.04	0.14	0.22	0.41	0.38	0.30	0.21	0.14	0.09	0.09	0.10
Copper-smelter	0.08	0.08	0.13	0.17	0.19	0.14	0.12	0.04	0.14	0.22	0.41	0.38	0.30	0.21	0.14	0.09	0.09	0.10
Feldspar	0.04	0.04	0.03	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.03	0.09	0.13	0.12	0.10
Ferrochromium	0.15	0.15	0.17	0.20	0.23	0.27	0.17	0.10	0.16	0.18	0.17	0.20	0.54	0.44	0.39	0.33	0.27	0.25
Ferromanganese					0.05	0.06	0.04	0.04	0.35	0.34	0.31	0.30	0.41	0.34	0.35	0.29	0.27	0.31
Ferromolybdenum					0.14	0.17	0.15	0.15	0.56	0.74	0.58	0.43	0.30	0.24	0.26	0.26	0.30	0.30
Ferronickel	0.11	0.08	0.14	0.14	0.15	0.14	0.13	0.16	0.21	0.22	0.34	0.40	0.31	0.28	0.26	0.23	0.26	0.13
Ferroniobium							0.03	0.04	0.04	0.04	0.06	0.08	0.21	0.26	0.25	0.21	0.12	0.04
Ferrosilicon	0.16	0.14	0.11	0.08	0.08	0.10	0.07	0.06	0.08	0.09	0.11	0.13	0.24	0.20	0.20	0.17	0.12	0.09
Ferrovanadium					0.42	0.54	0.72	0.93	0.59	0.70	0.59	0.47	0.36	0.30	0.30	0.27	0.29	0.32
Fluorspar	0.09	0.08	0.08	0.07	0.04	0.05	0.04	0.03	0.04	0.09	0.10	0.09	0.08	0.05	0.05	0.05	0.06	0.05
Gallium									0.32	0.31	0.31	0.09	0.12	0.11	0.06	0.05	0.04	0.08
Germanium	0.17	0.16	0.15	0.13	0.13	0.20	0.24	0.35	0.35	0.31	0.20	0.24	0.29	0.21	0.16	0.11	0.11	0.14
Gold	0.01	0.04	0.09	0.12	0.13	0.12	0.07	0.05	0.09	0.10	0.16	0.18	0.19	0.20	0.21	0.22	0.20	0.15
Graphite	0.09	0.04	0.04	0.02	0.04	0.08	0.09	0.11	0.11	0.05	0.03	0.04	0.11	0.14	0.12	0.14	0.13	0.10
Helium	0.07	0.03	0.02	0.02	0.05	0.06	0.05	0.05	0.03	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.07	0.07
Indium	0.23	0.23	0.22	0.20	0.18	0.27	0.33	0.34	0.53	0.65	0.56	0.42	0.27	0.17	0.19	0.17	0.12	0.08
Iodine	0.12	0.15	0.18	0.16	0.10	0.06	0.08	0.11	0.10	0.07	0.10	0.12	0.12	0.11	0.07	0.16	0.18	0.18
Iridium	0.34	0.36	0.63	0.57	0.45	0.32	0.18	0.28	0.33	0.38	0.34	0.33	0.34	0.24	0.23	0.28	0.28	0.24
Iron ore	0.08	0.07	0.03	0.04	0.06	0.09	0.09	0.08	0.10	0.15	0.19	0.19	0.18	0.19	0.18	0.15	0.11	0.07
Lead-mine	0.08	0.08	0.07	0.05	0.04	0.05	0.04	0.03	0.05	0.07	0.13	0.27	0.25	0.20	0.16	0.11	0.08	0.07
Lead-refinery	0.08	0.08	0.07	0.05	0.04	0.05	0.04	0.03	0.05	0.07	0.13	0.27	0.25	0.20	0.16	0.11	0.08	0.07
Lithium	0.02	0.02	0.01	0.02	0.01	0.22	0.31	0.39	0.43	0.43	0.10	0.23	0.29	0.28	0.23	0.13	0.06	0.04
Magnesite	0.43	0.53	0.47	0.39	0.42	0.43	0.43	0.46	0.11	0.13	0.14	0.09	0.06	0.62	0.54	0.45	0.36	0.26
