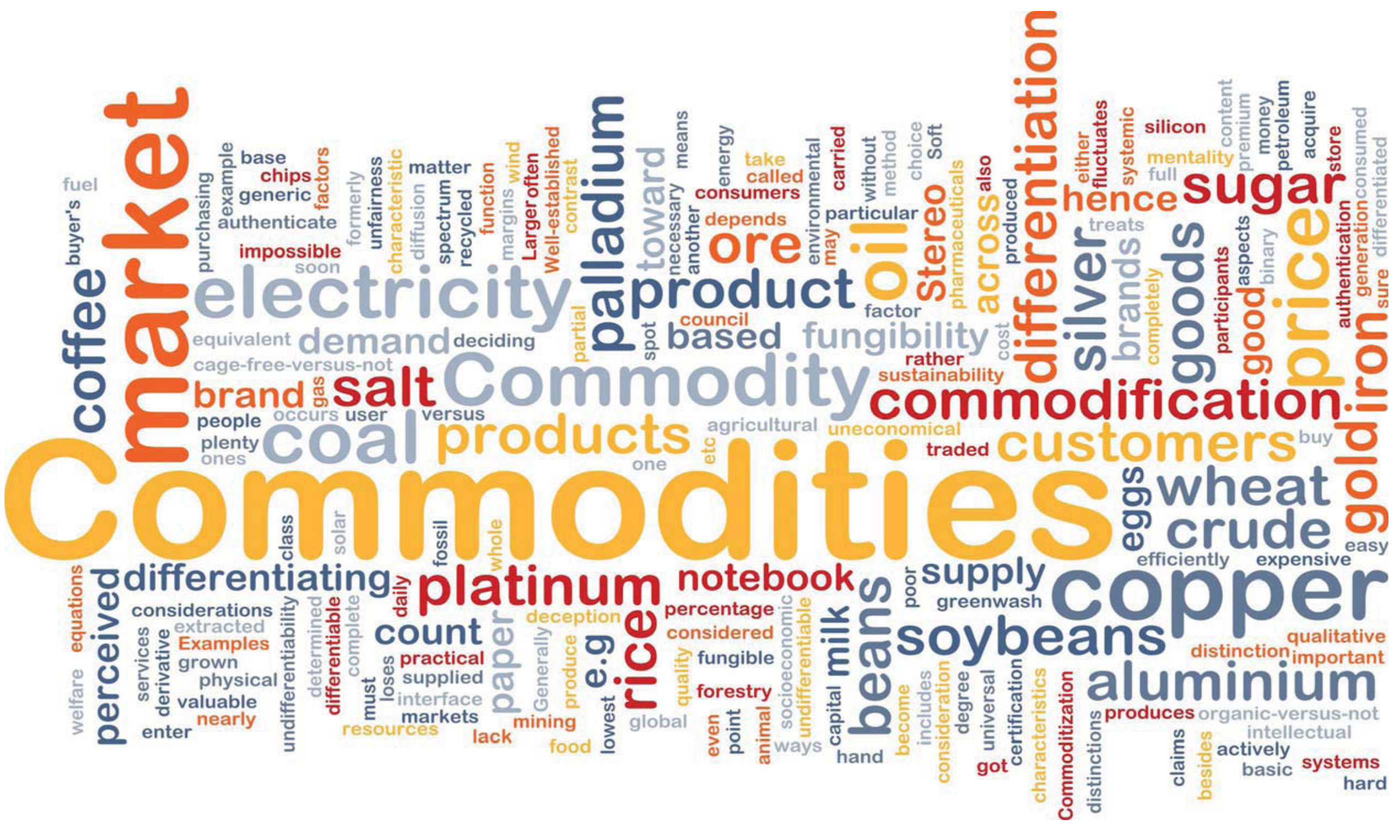
Commodity Special Feature

from WORLD ECONOMIC OUTLOOK
October 2015



International Monetary Fund

Special Feature: Commodity Market Developments and Forecasts, with a Focus on Metals in the World Economy

After experiencing large swings, commodity prices have declined significantly since the release of the April 2015 World Economic Outlook *(WEO). Following an initial recovery, oil prices have since declined on account of strong supply and concerns about future demand. Metal prices have fallen owing to slowing demand growth from China and substantial increases in the supply of most metals. Food prices have also declined owing to abundant harvests this year. With concerns over China's growth, risks to oil and metal prices are on the downside. Weather-related risks to food supplies have heightened. This special feature includes an in-depth analysis of metal markets in the world economy. It puts recent developments into perspective by documenting the dramatic demand and supply shifts over past decades and argues that the balance between demand and supply forces points to a "low-for-long" scenario in metal prices.*

Commodity prices have declined 14 percent since February 2015, the reference period for the April WEO (Figure 1.SF.1, panel 1). Oil prices had initially recovered in response to a sharp drop in investment in the sector, but have since declined again on account of strong supply from members of the Organization of the Petroleum Exporting Countries (OPEC) and the Islamic Republic of Iran nuclear deal. Natural gas and coal prices, which are mainly indexed to oil prices, albeit with a lag, have also declined. Nonfuel commodity prices have also weakened, with metal prices and those of agricultural commodities declining by 13 and 8 percent, respectively.

Global excess flow supply in oil (the difference between global production and global consumption) has continued to increase in 2015 on account of strong supply, in spite of the dramatic fall in investment in the oil sector. In the United States, the number of oil rigs—apparatuses for on-land oil drilling—is half what it was at its peak in October 2014 (Figure 1.SF.1, panel 2). In OPEC countries, production has been increasing despite low oil prices, exceeding OPEC's target of 30 million barrels a day (mbd) by more than 1.5 mbd in August. Russia has also been producing at record levels. In addition, the United Nations Security Council has adopted a resolution establishing a monitoring mechanism for the Iranian nuclear program, paving the way for eventual removal of all nuclear-related sanctions against the country. Iranian crude oil exports are thus expected to increase, and the country is believed to have 30 million barrels of oil inventory. Without sanctions, the Islamic Republic of Iran is also expected to increase its capacity to 500,000 to 800,000 barrels a day within two years. Most of the future increase in Iranian oil supply has been priced in spot markets, contributing to a flattening of futures curves.

While actual global oil demand is strong, there are concerns about what the future will bring. Global oil demand in 2015 is expected to grow at 1.7 mbd above trend growth, the fastest rate in five years, according to the International Energy Agency. It has been revised upward by 0.9 mbd relative to the March projection. However, the recent volatility in stock markets worldwide has triggered concerns about future global economic growth that may eventually affect demand for oil. The loss in confidence in global financial markets added downward pressure on oil prices in August.

Oil futures contracts point to rising prices (Figure 1.SF.1, panel 3). The baseline assumptions for the IMF's average petroleum spot price, which is based on futures prices, suggest average annual prices of $51.62 a barrel in 2015, $50.36 in 2016, and $55.42 in 2017 (Figure 1.SF.1, panel 4). There is still substantial uncertainty around the baseline assumptions for oil prices, but it is slightly less than at the time of the April 2015 WEO.

