Concentrated Production and Heavy Tails in Commodity Returns

NICOLAS MERENER *

Business School, Universidad Torcuato Di Tella
1010 Saenz Valiente, Buenos Aires, (1428), Agentina.
nmerener@utdt.edu

November 19, 2014

Abstract

I study the impact of commodity production concentration on the occurrence of extreme commodity returns. I explore this issue in a sample of 22 agricultural, mineral and energy commodities of global scope that are liquidly traded through futures at the most important exchanges. I find that measures of production concentration such as the Herfindahl index computed on national shares of global output, or the market share of the top three producers, had significant and positive effect on measures of extreme returns during 1995-2012, as implied by daily return kurtosis or the shape parameter of the distribution of extreme returns. Volatility persistence appears unlikely to generate the cross sectional kurtosis observed empirically unless heavy tailed conditional returns are also included in the dynamics. The results are economically significant and robust to the inclusion of controls for inventories, futures liquidity and country size. These findings are consistent with a simple mechanism of aggregation of globally distributed local supply shocks that impact global supply and hence commodity prices.

Keywords: Commodity Futures; Market concentration; Herfindahl index; Heavy tails
JEL codes: G13; G17; L11.

---

*I thank Sebastian Auguste, Juan Cruces, Scott Irwin, Michel Robe, Pat Fishe and seminar participants at BMF Bovespa CGRCC 2012, the University of Illinois at Urbana-Champaign, the Commodity Futures Trading Commission, Montana State University and Colorado State University for their valuable comments. David Quiroz, Samuel Kaplan and Clara Galeazzi provided superb research assistance. All remaining errors are mine.

1. Introduction

Commodity prices have historically experienced large sudden fluctuations. A large increase in commodity prices between 2003 and 2008 has led to a renewed interest in the determinants of commodity price volatility and dynamics (Arezki et al. (2014)). In this paper I explore the relationship between commodity price fluctuations and the distributed pattern of commodity production. More precisely, I focus on the effect of producer concentration on the occurrence of extreme returns.

Commodities are produced in many locations around the world. Yet the degree of production concentration is not homogeneous across commodities, but highly variable. For instance, between 1995 and 2012, 81 % of global soybeans were grown in the US, Brazil and Argentina. In comparison, the top three producers of oil, namely Russia, Saudi Arabia and the US, produced only 33 % of global output during the same period. This raises a natural question: is the dynamics of global commodity benchmarks (London Metal Exchange prices for metals, Chicago Mercantile Exchange prices for agricultural commodities, etc.) influenced by the degree of national diversification in the production of individual commodities?

The price of a globally traded commodity depends on global supply provided by the aggregation of distributed local supply. This, in turn, is sensitive to local economic conditions, weather events, logistical mishaps, labor and political unrest, among other factors. Therefore, in the absence of trading frictions, a simple economic intuition would suggest that a lack of production diversification could make concentrated commodities more likely to exhibit extreme global price fluctuations in response to local supply shocks. Yet commodity producing countries with large market shares might also act as stabilizers by releasing strategic reserves in a timely manner to mitigate price fluctuations. In addition, a comparison of price variability across commodities should take into account that the modes of production are often very different. For instance, metals are mined and refined through large scale industrial operations and therefore likely to be sensitive to organized labor strikes, but only partially affected by weather events. By comparison, the production of agricultural commodities in small farms in Latin America is very sensitive to weather events but less likely to suffer from strikes. Finally, price elasticities surely differ across commodities. Therefore shocks to the supply of minerals and agricultural commodities are likely to be caused by very different reasons and potentially lead to intrinsically different price fluctuations.

I explore these issues empirically by studying alternative measures of global production concentration and their relationship with some properties of commodity price returns. The sample in this paper is formed by 22 agricultural, mineral and energy commodities that are produced and traded globally in physical form, and also traded through liquid financial contracts at the most important futures exchanges.

In this paper I define a producing unit to be a country (except for the European Union that, in agreement with most published statistics, is taken as a whole). There is, of course, a degree of arbitrariness in choosing the boundaries of a producing unit to coincide with national borders, as I am making vast Russia and much smaller Ecuador comparable in the sensitivity of their national output to local shocks within their borders. This is justified, in part, by the fact that political shocks, regulatory changes, and macroeconomic shocks like currency fluctuations are plausibly felt in a uniform manner within a country, regardless of its area. However, a potential weakness of a partition in national units is that a weather related shock is, in reality, more likely to affect all of Ecuador than all of Russia. In my estimations I include the area of the largest producers as an explanatory variable in order to control for this effect. An additional reason for setting countries as producing units is the availability of detailed production statistics at the national level, which is to be contrasted with the scarcity of production statistics at the provincial or firm level. Based on national production data I construct, for each of the 22 physical commodities in my sample, measures of market concentration for the period 1995-2012. I also gather commodity return data with daily frequency between 1995 and 2012 and compute various statistics related to the occurrence of extreme events. I use returns in their raw form, and after subtracting the daily mean commodity return associated with cross-sample commodity price fluctuations that I interpret as caused by macro shocks that are unrelated to local supply shocks.