Magnesium-metal	0.07	0.07	0.08	0.10	0.14	0.12	0.12	0.12	0.09	0.08	0.07	0.16	0.26	0.22	0.21	0.16	0.11	0.12
Manganese-mine	0.11	0.04	0.03	0.06	0.06	0.08	0.09	0.07	0.22	0.21	0.20	0.21	0.36	0.30	0.29	0.23	0.19	0.17
Mercury	0.13	0.12	0.17	0.21	0.23	0.21	0.03	0.02	0.26	0.41	0.42	0.34	0.24	0.12	0.18	0.37	0.37	0.31
Mica	0.03	0.05	0.08	0.09	0.09	0.05	0.03	0.02	0.10	0.12	0.25	0.26	0.30	0.44	0.44	0.47	0.35	0.33
Molybdenum	0.37	0.33	0.30	0.30	0.36	0.19	0.18	0.20	0.66	0.76	0.59	0.43	0.29	0.23	0.25	0.26	0.31	0.30
Monazite	0.30	0.14	0.16	0.14	0.13	0.08	0.02	0.02	0.02	0.02	0.03	0.03	0.12	0.12	0.12	0.49	0.46	0.40
Nickel-intermediate	0.11	0.09	0.14	0.14	0.15	0.14	0.13	0.16	0.21	0.22	0.34	0.40	0.31	0.28	0.26	0.23	0.26	0.13
Nickel-mine	0.11	0.09	0.14	0.14	0.15	0.14	0.13	0.16	0.21	0.22	0.34	0.40	0.31	0.28	0.26	0.23	0.26	0.13
Nickel-plant	0.11	0.09	0.14	0.14	0.15	0.14	0.13	0.16	0.21	0.22	0.34	0.40	0.31	0.28	0.26	0.23	0.26	0.13
Niobium			0.03	0.03	0.01	0.03	0.04	0.04	0.05	0.07	0.14	0.14	0.18	0.20	0.20	0.21	0.13	0.07
Palladium	0.10	0.12	0.22	0.28	0.45	0.39	0.31	0.31	0.35	0.42	0.36	0.17	0.14	0.13	0.20	0.25	0.24	0.23
Phosphate	0.03	0.02	0.01	0.06	0.06	0.05	0.04	0.05	0.05	0.02	0.01	0.14	0.29	0.43	0.36	0.28	0.19	0.12
Pig iron and direct reduced iron	0.08	0.07	0.03	0.04	0.06	0.09	0.09	0.08	0.10	0.15	0.19	0.19	0.18	0.19	0.18	0.15	0.11	0.07
Platinum	0.02	0.02	0.04	0.05	0.09	0.09	0.10	0.13	0.15	0.13	0.17	0.17	0.17	0.13	0.12	0.09	0.07	0.07
Potash	0.06	0.07	0.05	0.04	0.04	0.05	0.05	0.05	0.02	0.13	0.17	0.16	0.27	0.34	0.27	0.23	0.19	0.10
Rare Earths	0.11	0.10	0.06	0.08	0.11	0.13	0.14	0.13	0.08	0.09	0.18	0.20	0.29	0.28	0.39	0.75	0.58	0.49
Rhenium	0.21	0.22	0.13	0.10	0.08	0.08	0.08	0.05	0.04	0.04	0.03	0.23	0.86	0.68	0.56	0.45	0.36	0.34
Rhodium	0.56	0.63	0.40	0.30	0.55	0.49	0.41	0.37	0.34	0.33	0.54	0.61	0.50	0.45	0.38	0.39	0.51	0.59
Ruthenium	0.23	0.21	0.23	0.19	0.44	0.40	0.38	0.40	0.39	0.34	0.40	0.83	0.67	0.62	0.54	0.48	0.54	0.41
Selenium	0.09	0.15	0.21	0.24	0.21	0.14	0.13	0.18	0.76	0.83	0.66	0.50	0.36	0.24	0.23	0.27	0.24	0.25
Silicomanganese					0.08	0.09	0.06	0.02	0.30	0.28	0.25	0.29	0.31	0.26	0.26	0.22	0.18	0.30
Silicon	0.10	0.10	0.08	0.09	0.11	0.14	0.11	0.07	0.06	0.08	0.09	0.08	0.13	0.12	0.14	0.23	0.18	0.14
Silver	0.06	0.05	0.04	0.03	0.03	0.07	0.07	0.08	0.09	0.12	0.24	0.27	0.25	0.19	0.18	0.30	0.27	0.23