Metal prices have declined 13 percent since February 2015 (Figure 1.SF.1, panel 5). Prices had initially rebounded as a result of supply concerns but have faced downward pressure since mid-May. China's currency decline and stock market correction have raised concern over the strength of metal demand. China represents roughly half of global demand for major base metals and has been the main engine of global growth since 2002 (see "Metals in the World Economy"). Metal prices are projected to decline by 22 percent in 2015 and 9 percent in 2016. Futures prices point to continued low prices but with rising uncertainty on account of both demand (especially from China) and stronger supply.

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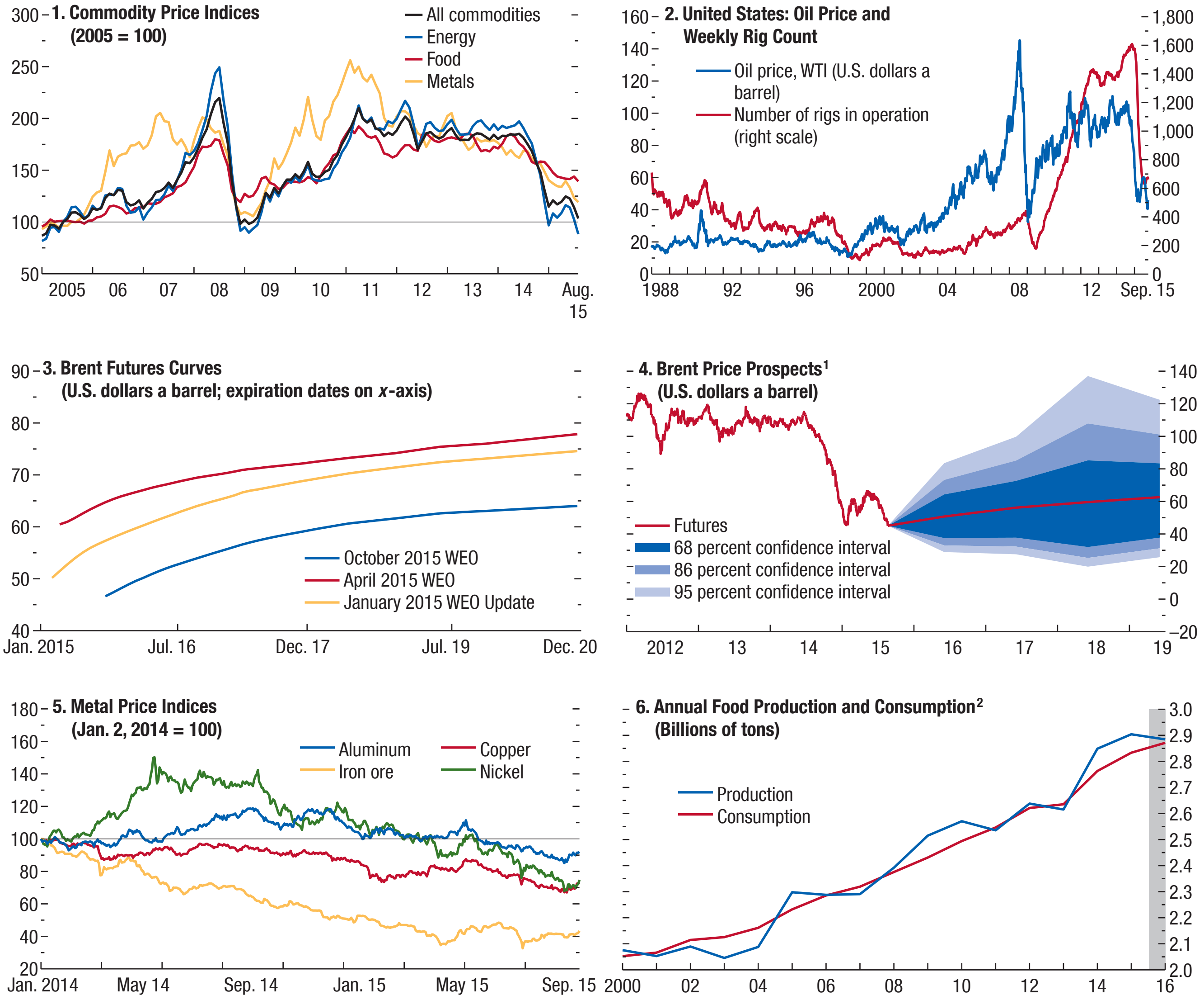
Figure 1.SF.1. Commodity Market Developments



Sources: Baker Hughes Inc.; Bloomberg, L.P.; IMF, Primary Commodity Price System; Thomson Reuters Datastream; U. S. Department of Agriculture; and IMF staff calculations.
Note: WTI = West Texas Intermediate.
[1]Derived from prices of futures options on August 20, 2015.
[2]Sum of data for major grains and oilseeds: barley, corn, millet, rice, rye, sorghum, wheat, palm kernel, rapeseed, soybean, and sunflower seed.

Prices of agricultural commodities have declined by 8 percent overall relative to February 2015. Food prices have decreased 6 percent, with declines in all main indices except that for meat, which has increased slightly. Prices of cereals have fallen despite unfavorable weather in North America and Europe. Prices of agricultural raw materials are also down relative to February 2015 and their highs in 2011. Cotton prices, which have climbed on weaker supply, are a notable exception. Prices of beverages have shown divergent trends: coffee prices have declined in response to a modest recovery in Brazil's arabica production, while tea prices have risen after recent drought in Kenya. Cocoa prices rose in the second quarter of 2015 as a result of weather-related supply shortfalls in Ghana, but demand remains strong.

Annual food prices are projected to decline by 17 percent in 2015 as supply growth, together with high levels of stocks, outpaces slower demand increases. Large declines are expected in prices for cereals and vegetable oil, particularly those for wheat and soybeans. For 2016 the expected drop is relatively smaller (5 percent), following marginal declines in projected production for major crops (Figure 1.SF.1, panel 6). Food price risks are associated with the usual weather variability, particularly concerns over El Niño conditions, which are expected to strengthen through the Northern Hemisphere and persist into the first quarter of 2016.

Metals in the World Economy

Although the recent fall has captured the public's attention, metal prices have been declining since 2011. Some analysts have argued that we are at a critical juncture, pointing to the end of the so-called commodities supercycle. While that is hard to assert with confidence, the prolonged fall in metal prices is consistent with a typical commodity boom-and-bust cycle. Indeed, after a period of high metal prices during the 2000s, investment and in turn capacity in the sector have increased substantially. At the same time, high prices have led to downward adjustments on the demand side. Those adjustments have contributed to a gradual decline in metal prices since 2011, which has led to less investment in the sector, especially in high-cost mines, considering the lower expected profits. The lower investment will eventually reduce capacity, and lower production should eventually lead to a rebound in metal prices. The more prolonged the slump in metal prices, the sharper the likely eventual reversal.