I then find that the occurrence of extreme price fluctuations, as implied by daily return kurtosis or by the shape parameter that characterizes the distribution of extreme returns, was positively correlated with measures of production concentration such as the Herfindahl index computed on national shares of global production, or the market share of the top three producers. These empirical findings are robust to the inclusion of appropriate controls for inventories and futures liquidity which are also potential causes for excess kurtosis. I also find that volatility persistence seems unlikely to generate the cross sectional kurtosis observed empirically unless heavy tailed conditional returns are also included in the dynamics. I show that a positive relationship between market concentration and commodity return kurtosis arises naturally from a very simple mechanism of supply shocks aggregation for a commodity that is produced in a spatially distributed manner. In summary, I find empirical support for the notion that some properties of commodity price fluctuations are determined, in part, by the global distribution of production.

This paper is related to several strands of the literature. The interaction between micro shocks and macro variables and the notion of systemic or aggregate risk have received much attention in recent years. In a macroeconomics context, the hypothesis in Gabaix (2011) is that the distribution of the size of producing units in the economy should not be assumed to fall rapidly enough to imply that micro shocks are irrelevant. On the contrary, Gabaix (2011) showed that shocks to relatively few but very large firms in the US are significant in explaining a fraction of the aggregate volatility of the economy. This paper is built around a similar hypothesis: commodity price fluctuations might, to some extent, be explained by shocks to very few commodity producing units. Therefore, the number of units (countries in this paper) involved in the production of a certain commodity might be a key determinant of some features of the global commodity price dynamics. Preliminary evidence in this direction is in Merener (2013), who studied the effect of changing global patterns of production in the dynamics of soybean prices exclusively. By relying on rain as an exogenous source of local supply shocks in Argentina and the US Midwest, Merener (2013) found that CME soybean prices have become increasingly sensitive to rain in Argentina and less sensitive to rain in the US Midwest. This change in sensitivity has correlated strongly with the increase in Argentina's share of global production and the decrease in the US share of global output between 1996 and 2010. This suggests that local supply shocks are relevant to explain global commodity prices and that the importance of local events is amplified by the market share of the region in which the shock occurs.

This paper is also related to a large literature of non-Gaussian returns in commodities and asset prices in general. Cont (2001) reviewed a taxonomy of statistical features that appear frequently in the analysis of asset price fluctuations. Among them, the presence of heavy tails in equities, currencies and commodities is a recurrent theme in the literature. Jumps, stochastic volatility, and auto-regressive dynamics are some of the mechanisms that lead to heavy tails. An incomplete list of related works in commodities includes Hall et al. (1989) who evaluated the relative merits of the stable Paretian and mixture of normals distributions in matching the heavy tailed behavior of commodity returns. Geman (2005) presented extensive evidence of non-Gaussian dynamics in many commodity markets and discussed numerous derivative pricing models that incorporate these features in their risk-neutral dynamics. Krehbiel and Adkins (2005) studied the tail of the distribution of returns for NYMEX energy contracts. Wright (2011) reviewed the theoretical consequences of the possibility of storage for the dynamics of prices and its impact in the occurrence of rare spikes. Etienne et al. (2014) studied the presence of bubbles in agricultural commodity markets. The presence of heavy tailed returns in commodities is economically important for risk management purposes (Tomek and Peterson (2001), Giot and Laurent (2003)) and derivatives pricing (Brooks and Prokopczuk (2013)).

This paper is related more generally to the literature that studies how fundamental information is reflected in commodity prices. Roll (1984) and Boudoukh et al. (2007) are examples of studies about the impact of weather events on agricultural futures prices. Several other studies investigated the effect of supply on prices. Among these, Hamilton (2009) reviewed the multiple causes, including the structure of supply, behind the dynamics of oil prices. Those focusing on variables that might affect demand and supply include Elder et al. (2012) who estimated the impact of macroeconomic news on metal prices, Chesney et al. (2011) on the impact of terrorist activity on certain commodity prices and Chiou-Wei et al. (2014) on natural gas futures fluctuations due to changes in storage. The potentially growing influence of speculative activity on global commodities prices has received much attention in recent years, for instance in the work of Tang and Xiong (2012) and Irwin and Sanders (2012). The analysis in this paper is built on the hypothesis that global commodities prices respond to supply shocks at various locations and from multiple causes, taking into account that commodities might differ in the nature of their supply shocks and elasticities, and hence in their intrinsic price variability. This last distinction is analogous to the issue of commodity price volatility relative to that of manufactured goods, studied by Arezki et al. (2013).

The paper is structured as follows: In Section 2, I describe a simple mechanism for the aggregation of globally distributed shocks in the production of a certain commodity.

As a consequence, global commodity returns exhibit kurtosis approximately linear in the degree of producer concentration. The testing strategy for this relationship is presented in Section 3. Price, turnover, and production data on 22 commodities are described in Section 4. Estimates of the impact of producer concentration on the occurrence of extreme returns are in Section 5, and I conclude in Section 6.

2. Supply shocks and extreme returns

I describe in this Section a very simple mechanism for the aggregation of spatially distributed supply shocks that leads to a relationship between market concentration and return kurtosis. This mechanism should not be understood as a comprehensive model for the functioning of physical commodity markets in reality. Rather, it is intended to provide an economic explanation for the very specific linkage between market structure and the occurrence of extreme returns.

