Testimony

Critical Materials, U.S. Import Dependence, and Recommended Actions

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Before the Committee on Energy and Natural Resources
United States Senate

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Chairwoman Murkowski, Ranking Member Cantwell, and distinguished members of the Senate Committee on Energy and Natural Resources, thank you for inviting me to testify at this hearing on S. 883, the American Mineral Security Act of 2015. My testimony is derived from a 2013 study conducted by the RAND Corporation at the request of the National Intelligence Council.[3] I have divided my comments into four sections. The first explains why a material should be considered as critical. The second discusses the concentration of producers of these materials, with a special emphasis on China. The third illustrates the current problems faced by U.S. manufacturers through a case study of tungsten. Finally, the concluding section suggests possible actions for U.S. federal policymakers to consider to help increase resiliency to supply disruptions or market distortions and to provide early warning of developing problems concerning the production of critical materials.

1. Critical Materials

While the United States has extensive mineral resources and is a leading global materials producer, it is dependent on imports for many materials that are critical inputs to manufacturing. The most well-known examples are metals of the rare earth family, which are essential to many technologies that we rely on for both civilian and defense applications, such as chemical catalysts, lasers, high-power magnets, batteries, LEDs, night-vision goggles, and computer hard drives.[4] However, U.S. import dependence is not limited to rare earths. Other important examples include semiconductor materials such as indium, gallium, and germanium; antimony, which is a critical component of flame-retardant

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[2] This testimony is available for free download at http://www.rand.org/pubs/testimonies/CT432html.

[3] The final report of that study was published as Richard Silberglitt, James T. Bartis, Brian G. Chow, David L. An, and Kyle Brady, *Critical Materials: Present Danger to U.S. Manufacturing*, Santa Monica, Calif.: RAND Corporation, RR-133-NIC, 2013.

[4] Definitions of the rare earth family of metals vary slightly. Here we adopt the definitions used by K. A. Gschneider Jr., "The Rare Earth Crisis—The Supply/Demand Situation for 2010-2015," *Material Matters*, Vol. 6, No. 2, 2012, pp. 32–37. The metals are Lanthanum, Cerium, Praseodymium, Neodymium, Samarium, Europium, Gadolinium, Terbium, Dysprosium, Holmium, Erbium, Thulium, Ytterbium, Lutetium, and Yttrium.

plastics and textiles; and tungsten, a critical component in materials used worldwide for drilling, cutting, and machining in industries that include mining and construction, oil and gas exploration, tools and dies, and the cutting of wood, plastics, and metals. In fact, a high percentage of many materials that are critical inputs to U.S. manufacturing are imported.[5] It is these materials that I address in this testimony.

The primary concern of the RAND study was that many of these materials are imported from countries that have a dominant position in the mining and processing of these materials into the forms used to manufacture products. Moreover, in some cases this dominant producer is a country that has weak governance or that exercises control over its materials production sector, or both. In such cases, U.S. manufacturers are vulnerable to export restrictions that limit their access to these materials and that can result in two-tier pricing, in which manufacturers in the exporting country have access to materials at lower prices than those charged for exports, thereby hindering the international competitiveness of U.S. manufacturers and creating pressure to move manufacturing away from the United States and into the producing country.

These considerations caused the study team to focus its attention on materials that met the following three criteria:

- The dominant producer is outside the United States
- The United States has appreciable net imports
- The dominant producer has shortfalls in its quality of governance, as measured by the Worldwide Governance Indicators published by the World Bank.[6]

2. Concentration of Production

As a measure of the concentration of production of critical materials, we used the most commonly used measure of the concentration of commodity markets: the Herfindahl-Hirschman Index (HHI), which is computed as the sum of the squares of the 50 largest producers. For example, the U.S. Department of Justice and the Federal Trade Commission use the HHI to examine antitrust issues involving corporate mergers. According to guidelines established by the U.S. Department of Justice, an HHI of between 0.15 and 0.25 signals a "moderately concentrated" market, and an HHI above 0.25 indicates a "highly concentrated market." Under these guidelines and the definition of the HHI,