Understanding the evolution of metal markets is important for at least two reasons. First, at the global level, metals are at the heart of the world economy because they are key intermediate inputs in industrial production and construction. Metal markets are thus shaped by shifts in the volume and composition of global demand and supply. As such, transformations in metal markets also signal important changes in the world economy. Second, for some countries, metal exports are a large portion of their total exports, and fluctuations in metal prices can have important macroeconomic consequences.[1] The remaining subsections of this Special Feature address the following questions:

[1]Chapter 2 discusses the macroeconomic consequences resulting from commodity price fluctuations in depth.

- What are metals?
- Where are the main centers of metal production and consumption?
- How have metal markets evolved?
- What lies ahead?

What Are Metals?

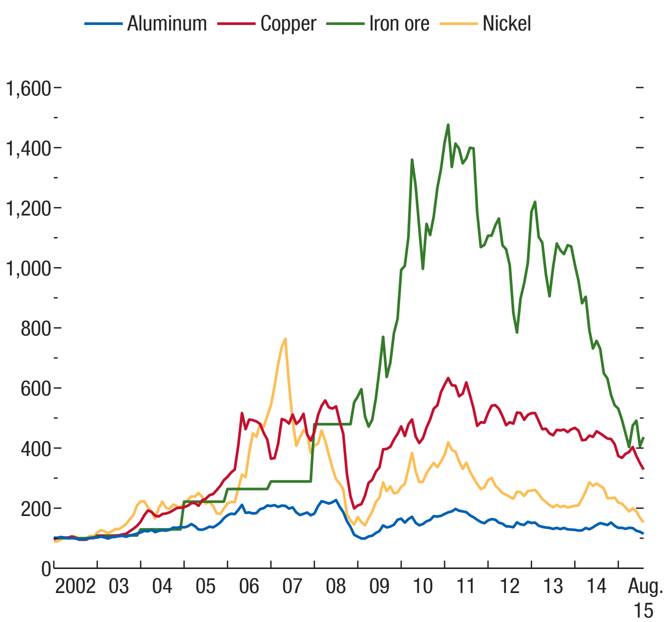
Metals are mineral bodies that come in a variety of forms, from base metals to precious metals. Base metals are those that oxidize or corrode relatively easily. Within base metals, a distinction is made between ferrous and nonferrous metals. Ferrous metals, typically iron, tend to be heavy and relatively abundant. Nonferrous metals do not contain iron in significant amounts. Generally more expensive than ferrous metals, nonferrous metals have desirable properties such as low weight (for example, aluminum), higher conductivity (for example, copper), nonmagnetic properties, or resistance to corrosion (for example, zinc and nickel). The term "base metals" is commonly used in contrast with "noble metals," which unlike most base metals are resistant to corrosion or oxidation. Noble metals tend to be precious metals, often because of their perceived scarcity. Examples include gold, platinum, silver, rhodium, iridium, and palladium. Chemically, precious metals are less reactive than most elements and have high luster and high electrical conductivity.

Unless otherwise indicated, this Special Feature focuses on four main base metals: iron ore, copper, aluminum, and nickel. All have experienced price declines, although to a varying extent (Figure 1.SF.2). The end use of these metals covers a wide spectrum, but construction and machinery are two key sectors for their use, given their ductile and malleable properties.

Where Are the Main Centers of Metal Production and Consumption?

Production and consumption centers for metals are concentrated in a few countries, but the location of production centers varies considerably with the metal under consideration. The main production and consumption centers, however, often overlap: iron ore, for example, given its bulk, must be close to markets. China is front and center for both metal consumption and metal production, also reflecting its importance in world industrial production. Selected multinational or state-owned corporations have large market shares in the production and refining of some of the main

Figure 1.SF.2. Metal Price Indices
(2002 = 100)



Sources: IMF, Primary Commodity Price System; and IMF staff calculations.

Table 1.SF.1. World Crude Steel Production, 2014
(Millions of metric tons)

World	1,643.51	Share (Percent)
China	822.70	50
Japan	110.67	7
United States	88.17	5
India	86.53	5
Russia	71.46	4
Korea	71.04	4
Germany	42.94	3
Turkey	34.04	2
Brazil	33.90	2
Ukraine	27.17	2
Italy	23.71	1
Taiwan Province of China	23.12	1

Source: World Steel Association.

metals. Those high degrees of concentration have at times led to concerns over market manipulation and collusion either through output restrictions, export bans, stock accumulations, or some combination of these (see Rausser and Stuermer 2014 for an analysis of collusion in the copper market).

From an economic point of view, iron ore is by far the most important base metal, with a $225 billion annual industry in terms of global sales.[2] Steel, which is produced from iron ore, is mostly used for construction, transportation equipment, and machinery. In the past, iron ore prices were mostly determined by negotiations between Japanese steel makers and producers. More recently, the market has become more transparent, with the price on delivery at Chinese ports used as the benchmark price. The top iron-ore-producing country is China, whose share is about half of the world's production, followed by Australia and Brazil.[3] Considering that mining iron ore is capital intensive, iron ore production is concentrated among top producers (Table 1.SF.1, Figure 1.SF.3). The production of iron ore depends crucially on the level of investment activity in the sector, which has been on the decline in the past few years. The demand for iron ore comes primarily from large steel-producing countries such as China, which consumes more than half of the world production of iron ore.

Copper is the second-most-important base metal by value—accounting for roughly a $130 billion industry annually.[4] Copper is used for construction and electrical wire. Chile is the largest producer, followed by China and Peru. A few companies are involved in copper production—Chile's Codelco is the largest. Copper prices have been more transparent than those for iron ore because copper futures markets and London Metal Exchange settlements are used as benchmarks. China consumes about half of the world's refined copper.

The third-most-important base metal is aluminum (with an annual $90 billion industry).[5] Aluminum is used in the aerospace industry as well as other industries requiring light metal. Large producers of aluminum are located where electricity is cheap and abundant. The largest producer is China, followed by Russia, Canada, and the United Arab Emirates. Aluminum prices are the most stable among those for metals because of the reliance on electricity in its production—electricity prices are heavily regulated in most countries.