There are N producing units (countries in this paper). Commodity k is produced in some, or all of these countries, with non-negative shares of global production $w_1^k, ..., w_N^k$ such that $\sum_{i=1}^N w_i^k = 1$. Expected global supply available for delivery at the expiration of the nearest future contract (typically a few weeks or months away) is Q_0^k. Shocks to production occur daily, are learned immediately by market participants, and I focus on the subsequent price response. The expected supply of commodity k by unit i after the shock is

$$Q_i^k = Q_0^k w_i^k (1 + Z_i^k), \tag{1}$$

for $Z_i^k, i = 1, ..., N$ i.i.d. shocks. These have zero mean, standard deviation σ^k and excess kurtosis κ^k. The assumption of independence across regions is made to stress the local nature of supply shocks. Heterogeneity in production across countries is assumed to depend solely on the weights w_i^k, therefore the parameters $\{\sigma^k, \kappa^k\}$ that describe shocks for a fixed commodity are identical for all countries. I allow parameters to vary across commodities since, as mentioned earlier, the technology and the intrinsic variability in the production of oil might be very different from that of soybeans. Notice that (1) is quite flexible. For instance, the shocks Z_i might arise from independent Poisson processes in each region, so that if the period under consideration is very short (e.g. a day), only a few regions might simultaneously have shocks with non-zero values.

Shocks to production occur in a single short period but might impact expected physical supply on different horizons as the physical impact of a flood might be different from that of a labor strike. I assume that the first future contract that expires after the occurrence of the shock to production (i.e. hurricane) responds to diminished expected supply even if the actual supply shortage (i.e. diminished harvest) happens later, even perhaps after the expiration of the contract. This is the case because of the standard intertemporal arbitrage relationship for futures with close maturities. This is also consistent with principal component studies showing that commodity term structures fluctuate mostly in a parallel manner (Cortazar and Schwartz (1994)). In similar vein, Merener (2013) shows that the empirical impact of an inch of summer rain in the US Midwest has instantaneous effect of similar magnitude on the price of the nearest November soybean contract and on the price of the subsequent year May soybean contract.

In this framework, total expected global supply of commodity k in the near term is

$$Q_{Supply,k}^{World} = \sum_{i=1}^{N} Q_i^k. \tag{2}$$

Let P^k be the global price of the commodity, represented in this paper by a globally recognized near term futures price, and let $Q_{Demand,k}^{World}$ be global expected demand for commodity k in the near term. I adopt a standard constant elasticity of demand curve

$$Q^{World}_{Demand,k} = a(P^k)^{b_k}, \tag{3}$$

with price elasticity of demand $b_k < 0$. I assume that the demand curve remains unaffected by local supply shocks because commodities are used primarily for industrial processes and consumption at widely spread locations (often overseas) that are far from the relatively small producing regions. Commodity supply changes, in response to price changes, tend to happen in the medium and long run rather than the short run. Roberts and Schenkler (2013) found that elasticities of agricultural supply are driven by changes in land usage, which operate slowly. Krichene (2005) estimated short and long run supply elasticities for oil and found that supply is very inelastic in the short term. Therefore, I assume that $Q^{World}_{Supply,k}$ is inelastic in the very short run with respect to prices. From (3), equilibrium of supply and demand implies

$$a(P^k)^{b_k} = Q^{World}_{Supply,k}. \tag{4}$$

Therefore, a supply shock generated by the aggregation of simultaneous local shocks $Z^k_i, i = 1, ..., N$ leads, through (1), (2) and (4) to a return that can be expressed by keeping linear terms as

$$\frac{\Delta P^k}{P^k} \approx \frac{1}{b_k} \frac{\Delta Q^{World}_{Supply,k}}{Q^{World}_{Supply,k}} \approx \frac{1}{b_k} \sum_{i=1}^{N} w^k_i Z^k_i \tag{5}$$

I focus in this paper on the effect of producer concentration on the occurrence of large commodity returns. As mentioned earlier, output for different commodities might be intrinsically more or less variable due to varying exposures to exogenous shocks such as weather, logistical accidents, labor unrest, etc. Moreover, the variance of (5) depends on the elasticity of demand b_k, which in reality is likely to vary across commodities. A convenient measure associated with the occurrence of extreme returns that is appropriately normalized by squared variance is the excess kurtosis, defined as

$$ExcessKurtosis = \frac{E[(X - E[X])^4]}{(E[(X - E[X])^2])^2} - 3 \tag{6}$$

for a generic random variable X. The kurtosis of commodity returns is economically important because it quantifies their departure from a normal distribution and, implicitly, a measure of extreme returns, useful in risk management (Tomek and Peterson (2001), Giot and Laurent (2003)). In the context of option pricing, excess kurtosis determines how expensive out-of-the-money options are relative to at-the-money options (Brooks and Prokopczuk (2013)). It is straightforward to show from (6) that the excess kurtosis of a sum of M equally weighted, independent and identically distributed random variables, each with excess kurtosis κ, is

$$ExcessKurtosis = \frac{\kappa}{M}. \tag{7}$$

However, the kurtosis of the commodity return (5) arises from a sum of shocks with typically unequal weights because a few countries produce the bulk of global output for a specific commodity and many others have small non zero weights. Therefore, in order to approximate the kurtosis of (5) through (7) it is appropriate to introduce the *effective number of producers*, defined as

$$N^{Eff,k} = \frac{1}{\sum_{i=1}^{N} (w_i^k)^2} = \frac{1}{HI^k}, \tag{8}$$

where HI^k is the Herfindahl index associated with commodity k. A large Herfindahl index indicates a highly concentrated market with a small effective number of producers. The Herfindahl index and its inverse are widely used in Industrial Organization as measures of market concentration. In particular, in the equally weighted case with $w_i = 1/N$ it naturally holds that $N^{Eff,k} = N$. Empirical evidence in Section 4 shows, for example, that the average effective number of producers of soybeans and oil were 4 and 17 respectively for the sample period in this paper. Combining (7) and (8) implies that

$$ReturnKurtosis^k \approx \frac{\kappa^k}{N^{Eff,k}} = \kappa^k HI^k. \tag{9}$$

Conveniently, as a consequence of the normalization by squared variance in (6), the excess kurtosis of commodity price returns (9) does not depend on the elasticity of demand. According to (9), under a simple global supply aggregation mechanism, the return kurtosis for any commodity is approximately linear in the Herfindahl index associated with its production and also proportional to the kurtosis parameter κ^k associated to its physical supply shocks.

