Estimates of Immediate Effects on World Markets of a Hypothetical Disruption to Russia's Supply of Six Mineral Commodities

Open-File Report 2017–1023

U.S. Department of the Interior
U.S. Geological Survey

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RYAN K. ZINKE, Secretary

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William H. Werkheiser, Acting Director

U.S. Geological Survey, Reston, Virginia: 2017

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Suggested citation:
Safirova, Elena, Barry, J.J., Hastorun, Sinan, Matos, G.R., and Perez, A.A., with contributions from Bedinger, G.M., Bray, E.L., Jasinski, S.M., Kuck, P.H., and Loferski, P.J., 2017, Estimates of immediate effects on world markets of a hypothetical disruption to Russia's supply of six mineral commodities: U.S. Geological Survey Open-File Report 2017–1023, 22 p., https://doi.org/10.3133/ofr20171023.

ISSN 2331-1258 (online)

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Mass	
troy ounce (oz t)	31.103	gram (g)

International System of Units to U.S. customary units

Multiply	By	To obtain
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)
megagram (Mg) = 1 metric ton (t) (1,000 kg)	1.102	ton, short (2,000 lb)
kiloton (kt) = 1,000 metric tons	1.102	1,000 short tons
megaton (Mt) = 1 million metric tons	1.102	1 million short tons

Abbreviations

Al	aluminum
ATI	Allegheny Technologies Inc.
BPC	Belarusian Potash Company
DSO	direct shipping ore
EECA	Eastern Europe and Central Asia
EU–28	European Union, which, as of 2014, consisted of 28 countries
HY	half year
IAI	International Aluminium Institute
IFA	International Fertilizer Association
INSG	International Nickel Study Group
K	potassium
K_2O	potassium oxide
KCl	potassium chloride
LME	London Metal Exchange
N	nitrogen

NESHAP	National Emission Standards for Hazardous Air Pollutants
P	phosphorus
Plc	public limited company
RTI	RTI International Metals
TIMET	Titanium Metal Corp.
UN Comtrade	United Nations Commodity Trade Statistics (database)
U.S.	United States
USGS	U.S. Geological Survey
VSMPO	VSMPO–AVISMA Corp.

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Abstract

The potential immediate effects of a hypothetical shock to Russia's supply of selected mineral commodities on the world market and on individual countries were determined and monetized (in 2014 U.S. dollars). The mineral commodities considered were aluminum (refined primary), nickel (refined primary), palladium (refined) and platinum (refined), potash, and titanium (mill products), and the regions and countries of primary interest were the United States, the European Union (EU–28), and China. The shock is assumed to have infinite duration, but only the immediate effects, those limited by a 1-year period, are considered.

A methodology for computing and monetizing the potential impacts was developed. Then the data pertaining to all six mineral commodities were collected and the most likely effects were computed. Because of the uncertainties associated with some of the data, sensitivity analyses were conducted to confirm the validity of the results.

Results indicate that the impact on the United States arising from a shock to Russia's supply, in terms of the value of net exports, would range from a gain of $336 million for titanium mill products to a loss of $237 million for potash; thus, the overall effect of a supply shock is likely to be quite modest. The study also demonstrates that, taken alone, Russia's share in the world production of a particular commodity is not necessarily indicative of the size of potential impacts resulting from a supply shock; other factors, such as prices, domestic production, and the structure of international commodity flows were found to be important as well.

Introduction

The world's economies depend on uninterrupted global trade of mineral commodities. Geopolitical instability and natural disasters may cause disruptions in mineral production, affecting supply chains that are vital to national economies. The resulting impact can be measured by the increase in cost incurred to import the affected commodity. Because minerals are not evenly distributed, some countries are richer in mineral resources than others. Countries such as Australia, Canada, China, Russia, and the United States possess a significant amount of wealth in a number of mineral commodities, and a catastrophic shock to mineral production in any one of these countries could create worldwide shortages, significant price increases, and instability in global and national economies.

In recent years, researchers examined vulnerabilities in supply chains due to some type of disruption. Supply chains were disrupted when mineral-related facilities were affected by the northern Honshu, Japan, earthquake on March 11, 2011, and the ensuing tsunami (Menzie and others, 2011). A notable example from this disaster was the temporary shutdown of a titanium dioxide processing facility. The facility was the sole source of a black automobile paint pigment. This shutdown resulted in a months-long shortage of black trucks (Harrington, 2011). Another significant example is the South African mining industry, which was affected by labor strikes in 2011, 2012, and early 2014. South Africa is the world's top platinum producer and second leading palladium producer. The loss of South African platinum to the global supply chain due to strikes is nearly impossible to make up from other producers in the short term and was predicted to cause shortages in world markets (Yager and others, 2013). However, platinum supply became adequate to meet demand because of the release into the market from investors' inventories.

Russia is rich in natural resources and is a leading producer of many mined and processed mineral commodities. A shock to Russian supply of key mineral commodities would have an impact on global and regional markets. In the study described in this report, the authors developed a methodology to estimate the immediate global impact of such a supply shock on six major mineral commodities produced in Russia: aluminum (refined primary), nickel (refined primary), palladium (refined) and platinum (refined), potash, and titanium (mill products) and the resulting economic impact to the United States, the European Union, and China. A case where

Table 1. Russia's share of world production of selected mineral commodities in 2013.

[Production quantities are in thousands of metric tons unless otherwise specified. Data in this table are from more recent publications than the data used in the study. These data were not used in the analytical work because they became available after the analytical work was completed]

Mineral commodity	World production	Russia's production	Russia's share of world production (percent)	Source
Aluminum	47,600	3,720	8	Bray (2015b).
Nickel	2,630	275	10	Kuck (2015).
Palladium*	203	80	40	Loferski (2015).
Platinum*	183	26	14	Loferski (2015).
Potash	34,500	6,100	18	Jasinski (2015).
Titanium mill products	191	31	16	Authors' calculations.**

*Palladium and platinum production quantities are in metric tons.

**Authors' calculations using average annual growth of the previous 10 years and data from Bedinger (2014b), VSMPO–AVISMA Corp. (2014), and Roskill Information Services Ltd. (2013).

Russia's production of the selected mineral commodities is halted completely in June 2014 was hypothesized. The supply of these commodities going forward would be reduced by the amount of estimated Russian production. It is assumed that Russia's production is halted forever; however, only immediate effects of the halt (those registered within 1 year from the initial impact) are computed in this study.

Table 1 illustrates Russia's role as of 2013 in world production of the six mineral commodities considered in this report. For all of these mineral commodities, Russia was a major producer, and the loss of Russian supply in June 2014 would have had a notable impact on regional markets, as well as on the world market. Russia's presence in the aluminum market reached beyond production within its borders. The Russian aluminum company called United Company RUSAL (RUSAL) had holdings and operations in many countries across the globe. Russian nickel was significant because the country was one of the world's leading producers of mined nickel and was the leading producer of refined nickel. In 2013, Russia was the second leading platinum producer and the leading palladium producer in the world. Russia was also the second leading potash producer in the world and the top source of imports for a significant number of countries across the world. Finally, Russia was a major manufacturer of titanium mill products. However, its role in supplying specific titanium mill products to the U.S. and European aerospace industries was even more crucial than its role in supplying such products to the rest of the world because such products are highly specialized and cannot be quickly produced by other companies if a shortage arises on the market.

Methodology and Assumptions

The immediate effects of the hypothesized disruption in supply of Russian mineral commodities to the world market were estimated and monetized in this study in 2014 U.S. dollars. The immediate effects are defined as the effects perceived by the market participants immediately after the disruption in supply occurs. Therefore, the primary impact of the disruption is reflected in the increase in the market price observed soon after the initial disruption takes place. As time goes by, market participants would adapt to the new market conditions and either (1) reduce the quantity demanded for the commodity in question by replacing it with other commodities or (2) increase the quantity supplied of the commodity in question, or do both. Later, if the supply disruption persisted, market participants would engage in activities usually associated with the long run, such as open new facilities and close old ones or develop and implement new technological processes. All such actions would eventually alleviate the impact of the initial shock and would reduce the equilibrium market price of the commodity. Arguably, this immediate price effect constitutes an upper bound—the highest level—of the impact of the disruption. This report focuses on estimation of the initial, immediate impact and does not address the impacts that would take place in the longer term.

Furthermore, in order to be able to compute and monetize the impact of the supply disruption, certain assumptions were made. Inventories typically are available to help mitigate shortages; in this study, they were explicitly taken into account for aluminum, nickel, and potash only. The central assumption is that the world market for each of the six commodities considered is in a competitive equilibrium, and the quantity supplied equals the quantity demanded. Although none of the six markets considered in the report is perfectly competitive, for most of them, the perfectly competitive equilibrium assumption is an acceptable approximation. How well a particular market fits the definition is discussed in the sections on individual commodities.