Steel	0.01	0.01	0.02	0.04	0.05	0.06	0.06	0.04	0.08	0.10	0.12	0.11	0.11	0.07	0.06	0.06	0.06	0.06
Strontium	0.06	0.07	0.06	0.06	0.03	0.02	0.02	0.02	0.10	0.11	0.11	0.14	0.14	0.17	0.14	0.12	0.13	0.21
Sulfur	0.28	0.15	0.11	0.11	0.16	0.26	0.34	0.33	0.33	0.28	0.28	0.18	0.89	1.00	0.91	0.74	0.62	0.56
Tantalum	0.05	0.04	0.05	0.05	0.82	0.80	0.80	0.82	0.85	0.87	0.08	0.05	0.07	0.07	0.10	0.40	0.37	0.31
Tellurium	0.16	0.20	0.18	0.14	0.12	0.12	0.14	0.18	0.19	0.27	0.24	0.24	0.44	0.34	0.28	0.35	0.31	0.29
Tin-mine	0.03	0.04	0.04	0.05	0.06	0.08	0.09	0.09	0.14	0.15	0.17	0.25	0.27	0.20	0.21	0.20	0.13	0.13
Tin-smelter	0.03	0.04	0.04	0.05	0.06	0.08	0.09	0.09	0.14	0.15	0.17	0.25	0.27	0.20	0.21	0.20	0.13	0.13
Titanium	0.06	0.05	0.04	0.03	0.03	0.02	0.02	0.03	0.04	0.04	0.03	0.05	0.05	0.05	0.04	0.12	0.16	0.13
Titanium-sponge	0.07	0.02	0.02	0.03	0.05	0.07	0.09	0.10	0.09	0.22	0.28	0.25	0.23	0.20	0.23	0.25	0.12	0.04
Tungsten	0.11	0.11	0.13	0.14	0.16	0.13	0.12	0.12	0.13	0.39	0.43	0.40	0.31	0.21	0.11	0.14	0.19	0.19
Vanadium	0.15	0.18	0.25	0.23	0.29	0.37	0.46	0.49	0.46	0.81	0.67	0.54	0.39	0.33	0.33	0.23	0.25	0.27
Yttrium	0.05	0.04	0.02	0.03	0.02	0.01	0.01	0.01	0.02	0.02	0.14	0.20	0.24	0.26	0.23	0.45	0.41	0.49
Zinc-mine	0.07	0.07	0.06	0.06	0.06	0.10	0.14	0.12	0.12	0.13	0.43	0.42	0.36	0.31	0.25	0.22	0.19	0.06
Zinc-smelter	0.07	0.07	0.06	0.06	0.06	0.10	0.14	0.12	0.12	0.13	0.43	0.42	0.36	0.31	0.25	0.22	0.19	0.06
Zirconium	0.11	0.12	0.11	0.11	0.11	0.11	0.09	0.02	0.06	0.09	0.17	0.17	0.14	0.10	0.06	0.44	0.44	0.42

Table 10. Potential Criticality (C) indicator values for years 1996-2013

Mineral	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Alumina	0.10	0.08	0.09	0.09	0.09	0.10	0.11	0.09	0.10	0.12	0.15	0.18	0.17	0.16	0.17	0.17	0.17	0.18
Aluminum	0.08	0.08	0.09	0.08	0.08	0.07	0.09	0.08	0.10	0.11	0.16	0.19	0.18	0.18	0.19	0.20	0.20	0.20
Antimony	0.49	0.52	0.49	0.45	0.47	0.45	0.24	0.33	0.41	0.44	0.45	0.48	0.45	0.36	0.36	0.42	0.39	0.35
Arsenic	0.13	0.12	0.13	0.14	0.21	0.23	0.21	0.20	0.17	0.25	0.28	0.28	0.27	0.28	0.15	0.16	0.17	0.19
Barite	0.20	0.22	0.20	0.22	0.20	0.20	0.19	0.21	0.18	0.14	0.15	0.22	0.23	0.20	0.21	0.18	0.24	0.23
Bauxite	0.13	0.13	0.13	0.14	0.13	0.14	0.13	0.13	0.12	0.12	0.12	0.13	0.13	0.11	0.10	0.09	0.10	0.11
Beryllium	0.21	0.21	0.21	0.19	0.11	0.21	0.14	0.16	0.25	0.36	0.29	0.25	0.27	0.25	0.33	0.31	0.29	0.27
