



# Volatility of by-product metal and mineral prices



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## ABSTRACT

Prices of by-product metals and minerals are often assumed to be inherently more volatile than prices of main and individual products. Yet there is limited analysis of their relative price volatilities. This paper applies regression analysis to compare the price volatility of by-product metals and minerals to commodities produced primarily or solely as main-products or individual products. This approach allows for estimating whether by-product supply is associated with greater price volatility and provides a framework for further research. By-products are found to have on average about 50% higher price volatility than main and individual products when evaluating annual prices over the last 50 years – although there are exceptions. However, when analyzing monthly prices over the past decade, the evidence that by-products have greater price volatility is mixed.

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## 1. Introduction

Many of the metals and minerals identified as “critical” to emerging technologies are produced dominantly as by-products (see, for example, Nassar et al. (2015) and U.S. Department of Energy, (2011)). Recovering a metal as a by-product has the advantage that much of the mining and processing cost is shared with the associated main-product.<sup>1</sup> But prices of by-products are potentially volatile because of two characteristics of their supply. First, by-product supply is limited by the amount of the by-product recoverable from the main-product ore. This limit causes by-product supply to become highly price inelastic as it approaches this constraint, which may increase price volatility. Second, fluctuations in the quantity of the main-product produced may cause the by-product supply curve to shift and amplify price volatility. Moreover, price volatility for by-products also may result from their “minor” nature; that is, by-products are usually considered minor metals due to their small scale of production and limited number of applications and end users. As a result, prices of by-products often are perceived to be more volatile than metals and

minerals produced as main products or individual products, hereafter referred to simply as main products (Humphreys, 2011; Nassar et al., 2015; Slade, 1991; Willis et al., 2012). Although this is the conventional wisdom, there is sparse formal analysis of the relative volatility of by-products.<sup>2</sup>

The purpose of this article is to assess whether by-product metals and minerals have greater price volatility than those produced as main-products. Regression analysis is used to evaluate price volatility for two samples: annual average prices for 36 metals or minerals from 1960 to 2013, and monthly average prices for 30 metals or minerals from January 2005 to May 2015. There are two primary contributions of this work. First, it evaluates the conventional wisdom and theory of by-product supply that suggests by-product prices are more volatile. Second, it provides insights into whether higher price volatility results from the nature of by-product supply or, alternatively, the characteristics of minor metals markets. The remainder of this paper is organized as follows. Section 2 provides simple and informal theoretical reasons why by-products may have greater price volatility than main products. Section 3 outlines the data and methods used in this analysis, and Section 4 presents the results. Section 5 summarizes the findings and opportunities for future work.

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<sup>1</sup> In cases where mineral commodities are jointly produced from a mine, a commodity is considered a main-product when it “alone determines the economic viability of a mine,” a by-product when “its price has no influence over the mine’s ore output,” and a co-product when it and another mineral jointly influence output (Tilton, 1985). A metal or mineral commodity is considered an “individual product” when it is the sole product of a mine. In the remainder of this paper, the term main-product includes commodities produced as individual products.

<sup>2</sup> A related article is Slade (1991), who estimates the effects of market structure and marketing method (i.e., exchange and producer prices) on price volatility for six major or precious metals. She finds no evidence that greater by-product production has an impact on price volatility for these metals.

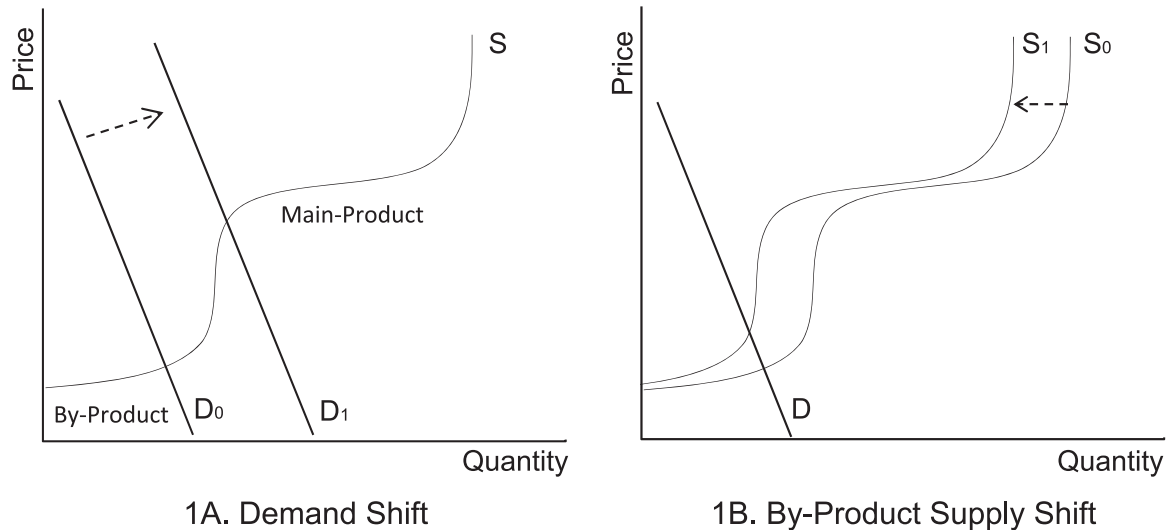


Fig. 1. Price effects of demand and supply shocks with by-product and main-product supplies.