By using a standard economic model of perfectly competitive market equilibrium, price increases due to the initial supply shock were estimated (fig. 1). Numerous studies provide evidence that for supply, the short-run elasticity

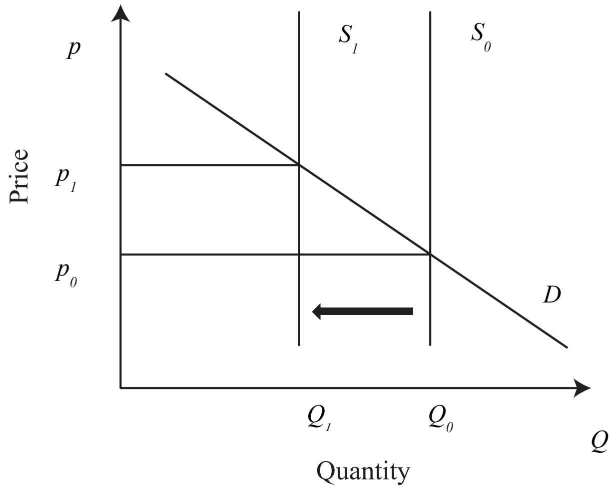

Figure 1. Graph showing a generalized depiction of the effect on the world market of a hypothetical disruption in Russian supply of a mineral commodity. S_0 and S_1 are supply curves before and after the disruption, respectively. D is the demand curve. Q_0 and Q_1 are the equilibrium quantities of world production, before and after the shock. Variables p_0 and p_1 are world prices.

of mineral commodities is usually either perfectly or almost perfectly inelastic (Cuddington and Zellou, 2012; Östensson, 2010; Stuermer, 2013). Thus, the supply was assumed to be perfectly inelastic, and therefore the supply curve S_0 on figure 1 is vertical. As such, the removal of Russian supply from world production due to a supply disruption results in a shift to the left of the supply curve. The magnitude of the shift is equivalent to total Russian production. The new point of equilibrium (the intersection between the curves D and S_1) is calculated by using the slope of the demand curve D, the initial point of equilibrium, and the total Russian production. As we are assuming a linear demand curve, the slope is equal to the short-run own-price elasticity of demand for the commodity in question. The issues related to the elasticity estimation are discussed in the "Data" section.

Once the initial change in the world price of a given commodity was estimated, the immediate losses and gains perceived by the individual countries and groups of countries were calculated. In this study, an issue of particular interest was the computation of losses and gains for the United States, the European Union (the EU–28),[1] and China. In this methodology, there is no explicit modeling of what happens to Russia's production of the mineral commodities; instead, a straightforward assumption was made that the Russia-produced supply becomes unavailable. Also, potential losses that Russia would suffer from this supply disruption were not calculated. Likewise, in the calculations of the losses and gains for the rest of the world, Russia is excluded. Separate calculations, however, are made for all other countries, excluding Russia, which are collectively referred to as "the rest of the world." The losses were computed as the additional cost the countries that were net importers would bear if they had to purchase the same amount of the commodities in question on the world market as they did prior to the price increase. Conversely, the countries that were net exporters of the commodity in question would realize gains due to the price increase.

[1]The European Union (EU) is a supranational entity that, as of 2014, consisted of the following 28 countries: Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom.

Caveats

The methodology described above is, by design, not comprehensive and does not take into account several potentially important consequences of supply restrictions. Most importantly, it is limited to the effects related to the market of the affected commodity and does not account for gains or losses realized in other related markets, in particular, those in the related downstream and upstream markets. For example, the supply restriction on the market for titanium mill products may negatively affect the aerospace industry, which is a significant consumer of those products. This methodology, however, does not include the effects on other linked industries.

Similarly, a supply restriction imposed on the market of one commodity is likely to increase demand for substitute commodities, and the producers of the substitute commodities may realize gains from the increased demand for their goods. Effects of this kind are not included for two reasons. First, the methodology is able to capture only the immediate effects, which are observed before the consumers of the commodity in question introduce any measures to reduce their losses. Second, the effects of the initial restriction on other industries are not included in the analysis.

Data

For the purposes of this study, it was assumed that the supply shock took place in June 2014, and when it took place, economic agents expected its impact to affect their operations for about 1 year. When the reported data were not available, the estimated quantity of supply was obtained by getting the closest, most reasonable estimate for June 2014 production. Because of the differences in reporting of data for different commodities, it was necessary to use different estimation methods. The estimates for monthly aluminum production come from the International Aluminium Institute (IAI). Reported data for nickel were obtained from the International Nickel Study Group (INSG). The palladium and platinum estimates were based on the quarterly production reports from 7 of the top 11 global producers. Potash production was taken as a simple average of the half-year worldwide production data for 2014 as reported by the International Fertilizer Association (IFA). A 10-year growth rate was applied to the production of titanium mill products to obtain an estimate for 2014 production and then the number was divided by 12 to obtain monthly production.

Initial prices for the commodities are the monthly market averages as reported by the various markets. The sources of data used for the prices of the individual commodities were the London Metal Exchange (LME, 2014) average monthly prices for aluminum and nickel, the Engelhard Unfab average price as reported by Platts Metals Daily (2014) for palladium and platinum, the World Bank's (2014) Commodity Markets Group's spot-market price for potash, and an average value for internationally traded goods for titanium mill products obtained from the United Nations Commodity Trade Statistics (UN Comtrade) database in 2014 (United Nations Statistics Division, 2014).

Price elasticities of demand used in this report had been estimated in other studies, and several issues were encountered. First of all, it was assumed that own-price demand elasticities are linear in close proximity to the market equilibrium point. To the extent that this assumption may not be valid, the demand elasticity values may be inaccurate. Second, many elasticity values reported in the literature are several decades old or were estimated for a geographically limited market. Because the end uses and particular mineral commodities may vary geographically and change over time, the elasticity assumptions may be overstated or understated. This concern was addressed by conducting sensitivity analysis with respect to the elasticity values.

The elasticity of aluminum prices was computed based on estimated elasticities found in Blomberg and Hellmer (2000), Ford (1999), Mikesell (2013), Pei and Tilton (1999), Stuckey (1983), and Stuermer (2013). The price elasticity for refined nickel was established on the basis of the range of elasticities found in reports that estimated elasticities for various metals (Evans and Lewis, 2002; Gallaher and Depro, 2002; Wagenhals, 1983). A single source of palladium and platinum price elasticity was identified (TIAX, LLC, 2003). There are extensive studies estimating the price elasticity of potash owing to its predominant use in agriculture. Thus, potash price elasticity was based on a recommendation from the agricultural economics literature (Acheampong and Dicks, 2012). Finally, no studies with estimations of price elasticity for titanium mill products were found. Instead, it was determined that it would be acceptable to use steel mill products as proxies and to use the price elasticity estimated in "Economic Impact Analysis of Final Integrated Iron and Steel NESHAP [National Emission Standards for Hazardous Air Pollutants]" (Gallaher and Depro, 2002).

Trade data were obtained from the UN Comtrade database (United Nations Statistics Division, 2014), the Russian Customs statistical database (Federal Customs Service of Russia, 2014), the INSG, and the IFA. These data were available for the year 2013. Trade was assumed to be constant and carried over 2013 to 2014, except for potash. Values for the year were divided by 12 to obtain estimates of monthly trade numbers.

Among all the data used to produce the results, the short-run-demand, own-price-demand elasticities for the commodities appear to be least reliable. Therefore, for each of the commodities, sensitivity analysis with respect to the values of the demand elasticities using lower and upper bounds was conducted. Those results are reported in the individual commodity sections.

Application of the Methodology to Estimate Immediate Effects of a Supply Shock on Six Mineral Commodities

The following sections provide background on the individual mineral commodities and their respective roles in the world economy. Russia's role as a producer of these commodities is described together with the analysis and how that production affects the United States, the EU–28, and China. Finally, the details of hypothetical disruptions in Russian supplies of the given mineral commodities are considered, and the results of such shocks are analyzed according to the methodology developed in this study.

Aluminum

Background

Aluminum is a mineral commodity having a wide range of uses across many sectors, including manufacturing, transportation, electrical production, and construction. Aluminum is commonly made by processing bauxite into alumina and then smelting refined alumina into aluminum. When aluminum is made, it is produced either with a high degree of purity or as an alloy to meet a wide range of technical specifications, meaning that certain other components are added in small percentages to increase the desired physical attributes of the end product. The most common form of commercial high-purity ingot aluminum (minimum 99.7 percent elemental aluminum, Al) is known as Aluminum P1020. This is the primary form in which aluminum is traded on the open market, as it is an undifferentiated, standardized, and freely exchangeable good whose price is set by international demand and supply.

Aluminum is not only traded as a mineral commodity, but it is also as used a financial instrument because aluminum contracts and futures are also traded in the open financial market. The trade of aluminum as wrought and cast products is also important; however, only the unwrought and uncast forms are normally referred to as primary aluminum. The world aluminum market resembles very closely a perfectly competitive market. Aluminum is publicly traded on the LME as well as the Shanghai Exchange, and supply is also available through producer stocks. The price of aluminum varies as information spreads and expectations develop about conditions of production, trade and availability of aluminum, and the perceived market demand.

Production and Trade

China was the top producer of aluminum in the world in 2013, when it produced 22,100 thousand metric tons (kt) of primary aluminum. Russia was the second leading producer of aluminum in the world, having produced 3,950 kt of primary aluminum, and Canada was the third leading, having produced 2,967 kt of primary aluminum in 2013. China, Russia, Canada, and the United States accounted for over 65 percent of the world production of primary aluminum, and China alone accounted for over 46 percent of world production. The main exporters of aluminum in the world were Russia, which exported 2,209 kt of primary aluminum in 2013; Canada, which exported 1,521 kt; and Australia, which exported 1,169 kt. The main importers of aluminum in the world in 2013, besides the United States, were the EU–28 as a whole, which imported in total 2,412 kt; Japan, 1,466 kt; the Republic of Korea, 1,011 kt; and Turkey, 627 kt (United Nations Statistics Division, 2014).