Bismuth-mine	0.17	0.20	0.17	0.17	0.14	0.13	0.18	0.23	0.23	0.24	0.24	0.44	0.48	0.49	0.48	0.44	0.36	0.35
Bismuth-refinery	0.15	0.16	0.14	0.10	0.11	0.11	0.19	0.27	0.38	0.34	0.37	0.60	0.57	0.46	0.47	0.42	0.36	0.31
Boron	0.13	0.15	0.15	0.14	0.13	0.13	0.14	0.13	0.13	0.13	0.10	0.12	0.13	0.13	0.27	0.29	0.25	0.24
Bromine	0.16	0.17	0.18	0.17	0.17	0.18	0.17	0.19	0.18	0.19	0.23	0.24	0.24	0.21	0.22	0.19	0.21	0.21
Cadmium		0.05	0.10	0.12	0.14	0.15	0.13	0.14	0.16	0.21	0.20	0.23	0.27	0.26	0.23	0.23	0.26	0.23
Chromite	0.19	0.22	0.23	0.24	0.22	0.20	0.20	0.17	0.23	0.23	0.23	0.26	0.29	0.25	0.26	0.25	0.22	0.22
Cobalt-mine	0.17	0.16	0.22	0.21	0.24	0.26	0.28	0.27	0.28	0.29	0.29	0.27	0.30	0.31	0.37	0.36	0.33	0.34
Cobalt-refinery	0.17	0.15	0.17	0.17	0.16	0.16	0.17	0.17	0.16	0.19	0.18	0.19	0.22	0.25	0.28	0.27	0.26	0.29
Copper-mine	0.11	0.12	0.14	0.17	0.17	0.15	0.14	0.10	0.15	0.17	0.21	0.21	0.19	0.16	0.14	0.12	0.12	0.12
Copper-refinery	0.07	0.08	0.09	0.10	0.09	0.08	0.08	0.06	0.10	0.12	0.16	0.17	0.17	0.16	0.14	0.13	0.14	0.15
Copper-smelter	0.05	0.06	0.07	0.06	0.06	0.06	0.06	0.06	0.09	0.11	0.16	0.17	0.17	0.16	0.15	0.14	0.15	0.16
Feldspar	0.09	0.09	0.09	0.09	0.07	0.04	0.04	0.03	0.03	0.05	0.07	0.07	0.08	0.10	0.15	0.15	0.14	0.14
Ferrochromium	0.18	0.21	0.23	0.24	0.25	0.27	0.23	0.20	0.24	0.23	0.25	0.27	0.35	0.31	0.33	0.31	0.28	0.28
Ferromanganese					0.11	0.12	0.10	0.11	0.27	0.26	0.27	0.31	0.34	0.31	0.31	0.29	0.30	0.32
Ferromolybdenum									0.67	0.71	0.66	0.54	0.45	0.43	0.41	0.30	0.55	0.53
Ferronickel	0.15	0.15	0.19	0.18	0.18	0.22	0.16	0.18	0.20	0.20	0.19	0.24	0.21	0.23	0.26	0.29	0.34	0.32
Ferroniobium													0.43	0.38	0.43	0.45	0.36	0.23
Ferrosilicon	0.19	0.17	0.16	0.14	0.15	0.16	0.15	0.17	0.23	0.24	0.29	0.32	0.38	0.36	0.35	0.33	0.29	0.26
Ferrovanadium									0.50	0.43	0.39	0.38	0.37	0.29	0.33	0.32	0.32	0.32
Fluorspar	0.20	0.20	0.20	0.20	0.17	0.18	0.17	0.16	0.17	0.23	0.24	0.24	0.25	0.21	0.22	0.21	0.23	0.20
Gallium										0.18	0.18	0.15	0.18	0.14	0.18	0.22	0.25	0.31
Germanium						0.31	0.32	0.35	0.35	0.36	0.33	0.36	0.55	0.50	0.44	0.37	0.36	0.37
Gold	0.05	0.08	0.09	0.09	0.09	0.09	0.07	0.06	0.07	0.07	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09
Graphite	0.17	0.15	0.13	0.13	0.17	0.24	0.28	0.31	0.30	0.22	0.18	0.21	0.26	0.24	0.27	0.31	0.29	0.26
