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# Is the convenience yield a good indicator of a commodity's supply risk?

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ABSTRACT

A strong increase in the demand for some commodities over the last decade will have a major impact on their future supply situation. Of increasing importance, therefore, is an assessment of a commodity's criticality, and especially its supply risk, by appropriate indicators. The literature has proposed numerous indicators of the supply risk. Here, we use the convenience yield of commodity futures as a supply risk indicator to address some of the major shortcomings of existing indicators, especially regarding their predictive power. This paper aims to test the applicability of the convenience yield as an indicator of a commodity's future supply risk. Therefore, we calculate historical convenience yields for 3-, 15-, and 27-month futures contracts for five major industrial metals (aluminum, copper, lead, nickel, and zinc) during the period 1999 to 2011. We compare the convenience yields at the beginning of the contract period to known indicators at maturity to find that the convenience yield has generally predictive power for the static stock lifetime (i.e., inventory volume/turnover) and future spot prices. Furthermore, we find that, with some restrictions, the convenience yield is an applicable indicator of a commodity's supply risk.


## Introduction

Industrial metals are important basic materials for almost all industrial products, including cars and electronic devices. Hence, their demand is closely related to business cycles (Rosenau-Tornow et al., 2009). The production and consumption of industrial metals have increased sharply in the past decade, especially because of rapid growth in emerging markets. With an increasing number of fast-growing economies in other emerging countries, the availability risk of economically very important industrial metals, such as aluminum, copper, nickel, and zinc, can easily increase to a critical level in the future (European Commission, 2010). It is, therefore, increasingly important that manufacturers assess the future availability of commodities to avoid disruptions in the production process. With already low stock levels, particularly in the case of just-in-time production strategies, a short delay in supply can cause production disruptions and hence financial losses for a single company or for the economic system as a whole.

To assess commodity risks, it is important that we know the commodity's criticality, which we define, following Graedel et al. (2012), with the three dimensions supply risk, vulnerability to supply restrictions, and environmental implications. Each of these dimensions contains several components, quantified in turn by several indicators. The literature provides a variety of such indicators. Indicators of supply risk are, for example, the inventory level, the spot price, the Herfindahl–Hirschman Index, or the production volume (Rosenau-Tornow et al., 2009; Graedel et al., 2012). Good indicators should provide managers and policy makers with appropriate, easy, and continuously accessible information on supply risk. However, all of the existing indicators have shortcomings. For example, there is no indicator that is (a) available with a sufficiently high frequency (e.g., daily), (b) forward-looking to a certain extent, and at the same time (c) easily accessible to avoid delays due to data acquisition. To address these shortcomings, we propose the convenience yield, which is derived from the term structure of commodity futures as an indicator of supply risk. This yield can be interpreted as the benefit of having the commodity physically in stock (Copeland et al., 2004; Geman, 2005). Weymar (1966) theoretically demonstrated a negative relationship between these benefit, quantified by the convenience yield, and the current as well as future inventory level. The present paper aims to confirm empirically that the latter relationship can be used as a short- to medium-term forward-looking indicator of future supply risk, which avoids the shortcomings of existing indicators. Statistical tests are presented with convenience yields calculated from trading prices and inventory data of the London Metal Exchange (LME) for five major industrial metals (aluminum, copper, lead, nickel, and zinc) with different maturities (3, 15, and 27 months).

Our paper is structured as follows: We first introduce the underlying theory of commodity criticality, commodity futures,

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and the theory of storage. We then derive our hypothesis and explain the methodology. Next, we statistically test our hypothesis with historical convenience yields and analyze the ability of the convenience yield to serve as an indicator of a commodity's future supply risk. Finally, we summarize the results of our empirical analysis and suggest avenues for further research.

## Theory and hypothesis

### *Criticality of commodities and supply risk*

The literature provides various approaches for the definition and designation of a commodity's criticality (see Erdmann and Graedel, 2011, for an overview of the most important studies concerning criticality of non-fuel minerals). According to Graedel et al. (2012), criticality comprises three dimensions: supply risk (risks that may at least lead to supply disruptions), vulnerability to supply restrictions (at a corporate, national, or global level), and environmental implications (environmental burden of a commodity caused, for example, by its toxicity or atmospheric emissions).

As the aim of our paper is to provide an indicator of future supply risk, we will focus on this dimension hereafter. The supply risk dimension consists in the medium term (5–10 years) of three components (Graedel et al., 2012): (1) geological, technological, and economic; (2) social and regulatory; (3) geopolitical. Several indicators quantify each component. Component (1) contains indicators of the time to depletion (e.g., reserves, production, and demand) and interdependencies with by-products. The development level and the impact of public policies on mining projects are included in component (2). Finally, indicators for the concentration of global production capacities (Herfindahl–Hirschman Index) and political stability (Worldwide Governance Indicator) are grouped in component (3).