## 2. Theoretical foundation of by-product price volatility

This section provides two theoretical justifications for higher price volatility of metals produced as by-products.<sup>3</sup> The first explanation is the shape of the total supply curve for a metal produced as a by-product. Fig. 1A depicts a total supply curve for a metal produced from low cost by-product supply and high cost main-product supply; this is similar to the short-run supply curve depicted by Campbell (1985). The total supply curve is initially relatively elastic and becomes price inelastic as the quantity supplied approaches the capacity constraint for by-product production (Maxwell, 2011; Tilton, 1985). Production of a mineral as a main product is typically more expensive than producing the same mineral as a by-product. For example, producing molybdenum as a by-product is usually less costly than mining molybdenum as a main-product, since by-product production shares much of the mining and processing costs with copper. The large difference between the cost of producing a mineral as a main-product and the cost of producing that the same mineral as a by-product creates a significant jump in the metal's total supply curve as the marginal source of supply switches from by-product to main-product. Given this total supply-curve shape, a shift in demand may lead to a significant increase in price. In contrast, the total supply curve for a metal produced exclusively as a main-product may not be as inelastic and will not have the abrupt jump. Second, by-products may also be affected by fluctuations in output of the main-product. Typically, metal supply curves are thought to be relatively stable over periods of one to a few years, and price volatility primarily results from shifts in demand due to cyclical fluctuations in economic activity. For by-products, however, changes in production of the main-product may shift the by-product supply curve and increase price volatility. Fig. 1B shows such a situation, where the total supply curve is shifted inward on account of an inward shift in by-product supply. Such a situation is consistent with the "by-product effect" described by Afflerbach et al. (2014), wherein a demand shock in the main-product market results in a negative relationship between the price of a main product metal and its associated by-product.

Greater price volatility of by-products may not be due *only* to the aforementioned characteristics of its supply but also the nature of

minor metals markets. While there is no widely-accepted and precise definition of minor metal, several characteristics of minor metals markets are noted in the literature. Minor metals are typically not traded on exchanges (Fizaine, 2015; Hagelüken and Mesker, 2010) and often have relatively small production quantities and total production value (Brooks, 1965; Fizaine, 2013).<sup>4</sup> For example, global primary production of the minor metal gallium was 440 metric tons in 2014 and its total production value was \$159 million (Jaskula, 2015). In contrast, global primary production of the major metal aluminum was about 49 million metric tons and the total production value was \$114 billion (Bray, 2015). The small number of producers, few consumers and end use applications, and opacity that characterize minor metals markets may lead to higher price volatility. A small number of producers (i.e. concentrated supply) may increase volatility as entry or exit of a single firm or mine dramatically alters global supply. A limited number of applications allows for demand shocks from new end uses to create significant changes in total demand. The lack of transparency in minor metals markets, where information is not widespread and disseminated among market participants, may lead to less-informed decisions, opportunistic pricing, and greater price variability. The following sections explore whether volatility is primarily due to these materials being by-products or minor metals.

## 3. Data and method

This analysis uses two datasets. The first consists of annual average price data from 1960 to 2013 for 36 metal and mineral commodities, which are sourced from the USGS Data Series 140 (Kelly and Matos, 2014). The second dataset is monthly average price data available for 30 metals and minerals from January 2005 to May 2015, which are sourced from Metal-Pages (2015) and the World Bank Global Economic Monitor (GEM) databases (World Bank, 2015). Full details on the data sources for each material can be found in Table A.1 of Appendix A.

Fig. 2 depicts estimates of each element's share of total supply as a by-product. With the exception of silicon, these data are sourced from Nassar et al. (2015), who estimate the share of each element's total production as a companion metal circa 2008. While

<sup>3</sup> There are several articles that develop in-depth theoretical models of by-product and co-product production. See, for example, Pindyck (1982), Packey (2012), and Afflerbach et al. (2014).

<sup>4</sup> Fizaine (2015) outlines several of the typical characteristics of minor metals markets, including low production volumes and high geographic concentration of supply.

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