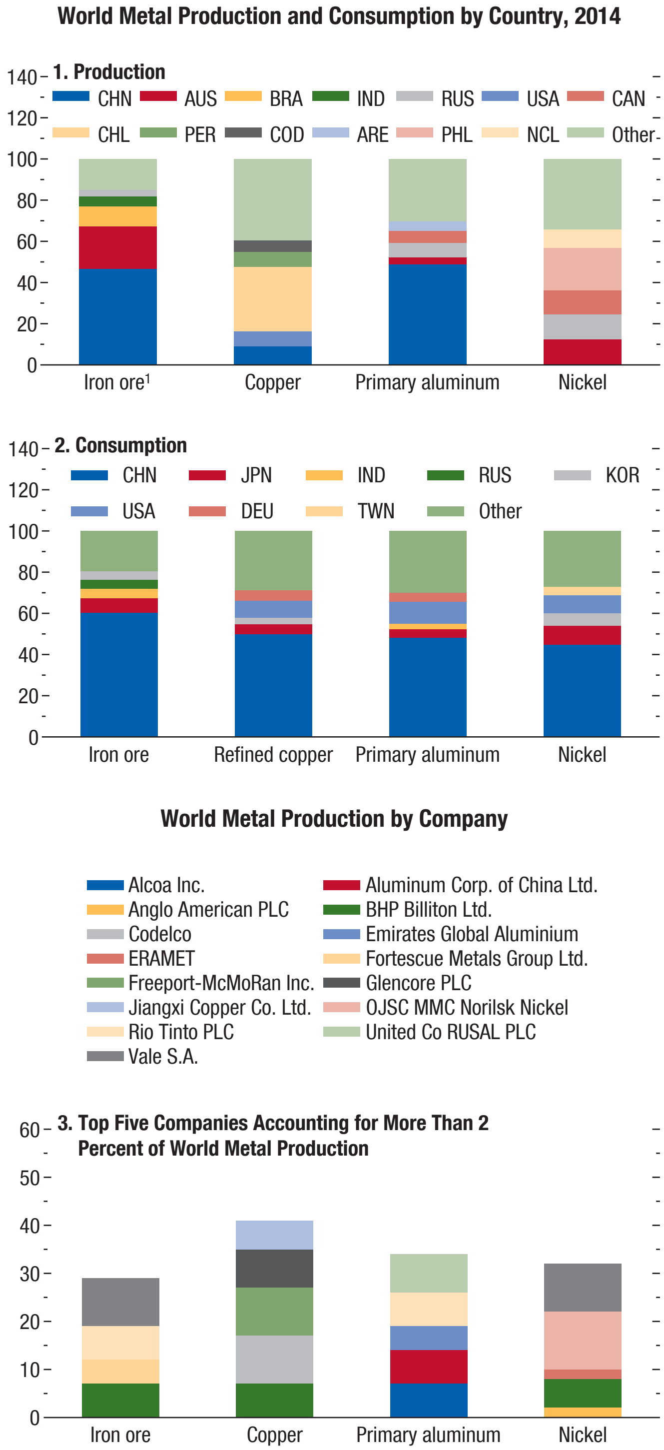
[2]World production of iron ore is currently 3 billion metric tons; its metal content weighs about 1.4 billion tons, according to the U.S. Geological Survey. The price of iron ore with 62 percent iron content has been roughly $100 a metric ton in the past year.

[3]China's share, however, is much smaller when the ore's metal content is taken into consideration. Iron ore is also important for individual countries, such as Ukraine, which relies on coal and iron ore to produce steel.

[4]World mine production was 18.7 million metric tons in 2014. It is evaluated at $7,000 a metric ton, close to the average price in 2014.

[5]World primary aluminum production last year was 49.3 million metric tons, and the associated price was $1,900 a metric ton.

Figure 1.SF.3. Production and Consumption of Metals
(Percent of world production or consumption)



Sources: Bloomberg, L.P.; World Bureau of Metal Statistics; and IMF staff calculations.
Note: Data labels in the figure use International Organization for Standardization (ISO) country codes.
[1]Mine production for China is based on crude ore, rather than usable ore, which is reported for the other countries.

Recycling has become an important part of aluminum production because the recycling process is much less energy intensive than the production of primary aluminum. China consumes about half of the world's production of primary aluminum. In contrast, advanced economies rely more on recycling and in turn have less influence over primary aluminum prices.

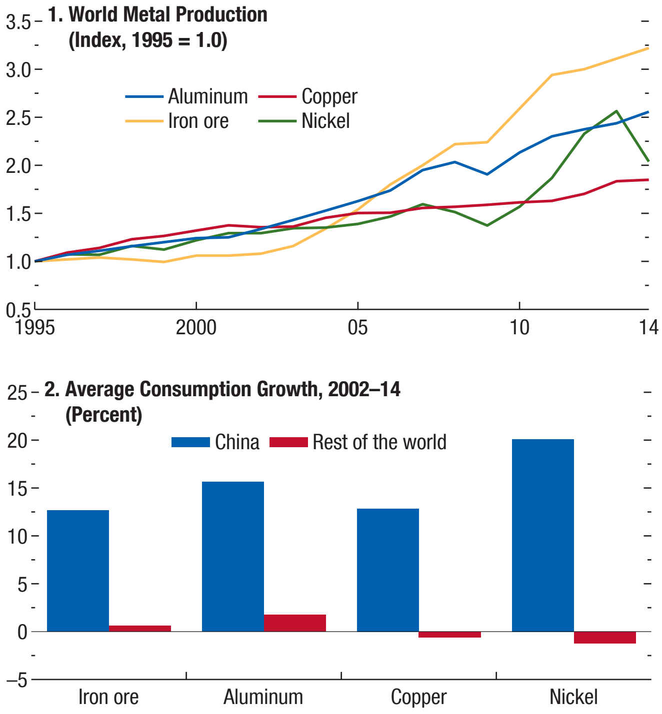
The fourth-most-important base metal is nickel (accounting for a \$40 billion market),[6] which is used for alloys such as stainless steel. Nickel ore is mined in several countries, including the Philippines. The Brazilian Vale groups and Russia-based Norilsk are the two top producers, and their combined share is 23 percent of global production. Nickel is typically extracted from its ores by conventional roasting and reduction processes that yield a metal of greater than 75 percent purity. China consumes about half of the world's smelted and refined nickel, followed by Japan. Indonesia, whose production share was 27 percent in 2012, imposed an export ban on nickel ore in January 2014 to increase incentives for domestic processing. The Philippines and New Caledonia have used the opportunity created by the ban to increase their market shares, but may not be in a position to meet the portion of Chinese demand that relied on Indonesian production. On the other hand, global inventory of refined nickel has been increasing, suggesting a supply glut.

How Have Metal Markets Evolved?