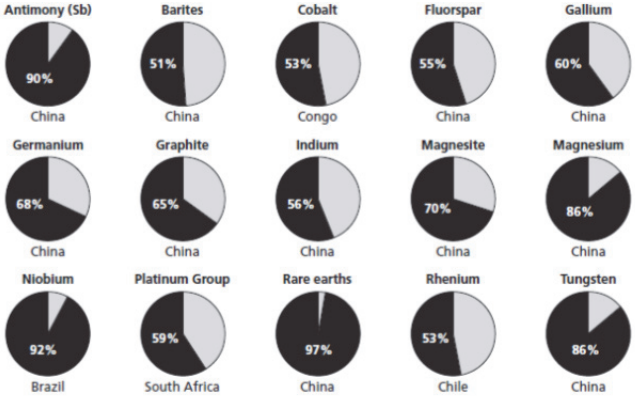
[5] Comprehensive lists of U.S. import percentages are given in U.S. Geological Survey, *Minerals Commodity Summaries*, Pittsburgh, Penn.: U.S. Government Printing Office, 1996–2015.
[6] The World Bank, *Worldwide Governance Indicators*, 2014. As of May 5, 2015: http://info.worldbank.org/governance/wgi/index.aspx#home

whenever a single firm has a market share of over 50 percent, the market would be considered highly concentrated.[7]

The extension of the above guidelines for market concentration from firms to nations would be exact only if all nations exercised government control over their producing firms. However, it is consistent with our focus on nations with weak governance or that control production. In these instances, there is a strong potential for export restrictions or supply disruptions to affect all producers within a country, in which case the government is a surrogate for a company, in that it controls the availability of materials to the rest of the world.

Several nations dominate production of critical materials with a greater than 50-percent market share of a single material. *However, as illustrated in Figure 1, only China has a market share greater than 50 percent for more than one such material. In fact, China has a greater than 50-percent market share for 11 different materials.*

Figure 1. Percentage of Global Production Within a Single Country



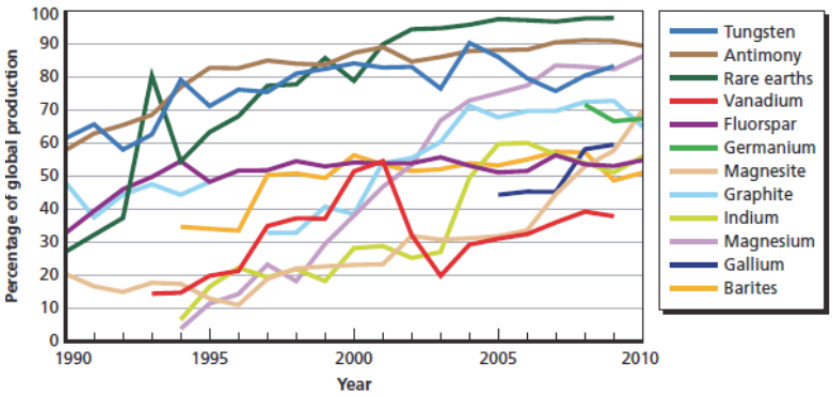
SOURCE: U.S. Geological Survey, *Minerals Commodity Summaries*, Pittsburgh, Penn.: U.S. Government Printing Office, 2012; International Organizing Committee for the World Mining Congresses, *World Mining Data*, Vol. 26, 2011.

China was able to become such a dominant global raw materials producer because of its large resource base and its long-term emphasis on mineral production, as well as its ability to produce raw materials at lower cost because of its relatively lax environmental and occupational health and safety standards. Figure 2 shows how China's dominance in materials production grew from 1990 to 2010,

[7] U.S. Department of Justice, "Herfindahl-Hirschman Index," web page, undated. As of May 5, 2015: http://www.justice.gov./atr/public/guidelines/hhi.html

as mines and processing plants in other countries closed because of their inability to compete with China's low-price exports.[8]