3. Testing strategy

Motivated by (9), this Section describes a strategy to test for a relationship between market concentration and extreme returns. High frequency return data is readily available but daily data on national output shocks to the production of commodity k (i.e. high frequency information on variations of expected output rather than prices), needed to estimate the kurtosis of physical shocks κ^k is not available. The parameter κ^k is determined exclusively by the technology in the production of the commodity. Table 1 presents the sample of commodities in this paper, including 8 metals and crude Oil which require mining and drilling, and 13 commodities of agricultural origin. Because these two classes differ strongly in their modes of production it is quite possible that unobservable $\kappa^{mining} \neq \kappa^{agriculture}$. However, inspection of Table 2 reveals that the average Herfindahl index for minerals and oil in the sample is 0.22 (std. dev. 0.17) and that for the agricultural commodities the average Herfindahl index is 0.21 (std. dev. 0.09). Therefore, the mean Herfindahl index for non-agricultural commodities is not significantly different from the mean Herfindahl index for agricultural commodities. This suggests that, even if the commodity class is perhaps a determinant of the unobservable kurtosis of physical shocks κ, it is not a primary determinant of the Herfindahl index. This leads me to assume that the unobservable kurtosis of physical shocks κ^k, determined by the technology employed in the production of the commodity, is not correlated with the index HI^k associated to the availability of this natural resource across the globe. Taking this and (9) into account I implement various tests for

$$MeasureLargeReturns = \beta ConcentrationMeasure + Controls + \epsilon \tag{10}$$

Concentration measures are available for each commodity with yearly frequency. Measures of large returns, such as kurtosis, are computed using all daily returns within a certain period. I first present results for (10) implemented as panel regressions. There is a trade-off between effective sample size in the panel, which increases for a finer partition on 1995-2012 in shorter time periods, and precision in the estimation of extreme return statistics, which decreases for such finer partition as there are less days within each period. I take six triennial periods, each with roughly 780 trading days, in 1995-2012. Yearly concentration measures are averaged over the three years in each period.

The first measure of large returns that I test is the excess kurtosis of daily commodity returns. I consider two variations of this measure: that computed over raw returns, and the kurtosis of *excess returns* after subtracting the daily return for the commodity cross section where each commodity is weighted equally. The latter is constructed to take into account that the very simple mechanism in Section 2, which postulates that global commodity price fluctuations are driven by the aggregation of local supply shocks, is incomplete. In reality, commodity prices fluctuate because of many factors that impact all commodities simultaneously. Asian demand has contributed to widespread commodity price increases in recent years. Increasing investment in commodity linked financial products, a phenomenon termed financialization (Tang and Xiong (2012)), has likely led to heightened price correlation across commodities. The global recession triggered by the collapse of Lehman Brothers led to massive commodity price decreases in 2008/09. Fluctuations in the exchange rate between world currencies and the US dollar led to nominal price changes in USD denominated prices. All these effects might mask extreme returns that arise from the aggregation of local supply shocks, and which are the focus of this paper. In order to eliminate these common fluctuations I subtract the daily return of the commodity cross section. I interpret the resultant vector of excess returns as being less likely to be due to macroeconomic reasons, and more likely to be due to commodity-specific shocks.

For robustness, I also consider a second measure of extreme returns, alternative to kurtosis. The presence of extreme fluctuations in a time series of returns can be quantified explicitly by estimating the tail of the empirical distribution. Unlike the case of kurtosis, which is a single number, it is possible to estimate separately the right and left tails of the underlying distribution of returns. Extreme value theory (Kotz and Nadarajah (2000)) provides the relevant framework and Cont (2001) discussed its application to asset pricing. The tail of the distribution of commodity returns was also studied by Hall et al. (1989) and Krehbiel and Adkins (2005).

I follow next the notation in Gençay et al. (2001). For a sequence of returns arising from a distribution F, a measure of large returns is given by the shape parameter associated with the distribution of exceedances over a certain threshold u. This is

$$F_u(y) = Pr\{x - u \leq y | x > u\} = \frac{F(y+u) - F(u)}{1 - F(u)}$$

It can be shown under very mild conditions and without assuming any specific return distribution F that, as u becomes large, $F_u(y)$ converges to the Generalized Pareto Distribution with form

$$\begin{aligned} G_\xi(x) &= 1-(1+\xi\frac{x}{\beta})^{-1/\xi}, \;\; \xi \neq 0 \\ G_\xi(x) &= 1-e^{-x/\beta}, \;\; \xi = 0 \end{aligned}$$

The value of the *shape parameter* ξ is related to the tail of F. In particular, if F has finite support then $\xi < 0$. Many commonly used return distributions, such as the normal, lognormal and exponential distributions, imply $\xi = 0$. And a distribution F with power-law tail with exponent α implies $\xi = \frac{1}{\alpha} > 0$. Low α, or high ξ, imply slow tail decay. This class includes the Pareto and Student-t distributions among others. Therefore a higher shape parameter ξ implies a stronger presence of extreme returns. This justifies using estimates of the shape parameter for various commodities as a measure of extreme returns in (10).