The United States was a significant producer and importer of aluminum, producing 1,950 kt of primary aluminum and 1,650 kt of secondary (recycled) aluminum in 2013. The country imported about 4,360 kt of crude and semimanufactured aluminum for domestic consumption in 2013 and exported 3,350 kt of primary aluminum and secondary scrap. The United States imported aluminum in 2013 from Canada (61 percent), Russia (7 percent), China (5 percent), and Mexico (4 percent), and the remainder came from other countries. At least three aluminum smelters in the United States were idle for all of 2013; prices of aluminum in the United States and the world decreased by the end of 2013 from the end of 2012 (Bray, 2014).

The main Russian producer of aluminum is United Company RUSAL (RUSAL). The company accounted for about 9 percent of the world's primary aluminum production in 2013. RUSAL's aluminum output, however, did not come entirely from Russia, as RUSAL also owned operations in Sweden and Nigeria, as well as alumina and bauxite production facilities in Australia, Guinea, Guyana, Ireland, Italy, Jamaica, and Ukraine.

Because of the world economic downturn and the declining international price of aluminum, many aluminum smelters throughout the world announced shutdowns in the end of 2008, which continued through 2010. In 2011, several restarts of operations were announced in response to changing world economic conditions and increases in demand and aluminum prices. In 2012 and 2013, aluminum price fluctuations led to the permanent closing of older, higher cost smelters, and by 2013, as demand increased, world production was 19 percent higher than the pre-recession level of 2008. Because of price fluctuations and a generally declining price, world aluminum stocks at yearend 2013 were higher than those in 2012 and, in June 2014, primary aluminum stocks at LME warehouses reached 5 million metric tons (Mt) (Bray, 2015a).

The world production of aluminum is determined by its world price, the international demand for aluminum, and the cost of energy, as the manufacture of aluminum requires vast amounts of power. This need for power makes aluminum production costs sensitive to regional prices of energy, in particular to electricity prices. Countries with the ability to produce cheap electricity have a competitive advantage in the production of aluminum. As energy costs increase, a country usually reduces domestic production or entirely shuts down its own facilities and imports aluminum from countries with cheaper energy costs.

Immediate Effects of a Supply Shock

A supply shock to primary aluminum production owing to a disruption in the Russian production would increase the world price and would affect production and trade in aluminum (tables 2, 3, and 4). Furthermore, net importers and exporters of primary aluminum would face this new, higher price. It is likely that a price increase caused by a Russian supply shock would attract at least some existing stocks back to the market and therefore mitigate to some degree the potential price increase. This mitigation effect was included in the calculations of the new price (table 4). With the low-elasticity estimate, the price of the commodity would increase by 17.4 percent. With the central- and high-elasticity estimates, the price would increase by 12.3 percent and 6.6 percent, respectively. When these increases are compared with historical price increases, one can conclude that, in the long term, the modeled increases are modest, as the price of aluminum increased from 1994 to late 2008 by almost 171.6 percent. However, these modeled increases would be immediate, and, under those circumstances, the effects of such increases in price would be considerable.

World production data that were used to calculate this effect as of June 2014 were obtained from the IAI (International Aluminium Institute, 2014). The price was the LME monthly average price for the month of June (London Metal Exchange, 2014). As the scope of the study described in this report did not allow for the estimation or calculation of elasticity, a survey of the available studies with estimated short-run and long-run elasticities in the past was conducted. The acceptable measure for short-run elasticity of primary aluminum was determined to be –0.27, the elasticity for the electrical and transportation sectors estimated in the study by the Charles River Associates (1971). Although the 1971 study is more than 40 years old, the elasticity from the study is still widely used and quoted in the industry as the best available because no other study has been done on the same scale to estimate such elasticity. The Charles River Associates (1971) estimate was found to be the most reasonable for the purposes of the present work after it was compared with other sources, including the following: Pei and Tilton's (1999) study on the income elasticity of metal demand, Stuermer's (2013) study on "Industrialization and the Demand for Mineral Commodities," Blomberg and Hellmer's (2000) work on the "Short-Run Demand and Supply Elasticities in the West European Market for Secondary Aluminium," and works by

Table 2. World production of refined primary aluminum in 2014 before and after a hypothetical supply shock—the complete disruption of Russian production in June 2014.

[Production quantities are in thousands of metric tons. The data in row 3 show results projected by the authors for a model that considered the effects of a complete disruption of Russian production of refined primary aluminum in June 2014. The preshock production data came from the International Aluminium Institute (2014)]

Production	Time period	
	2014	June 2014
World production (including Russia).	51,648	4,304
Russian production	3,708	309
World production (excluding Russia) after a supply shock.	47,940	3,995

Table 3. International trade of refined primary aluminum in 2013.

[Quantities are in thousands of metric tons. Data are from the United Nations Statistics Division (2014). NA, not applicable]

Country or region	Imports	Exports	Net imports
China	371	116	255
European Union (EU–28).	2,412	16	2,396
United States	4,360	3,350	1,010
Rest of the world (excluding Russia).	NA	NA	–1,600

Table 4. Potential price changes for refined primary aluminum after a hypothetical supply shock—the complete disruption of Russian production in June 2014.

[Prices are in U.S. dollars per metric ton. Sources of elasticity estimates are described in the "Aluminum" section. Price changes calculated by the authors were added to $1,834/metric ton, the monthly average world price for June 2014 (London Metal Exchange, 2014), to obtain the new world prices]

Variable	Levels for price elasticity of demand		
	Low	Central	High
Price elasticity of demand.	–0.19	–0.27	–0.50
Price increase	321	226	122
New calculated world price.	2,155	2,060	1,956

Ford (1999), Mikesell (2013), and Stuckey (1983). The low-elasticity estimate of –0.19 is a weighted average of elasticities across sectors in the same study, and the high-elasticity estimate of –0.50 is the top range of copper (a close substitute of aluminum). The results of the sensitivity analysis are shown in table 5.

Table 5 shows that the EU–28 countries would be most affected by a shock to Russia's supply of aluminum. Since the economic downturn, many of the aluminum-producing facilities in the EU–28 countries have been either idle or shut down due to increasing energy costs and lower prices and demand for aluminum. Therefore, to satisfy local demand, the EU–28 countries replaced some of their domestic production with imports. The EU–28 countries have relatively large amounts of imports compared to the amount of primary aluminum that they export, and therefore the negative impact of the price increase would be larger than the impacts for the United States and China. China, in particular, would have smaller losses, as its imports are not as significant as those of other countries when compared with its exports; the relatively small impact is primarily due to China's position as the leading producer of aluminum in the world. U.S. losses would be partially offset by robust exports, as well as its capacity to produce primary aluminum. The rest of the world, including such aluminum-exporting countries as Canada and Australia, would benefit from the supply shock, as shown in table 5.

Table 5. Immediate losses or gains after a hypothetical supply shock—the complete disruption of Russian production of refined primary aluminum in June 2014.

[Economic losses and gains are in thousands of U.S. dollars and were projected by the authors. Elasticity estimates are in table 4]

Country or region	Losses or gains at three levels for price elasticity of demand		
	Low	Central	High
China	–81,900	–57,600	–31,100
European Union (EU–28).	–768,000	–541,000	–292,000
United States	–324,000	–228,000	–123,000
Rest of the world (excluding Russia).	512,000	360,000	194,000

Nickel

Background

Nickel is a silvery-white metal with such key characteristics as a high melting point, resistance to corrosion and oxidation, magnetism at room temperature, the ability to be electroplated, and the propensity to be alloyed. Because of those characteristics, nickel is used in more than 300,000 products for a wide variety of applications. As of 2014, more than 65 percent of nickel is used to manufacture stainless steel, and this percentage has been increasing throughout the last decade. The other 35 percent of consumption is split among other steel and nonferrous alloys, electroplating and other uses, including batteries for portable equipment, coins, and electronics (Nickel Institute, 2010).

Production and Trade

Russia is one of the world's leading producers of both mined nickel and refined nickel. As of 2008, it was ranked first in the world in production of both; more recently, however, increasing production in Indonesia and the Philippines pushed Russia's rank in nickel mining to the third place.[2] Nevertheless, the country remained one of the world leaders in production of primary refined nickel. Russia had three significant nickel producers: OJSC MMC Norilsk Nickel (Nornickel), OAO Ufaleynickel, and OAO Yuzhuralnickel. Nornickel's annual domestic production was by far the largest among the three companies, and Nornickel also owned nickel assets outside of Russia. On the basis of its worldwide production, Nornickel was the largest producer in the world in 2013 (International Nickel Study Group, 2013, 2014a, b; Kuck, 2013; P.H. Kuck, oral commun., 2014; OJSC MMC Norilsk Nickel, 2014; Safirova, 2013).