Figure 2. Growth of China's Raw Materials Production

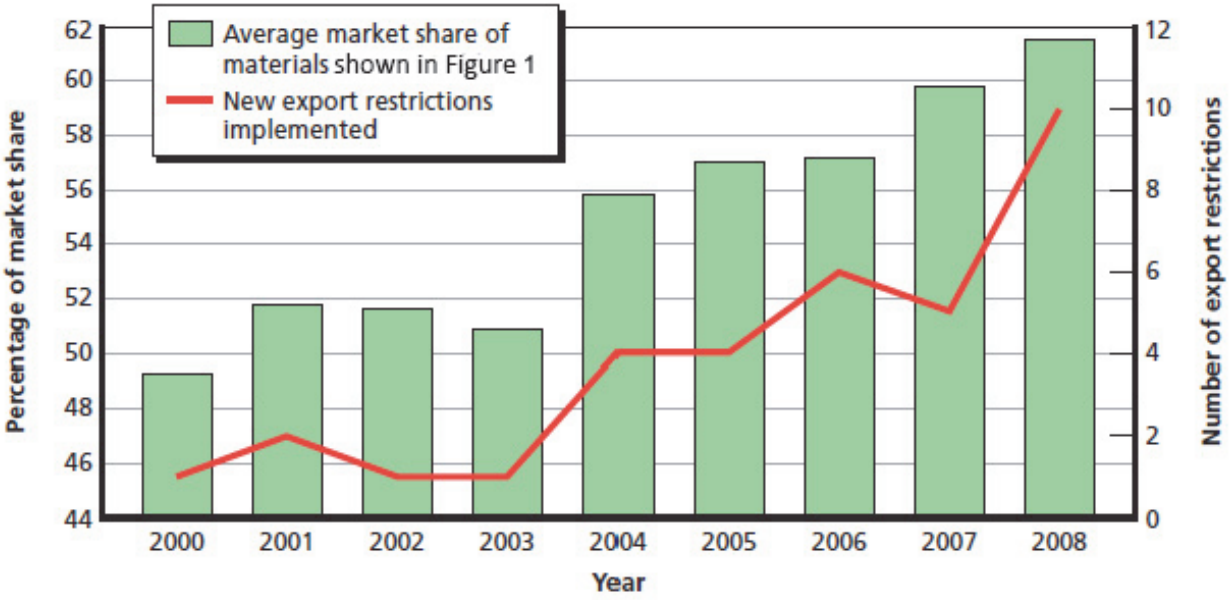


SOURCES: U.S. Geological Survey, 1996–2011; International Organizing Committee for the World Mining Congresses, 2011.
NOTE: Data unavailable on Chinese market share for germanium prior to 2008. Gallium data are from International Organizing Committee for the World Mining Congresses, 2011.

China was once viewed as a reliable, low-cost supplier of raw materials. However, as China's market share and domestic consumption grew, changes to its material export policies created concern among its customers. In particular, a combination of production controls, export restrictions (e.g., quotas and tariffs), mine closings, and company consolidation[9] contributed to significant price increases and, in some cases, volatility on the world market,[10] with major ramifications for global manufacturing. Because of export tariffs and price increases stemming from export restrictions, China's domestic manufacturers have had access to raw materials at lower prices than those charged on the world market. Figure 3 shows how the level of export restrictions grew as China's market dominance grew.

[8] For a tungsten example, see Chelsea J. Carter, "At 8,000 Feet, California 'Mine in the Sky' Is About to Enter Valhalla," *Los Angeles Times*, August 27, 2000; for a rare earth example, the history of the Mountain Pass mine, see Danielle Venton, "Rare Earth Mining Rises Again in the United States," *Wired*, May 11, 2012.
[9] Jeonghoi Kim, "Recent Trends in Export Restrictions," OECD Trade Policy Paper No. 101, Paris: OECD Publishing, 2010.
[10] For example, see K.A. Gschneider, 2012, and Michael Montgomery, "Tungsten Price Pushes to Historic Highs," *Tungsten Investing News*, February 23, 2011.

Figure 3. China's Export Restrictions and Market Share



SOURCES: U.S. Geological Survey, *Minerals Commodity Summaries*, 2003–2010; Jane Korinek and Jeonghoi Kim, "Export Restrictions on Strategic Raw Materials and Their Impact on Trade and the Global Supply," *OECD Trade Policy Papers*, No. 95, Paris: OECD Publishing, 2010; Strategic Metal Investments, Ltd., *China's Growing Role in the Production and Supply of Minor Metals: Part II*, May 10, 2010.