Over the past decades, metal markets have undergone dramatic shifts in the volume and structure of both demand and supply. Global production has increased across the board for most metals owing to the rapid investment in capacity in the 2000s (Figure 1.SF.4, panel 1). On the demand side, demand has shifted from West to East; that is, from consumption concentrated in advanced economies toward that concentrated in emerging markets—especially China on account of its rapid growth (Figure 1.SF.4, panel 2). On the supply side, the so-called frontier of extraction of nonferrous metals, including precious metals such as gold, has shifted from North to South—that is, from advanced to developing economies—because of the rapid improvement in the investment climate, first in Latin America and then in sub-Saharan Africa (see Box 1.SF.1). While high-income member coun-

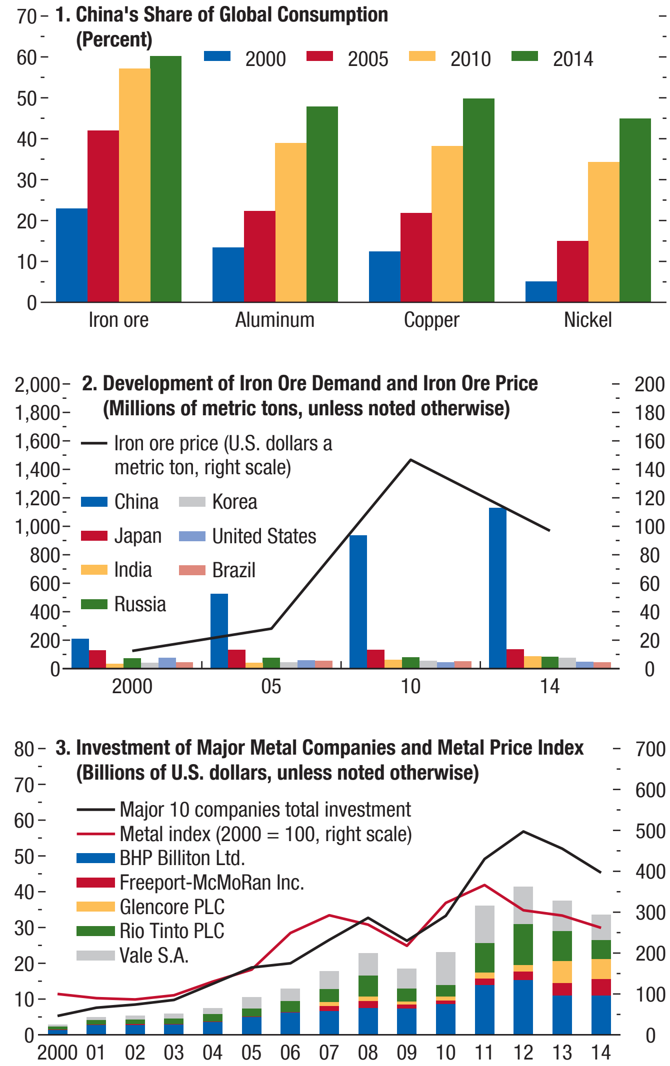
[6]Nickel mine production was 2.4 million tons in 2014, and the price of refined nickel was roughly \$17,000 a metric ton.

Figure 1.SF.4. Evolution of Metal Market



Sources: Bloomberg, L.P.; World Bureau of Metal Statistics; and IMF staff calculations.
Note: The figures reported for iron ore production in China are in crude terms, contrary to what other countries report. Iron ore production data should thus be interpreted with caution. The production figures for iron ore are thus not consistent with those for consumption, because the latter are based on effectively usable iron ore.

Figure 1.SF.5. Development of Metal Market



Sources: Bloomberg, L.P.; IMF, Primary Commodity Price System; World Bureau of Metal Statistics; and IMF staff estimates.
Note: Investments are deflated by the price index for mining and oil field machinery. Total investment is the sum of capital expenditures for Anglo American PLC, BHP Billiton Ltd, Codeleo, Freeport McMoRan Inc., Glencore PLC, Grupo Mexico S.A.B. de C.V., Mitsubishi Corp., Mitsui & Co. Ltd., Rio Tinto PLC, and Vale S.A.

tries of the Organisation for Economic Co-operation and Development accounted for close to half of global discoveries of major mines between 1950 and 1990, sub-Saharan Africa and Latin America and the Caribbean have doubled their shares in total discoveries since 1990, which are about half what they were in the preceding period. The pattern of global trade in metals has radically changed as a result of those shifts in the loci of major discoveries. It should be noted that for steel and aluminum, production tends to be located in countries with combined deposits of iron ore or bauxite—which are abundant worldwide—and port facilities, easy access to energy, and proximity to markets.

On the demand side, the most dramatic development explaining the shift from West to East is the formidable growth performance of China. China's growth in consumption of metals has been the main driving force behind global metal consumption since the early 2000s (Figure 1.SF.5, panels 1 and 2). As a result China is now the main consumption locus for most metals. Far behind, India, Russia, and Korea have also increased their metal consumption, while consumption in Japan has stagnated somewhat. The rapid rise in demand from emerging markets has been a key driver of metal and other commodity prices (see Gauvin and Rebillard 2015 and Aastveit, Bjørnland, and Thorsrud, forthcoming, for systematic evidence on the importance of China and emerging markets in driving metal and oil prices).

On the supply side, investment in the sector has been on the decline. Indeed, available data on investment by

Table 1.SF.2. Metal Trade Evolution
(Millions of U.S. dollars)

1. Bilateral Metal Trade, 2002

Country	China	Germany	Japan	Korea	United States
Australia	1,043	63	2,309	1,067	181
Brazil	605	360	700	179	754
Canada	90	270	353	212	4,232
Chile	784	197	768	541	687
Russia	196	161	716	93	1,061

2. Bilateral Metal Trade, 2014

Country	China	Germany	Japan	Korea	United States
Australia	52,153	53	10,985	6,283	268
Brazil	12,851	1,194	3,004	1,368	1,207
Canada	2,496	311	1,522	1,074	8,815
Chile	15,249	415	4,875	3,252	2,349
Peru	5,621	593	1,030	856	351

Sources: UN Comtrade; and IMF staff calculations.
Note: Data show exports of metals from the countries listed at the left of the rows to the countries listed at the tops of the columns. The gradient of color from green to red refers to the absolute size of trade volume in each panel.

major metal companies producing iron ore suggest that the rapid increase in investment during the period of high metal prices in the early 2000s has been followed by a gradual decline since 2011, closely following the trajectory of metal prices (Figure 1.SF.5, panel 3). As mentioned earlier, for ferrous metals, investment is a good indicator of future supply capacity. For nonferrous metals, the actual quantity available from mineral deposits is much more relevant for predicting supply. A unique data set of discoveries is used here to allow an assessment of the emergence of new frontiers of metal extraction. That assessment offers evidence that prices have played little role in driving discoveries of mineral deposits (see Box 1.SF.1). Instead, rapid improvements in institutions, including those related to property rights in Latin America and Africa, have led to a gradual increase in the number of major discoveries of metals in those regions since the 1990s. The results have important implications both for the welfare of individual countries and for our global understanding of the balance of forces shaping metal markets and the pattern of global trade in metals.

The pattern of global metal trade has evolved dramatically over the past decades,[7] with the major destination countries shifting from West to East and the source countries from North to South. In 2002, metals were exported mainly from Canada and Russia to the United States or from Australia to Japan, Korea, and China. In contrast, by 2014 almost half of metal exports were going from Australia, Brazil, and Chile to China. China has become the largest importer of metals, with its share increasing from less than 10 percent to 46 percent from 2002 to 2014 (Table 1.SF.2).