For the purposes of this analysis, the world market for refined nickel was selected. In particular, the focus is on unwrought nickel metal, ferronickel, and nickel pig iron. Although the nickel pig iron is currently produced only in China and Indonesia and is not actively traded internationally, it could compete globally with other refined products in the future if the nickel content could be successfully raised above 18 percent by using advanced electric furnace technology. The world market for refined-nickel products has many characteristics that resemble those of perfectly competitive markets. Those characteristics (a large number of market participants, the existence of the LME single price per unit of pure metal, and stock exchange activity) suggest that the refined-nickel market can be treated in our analysis as competitive. Some noncompetitive characteristics, such as use of individual contracts, are supplemented by the existence of the spot market. In contrast to the market for mined nickel, where many downstream business decisions are complicated by ownership structure and difficult-to-monetize conditions in contracts, the refined-nickel market appears to be quite close to a competitive one.

As of 2013, China was the leading producer of refined primary nickel, having produced 693.5 kt, or 35.8 percent of the total world production. It was followed by Russia (240 kt), Japan (178 kt), Australia (141.5 kt), and Canada (137.4 kt). Together, those five countries produced 71.9 percent of the world's refined primary nickel. The countries of the EU–28 altogether produced only 116.6 kt of refined primary nickel; the major EU producers were Finland and the United Kingdom, which produced 44.3 kt and 42.4 kt, respectively. In terms of nickel consumption, however, the distribution of countries was quite different. While China used 50.5 percent of all nickel produced in the world, the second leading nickel consumer was the EU–28 (17.9 percent), which was followed by the United States (8.0 percent) and Japan (7.4 percent) (International Nickel Study Group, 2014a, b). Consequently, China, the EU–28, and the United States were importing refined-nickel products from the producing countries, including Russia.

In terms of the market conditions, 2012 and 2013 were very difficult years for the nickel industry. Nickel prices continued to be low by historic standards, and inventories continued to accumulate. Even in the absence of potential supply restrictions triggered by political events, the 2014 market was expected to be influenced by the Indonesian ban on exports of limonitic and saprolitic direct shipping ore (DSO), which would likely limit Chinese production of nickel pig iron in the short run. In the longer run, however, it could lead to increased exports of DSO to China from the Philippines and possibly Burma. A recovery in economic growth, particularly in the United States and parts of Western Europe, improved nickel demand in the first half of 2014. The price of nickel increased from just above $14,000 per metric ton (t) in January to about $18,600 in June, and it is likely that the expectations of potential supply restrictions also contributed to this price increase. Throughout 2012 and 2013, nickel prices were significantly lower than in 2011, and the LME inventories of metal were growing; inventories continued to increase in 2014 and reached 305,000 t in June 2014. It appeared, however, that the inventory increase was not directly related to the prices, but to attempts by some Asian producers to transfer their inventories from domestic warehouses to LME-approved warehouses (Fedorinova and Kolesnikova, 2014; Hume, 2014). As a result, an assumption was made that only about 10,000 t of nickel inventories would enter the world market in the event of the loss of Russia's supply.

Immediate Effects of a Supply Shock

Some caveats about this analysis are in order. First, only the market for the primary production is considered, and the secondary production is excluded. It is assumed that

[2]As of 2013, Russia was the third leading producer of mined nickel in the world behind Indonesia and the Philippines. In 2014, however, the ranking may have changed because of the Indonesian ban on exports of mined nickel (Kuck, 2015).

secondary production may affect the primary nickel market in the medium and long term but is unlikely to have any impact in the immediate term. Second, throughout the report, the emphasis is on the effects of supply restrictions on the market for refined nickel and not on the related markets either upstream (mined nickel) or downstream (primarily, stainless steel production). In that sense, the results may be limited to the specific market; however, this is the market where the effect of Russia-related supply restrictions is likely to be most significant. A more detailed investigation of the impact of those restrictions on downstream industries is outside the scope of this study.

The June 2014 production data for the world and for Russia (table 6) were obtained from the International Nickel Study Group data (International Nickel Study Group, 2014b). The LME price data for June 2014 were available and were used in the analysis. In addition to the price and production data, the short-term own-price demand elasticity for nickel metal was needed to conduct the analysis. On the basis of the existing literature (Evans and Lewis, 2002; Gallaher and Depro, 2002; Wagenhals, 1983), a value of –0.50 was chosen. Because the literature on nickel price elasticities is very limited, a band between –0.40 and –0.60 was used to establish a range of plausible losses based on elasticities of metals that may serve as nickel substitutes. The recent trend of increase in demand for nickel used for stainless steel applications and a shift to the production of stainless steel series with reduced nickel content would likely render the demand elasticity even higher in absolute terms (more elastic).

The data on international trade were obtained from several sources, mainly the UN Comtrade database (United Nations Statistics Division, 2014), Russian Customs statistical database (Federal Customs Service of Russia, 2014), and INSG reports (International Nickel Study Group, 2013, 2014a, b). International trade flows between countries of interest were assumed to be unchanged between 2013 and June 2014 (table 7).

Table 6. World production of refined primary nickel in 2014 before and after a hypothetical supply shock—the complete disruption of Russian production in June 2014.

[Production quantities are in thousands of metric tons. The data in row 3 show results projected by the authors for a model that considered the effects of a complete disruption of Russian production of refined primary nickel in June 2014. The preshock production data came from the International Nickel Study Group (2014b)]

Production	Time period	
	2014	June 2014
World production (including Russia).	1,949	163
Russian production	248	21
World production (excluding Russia) after a supply shock.	1,701	142

The same methodology that was used for computation of losses for all mineral commodities in this report was followed in the case of nickel. First, the new market equilibrium reflecting how a supply restriction (modeled as a complete elimination of the Russia-produced refined nickel) would affect world prices for this commodity was established and computed. Table 8 shows the results obtained by using the range of values of the demand elasticity.

In the next step, losses (gains) that a country would suffer (reap) immediately after the initial shock (so that the market participants are unable to react to the shock and change their behavior) were computed. The hypothesized shock constitutes an absolute disruption of the Russia-produced supply of refined nickel; as such, the losses for Russia were not explicitly considered.

Table 7. International trade of refined primary nickel in 2013.

[Quantities are in thousands of metric tons. Data are from the Federal Customs Service of Russia (2014), International Nickel Study Group (2013, 2014a, b), and United Nations Statistics Division (2014). NA, not applicable]

Country or region	Imports	Exports	Net imports
China	169	40	129
European Union (EU–28).	297	210	88
United States	109	3	106
Rest of the world (excluding Russia).	NA	NA	–110

Table 8. Potential price changes for refined primary nickel after a hypothetical supply shock—the complete disruption of Russian production in June 2014.

[Prices are in U.S. dollars per metric ton. Sources of elasticity estimates are described in the "Nickel" section. Price changes calculated by the authors were added to $18,594/metric ton, the monthly average world price for June 2014 (London Metal Exchange, 2014), to obtain the new world prices]

Variable	Levels for price elasticity of demand		
	Low	Central	High
Price elasticity of demand.	–0.40	–0.50	–0.60
Price increase	672	560	448
New calculated world price.	19,266	19,154	19,042

Table 9. Immediate losses or gains after a hypothetical supply shock—the complete disruption of Russian production of refined primary nickel in June 2014.

[Economic losses and gains are in thousands of U.S. dollars and were projected by the authors. Elasticity estimates are in table 8]

Country or region	Losses or gains at three levels for price elasticity of demand		
	Low	Central	High
China	–57,600	–72,000	–86,400
European Union (EU–28).	–39,200	–49,000	–58,800
United States	–47,600	–59,400	–71,300
Rest of the world (excluding Russia).	73,900	61,600	49,300

The results are shown in table 9. It appears that, in the central scenario, the United States and the EU–28 together would incur a total loss of about $108 million, which is quite insignificant. The three major market participants (the United States, the EU–28, and China) would incur losses of $59.4 million, $49 million, and $72 million, respectively. The other countries in the world, notably Australia and Canada, however, would benefit from the supply shock. In the central scenario, such benefits ($61.6 million) also appear to be very modest.

Palladium and Platinum

Background

Palladium and platinum are precious metals belonging to the platinum-group metals (major PGMs: palladium and platinum; minor PGMs: iridium, osmium, rhodium, and ruthenium). Palladium and platinum are highly resistant to corrosion and are also excellent catalysts. These are two of the rarest metals found on the planet. The largest use of both palladium and platinum is as catalysts in vehicles. There are also multiple uses within the chemical, petroleum refining, glass, and electronics sectors. They are also used as investments as exchange-trade notes and funds (Loferski, 2014).

Production and Trade

The mine production of palladium and platinum is highly concentrated; South Africa, Russia, Canada, Zimbabwe, and the United States accounted for over 90 percent of world production in 2012 (Loferski, 2013). A few mining companies produce most of the world's palladium and platinum. The Stillwater Mining Company is the only producer in the United States. Vale, Glencore, and North American Palladium Limited are the other North American producers, and they have mining operations in Canada. Nornickel is Russia's main palladium and platinum producer and is the leading palladium producer in the world. Nornickel's mining operations go beyond Russia, with production taking place in South Africa and Botswana (Loferski, 2013). Other large palladium and platinum companies, predominantly operating in South Africa and Zimbabwe, include Anglo American Platinum Limited (Amplats), Impala Platinum Holdings Limited, and Lonmin, Plc. The market for palladium and platinum resembles a perfectly competitive market. While there are relatively few major producing companies, they exhibit competitive behavior in maximizing output in an attempt to meet increasing world demand. Single unit prices are set based on the Engelhard Unfab price as reported by Platts Metals Daily for palladium and platinum, and the metals are traded on open market exchanges.