The negative effects on competitiveness of non-Chinese manufacturers and the pressure to move manufacturing plants to China from other countries created by this situation led China's trading partners to bring an unprecedented series of complaints before the World Trade Organization (WTO) in the past several years.[11]

- In 2009, the United States and the European Union (EU) brought a complaint against China's trade restrictions on various forms of bauxite, coke, fluorspar, magnesium, manganese, silicon carbide, silicon metal, yellow phosphorus, and zinc. When the WTO ruled in favor of the United States and the EU, China appealed and lost, then took full advantage of the "reasonable period of time" allowed under WTO rules before finally removing export duties and export quotas on these materials on January 1, 2013, the very day the time for compliance expired.

- In 2012, with China not yet having acted on the dispute just described, the United States, EU, and Japan brought an additional complaint against China's trade restrictions on rare earths,

[11] World Trade Organization, *China—Measures Related to the Exportation of Various Raw Materials*, Dispute Settlement DS394, January 28, 2013; and World Trade Organization, *China—Measures Related to the Exportation of Rare Earths, Tungsten and Molybdenum*, Dispute Settlement DS431, DS432, DS433, August 29, 2014.

tungsten, and molybdenum. This dispute was also settled in favor of the U.S., EU, and Japan, and China recently removed export quotas on these materials—on the agreed date for compliance of May 2, 2015.[12]

At the heart of all of these complaints was the assertion that China's export policies, which have now been ruled to be inconsistent with WTO rules, created a situation in which Chinese manufacturers had access to raw materials at lower prices than those same materials could be acquired via export—the two-tier pricing structure. While the removal of export quotas and export duties should, in principle, eliminate two-tier pricing, it remains to been seen whether China finds other ways to continue to provide its manufacturers with competitive advantages based on its position as a dominant producer.

3. Tungsten: Case Example of a Critical Material

Because of its unique combination of high-temperature mechanical and electrical properties, tungsten provides superior performance in many applications, such as electrical lighting, high-temperature metal alloys, and wear-resistant components. As noted previously, cemented carbides, composite materials consisting of tungsten carbide particles in a binder, are critical to every industrial application that involves cutting or involves component wear. Other important uses are in high-strength steels; electrodes; and wires, sheets, and rods used for a variety of industrial applications.[13] Tungsten is thus a basic commodity underpinning the global manufacturing sector.

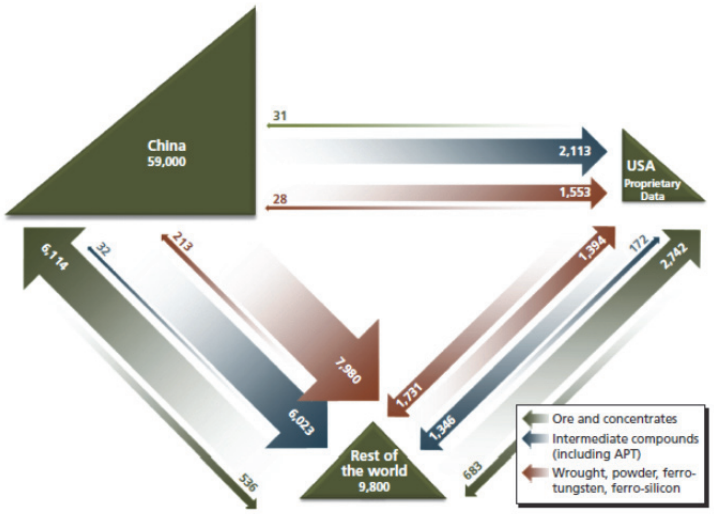
Tungsten is found in many places in the world but China has the largest reserves, which are defined as the part of the resource that is "fully geologically evaluated and legally mineable with current technology."[14] China has been the leading producer of tungsten for many years, producing at a rate far greater than any other country relative to its reserves. For the same reasons discussed earlier, as China increased its production, several countries with tungsten reserves ceased or reduced their production, including the United States.

The extent to which China dominates the production and processing of tungsten is illustrated in Figure 4, which shows the flows of raw and processed tungsten between China, the United States, and the rest of the world. The most important feature in this figure is that China imports the lion's

[12] For example, see International Centre for Trade and Sustainable Development, "Chinese Government Abolishes Rare Earth Export Quotas," *Bridges Weekly*, Vol. 19, No.1, January 15, 2015..
[13] For a detailed description of tungsten applications, see International Tungsten Industry Association, *Tungsten*, 2008.
[14] Data from U.S. Geological Survey, 1996–2015. Reserve definition from British Geological Society, *Tungsten*, 2011, p. 15.

share of raw tungsten (ore and concentrate) produced by the rest of the world, and is the dominant producer of the intermediate compounds from which many tungsten-containing products are manufactured. This includes ammonium paratungstate (APT), which is used to set prices on the world market. China is thus not only the dominant producer of mined tungsten ore and concentrate; it is also the dominant processor of the intermediate products that are traded on commodity markets.