Maximum likelihood estimators for the shape parameter based on observations that exceed a certain threshold, and an associated MATLAB package, are discussed by Gençay et al. (2001). I use their routines in my estimations. I choose, for each commodity, the threshold u such that 300 returns out of 4682 daily recordings are exceedances (with positive and negative sign). I verify that the estimated parameter ξ is stable for neighboring values of u. The choice of threshold is high enough to imply that exceedances are extreme returns yet low enough to obtain estimates of ξ with relatively low standard errors.

Using the shape parameter as a measure of extreme returns I estimate (10) through a cross-sectional regression in which the yearly concentration measure is averaged over 1995-2012 and the return statistic uses all 4682 trading days in 1995-2012.

I consider two alternative measures of market concentration in the panel and cross-sectional implementations of (10). First, motivated by (9), I take the Herfindahl index, defined as the sum of squared market shares, computed for each commodity using national shares of global production with yearly frequency between 1995 and 2012. A second measure of market concentration is the total market share of the top three producers on each year over the same period. The appeal of this second measure lies in its simplicity. Futures traders, who set prices through their trading, are likely to be rapidly aware of events happening in the top three producers of the underlying commodity. The correlation between these two concentration measures in the period 1995-2012 across the commodity sample was 0.91, although the relationship between these two measures is nonlinear.

In addition, the likelihood of extreme returns is plausibly affected by other issues specific to each commodity. It is well known in the commodities literature that low physical inventory tends to generate an inverted futures curve (Gorton et al. (2012)) and increased futures volatility (Symeonidis et al. (2012)). Therefore, I include the slope of the futures term structure as a control. The liquidity of a futures contract might be correlated with the occurrence of extreme returns. For example, a more illiquid contract might experience more pronounced temporary imbalances of supply and demand and more violent price fluctuations. I control for this effect, represented by futures turnover (in number of contracts). The computation of concentration measures based on national shares of production is oblivious to the fact that some countries are much larger than others, potentially diluting the actual degree of geographical concentration. Therefore, I also include as a control the area of the top three producers of each commodity.

4. The Data

4.1. Commodity Futures

The sample, reported in Table 1, is an exhaustive list of commodities that were liquidly traded in futures exchanges of global importance during 1995-2012 and which were international in the scope of their physical trading. Table 1 displays the list of commodities, their venue of trading, contract size, average yearly futures turnover in number of contracts and futures market size in US dollars.

Metals traded at the London Metals Exchange (LME) are aluminum, lead, nickel, copper, zinc and tin. Brent oil and canola are traded at the InterContinental Exchange. Platinum and palladium are traded at NYMEX. Soybeans, wheat, corn, rough rice and soybean oil are traded at the CBOT. Coffee, cotton, cocoa, sugar and orange juice are traded at ICE and at the NYBOT prior to 2007. Rubber is traded at the Tokyo Commodity Exchange and palm oil is traded at the Bursa Malaysia exchange. For each physical commodity I have selected the exchange where it is most liquidly traded and the associated price widely considered a global benchmark.

I do not include cobalt (LME), molybdenum (LME), uranium (NYMEX) and coal (ICE Rotterdam) because they have been traded through futures only since recently, therefore return data for them are not available for the entire time interval used in this paper. I do not include gold and silver due to their dual role as physical commodity and storage of financial value. I do not include electricity or natural gas because they are largely produced and consumed domestically, with significantly less global trading and pricing than the commodities in my sample. I focus on Brent oil, which is waterborne oil in the North Sea and widely seen as an international benchmark, rather that West Texas Intermediate oil because WTI is heavily influenced by logistical and storage bottlenecks at the point of delivery in Cushing, Oklahoma. These disruptions, although concentrated geographically, are not due to local supply shocks at production points which are the focus of this paper but merely a consequence of the fact that Cushing can not be accessed by oil tankers. As a consequence of disruptions of this kind the WTI price often decoupled between 2006 and 2010 from the fundamental supply and demand balance of global oil.

From Datastream I obtained daily price, return and turnover data from January 1st, 1995 to December 31st, 2012. Datastream provides several alternative continuous indices constructed from a series of futures contracts with fixed expiration dates. The Type CS00 is generated by concatenating the time series of the nearest future price. It reflects actual prices, but it leads to a spurious return on contract expiration dates by using two different contracts for prices on consecutive dates. I use this continuous series for the calculation of average prices and total turnover from all live future contracts. The Type CS04 continuous index is generated by concatenating daily returns computed from the prices of a fixed nearest contract, therefore avoiding possibly large spurious returns. I use this series for the computation of return based statistics such as kurtosis and the shape parameter of the extreme return distribution. Finally, Datastream also provides price series for many contract maturities. Hence, the difference between the contract closest to the six month horizon and the first contract, divided by the first contract, is a measure of curve slope. A negative slope is widely agreed to be a signal of low inventories (Gorton et al. (2012)). Statistics for turnover are reported in Table 1 and statistics for returns are in Table 3.