The consumption of palladium and platinum has exceeded combined primary and secondary production for the past several years (O'Byrne, 2014). The deficit has increased recently due to a variety of factors, notably labor strikes in South African mines and increased automobile production, which uses the metals for catalytic converters, particularly in the United States and China. In 2013, the main consumers of Russian palladium were Japan (43 percent), the United States (26 percent), and Germany (20 percent) (United Nations Statistics Division, 2014). The leading consumers of Russian platinum are Germany (53 percent), the United Kingdom (25 percent), and Japan (13 percent). A supply shock to Russian production would have a significant impact on world production levels. Russia is the top producer of palladium and second leading producer of platinum, accounting for around 39 percent and 13 percent of total world production, respectively.

Immediate Effects of a Supply Shock

In the event of a supply disruption, manufacturers of catalytic converters would be faced with higher palladium prices, as well as the possibility of a shortage in supply significant enough to cause a disruption in catalytic converter production. However, the option exists for manufacturers to switch from palladium to rhodium or platinum as the catalyst, but that requires a 6- to 12-month lead time for retooling and reprocessing. This option has become more appealing as the price of palladium continues to rise (Odendall, 2014), and it will remain appealing if the production in South Africa remains stable.

The following data were used in estimating the costs of a supply disruption. Annual growth rates of production were calculated for palladium and platinum on the basis of U.S. Geological Survey (USGS) annual production data (Loferski, 2013), and production data for 2013 were based on USGS estimates (Loferski, 2014). Palladium and platinum production for 2014 were projected by using a 5-year growth rate of 1.6 percent for palladium and 0.9 percent for platinum. Additionally, quarterly production data were gathered from the quarterly and annual reports from seven leading palladium and platinum producers: Anglo American Platinum Limited (2011–14, 2012–14); Glencore (2011–14, 2012–14); Impala Platinum

Table 10. World production of refined palladium and platinum in 2014 before and after a hypothetical supply shock—the complete disruption of Russian production in June 2014.

[Production quantities are in metric tons. The data in row 3 show results projected by the authors for a model that considered the effects of a complete disruption of Russian production of refined palladium and platinum in June 2014. Because of rounding, values in rows 2 and 3 may not add up to the values in row 1. The sources of preshock production data are described in the section "Palladium and Platinum"]

Production	Palladium		Platinum	
	Time period		Time period	
	2014	June 2014	2014	June 2014
World production (including Russia).	214	20	194	17
Russian production	82	7	25	2
World production (excluding Russia) after a supply shock.	133	12	169	14

Holdings Limited (2011–14, 2012–14); North American Palladium Ltd. (2011–14, 2012–14); OJSC MMC Norilsk Nickel (2011–14, 2012–14); Stillwater Mining Company (2011–14, 2012–14); and Vale (2011–14, 2012–14). The monthly production for June 2014 was estimated by taking the average amount of second quarter production from these reports over the previous 3 years and calculating the percentage of annual production produced in the second quarter. This quarterly number was then used to obtain monthly production estimates (table 10).

Trade data from the UN Comtrade database (United Nations Statistics Division, 2014) were used as a measure of U.S., EU–28, and Chinese demand for Russian palladium and platinum. International trade data for palladium and platinum are shown in table 11. The following notes should be taken into consideration when looking at the palladium and platinum trade data. The U.S. International Trade Commission (2014) reported different numbers for imports of Russian palladium and platinum than some other information sources. According to the U.S. trade data, the United States imported from Russia 22.340 t of palladium, representing 33 percent of total palladium imports, and 0.395 t of platinum, or 1 percent of total platinum imports. Recently, however, it was reported that China was importing 12.4 t of palladium from Russia for the first half of 2014 (Tan, 2014). If the same amount were to be imported for the remainder of the year, China would be the largest importer of Russian palladium when matched against the UN Comtrade database.

The Englelhard Unfab average June 2014 price of palladium and platinum as reported by Platts Metals Daily (2014) was used with the initial June 2014 average prices of $841.19 per troy ounce for palladium and $1,457.81 per troy ounce for platinum. A new price was estimated by using the price elasticity of demand and the estimated global and Russian monthly production for June. In determining the change in price, a measure of price elasticity was needed. A single estimate, –0.344, representing the price elasticity of total world demand for platinum, was found in the literature (TIAX, LLC, 2003). A corresponding elasticity for palladium was not found. The assumption was made that this elasticity estimate for platinum would be an appropriate proxy for palladium's elasticity.

A supply disruption would cause the price of palladium to increase by 110.9 percent from its June 2014 price of about $841 per troy ounce to $1,774 per troy ounce. The price of platinum would increase by 37.7 percent from its June 2014 price of about $1,458 per troy ounce to $2,007 per troy ounce. This impact on price due to a supply disruption is shown in table 12. The high and low ranges in elasticity are the standard deviations of the elasticity estimate (TIAX, LLC, 2003). The change in price due to a loss of Russian production is an increase in the range of $1,533 to $2,273 per troy ounce for palladium and $1,865 to $2,301 per troy ounce for platinum.

The corresponding losses from the initial disruption are presented in table 13. The United States would see the cost of importing palladium increase by $7.29 million if it imported 68.5 t, as it did in 2013, and the total cost of U.S. palladium imports would be $822.7 million. The U.S. platinum import cost would increase by $165 million if the United States imported 33.7 t, as it did in 2013, and the total cost of U.S. platinum imports would be $1.06 billion. The increase in the cost of imports for the EU–28 would be $469 million for palladium, based on EU–28 imports of 46.5 t in 2013, and the total cost of palladium imports would be $1.73 billion. The increase in the cost of platinum imports would be $415 million, based on EU–28 imports of 47 t in 2013, and the total cost would be $2.74 billion. China would face an increase of $145 million for palladium imports if it imported 20.2 t as in 2013, and its total cost of palladium imports would be $691 million. China's increased cost of platinum imports would be $436 million if it imported 68.8 t of platinum as it did in 2013, and its total cost of platinum imports would be $3.66 billion. When the medium (central) value of elasticity is used in the model, the effects on the U.S. palladium costs are partially offset by the 38.3 t of palladium that the United States would export. However, those exports are large enough that when demand is more elastic, the change in price is not large enough to offset the gains from exports. Under this elasticity, the United States would see a net gain of $49 million.

Table 11. International trade of refined palladium and platinum in 2013.

[Quantities are in metric tons. Data are from the United Nations Statistics Division (2014). NA, not applicable]

Country or region	Palladium			Platinum		
	Imports	Exports	Net imports	Imports	Exports	Net imports
China	20	0	20	69	0	69
European Union (EU–28)	46	0	46	47	0	47
United States	68	38	30	34	15	19
Rest of the world (excluding Russia)	NA	NA	–87	NA	NA	–123

Table 12. Potential price changes for refined palladium and platinum after a hypothetical supply shock—the complete disruption of Russian production in June 2014.

[Prices are in U.S. dollars per troy ounce. The medium elasticity estimate of –0.34 is from TIAX, LLC (2003), as described in the "Palladium and Platinum" section. Price changes calculated by the authors for refined palladium were added to $841.19/troy ounce, the monthly average world price for June 2014 to obtain the new world prices. Price changes calculated by the authors for refined platinum were added to $1,457.81/troy ounce. Values may not add to new prices shown because of rounding. The June 2014 prices were the Engelhard Unfab prices as reported by Platts Metals Daily (2014)]

Variable	Palladium			Platinum		
	Levels for price elasticity of demand			Levels for price elasticity of demand		
	Low	Central	High	Low	Central	High
Price elasticity of demand	–0.22	–0.34	–0.46	–0.22	–0.34	–0.46
Price increase	1,432	933	691	843	549	407
New calculated world price	2,273	1,774	1,533	2,301	2,007	1,865

Table 13. Immediate losses or gains after a hypothetical supply shock—the complete disruption of Russian production of refined palladium and platinum in June 2014.

[Economic losses and gains are in thousands of U.S. dollars and were projected by the authors. Elasticity estimates are in table 12]

Country or region	Palladium			Platinum		
	Losses or gains at three levels for price elasticity of demand			Losses or gains at three levels for price elasticity of demand		
	Low	Central	High	Low	Central	High
China	–88,000	–145,000	–263,000	–291,000	–436,000	–255,000
European Union (EU–28).	–319,000	–469,000	–778,000	–303,000	–415,000	–646,000
United States	49,100	–7,290	–124,000	–122,000	–165,000	–736,000
Rest of the world (excluding Russia).	155,000	198,000	134,000	200,000	175,000	162,000

Potash (Potassium Chloride)

Background

Potash is a key agricultural fertilizer and plant nutrient that is widely used around the world as a source of soluble potassium. Along with fixed nitrogen (ammonia and urea) and soluble phosphorus (phosphate rock and phosphoric acid), it is one of the three primary nutrients required for plant growth and maturation. The type of potash considered in this study is potassium chloride (KCl) because it is the most common form of potassium fertilizers available on the world market. Potassium is a critical input for improving agricultural yields, as it strengthens plants' ability to resist insects, disease, and changes in temperature. Potassium also enhances efficient water use by plants, assists in nutrient transfer, and helps keep food fresh for longer time periods. With higher levels of population, urbanization, and demand for grains and more nutritious crops around the world and, in particular, in developing countries, the importance of potassium in agriculture has increased along with rising food consumption (Encanto Potash Corporation, 2014; Gulati, 2014; PotashCorp, 2013).