Rosenau-Tornow et al. (2009) provided another approach to supply risk assessment, which is similar to the components approach of Graedel et al. (2012). They described supply risk using a framework of five so-called main indicators: (a) current supply and demand; (b) production cost; (c) geostrategic risks; (d) market power; and (e) (future) supply and demand trends. These main indicators include specific indicators, corresponding in part to those of Graedel et al. (2012). In particular, the main indicator "current supply and demand" includes the current market balance, calculated as the difference between supply, demand, and the change in the stock level. Market imbalances are as far as possible smoothed by additional supply from inventories or by building up stocks. However, this is only possible if the "stock keeping", which is a second indicator for this main indicator, is sufficiently high. Hence, for producers of industrial goods, a low inventory level bears considerable risk of a supply disruption in the short run if an excess demand occurs. Therefore, a measure for the inventory of a commodity is a very important short-term ( $<5$ years) indicator in the supply risk dimension. In the Graedel et al. (2012) framework, this would be located in component (1) (geological, technological, and economic) in a short-term perspective.[3] We stress that in the Rosenau-Tornow et al. (2009) approach "current market balance" and "stock keeping" are assessed by current values in conjunction with a qualitative outlook. However, for a manufacturer's assessment of the short-term supply risk, it would be interesting to also access more quantitative forward-looking data.

[3] Note that Graedel et al. (2012) discuss the supply risk only from medium- and long-term perspectives with slightly different components, but the short-term perspective is not presented. They admit that individual indicators can be adjusted if necessary. Hence, users can be provided this way with a broad short-term perspective.

Another well-known approach is the cumulative availability curve, which accounts for dynamic effects (Yaksic and Tilton, 2009) but makes extensive use of data that are difficult to acquire. It incorporates as indicators a measure for the size of the reserves (or, where possible, the reserve base, respectively, the resources) and the price structure of their profitable exploitation. As it reflects depletion risk, it is mainly a long-term assessment tool containing geological, technological, and economic aspects.

To sum up, one can see that a variety of indicators for measuring supply risk was discussed in the literature. However, we notice a lack of feasible indicators of short-term supply risk. For a short-term perspective, it is important that we have an indicator with a sufficiently high frequency (e.g., daily) so that shifts in the supply situation are visible immediately. Furthermore, it should be forward looking to a certain extent to allow managers to initiate countermeasures in advance. Finally, the data should be easily accessible so that new information is available quickly.

To close this gap in the literature, we analyze the convenience yield (i.e., the benefit derived from having the commodity physically in stock) of commodity futures as an indicator of future supply risk. We draw on the extended theory of storage from Weymar (1966), which states that this quantity is related to future inventory levels (see next chapter). The convenience yield, as a forward-looking indicator for supply risk, would be accessible easily from futures trading prices with daily frequencies as many commodity futures with different delivery dates are traded daily on international stock exchanges.[4]

### *Commodity futures and convenience yields*

Forward curves of commodity futures exhibit a variety of different shapes. One of their main features is the slope of the curve, which largely determines whether the future price is above or below the current spot price. Of particularly significance, from a financial economics perspective, is the negative slope of this curve, which is termed backwardation (i.e., shorter-dated contracts have a higher price than longer-dated ones). This is a major difference compared to futures on financial assets (e.g., stocks and bonds). For example, futures on stocks that pay no dividend, and hence generate no direct cash flows like commodities, exhibit a positive slope. Therefore, a suitable explanation for negative slopes of forward curves has to be found.

The future price, $F_{tT}$, at time $t$ for the delivery of a commodity at time $T$ can be calculated from arbitrage arguments by a cost-of-carry valuation formula. In general, $F_{tT}$ equals the spot price, $S_t$, plus the cost of carrying the underlying asset until the maturity of the contract. Furthermore, the benefits for the holder of the commodity until maturity have to be deducted. In its continuous form, the cost-of-carry pricing formula of a commodity future can be expressed as follows:

$$F_{tT} = S_t e^{(r_{tT} + c_{tT} - CY_{tT})(T-t)} \tag{1}$$

The cost of carry consists of the cost of capital, which can be calculated using the interest rate, $r_{tT}$, and the cost of storage rate, expressed as $c_{tT}$, which covers all expenditures for storing the commodity (e.g., warehouse rent or insurance fees). The residual between the observed future price and the spot price plus the cost of carry is captured in the convenience yield, $CY_{tT}$, in the form of a rate, which allows future prices below the current spot price.

It is analogous to the dividend yield in the price of a stock future and quantifies the income for the owner of the underlying

[4] We wish to point out that our analysis does not necessarily require a completely weak or semi-strong form of commodity market efficiency (Fama, 1970, 1991). It is only required that market prices reflect the equilibrium from supply and demand, which appears to be a reasonable assumption for LME prices.