4.2. **Production data**

Production data discriminated by national origin and with yearly frequency were obtained for all commodities in the sample. For aluminium, copper, nickel, tin, zinc, lead, platinum and palladium data were gathered from reports produced by the United States

Geological Survey (USGS)[1]. Data for oil was obtained from the British Geological Survey (BGS)[2]. Soybean, wheat, corn, cotton, coffee, sugar, orange juice, soy oil and canola output statistics were collected from the Foreign Agricultural Service at the United States Department of Agriculture (USDA)[3]. Finally, cocoa, palm oil, rubber and rough rice data was obtained from the Food and Agriculture Organization (FAO) of the United Nations [4]. Table 2 displays the average Herfindahl index over triennial periods and over 1995-2012 for the 22 commodities in the sample. It also displays the market share of the top three producers during 1995-2012 and the surface area of the top three producers of each commodity in millions of square kilometres. More detailed production statistics are shown in the upper panel of Tables A.1 to A.22 in the Online Appendix, including triennial output by national origin between 1995 and 2012. These tables also show measures of market concentration at the bottom.

5. Results and Analysis

5.1. Heavy tailed returns

As discussed in Section 3, commodity prices are influenced by certain factors that are common to all commodities and that are unrelated to the local supply shocks that are the focus of this paper. This is the case, for instance, of global demand shocks, global interest rate fluctuations, or changes in attitudes toward risk. I partially remove the effect of overall commodity price variation by subtracting the daily mean commodity return for the equally weighted basket of commodities from the daily individual commodity returns. Table 3 displays various return statistics for daily raw and excess commodity returns. Excess kurtosis is positive for all commodities indicating heavier tails than in a normal

---

[1] http://minerals.usgs.gov/minerals/pubs/commodity

[2] http://www.bgs.ac.uk/

[3] http://www.fas.usda.gov

[4] http://www.faostat.fao.org

distribution. Interestingly, the kurtosis of raw and excess returns in Table 3 are very similar in their levels and variation across the commodity sample. Their correlation in levels is 0.97. This suggests that many of the extreme fluctuations present in the raw returns are also present in the excess returns.

Although heavy tails can arise in principle from GARCH type of dynamics with conditionally normal innovations, it has been found in financial applications that persistence in volatility is often not strong enough to generate the large level of kurtosis observed empirically (Bai et al. (2003)). I explore such possibility by estimating an univariate GARCH(1,1) model on daily raw returns for each commodity, using Gaussian and Student's t distributed conditional innovations. Results, in Table 4 show that a GARCH(1,1) model with Gaussian innovations is unable to generate the high level of kurtosis seen empirically in commodities. Moreover, the correlation across commodities between sample kurtosis and model kurtosis is in this case very low. However, the correlation between sample kurtosis and the kurtosis of the innovations in a GARCH(1,1) model with Student's t innovations and freely estimated degrees of freedom is much higher at 0.74. The computation of this correlation naturally leaves out those commodities (tin, orange juice, platinum) for which the model kurtosis is not even finite. However, these three commodities are precisely those that exhibit the highest sample kurtosis in Table 3 therefore suggesting further support for non-Gaussian innovations. These remarks suggest that the levels of kurtosis observed in daily commodity returns are not due solely to the persistence of volatility but, rather significantly, to the presence of non-Gaussian conditional innovations.

The presence of extreme returns can also be inferred by direct estimation of their distribution. Table 5 shows point estimates for the shape parameters of large, positive and negative returns estimated for raw and excess returns. I also display, for each commodity and distribution tail, the threshold such that the subsample used in the estimation of the tail contains 300 returns of even larger magnitude. Left and right thresholds are very similar for any specific commodity but they vary strongly in the cross sample. Interestingly, similar thresholds for a fixed commodity do not imply similar shape parameters. Although only 22 out of 88 of the shape parameter estimates are strongly significant in being different from zero it is striking that all of these are positive, signalling heavy tails. Remarkably, sample kurtosis is highly correlated with the shape parameters of the right tail and very weakly correlated with the left tail.

5.2. Extreme returns and market concentration

The existence of a relationship between concentration of production and excess commodity returns is tested empirically through various specifications of (10). Table 6, for raw returns, and Table 7, for excess returns, present results for a panel based estimation of (10). The impact of measures of market concentration, defined as the Herfindahl index or the market share of top three producers, on the kurtosis of raw or excess returns is positive, and strongly significant in all cases. The coefficients for Herfindahl index and the market share of the top three producers are close in magnitude because these two measures are strongly correlated with slope close to 1. In order to mitigate the potential influence of outliers in kurtosis, such as perhaps orange juice and platinum as seen in Table 3, I rank commodities in increasing order according to their kurtosis and use this rank as dependent variable in (10). Results in the rightmost columns of Tables 6 and 7 are very strongly significant for the effect of market concentration on the measure of extreme returns. Therefore this effect is unlikely to be driven by just a few commodities in the sample.

The effects of futures slope on measures of extreme returns is negative in every specification in Tables 6 and 7, although not statistically significant. A negative coefficient suggests that an inverted futures curve, which tends to coincide with low inventories (Gorton et al. (2012)) and heightened volatility (Symeonidis et al. (2012)) also leads to the occurrence of extreme returns. The effect of futures turnover and producer area are not significant. The insignificance of the latter could be due to the fact that, even in a large countries such as Russia, China and the US, the production of specific commodities is often concentrated in small regions. It could also be the case that the many significant local effects are of political and economic nature, rather than related to weather. Estimates of the constant term in Tables 6 and 7 are both positive and negative and not significantly different from zero in most cases. By comparison, the aggregation mechanism in Section 2 implies zero kurtosis for the zero concentration limit in (9). Strongly significant time dummies are apparent in several periods for kurtosis as dependent variable. However this effect vanishes for kurtosis rank in both Tables. The estimations in Tables 6 and 7 use a detrended measure for turnover but results remain essentially unchanged for actual historical measures of turnover. The bulk of the R-squared is due to explanatory power across commodities rather than from time variation in market concentration and kurtosis.