There is no known substitute for potash, a major ingredient in most commercial fertilizers that contain a mix of potassium (K), nitrogen (N), and phosphorus (P). However, end users of potash do not have to use it every year. Agricultural producers have the option of leaving their land fallow for a year or so and making use of residual fertilizer on their fields for cost effectiveness. This option acts as a strong deterrent to price increases in the short run (EclectEcon, 2010).

Production and Trade

Although potash is used by nearly every country with an agricultural sector, the global potash industry is tightly concentrated among only a handful of major suppliers on the producer side. This is the case both in terms of originating countries and leading commercial enterprises operating in the market. Until the breakup of the Belarusian Potash Company (BPC, the Russian-Belarussian cartel) in 2013, the potash market was dominated by two state-supported private export corporations: Canpotex of Canada and the United States and BPC of Belarus and Russia (Jenny, 2012; Kooroshy and Preston, 2014). In 2013, there were 12 countries where potash was produced on a significant scale. Approximately 80 percent of all potash production was exported from these countries to meet the needs of about 100 importers. The world's largest supplier was Canpotex, a United States-Canadian joint venture among Potash Corporation, Mosaic, and Agrium, whose share of global exports stood at 39 percent in 2013, up from 36 percent in 2012. Uralkali, the leading Russian producer of potash, increased its individual market share from 18 percent to 19 percent in 2013, while Belaruskali of Belarus accounted for 14 percent of global potash exports, down from 19 percent in 2012 (JSC Uralkali, 2013).

After the breakup of BPC, the global potash market became much more competitive. In 2013, there were 13 large-scale producers based in Canada, Russia, Belarus, Israel, Germany, Spain, the United Kingdom, Jordan, and Chile. The share of the six biggest producers (of which three were from Canada, two were from Russia, and one was from Belarus) in global exports slightly increased to 67 percent from 65 percent in terms of volume after the breakup of the BPC. However, competition between Russian and Belarusian producers for individual market share and Uralkali's decision to switch to a volume instead of price strategy resulted in significant downward pressure on potash prices, both on the spot market and in contracts. Key potash buyers, including Brazil, China, and India, were able to secure imports at much lower prices than before owing to the additional 8 percent of supply provided by Uralkali, as well as new capacity expansion projects around the world. With the dissolution of the BPC cartel, approximately 37 percent of the global potash sector entered into the free market arrangement. Market prices reflected more competitive market dynamics among 13 suppliers, with excess global supply of recent years leading to significant price corrections (Gulati, 2014; International Fertilizer Association, 2014b; JSC Uralkali, 2014b; Koch, 2013; Lee, 2013).

In 2013, Russia was both a key producer and a key exporter of potash in the world, accounting for a rising share of global trade. It was second only to Canada in the global potash market in terms of production and exports. Uralkali delivered potash to nearly all major potash consumers in the world. The main export markets of Russia, ranked in order of size, were China, Brazil, India, the EU–28, and the United States. Russia was the top supplier for all major importers of potash except for the United States, which augmented its importance in the world potash market. According to the U.S. Geological Survey and the International Fertilizer Association (IFA), the United States imported 88 percent of its potash from Canada. Russia's share of U.S. imports was less than 10 percent. However, in 2013, Russia supplied 30 percent of the potash imported by the EU–28 and 42 percent of that imported by China (International Fertilizer Association, 2013a, 2014b; Jasinski, 2014; JSC Uralkali, 2014a, d).

The IFA provides comprehensive aggregate statistics for potash along with other fertilizers in terms of production and sales. However, production and export data are released on the individual country level only after a 2-year delay. Potash import data by country are readily available with a time lag of a few months. Production and trade data used here to estimate the economic impact of Russian supply disruptions come from the IFA, unless otherwise noted (International Fertilizer Association, 2014a).

In 2013, potash production decreased in half of producing countries, but increased in Canada, China, and Russia, compared to 2012. World potash production was 34.6 Mt in potassium oxide (K_2O) equivalent terms in 2013 (Jasinski, 2014). The world's top five potash producers, ranked in order of size, were Canada, Russia, Belarus, China, and Germany, which cumulatively accounted for nearly 80 percent of world production. Russia's production was estimated to be 5.3 Mt in 2013, which was equivalent to 15.3 percent of global potash production. China's production went towards meeting part of its domestic potash demand, and the country had to resort to imports to cover the rest. As a result, its exports were insignificant (International Fertilizer Association, 2013b, 2014b). Because of prevailing low unit prices, many countries and producers have stockpiled potash. These inventories would enter the market should potash prices increase. Total world inventories were estimated to be 5.57 Mt, out of which Russia accounted for 0.3 Mt. These stockpiles were assumed to be offered for sale and thereby to have an impact on the equilibrium price if the Russian supply shock took place.

Immediate Effects of a Supply Shock

According to most recent potash production and deliveries data, half-year (HY) production increased in Europe, Western Asia, and the Eastern Europe and Central Asia (EECA) region, which includes Russia. Total world exports of potash in the first 6 months of 2014 were 15.8 Mt. On the basis of a projected 23-percent market share in global exports in 2014, Russia's exports in the first HY 2014 were estimated to be 3.64 Mt (International Fertilizer Association, 2014c). This Russian export estimate for January–June 2014 is also compatible with the first half-year results that were released by Uralkali at the end of August 2014 (JSC Uralkali, 2014a, c).

According to Uralkali's second-quarter report for 2014, global demand for potash increased in the second quarter relative to the first quarter (JSC Uralkali, 2014a, c). Russia's second quarterly potash production was 3.1 Mt of potassium chloride (KCl), which is equivalent to 1.96 Mt of K_2O. The Russian monthly production figure of 0.65 Mt for June 2014 was obtained by dividing the quarterly production by 3 (JSC Uralkali, 2014a, d).

According to IFA's HY 2014 statistics, total world potash production in the first 6 months of the year was 19 Mt (International Fertilizer Association, 2014d). Monthly world production for June 2014 of 4.04 Mt was estimated from that number by incorporating world inventories (excluding Russia's inventories) of 5.27 Mt and by assuming a steady production pace over the 6-month period and thus by dividing 24.27 by 6 (table 14).

For the purposes of this study, potash prices were obtained from the World Bank's Commodity Markets Group. There are two main price ranges for potash in world markets: a contract price and a spot-market price. In order to use one representative global price, this section uses the World Bank's commodity price database. According to the World Bank's "Commodity Markets Outlook" of July 2014, potash prices were $287 per metric ton on average in June and for the 2014 second quarter as a whole (World Bank, 2014).

Potash demand elasticity estimates range between –0.21 and –3.26 according to studies of developed markets like the United States and of developing countries such as Pakistan (Acheampong and Dicks, 2012; Carman, 1979; Quddus, Siddiqi, and Riaz, 2008). Most studies prior to 2008 indicated that the short-run price elasticity of demand for potash was lower than the long-run elasticity. In other words, if the price of potash increased, consumers would not or could not immediately reduce the quantity of potash that they demanded. According to the emerging consensus in the field of agricultural economics, potash demand is posited to be price elastic in the short term; hence, an elasticity of –0.95 was selected. As farmers have the option to leave their fields fallow for 1 year and make use of fertilizer residue from previous years if prices rise too much, demand for potash is quite elastic in the short run (EclectEcon, 2010). The low-elasticity estimate for short-term price elasticity of demand of potash is –0.403 and is based on U.S. data, and the high-elasticity estimate of –1.85 is based on Pakistani data (Heady and Yeh, 1959; Quddus, Siddiqi, and Riaz, 2008).

In order to calculate the potential losses and benefits to potash consumers and producers, detailed trade data were also required. The international trade statistics for 2013 are shown in table 15. Also, the IFA report for the first HY of 2014 contained detailed import data by country (International Fertilizer Association, 2014c). However, production and export data were aggregated. As a result, production and exports by country had to be estimated. According to the IFA, U.S. imports of potash from all countries in 2014 as of June were 2.88 Mt, while EU–28 imports were 1.78 Mt and China's imports were 2.44 Mt. As noted above, Russian exports in the first HY of 2014 are estimated to be 3.64 Mt.

On the basis of June 2014 data, world monthly potash production excluding Russia's production would be 3.39 Mt. By using this percentage change in production and an elasticity of demand of –0.95, the percentage change in price was estimated to be 18.35 percent, which corresponds to an increase of $53 in unit price. As a result, the world price of potash would rise to $340 in the case of a disruption to Russian supply (table 16).

Table 14. World production of potash (potassium chloride) in 2014 before and after a hypothetical supply shock—the complete disruption of Russian production in June 2014.