Figure 4. Tungsten Raw Materials Supply Network

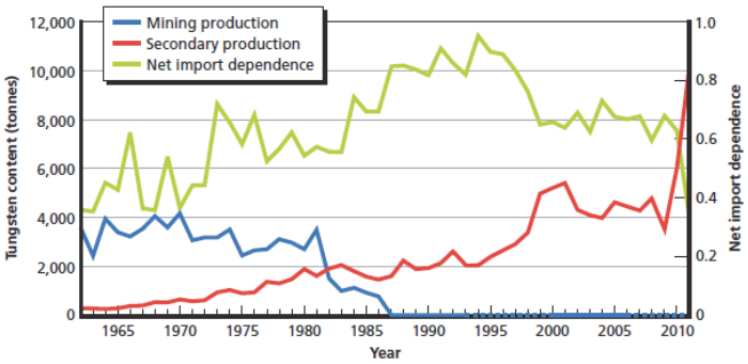


SOURCES: U.S. Geological Survey; United Nations Comtrade, undated.
NOTE: Units are metric tons (tonnes). Figures below country names denote domestic production. U.S. data is proprietary and not disclosed by the USGS.

Supplies of tungsten on the world market have tightened in recent years as Chinese domestic consumption has increased and its exports have remained relatively constant, resulting in a doubling of the APT price on the world market. U.S. manufacturers have also encountered difficulty in negotiating long-term contracts, as well as pressure to move manufacturing plants to China to access raw materials. In response to this tight supply situation, “in the next few years, mine production outside China is expected to increase.” U.S. industry has also responded with a remarkable increase in secondary production from waste and scrap, reducing U.S. import dependence from 2010 to 2011 by one-third, from 60 percent to 40 percent (see Figure 5). This level of secondary production has been maintained through 2014.[15]

[15] Quote on mine production outside China and figures for 2012–2014 secondary production from U.S. Geological Survey, 1996–2015.

Figure 5. U.S. Tungsten Production and Import Dependence



SOURCES: Thomas D. Kelly and Grecia R. Matos, *Historical Statistics for Mineral and Material Commodities in the United States*, U.S. Geological Survey, Data Series 140, 2011; U.S. Geological Survey, 1997–2012.
NOTE: Mining and secondary production are shown on the left-hand axis; net import dependence on the right.

The tungsten supply situation illustrates the problems faced by U.S. manufacturers, and indeed by the global manufacturing community, when a dominant producer is able to create global market distortions that favor its domestic manufacturers. Production in other countries is projected to increase, but the lead times are long and financing for large projects such as mines and processing plants can be hindered by the uncertainties associated with the effect on prices of future actions by the dominant producer. The resolution of the WTO cases and the elimination of export quotas and duties are welcome signs, but whether they lead to the elimination of two-tier pricing and pressure on U.S. manufacturers to move plants to China remains to be seen.

4. Recommended Actions

As the case study of tungsten illustrates, issues with the supply of materials are often less about the materials themselves and more about where the materials are produced and processed. As China's export restrictions and the WTO disputes that stemmed from them illustrate, a dominant producer, especially one with weak governance or that controls production, can contribute significantly to market distortions and supply disruptions with strong impact on the manufacturing sector, where materials are a critical input. In this respect, it is important to distinguish between dominant producers who have used export restrictions and those who allow market forces to largely determine supply and demand of the materials they produce. For example, Chile, producer of 53 percent of the world's rhenium, and Australia, producer of 51 percent of the world's zirconium, fall into the latter category.

The RAND report recommended two types of actions to address the potential for supply disruptions of critical materials: (1) actions that can increase resiliency to supply disruptions or market distortions; and (2) actions that can provide early warning of developing problems concerning the concentration of production.