Helium				0.15	0.18	0.19	0.17	0.19	0.17	0.05	0.06	0.06		0.08	0.11	0.16	0.20	0.19
Indium				0.18	0.28	0.32	0.32	0.36	0.42	0.49	0.48	0.43	0.35	0.30	0.27	0.27	0.24	0.21
Iodine	0.18	0.22	0.26	0.25	0.22	0.19	0.20	0.24	0.22	0.20	0.22	0.23	0.22	0.23	0.18	0.23	0.25	0.27
Iridium	0.44	0.42	0.60	0.63	0.54	0.45	0.39	0.51	0.47	0.49	0.49	0.52	0.44	0.41	0.40	0.43	0.38	0.37
Iron ore	0.12	0.12	0.09	0.10	0.11	0.13	0.13	0.13	0.14	0.17	0.21	0.21	0.21	0.21	0.21	0.21	0.18	0.16
Lead-mine	0.10	0.12	0.11	0.09	0.10	0.10	0.10	0.11	0.12	0.15	0.20	0.26	0.25	0.24	0.24	0.23	0.22	0.21
Lead-refinery	0.08	0.08	0.08	0.07	0.07	0.09	0.08	0.08	0.11	0.14	0.18	0.23	0.24	0.24	0.23	0.21	0.19	0.18
Lithium	0.10	0.10	0.09	0.10	0.10	0.22	0.24	0.29	0.30	0.29	0.19	0.27	0.27	0.23	0.23	0.21	0.15	0.13
Magnesite	0.25	0.22	0.28	0.23	0.28	0.26	0.30	0.31	0.23	0.22	0.24	0.27	0.25	0.50	0.48	0.51	0.41	0.37
Magnesium-metal	0.17	0.18	0.15	0.16	0.20	0.19	0.21	0.25	0.24	0.23	0.24	0.34	0.37	0.33	0.36	0.32	0.28	0.31
Manganese-mine	0.15	0.10	0.09	0.11	0.11	0.12	0.13	0.12	0.19	0.20	0.19	0.21	0.24	0.21	0.22	0.21	0.20	0.19
Mercury	0.19	0.21	0.17	0.19	0.13	0.17	0.12	0.11	0.37	0.45	0.38	0.31	0.37	0.28	0.37	0.51	0.51	0.44
Mica	0.14	0.17	0.16	0.17	0.17	0.15	0.11	0.10	0.16	0.16	0.45	0.47	0.46	0.52	0.56	0.44	0.40	0.38
Molybdenum	0.27	0.27	0.26	0.24	0.23	0.19	0.18	0.19	0.32	0.35	0.32	0.33	0.30	0.28	0.28	0.28	0.29	0.28
Monazite		0.17	0.22	0.30	0.28	0.28	0.18	0.18	0.16	0.18	0.18	0.18	0.29	0.31	0.34	0.47	0.43	0.43
Nickel-intermediate	0.18	0.16	0.19	0.18	0.19	0.19	0.18	0.19	0.21	0.21	0.25	0.27	0.24	0.25	0.23	0.23	0.24	0.19
Nickel-mine	0.13	0.13	0.16	0.17	0.16	0.16	0.15	0.15	0.16	0.16	0.18	0.20	0.18	0.18	0.18	0.20	0.22	0.19
Nickel-plant	0.11	0.12	0.14	0.14	0.14	0.15	0.13	0.14	0.15	0.16	0.18	0.19	0.18	0.19	0.19	0.20	0.23	0.21
Niobium			0.25	0.22	0.16	0.24	0.24	0.26	0.24	0.31	0.39	0.41	0.48	0.48	0.39	0.37	0.32	0.19
Palladium	0.25	0.26	0.32	0.35	0.37	0.39	0.36	0.36	0.37	0.40	0.36	0.27	0.24	0.23	0.27	0.28	0.27	0.28
Phosphate	0.09	0.08	0.07	0.11	0.11	0.10	0.10	0.10	0.11	0.08	0.08	0.19	0.23	0.29	0.28	0.28	0.25	0.23
Pig iron and direct reduced iron	0.09	0.09	0.07	0.08	0.09	0.12	0.13	0.14	0.16	0.22	0.26	0.27	0.26	0.30	0.29	0.27	0.24	0.21
Platinum	0.15	0.16	0.20	0.21	0.25	0.27	0.26	0.30	0.32	0.30	0.33	0.33	0.30	0.28	0.27	0.23	0.21	0.22
Potash	0.11	0.12	0.12	0.11	0.10	0.11	0.11	0.11	0.10	0.17	0.18	0.18	0.21	0.17	0.20	0.20	0.17	0.14