[Production quantities are in millions of metric tons of potassium oxide (K_2O) equivalent. The data in row 3 show results projected by the authors for a model that considered the effects of a complete disruption of Russian production of potash (potassium chloride) in June 2014. The sources of preshock production data are listed in the "Potash (Potassium Chloride)" section]

Production	Time period	
	2014	June 2014
World production (including Russia).	38.00	4.04
Russian production	7.66	0.65
World production (excluding Russia) after a supply shock.	30.34	3.39

Table 15. International trade of potash (potassium chloride) in 2013.

[Quantities are in millions of metric tons of potassium oxide (K_2O) equivalent. Data are from the United Nations Statistics Division (2014). NA, not applicable]

Country or region	Imports	Exports	Net imports
China	3.72	0	3.72
European Union (EU–28).	3.02	0.51	2.51
United States	4.49	0	4.49
Rest of the world (excluding Russia).	NA	NA	–5.66

Table 16. Potential price changes for potash (potassium chloride) after a hypothetical supply shock—the complete disruption of Russian production in June 2014.

[Prices are in U.S. dollars per metric ton. Sources of elasticity estimates are described in the "Potash (Potassium Chloride)" section. Price changes calculated by the authors were added to $287/metric ton, the monthly average world price for June 2014 (World Bank, 2014), to obtain the new world prices]

Variable	Levels for price elasticity of demand		
	Low	Central	High
Price elasticity of demand.	–0.40	–0.95	–1.85
Price increase	103	53	22
New calculated world price.	390	340	309

Table 17. Immediate losses or gains after a hypothetical supply shock—the complete disruption of Russian production of potash (potassium chloride) in June 2014.

[Economic losses and gains are in thousands of U.S. dollars and were projected by the authors. Elasticity estimates are in table 16]

Country or region	Losses or gains at three levels for price elasticity of demand		
	Low	Central	High
China	–381,000	–196,000	–83,000
European Union (EU–28).	–258,000	–132,000	–56,000
United States	–461,000	–237,000	–100,000
Rest of the world (excluding Russia).	580,000	298,000	126,000

The losses to Russia's trading partners were calculated as a result of the new higher price of potash. Losses arise due to higher import costs for the second half of 2014 and the positive change in price per metric ton of potash. As the supply disruption is presumed to have taken place at the end of June 2014, these losses correspond to losses for the year of 2014 as a whole. According to the model, the price for all potash importers would increase by about 18 percent. For the United States, the total cost of potash imports would be $237 million higher if it imported 4.49 Mt as in 2013, for a total cost of $1.53 billion. The EU–28 would have to incur $132 million more for net imports of 2.51 Mt for a total cost of $854 million. Finally, China would have a higher import bill of $196 million to import 3.72 Mt for a total of $1.26 billion (table 17).

The negative shock to consumers of potash from the loss of Russian supplies may be expected to be the highest for the countries that rely on Russian imports the most: China and India. With shares of 42 percent and 32 percent, respectively, Russian supplies would not be easily replaced in these two countries. In addition to accruing a loss in the form of higher costs of imports caused by higher unit prices, China and India would probably experience lower domestic food production and resort to increased food imports. The countries in the rest of the world, such as Canada and Belarus, would probably benefit from the supply shock. The total benefits to the other countries in the world were estimated to be almost $300 million (table 17).

As these results clearly indicate, Russia is an extremely important player in the global potash market as both a producer and an exporter. The disruption of Russian supplies to the world market would translate into much higher prices and higher costs for all major consumers of potash in the immediate term. If one assumes a perfectly competitive global potash market with a global commodity price, the United States would incur a higher loss than China and the EU–28, as its potash imports exceed those of other countries. At the same time, however, the United States has greater security of supply than other countries in the case of a Russian supply disruption, since the EU–28 and China depend on Russia for a higher percentage of their potash needs, whereas the United States obtains most of its imports from Canada.

Titanium Mill Products

Background

Titanium metal is widely used for military and commercial aircraft production, power generation, chemical processing, other industrial applications, and several consumer goods. Few materials possess titanium metal's properties of high strength, corrosion resistance, and high-temperature resistance, making it a unique commodity for aircraft and spacecraft industries. Titanium metal is produced by the reduction of titanium mineral concentrates into the primary metal stage called "sponge," a porous form. Subsequent refinement of titanium metal includes the melting of sponge, scrap, and sponge/scrap plus a dominant alloy metal to form an ingot or slab. Primary fabrication occurs when an ingot or slab is converted into general mill products. Titanium mill products are then formed by using various techniques such as drawing, forging, and rolling of titanium into products of different sizes and shapes and range from bars and rods to wires, slabs, foil, and pipe (Bedinger, 2014a, b; Lynd, 1985).

Production and Trade

To assess the potential impact of supply restrictions from Russia, this study focused on titanium mill products, which are the principal forms in which titanium metal is marketed. Additionally, castings and other titanium casting products were included in the group of wrought titanium mill products. The results presented are specific to this market and do not include effects in the market of titanium minerals, titanium sponge, or titanium ingots, slabs, or scrap.

Titanium is traded at different stages of processing and also traded independently by specific products. The global market structure for titanium mill products presents characteristics of a competitive market, even though buyers and suppliers are highly consolidated. The feedstock to manufacture these products depends on a diverse and widespread set of companies that exhibit competitive behavior in an effort to satisfy global demand. Prices are set by supply-and-demand forces; however, long-term contracts are preferred by the commercial and military aircraft manufacturing industry. There are several titanium buyers in the industrial equipment sector and in the consumer goods sector. Prices for titanium mill products are based on spot-market transactions and longer term contracts. Titanium is not traded on the LME market. In terms of market conditions, the global titanium mill products industry experienced growth over the last 5 years (2009–13) and was expected to continue its expansion as the global economy improves and the demand for titanium in emerging economies continues to increase.

Titanium Metal Corp. (TIMET), Allegheny Technologies Inc. (ATI), RTI International Metals (RTI), all of the United States, and VSMPO–AVISMA Corp. (VSMPO) of Russia were the leading manufacturers of titanium mill products in 2013. U.S. production was the largest globally until 2011, when it was overtaken by that of China. By 2013, Chinese production was double that of the United States, accounting for 72 kt representing 43 percent of the titanium market; however, most of that was consumed in China. Chinese output of titanium mill products was used mostly for industrial applications and not for aircraft or spacecraft manufacturing. In 2013, the United States was the second leading producer of titanium mill products in the world with 36 kt, and Russia was the third-ranked producer with 29 kt. These three countries accounted for about 80 percent of the world titanium mill products.

In 2013, most titanium production in Russia was in the hands of VSMPO, whether in the form of sponge, ingot, or mill products. It was one of the few producers whose production process was integrated from raw materials through to partially fabricated titanium products. The main focus of VSMPO was on exports, particularly to the major aerospace companies in the United States and Europe (VSMPO–AVISMA Corp., 2014). It sold much of its output on long-term contracts to Boeing, Airbus, General Electric, and Rolls Royce. A supply disruption may not be critical to these companies in the short term owing to high industry stocks and very long production cycles. The potential worldwide disruption in the supply chain of titanium mill products would alter the market and result in higher prices. However, experts in the industry believe that fluctuations in titanium demand and prices are mainly a result of demand in the aerospace and defense industries (Bedinger, 2014a; Seong and others, 2009).

The leading exporters of titanium mill products in the world in 2013 were the United States, exporting 22 kt, representing 24 percent of global exports, followed distantly by Russia, with 14 kt or 15 percent of global exports, and China, exporting 10 kt, accounting for 11 percent of global exports. However, the EU–28 as a whole exported 24 kt, representing 26 percent of total world exports. The main importers of titanium mill products in the world in 2013 were Germany, importing 12 kt, followed by the Republic of Korea, importing 10 kt, and the United States, importing 7 kt. The EU–28 imported a total of 43 kt, or 54 percent of world imports. Russia's production was an important source of titanium metal to the EU–38 (Germany alone accounted for 31.4 percent of Russian exports) and the United States (28.4 percent of Russian exports), and to the commercial and military aerospace industry (United Nations Statistics Division, 2014).

Immediate Effects of a Supply Shock

In 2013, the U.S. production of titanium mill products was 36 kt. The country imported 7 kt of titanium mill products from several countries; 3.9 kt, or about 60 percent, of annual imports came from Russia in 2012 and 2013. Although the 60-percent figure represented a high percentage of imported wrought and castings titanium products in comparison to the domestic production, it represented limited dependence and, therefore, a potential restriction on Russian supply would not be significant for the U.S. domestic market. Consumption in

2013 was estimated for the United States at 43 kt on the basis of consumption estimates reported by Roskill Information Services Ltd. (2013); of the 43 kt, approximately 74 percent of mill products and castings were used for commercial and military aerospace applications (Bedinger, 2014b; United Nations Statistics Division, 2014).

The model predicted that a price increase would result from supply restriction of titanium mill products owing to Russian supply not being available in June 2014 to the world market. The following data were used in calculating and monetizing the cost of this supply disruption. The quantity supplied was first estimated by using apparent consumption of titanium mill products but, after further examination, it was decided that actual global production provided a better fit in terms of data quality. Production data for major producing countries were available from 2004 to 2012 (Bedinger, 2014b; Roskill Information Services Ltd., 2013; VSMPO–AVISMA Corp., 2014). A 10-year growth rate was applied to estimate global production for 2014 at 191 kt. A monthly production average was then used to get the estimate of 15.9 kt for June 2014 production (table 18).