Increasing Resiliency to Supply Disruptions or Market Distortions

The first line of defense against supply disruption or market distortion is to reduce the magnitude of the potential problem by preventing any controlling producer from further increasing its market share of a material. For example, China's attempt to acquire a controlling interest in Lynas Corporation, the owner of the Mount Weld rare earth mining project in Australia that, once in operation, would have increased China's 98-percent market share of rare earths, was blocked by Australia's Foreign Investment Review Board.[16] Wherever possible and consistent with WTO rules, action to deny a dominant producer an opportunity to further increase their dominance should be taken.

Coordination among multiple countries dependent upon a controlling producer for raw or semi-finished materials will sometimes be necessary to limit the potential for market distortion or supply disruption. For example, as illustrated in Figure 4, in addition to being the controlling producer, China is also the world's largest importer of tungsten ore and concentrate, and the controlling processor of this ore and concentrate into intermediate products. A coordinated effort to increase processing in other countries would reduce the level of China's control over the tungsten supply chain.

Since the main source of the supply problems discussed here is the concentration of production, the most effective action that can be taken to increase resiliency would be to encourage diversified production—i.e., the operation of mines in several different countries. Indeed, as noted in the tungsten case, such diversification is already beginning to take place. However, the uncertainty created by a highly concentrated market is a barrier that must be overcome by actions at the local, national, regional, and global levels to create a favorable and sustainable climate for the investments and time needed to bring diversified supplies into place. Coordinated actions by importing countries may be effective here as well. Other areas where coordination is possible include the filling of stockpiles and the establishment of agreements about sharing limited resources in the event of supply disruptions.

Over the long term, actions to increase resiliency may include the development of new methods of extraction, processing, and manufacturing that promote the efficient use of materials; increased recovery of materials from waste and scrap (secondary production, as described in the tungsten case example); and research and development of alternative materials and new product designs to reduce the demand for limited materials.

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[16] See "China Fails in Another Bid for Resources Firm," *Sydney Morning Herald*, September 24, 2009.

Foresight of Developing Problems

Many organizations collect and report data on the production, processing, and trade of minerals. For example, we were able to develop a comprehensive picture of the tungsten supply situation using data from the U.S. Geological Survey, the British Geological Survey, the International Tungsten Industry Association, and the United Nation's Comtrade database. However, early warning of a developing problem related to the control of a mineral market by one or a few producing countries requires an understanding of the motivation and intent of producing countries and companies, as well as the tracking and monitoring of international agreements and activities among both producing and consuming countries.

How might we recognize a developing pattern, such as an increasing concentration of production, increasing export restrictions, two-tier pricing, price spikes, or price volatility, before it creates harmful market distortions? How can we tell whether a trend is part of the natural development of a producing country from an economy dependent on the export of raw and semi-finished materials to one that produces and exports more value-added products? Here, international coordination and the benchmarking of market activity with diversified commodity markets can provide a guide. For example, the U.S. Department of Justice's (DOJ's) criterion for a transaction that is "presumed likely to enhance market power in a highly concentrated market" is a change of 0.02 in the HHI. Consider a hypothetical case in which each of five countries has a 20-percent market share, which gives an HHI of 0.2, a moderately concentrated market by our criteria. If one of these countries acquired an additional 10-percent market share from one of the others, then the HHI would increase from 0.20 to 0.22, which would meet the DOJ threshold for enhancing market power. When such situations occur, international coordination and cooperation could prevent market concentration from reaching the level of concern that led to the recent actions against China brought before the WTO by the United States, the EU, and Japan. The goal of such coordination and cooperation should be to smooth market distortions while allowing for the natural economic development of producing countries.

While, as an independent and non-partisan organization, RAND does not endorse or oppose legislation, we note the parallels between some aspects of the American Mineral Security Act of 2015 and our recommended actions:

- The actions and requirements to expedite the permitting "of activities that will increase exploration for, and development of, domestic critical materials, while maintaining environmental standards" parallel our recommended action to diversify production.
- The section on recycling, efficiency, and alternatives parallels our recommended actions to increase resiliency over the long term.

- The section on analysis and forecasting parallels our recommended action on foresight of developing problems and could provide the data for the type of benchmarking against diversified commodity markets that we recommend. Inclusion of language concerning international coordination and cooperation aimed at smoothing market distortions while allowing for the natural economic development of producing countries, when the benchmarking reveals a problem with market concentration, would further strengthen the bill.