Many developing economies depend heavily on metal exports. These exports have risen sharply as a percentage of GDP, and the group of largest metal exporters (as a percentage of GDP) has changed substantially as a result (Table 1.SF.3). Metal exports from Chile, Mauritania, and Niger now account for more than half of these countries' total exports of goods. These countries are thus vulnerable to fluctuations in metal prices such as those that have recently occurred as a result of shifts in demand from large importers such as China. Discoveries of new metal deposits have expanded the list of resource-dependent countries that face new challenges in terms of macroeconomic management.

China's recent attempts to rebalance its economy away from investment toward domestic consumption are leading not only to lower Chinese demand for metals, but also to a compositional shift in that demand, which may have different implications for different metals. Metals are heavily used in machinery, construction, transportation equipment, and manufacturing industries, while oil is used mainly in transportation. Thus the decline in growth of manufacturing, machinery, and construction has led to slowing demand for metal since 2010 (Figure 1.SF.6). The metal price index has decreased correspondingly. The potential future rise in the share of the service sector should lead to lower

[7]Here, metals include aluminum, copper, iron ore, lead, nickel, tin, uranium, and zinc.

Table 1.SF.3. Net Metal Exports
(Percent of GDP)

2002	Zambia	11.27
	Chile	8.82
	Guinea	8.02
	Mozambique	7.27
	Papua New Guinea	7.07
	Niger	4.31
	Iceland	4.21
	Peru	3.62
	Namibia	2.88
	Bolivia	2.16
2014	Mongolia	26.52
	Mauritania	21.06
	Chile	15.00
	Zambia	14.76
	Iceland	8.67
	Peru	6.23
	Niger	5.94
	Australia	5.23
	Bolivia	4.75
	Guyana	4.64

Sources: UN Comtrade; and IMF staff calculations.

consumption of metals. Notwithstanding the dramatic increase in Chinese imports of metals, these represent less than 2 percent of China's GDP (Figure 1.SF.7).

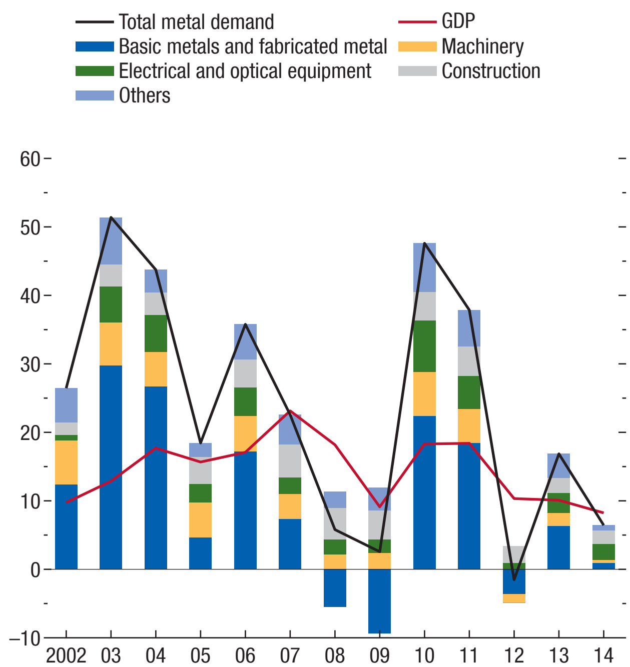
What Lies Ahead?

The slower pace of investment in China, that country's sharp stock market decline since June, and the ample supply of metals have been exerting downward pressure on metal prices. Considering that the decline in metal prices started much earlier, it makes sense to ask what should be expected. As mentioned earlier, futures markets point to lower prices, though the decline is projected to bottom out. But it is helpful in this regard to go beyond futures and review the forces underpinning demand and supply of metals.

On the demand side, the Chinese economy is projected to slow further, albeit gradually, but with considerable uncertainty as to both the time frame for the slowdown and the full extent of the slowing. A basic econometric exercise using historical data and relating the IMF's metal price index to China's industrial production (with both variables expressed as logarithms) shows that the fall in prices can be explained quite well by the decline in industrial production (Figure 1.SF.8), with 60 percent of the variance in metal prices explained by fluctuations in China's industrial production. In addition, this simple regression suggests that the fall in China's industrial production in recent months could produce further metal price declines, as evidenced by the decoupling between the fitted and actual growth rates in the metal price index.

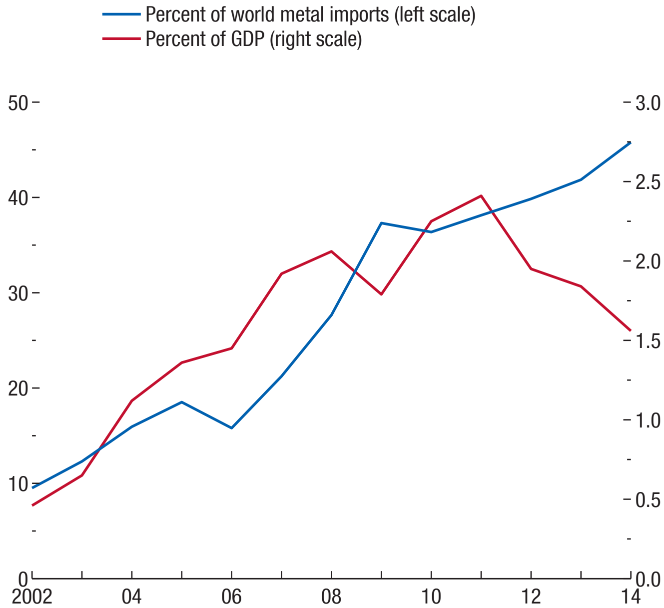
On the supply side, the drop in investment is unlikely to lead to a substantial price rebound in the near future. Low energy prices have in fact helped reduce mining and refining costs, including those for copper, steel, and aluminum. High-cost mines will certainly close down first, considering that current metal prices may be close to these mines' break-even point. However, a recent analysis of the cost-price relationship released by consulting firm SNL Metals & Mining concludes that during cyclical low points in metal prices, the copper price has fallen to at least the ninth decile of high-cost producers, which indicates that prices would need to fall further before substantial

Figure 1.SF.6. China: Composition of Metal Use and Growth Rates by Sector
(Percent)



Sources: Bureau of National Statistics, China; World Input-Output Database; and IMF staff calculations.
Note: The growth rates of total demand for metals are calculated as the sum of output growth rates for each sector, weighted by the shares of metal input in the individual sector in the total economy. The share of metal input for each sector is calculated based on the World Input-Output Database. For the calculation, the value of the share of metal input in the most recent year is chosen, that is, 2011, considering that the share of metal input has been quite stable over the years. Given that the output data for China are not available at the sector level, profit data by sector are used as a proxy for most of the industries, and for nonindustry sectors, GDP data by industrial classification are used.