Information about the 2013 global trade in titanium mill products by country was obtained from the UN Comtrade database (United Nations Statistics Division, 2014). It was assumed that the trade flows of this year would be unchanged through June 2014. This data source was verified by comparing the import and export reports from the U.S. International Trade Commission's (2014) "Interactive Tariff and Trade DataWeb" for the United States and Russia (table 19). Prices for titanium mill products vary widely depending on the type of alloy and product. An average value for international trade in titanium mill products for June 2014 was used (United Nations Statistics Division, 2014). This price, $48,518 per metric ton, was used for obtaining a new price after the hypothetical Russian supply shock (table 20). This price is also comparable to the average price for shipments of titanium mill products in companies like TIMET, RTI, and ATI in 2011–13 (Roskill Information Services Ltd., 2013).

For this calculation, it was also necessary to explore the available literature and decide on a value for price elasticity of demand, as the scope of this study did not allow the USGS researchers to estimate the elasticity. However, no studies with estimates of short-run or long-run price elasticity for titanium mill products were found. Therefore, the decision was made to use steel mill products, structural plates, and shapes as proxies for titanium mill products, because the steel manufacturing supply chain consists of a wide range of products and services similar to those for titanium mill products. For this study, a price elasticity of demand for titanium mill products of –0.35 and a band between –0.25 and –0.45 were chosen; these values were derived from data for steel mill products and were used to establish a range of probable losses in the global market (Gallaher and Depro, 2002; Zhu, 2012).

The results of a hypothetical worldwide disruption of the Russian supply of titanium mill products in June 2014 were computed on the basis of the 2013 values of global net

Table 18. World production of titanium mill products in 2014 before and after a hypothetical supply shock—the complete disruption of Russian production in June 2014.

[Production quantities are in thousands of metric tons. The data in row 3 show results projected by the authors for a model that considered the effects of a complete disruption of Russian production of titanium mill products in June 2014. Sources of the preshock production data are described in the "Titanium Mill Products" section]

Production	Time period	
	2014	June 2014
World production (including Russia).	190.87	15.91
Russian production	31.30	2.61
World production (excluding Russia) after a supply shock.	159.57	13.30

Table 19. International trade of titanium mill products in 2013.

[Quantities are in thousands of metric tons. Data are from the United Nations Statistics Division (2014). NA, not applicable]

Country or region	Imports	Exports	Net imports
China	4.04	9.97	–5.94
European Union (EU–28).	43.02	23.60	19.42
United States	7.18	21.97	–14.79
Rest of the world (excluding Russia).	NA	NA	–13.50

Table 20. Potential price changes for titanium mill products after a hypothetical supply shock—the complete disruption of Russian production in June 2014.

[Prices are in U.S. dollars per metric ton. Sources of elasticity estimates are described in the "Titanium Mill Products" section. Price changes calculated by the authors were added to $48,518/metric ton, the monthly average world price for June 2014 (United Nations Statistics Division, 2014), to obtain the new world prices]

Variable	Levels for price elasticity of demand		
	Low	Central	High
Price elasticity of demand.	–0.25	–0.35	–0.45
Price increase	31,822	22,730	17,679
New calculated world price.	80,340	71,248	66,197

trade and a new calculated commodity price as of June 2014 in thousands of U.S. dollars. This new price was assessed by using the price elasticity of demand and the estimated global and Russian monthly production of June 2014. With the low-elasticity estimate, the price would increase by 65.6 percent. With the central-elasticity estimate, the increase would be 46.8 percent, and with the high estimate, 36.4 percent. In other words, after removing the Russian production from the market, the world prices would increase and would be in the range of $66,197 to $80,340 per metric ton (table 20). In the immediate term, price changes would be significant; however, historically, the three principal U.S. manufacturers exhibited increasing prices in 2006 of shipments of titanium mill products to almost $70,000 per metric ton (Roskill Information Services Ltd., 2013).

The modeled results from this disruption of the Russian supply of titanium mill products and castings are presented in table 21; the economic impact on Russia is not analyzed. The immediate shock would significantly affect the EU–28 countries, as they are import reliant on these products, mainly for aircraft manufacturing, and would face higher prices in acquiring them. The major factor in EU–28 demand is the commercial aerospace industry, principally Airbus, which has production and manufacturing facilities for aircraft in France, Germany, Spain, and the United Kingdom; products include the Airbus A320 and the world's largest passenger airliner, the A380 (Airbus, 2014).

Table 21. Immediate losses or gains after a hypothetical supply shock—the complete disruption of Russian production of titanium mill products in June 2014.

[Economic losses and gains are in thousands of U.S. dollars and were projected by the authors. Elasticity estimates are in table 20]

Country or region	Losses or gains at three levels for price elasticity of demand		
	Low	Central	High
China	189,000	135,000	105,000
European Union (EU–28).	–618,000	–441,000	–343,000
United States	471,000	336,000	262,000
Rest of the world (excluding Russia).	430,000	307,000	239,000

Unavailability of the Russian supply in the world market would benefit the United States across the low and high ranges, as it would enhance its role as the leading exporter of titanium mill products; the United States would sell these products at a higher price in the immediate term. U.S. production capacity would be adequate to meet demand if the supply of titanium mill products from Russia contracted. Given the modeled duration and extent of the potential disruption, the result would be a definite benefit for the three major U.S. suppliers.

China, on the other hand, has seen a rapid expansion in production of titanium mill products and has a diverse domestic consumption—chemical industry, petrochemicals and chlor-alkali in particular (Roskill Information Services Ltd., 2013). However, most of China's production of titanium mill products is not for exports, and the output of the Chinese titanium industry is for industrial use in China. Chinese sponge producers would need several years to become certified for aerospace-grade sponge production, and Chinese gains in the immediate period after the supply shock would be modest.

Conclusions

In this study, a methodology for estimating the potential costs of supply disruptions on a selected set of Russia-produced mineral commodities was developed. The focus was on the very short term, immediate costs that would be encountered by the affected countries soon after the Russia-produced supply was no longer available.

The results are summarized in table 22. The magnitude of the losses varies by mineral commodity and country (or by group of countries), depending on each country's domestic production of the mineral commodity and the extent to which a country exports, if at all, a given mineral commodity. U.S. palladium production and exports are large enough that a complete disruption of Russian palladium supply would cause a significantly lower impact to the United States than would

Table 22. Immediate losses or gains after a hypothetical supply shock—the complete disruption of Russian production of six mineral commodities in June 2014.

[Economic losses and gains are in thousands of U.S. dollars. Data are from tables 5, 9, 13, 17, and 21]

Commodity	United States	European Union (EU–28)	China	Rest of the world (excluding Russia)
Aluminum (refined primary)	–228,000	–541,000	–57,600	360,000
Nickel (refined primary)	–59,400	–49,000	–72,000	61,600
Palladium (refined)	–7,290	–469,000	–145,000	198,000
Platinum (refined)	–165,000	–415,000	–436,000	175,000
Potash (potassium chloride)	–237,000	–132,000	–196,000	298,000
Titanium mill products	336,000	–441,000	135,000	307,000

disruptions to the supplies of other commodities examined in this study. China, being itself a large producer, would actually realize modest gains from the price effects of a supply disruption in titanium mill products.

A few observations from table 22 clearly demonstrate that Russia's market share of a particular commodity may not necessarily be a good predictor of potential losses from the supply disruption. For example, from table 1, Russia produces 40 percent of world's palladium. Yet, the potential losses that the United States would suffer from a complete disruption are only $7.3 million. At the same time, Russia produces only 18 percent of the world's potash, but the losses to the United States would be significantly higher and amount to $237 million. The analysis obtains these results by explicitly taking into account market structure, production, and export distribution across the countries, as well as price and demand characteristics in particular industries.

A supply disruption in the market of titanium mill products is likely to benefit the United States and China, primarily because those counties produce and export more titanium mill products than they import. The analysis does not account for the impact of the disruption on the downstream industries, such as the aerospace industry.

Finally, despite the fact that the United States imports most of its potash from Canada and not Russia, the United States is likely to experience higher losses than either the EU–28 or China if the supply of Russian potash were disrupted. The extent of the U.S. loss would result from the price effect of the supply disruption on the world market.

The results presented here are a simplification in quantifying the effect of such a large supply shock. Two critical parts of this study—the assumption of a complete supply disruption and methods used to quantify the immediate effects—are very theoretical. Further research and analysis are needed to obtain estimates for more likely scenarios. These scenarios might include situations where the supply disruption is not universal, so that some countries benefit from a larger supply source while others face a smaller supply pool. For example, it would be of interest to see how the results would change if the supply shock were only partial, and if some countries continued to purchase Russia's mineral commodities. Additionally, this study looked only at the immediate effects of a supply disruption. In the longer term, the markets are expected to adjust to the new supply level, establishing a new price and a new point of equilibrium. The adjusted price and supply would have different impacts on individual countries and the movement of the various mineral commodities across borders. Finally, it would be of significant interest to look at the effects of supply disruptions in a particular sector on downstream industries that use the commodities considered in this report as inputs.

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Safirova and others—**Immediate Effects of a Hypothetical Disruption to Russia's Supply of Six Mineral Commodities**—Open-File Report 2017–1023

ISSN 2331-1258 (online)
https://doi.org/10.3133/ofr20171023