Rare Earths	0.31	0.30	0.27	0.31	0.31	0.36	0.39	0.38	0.32	0.34	0.45	0.45	0.50	0.50	0.52	0.58	0.54	0.48
Rhenium	0.20	0.23	0.20	0.18	0.16	0.18	0.17	0.15	0.14	0.13	0.13	0.27	0.41	0.37	0.32	0.29	0.29	0.26
Rhodium	0.53	0.56	0.44	0.40	0.48	0.47	0.45	0.45	0.42	0.45	0.51	0.53	0.48	0.47	0.42	0.43	0.44	0.47
Ruthenium	0.42	0.37	0.42	0.43	0.50	0.49	0.53	0.54	0.49	0.49	0.51	0.66	0.58	0.57	0.52	0.52	0.50	0.46
Selenium	0.15	0.16	0.17	0.17	0.17	0.16	0.17	0.19	0.28	0.31	0.30	0.28	0.23	0.21	0.20	0.21	0.19	0.19
Silicomanganese					0.14	0.16	0.16	0.13	0.34	0.33	0.34	0.37	0.40	0.37	0.36	0.34	0.33	0.40
Silicon		0.13	0.13	0.13	0.14	0.13	0.12	0.11	0.12	0.25	0.28	0.26	0.32	0.31	0.28	0.36	0.30	0.28
Silver	0.08	0.08	0.07	0.07	0.07	0.10	0.10	0.10	0.11	0.12	0.16	0.17	0.17	0.15	0.15	0.18	0.18	0.17
Steel	0.04	0.04	0.05	0.06	0.06	0.08	0.09	0.09	0.12	0.16	0.18	0.19	0.19	0.18	0.17	0.17	0.17	0.18
Strontium	0.21	0.22	0.20	0.20	0.13	0.12	0.13	0.14	0.21	0.23	0.23	0.24	0.23	0.24	0.23	0.21	0.21	0.28
Sulfur	0.14	0.12	0.10	0.10	0.10	0.11	0.12	0.12	0.13	0.12	0.12	0.10	0.16	0.18	0.18	0.16	0.16	0.16
Tantalum	0.12	0.14	0.18	0.17	0.41	0.43	0.44	0.42	0.42	0.40	0.14	0.12	0.15	0.14	0.15	0.28	0.24	0.26
Tellurium	0.24	0.23	0.24	0.20	0.16	0.18	0.18	0.19	0.21	0.26	0.26	0.25	0.30	0.27	0.26	0.27	0.26	0.25
Tin-mine	0.13	0.14	0.14	0.16	0.18	0.19	0.20	0.20	0.24	0.25	0.26	0.32	0.28	0.22	0.24	0.25	0.21	0.23
Tin-smelter	0.12	0.13	0.13	0.15	0.17	0.18	0.18	0.19	0.22	0.22	0.24	0.28	0.28	0.25	0.25	0.25	0.22	0.22
Titanium	0.12	0.11	0.10	0.09	0.09	0.08	0.07	0.08	0.09	0.09	0.09	0.10	0.10	0.09	0.09	0.13	0.15	0.14
Titanium-sponge	0.17	0.12	0.13	0.12	0.15	0.17	0.18	0.17	0.19	0.26	0.28	0.29	0.29	0.28	0.28	0.27	0.23	0.18
Tungsten	0.25	0.26	0.32	0.34	0.36	0.36	0.38	0.32	0.40	0.52	0.48	0.41	0.46	0.37	0.33	0.36	0.41	0.40
Vanadium	0.25	0.27	0.31	0.28	0.29	0.31	0.38	0.40	0.40	0.47	0.44	0.39	0.38	0.35	0.36	0.33	0.34	0.35
Yttrium				0.28	0.20	0.18	0.16	0.16	0.18	0.26	0.51	0.57	0.60	0.62	0.49	0.55	0.49	0.51
Zinc-mine	0.08	0.09	0.09	0.09	0.10	0.12	0.13	0.14	0.14	0.15	0.24	0.24	0.23	0.22	0.21	0.21	0.22	0.15
Zinc-smelter	0.04	0.07	0.07	0.08	0.09	0.10	0.12	0.12	0.13	0.14	0.23	0.25	0.24	0.24	0.25	0.24	0.21	0.15
Zirconium	0.20	0.19	0.20	0.18	0.18	0.19	0.20	0.12	0.17	0.19	0.25	0.22	0.20	0.17	0.16	0.30	0.27	0.29