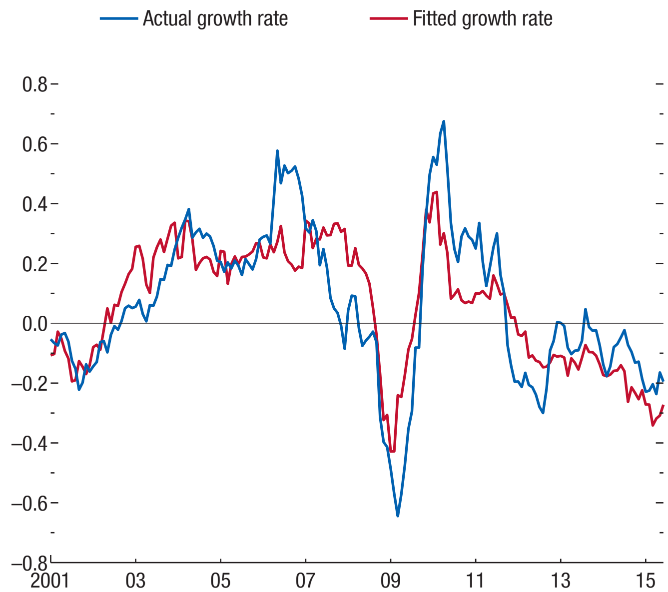
Figure 1.SF.7. China: Metal Imports



Sources: UN Comtrade; and IMF staff calculations.

Figure 1.SF.8. Growth Rates of Metal Price Index

(Percent)



Sources: IMF, Primary Commodity Price System; and IMF staff calculations.
Note: The figure shows the actual and fitted annual growth rate of the metal price index. The fitted growth rate is based on the regression of the annual growth rate of the metal price index on the annual growth rate of China's industrial production.

capacity becomes vulnerable to closure.[8] Moreover, the secular expansion of the frontier of metal extraction to Latin America and Africa as a result of improvements in the investment climate is unlikely to revert to any great extent. Instead, those improvements should continue steadily. Thus ample supply is likely to continue pushing metal prices farther down.

The balance between weaker demand and a steady increase in supply suggests that given the existing cost structure, metal markets are likely to experience a continued glut, leading to a low-for-long price scenario. In turn, the risks associated with such a scenario are that investment will continue to falter and lead to a sharp increase in prices down the road.

[8]See http://www.snl.com/Sectors/MetalsMining/Default.aspx.

Box 1.SF.1. The New Frontiers of Metal Extraction: The North-to-South Shift

Fundamental factors underpinning the demand for primary commodities, including metals, have received much attention, but supply-side factors have not. As noted in the Special Feature text, the center of gravity of global demand has shifted from West to East as a result of the high growth in emerging markets—especially China—in the past two decades. This box argues that developments in the supply of metals have been perhaps just as dramatic. The box focuses on discoveries of major metal deposits that signal previously unknown possibilities to expand global supply.[1] The main finding is that the new frontiers of metal exploitation have shifted from North to South, that is, from advanced to emerging market and developing economies.

Metal Discoveries through Space and Time

A critical look at the data on known reserves of subsoil assets suggests that emerging market and developing economies have substantial deposits of metals that have yet to be discovered. There is an estimated $130,000 in known subsoil assets beneath the average square kilometer of Organisation for Economic Co-operation and Development (OECD) countries, which contrasts with only about $25,000 in Africa (see Collier 2010 and McKinsey Global Institute 2013). It is unlikely that those differences represent differences in geological formations between advanced and developing economies. Rather, differences in the quality of property rights and political stability can help explain why relatively less exploration effort has been devoted to emerging market and developing economies. Improvements in the institutional environments of these economies accelerated rapidly in the 1990s, however, and a cursory look at the data on political risk seems to indicate that the timing of the improvements coincides with the increase in the share of discoveries in Latin America and Africa (Figure 1.SF.1.1).

Data on discoveries of a wide range of metal deposits obtained from the consulting firm MinEx suggest that the frontier of metal exploitation has gradually moved from advanced to emerging market and developing economies (Figure 1.SF.1.2). The total number of discoveries has remained broadly constant, but the distribution has changed. Although high-income OECD countries accounted for 37 to 50 percent of all discoveries during 1950–89, this share fell to 26 percent in the first decade of this century, with sub-Saharan Africa and Latin America and the Caribbean doubling their shares. Latin America has experienced the most discoveries of metal deposits in the past two decades.

Figure 1.SF.1.1. Metal Deposit Discoveries in Latin America and the Caribbean and Sub-Saharan Africa

Sources: MinEx Consulting; PRS Group, *International Country Risk Guide;* and IMF staff calculations.

What Do the Data Show about the Drivers of Discoveries?

Investments in exploration and extraction activities involve sunk costs and are thus subject to the holdup problem.[2] For an investment to be expected to be profitable, a stable political environment, a low risk of expropriation,

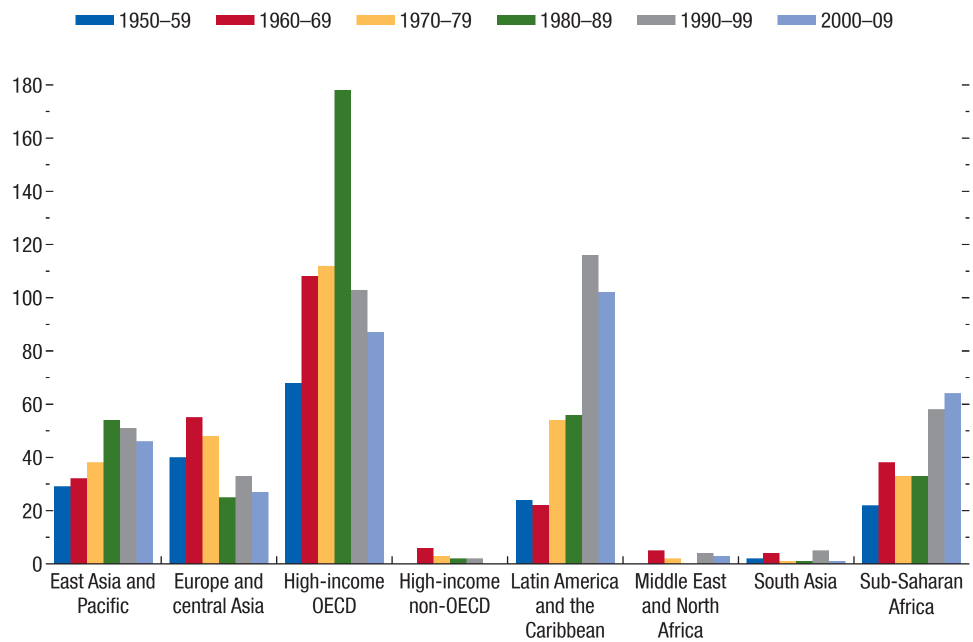
The authors of this box are Rabah Arezki and Frederik Toscani.