The next set of experiments estimates (10) using the shape parameter of the distribution of extreme returns as dependent variable. A higher shape parameter signals heavier tails. Results in Table 8 are estimated using raw and excess returns. The upper panel in Table 8 shows that the effect of the Herfindahl index is positive and strongly significant on the shape parameter of the right tail, both for raw and excess returns. However, this is not the case for the shape parameter of the left tail, associated with extreme negative returns and reported in the bottom panel. This would suggest that local effects have more incidence in the generation of sudden price increases than sudden price decreases. The effect of futures slope and producer area are not significant. Unreported results including futures turnover as control for liquidity are very similar.

5.3. **Economic significance**

The point estimates for the Herfindahl index coefficients in Tables 6 and 7 imply that commodities that differ in market concentration by 0.1 in their Herfindahl index tend to have, roughly, a 1.0 difference in excess kurtosis. This is a large effect, comparable in magnitude to the excess kurtosis of individual commodities reported in Table 3. For instance, having production equally distributed in three countries, rather than in six countries, increases the Herfindahl index by 0.17 and implies a 1.7 difference in excess kurtosis. In order to quantify the economic significance of such a varying degree of kurtosis, I present in Table 9 the kurtosis, option prices and probabilities of extreme events implied by a set of standard models of returns parameterized by the intensity of the jumps in their dynamics. I consider the standard continuous time Black-Scholes model with Gaussian instantaneous returns and add lognormally distributed jumps that arrive on random Poisson times. The future price follows

$$\frac{dF}{F} = \sigma dW + (Z_\tau - 1)\mathbb{1}_\tau$$

where W is a standard Brownian motion, the diffusive volatility is σ, the jump times τ follow a Poisson process with arrival rate λ and the logarithm of Z_τ is normally distributed with mean 0 and standard deviation γ. Model A in Table 9 is a pure diffusion, with no jumps and with zero excess kurtosis of daily returns. Models B-D are parameterized by increasingly higher jump rates which lead to higher measures of return kurtosis, in a range of values similar to those found empirically in Table 3. Model parameter values are typical of commodity dynamics: $\sigma = 0.25$ means an annual volatility of 25%, which is equivalent to a 0.016 daily standard deviation, in line with Table 3. The jump rate $\lambda = 0.5$ in model D implies one jump every two years on average. For example, soybeans, wheat and corn have empirical kurtosis similar to that in Model B. Coffee, tin and platinum are between model C and D in terms of their kurtosis. Notice that I decrease the diffusive volatility from model A to model D so that the overall model variance remains roughly constant hence keeping at-the-money option prices very similar across models. However, models exhibit very different levels of kurtosis and this coincides with differences in out-of-the-money option prices of up to 10%. Another measure of economic significance from a risk management point of view is the probability of a large return in a fixed time interval. For example, the probability of a daily return larger than 10% is about 4% in model D and less than 1% in model B. In sum, the variation in kurtosis explained by variation in producer concentration is also correlated with significant effects in option prices and probabilities of extreme events.

6. Conclusions

I study in this paper the relevance of the distributed nature of commodity production in explaining commodity price returns. I focus on 22 agricultural, mineral and energy commodities that were liquidly traded through futures in the most important global exchanges between 1995 and 2012 and which were global in the scope of their physical trading. I find that measures of producer concentration constructed using national production data had significant and positive effect on return kurtosis and extreme return tail parameters. Volatility persistence appears unlikely to generate the cross sectional kurtosis observed empirically unless heavy tailed conditional returns are also included in the dynamics. The estimated effect is economically large and the findings are robust to the inclusion of controls for inventories, futures liquidity and producer area. These empirical results can be reconciled with a very simple mechanism for the aggregation of local supply shocks that impact global commodity prices. The potential impact of producer concentration and geographical overlap in the production of commodities, on other aspects of commodity price dynamics, such as return correlations, persistence of shocks, and the dynamics of the convenience yield, are open questions left for future research.

References

Arezki, R., Lederman, D. Zhao, H., 2013. The relative volatility of commodity prices: A reappraisal. American Journal of Agricultural Economics. doi:10.1093/ajae/aat050

Arezki, R., Loungani, P., van der Ploeg, R., Venables, A. J., 2014. Understanding international commodity price fluctuations. Journal of International Money and Finance, 42, 18

Bai, X., Russell, J. R., Tiao, G. C., 2003. Kurtosis of GARCH and stochastic volatility models with non-normal innovations. Journal of Econometrics, 114, 349-360.

Boudoukh, J., Richardson, M.P., Shen, Y.Q., Whitelaw, R., 2007. Do asset prices reflect fundamentals? Freshly squeezed evidence from the FCOJ market. Journal of Financial Economics, 83, 397-412.

Brooks, C., Prokopczuk, M., 2013. The dynamics of commodity prices. Quantitative Finance, 13, 4, 527-542.