[1]The data used in this box are from MinEx Consulting. The list of metals used in the analysis is comprehensive and includes precious metals and rare earth. The data set excludes iron ore and bauxite, which tend to be relatively more abundant than other metals and require for their exploitation proximity to port facilities in the case of the former and substantial energy availability for the latter.

[2]The results presented in this section are also robust to an array of checks, including additional controls and estimators.

Box 1.SF.1 *(continued)*

Figure 1.SF.1.2. Number of Metal Deposit Discoveries by Region and Decade



Source: MinEx Consulting.
Note: OECD = Organisation for Economic Co-operation and Development.

and a favorable investment climate are crucial (Acemoglu, Johnson, and Robinson 2001; Bohn and Deacon 2000). Cust and Harding (2014) provide evidence that institutions substantially affect oil and gas exploration.[3] Mining could be seen as more expropriable than oil extraction because mining output does not move through pipelines and takes place exclusively on land.

The approach in this box is to estimate, using a panel data set, a zero-inflated Poisson model with the number of mine discoveries by country, year, and metal as the dependent variable.[4] N_{itm} denotes the number of mines discovered in country i at time t and for a specific metal m. N_{itm} is assumed to follow a Poisson distribution.

The main explanatory variable of interest is a country's political risk rating, obtained from the *International Country Risk Guide*'s (ICRG's) Political Risk Index. The regressions include metal fixed effects because metals differ in their abundance and location. They also include country fixed effects to capture time-invariant country characteristics that are hard to observe, such as actual geology, and year fixed effects to control for technology and other global shocks. In addition, price changes for the corresponding metals over the past five years are controlled for. The baseline specification uses the standard log-linear approach to model the expected number of mine discoveries for metal m in country i at time t in the three-way Poisson regression model:

$$\ln E(N_{itm}) = \alpha + \beta \Delta p_{t-1,m} + \gamma ICRG_{it-1} + \delta X_{itm},$$

Arezki, van der Ploeg, and Toscani (forthcoming) present extensive technical details and an in-depth discussion of endogeneity.

[3]These authors' identification strategy relies on exploiting variations in institutions and oil deposits sitting on both sides of a border.

[4]Large numbers of zeros and the heteroscedasticity of errors may imply that ordinary least-squares results will be biased and inconsistent. Silva and Tenreyro (2006) suggest the Poisson pseudo–maximum likelihood estimator to address this issue. This box follows this suggestion and uses zero-inflated Poisson models. The count data are modeled as a Poisson count model, and a logit model is used to predict zeros.

Box 1.SF.1 *(continued)*

Table 1.SF.1.1. Impact of Political Institutions on Mineral Discoveries

Variables	(1)	(2)	(3)	(4)
Political Risk Rating, Lagged	0.0216*** (0.00729)	0.0171** (0.00782)	0.0192** (0.00783)	0.0195** (0.00787)
Polity2 Score, Lagged		0.0128 (0.0155)	0.0179 (0.0156)	0.0173 (0.0155)
Stock of Discoveries, Lagged			0.0161*** (0.00343)	0.0162*** (0.00344)
Political Risk Rating x Change in Metals Price				–0.00635 (0.0165)
Log Change in Metals Price	–0.449 (0.316)	–0.464 (0.320)	–0.466 (0.320)	–0.0207 (1.159)
Log Change in Metals Price, Lagged	–0.334 (0.315)	–0.341 (0.314)	–0.345 (0.322)	–0.345 (0.322)
Number of Observations	37,252	35,480	31,812	31,812

Source: IMF staff estimates.
Note: Robust standard errors are in parentheses. Country, year, and metal fixed effects are included in all regressions.
*$p < .1$; **$p < .05$; ***$p < .01$.

in which the vector α includes country, time, and metal fixed effects. The key controls of interest are the natural logarithm of the world market price for metal *m* and the measure of political risk *ICRG*. The vector *X* includes other controls. It should be noted that the quality of institutions may be endogenous to metal discoveries in that these discoveries may, for instance, trigger conflicts over resources and erode institutions (Ross 2001, 2012). Any such endogeneity will, however, tend to bias the coefficient associated with institutions toward zero, and as such, that coefficient should be interpreted as presenting a lower bound. To alleviate issues of reverse causality somewhat, the political risk rating is included with a one-year lag. In addition, lagged discoveries are controlled for, to account for the clustering of discoveries. The interactions between *ICRG* and metal price and between price and fixed effects are also explored. Other robustness checks consist of adding controls such as GDP per capita and the initial capital stock and using price levels instead of changes. The main results remain unchanged.

The political risk rating, reflecting property rights and political stability, is found to be statistically and economically significant (Table 1.SF.1.1). The results indicate that a one standard deviation improvement in the political risk rating (which corresponds to a move from, for example, Mali to South Africa, South Africa to Chile, or Chile to Canada) would lead to 1.2 times as many metal discoveries in those countries. To provide a further sense of the relevant magnitude, a thought experiment is conducted in which Latin America's and sub-Saharan Africa's median property rights suddenly jump to the levels of the most advanced economies in each of these regions, which are, respectively, Chile and Botswana. This experiment yields a 15 percent increase in the number of mines discovered worldwide, all else equal. The figure increases to 25 percent if instead Latin America and sub-Saharan Africa were to suddenly adopt the same level of property rights as in the United States, again all else equal. Notwithstanding the dramatic increase in institutions forced by the thought experiment, the magnitudes suggest that institutions play an important role in driving exploration for and ultimately discoveries of metals. Institutions affect discoveries through a variety of channels besides the perception of risk on the part of the potential foreign investors. For instance, better institutions could affect the adoption of better technology or improve the quality of the labor force and in turn affect the number of discoveries. The analysis here does not attempt to separate those channels.

Results also suggest that movements in metal prices over the past five years are not statistically significant in explaining the number of discoveries. The likelihood of additional discoveries appears to increase with

Box 1.SF.1 *(continued)*

previous discoveries, as would be expected given the reduced risk of exploring close to a known deposit.

What Are the Implications?

The North-South shift in the frontier of metal exploitation is likely to have important consequences for individual economies with newly found metal deposits, especially in Latin America and Africa. Indeed, these discoveries expand the list of resource-rich countries. New mines mean more investment and jobs, especially in the resource sector, and increased government revenues. New trade routes have been inaugurated from Latin America and Africa to emerging Asia. However, these newly found resources pose challenges for the conduct of macroeconomic policy in developing economies in both the short and the long term.

While demand for metals emanating from emerging markets has been a key driver of recent global metal market developments, progress in the quality of institutions has helped increase the supply of metals and shifted its composition. A future steady increase in institutions along with slowing demand could lead to excess supply and exercise further downward pressure on prices.

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