Chesney, M., Reshetar, G., Karaman, M., 2011. The impact of terrorism on financial markets: An empirical study. Journal of Banking and Finance, 35, 253-267.

Chiou-Wei, S. Z., Linn, S. C., Zhu, Z., 2014. The response of US natural gas futures and spot prices to storage change surprises: Fundamental information and the effect of escalating physical gas production. Journal of International Money and Finance, 42, 156-173

Cont, R., 2001. Empirical properties of asset returns: Stylized facts and statistical issues. Quantitative Finance, 1, 223-236

Cortazar, G., Schwartz, E. S., 1994. The valuation of commodity contingent claims. The Journal of Derivatives, 1 , 27-39.

Elder, J., Miao, H., Ramchander, S., 2012. Impact of macroeconomic news on metal futures. Journal of Banking and Finance, 36, 51-65.

Etienne, X. L., Irwin, S. H., Garcia, P., 2014. Bubbles in food commodity markets: Four decades of evidence. Journal of International Money and Finance, 42, 129-155.

Gabaix, X., 2011. The granular origins of aggregate fluctuations. Econometrica, 79, 733-772.

Geman, H., 2005. Commodities and Commodity Derivatives: Pricing and Modeling Agricultural, Metals and Energy. Wiley Finance.

Gençay, R., Selçuk, F., Ulugülyağci, A., 2001. EVIM: a software package for extreme value analysis in Matlab. Studies in nonlinear dynamics and econometrics, 5, 213-239.

Giot, P., Laurent, S., 2003. Market risk in commodity markets: A VaR approach. Energy Economics, 25, 435-457.

Gorton, G. B., Hayashi, F., Rouwenhorst, K. G., 2012. The fundamentals of commodity futures returns. Review of Finance, doi: 10.1093/rof/rfs019.

Hall, J.A., Brorsen, B. W., Irwin S.H., 1989. The distribution of futures prices: A test of the stable paretian and mixture of normals hypotheses. The Journal of Financial and Quantitative Analysis, 24, 105-116.

Hamilton, J.D., 2009. Understanding crude oil prices. The Energy Journal, 30, 179-206.

Irwin, S.H., Sanders, D.R., 2012. Testing the Masters hypothesis in commodity futures markets. Energy Economics, 34, 256-269.

Kotz, S., Nadarajah, S., 2000. Extreme Value Distributions: Theory and Applications. Imperial College Press. London.

Krehbiel, T., Adkins, L.C., 2005. Price risk in the NYMEX energy complex: An extreme value approach. Journal of Futures Markets, 25, 309-337

Krichene, N., 2005. A simultaneous equations model for world crude oil and natural gas markets.
IMF Working paper at http://www.imf.org/external/pubs/ft/wp/2005/wp0532.pdf

Merener, N., 2013. Globally distributed production and the pricing of CME commodity futures. Forthcoming at the Journal of Futures Markets
DOI:10.1002/fut.21642

Roberts M. J., Schlenker, W., 2013. Identifying supply and demand elasticities of agricultural commodities: Implications for the US ethanol mandate. American Economic Review, 102, 3749-3760.

Roll, R., 1984. Orange juice and weather. American Economic Review, 74, 861-880.

Symeonidis, L., Prokopczuk, M., Brooks, C., Lazar, E., 2012. Futures basis, inventory and commodity price volatility: An empirical analysis. Economic Modelling, 29, 2651-2663.

Tang, K., Xiong, W., 2012. Index investment and financialization of commodities. Financial Analysts Journal, 68, 54-74

Tomek, W. G., Peterson, H., 2001. Risk management in agricultural markets: a review. Journal of Futures Markets, 21, 953-985.

Wright, B. D., 2011. The economics of grain price volatility. Applied Economic Perspectives and Policy, 33, 32-58.

Commodity	Market	Contract Size	Avg. Turnover	Avg. Mkt. Size
Aluminum	LME	25 tonnes	33377	1638
Lead	LME	25 tonnes	5370	195
Nickel	LME	6 tonnes	4742	450
Copper	LME	25 tonnes	21094	2520
Zinc	LME	25 tonnes	12518	540
Tin	LME	5 tonnes	1509	88
Oil Brent	ICE	1000 barrels	50404	3425
Platinum	NYMEX	50 troy oz.	753	43
Palladium	NYMEX	100 troy oz.	364	17
Soybeans	CBOT	5000 bushels	21214	983
Wheat	CBOT	5000 bushels	10915	290
Corn	CBOT	5000 bushels	31836	670
Coffee	NYBOT/ICE	37500 pounds	3574	174
Cotton	NYBOT/ICE	50000 pounds	3731	131
Cocoa	NYBOT/ICE	10 tonnes	2803	55
Sugar	NYBOT/ICE	112000 pounds	13362	228
Orange juice	NYBOT/ICE	15000 pounds	746	12
Palm oil	MYX	25 tonnes	1978	37
Rubber	TOCOM	5 tonnes	5786	44
Canola	ICE	20 tonnes	2249	17
Rough rice	CBOT	2000 cwt	253	6
Soy oil	CBOT	60000 pounds	10273	228

Table 1: List of commodities, exchanges and contract specifications. Average annual turnover in thousands of contracts and futures market size in billions of USD.

Commodity	Herf. 95-97	Herf. 98-00	Herf. 01-03	Herf. 04-06	Herf. 07-09	Herf. 10-12	Herf. Avg. 95-12	Top 3 Share	Top 3 Area
Aluminium	0.08	0.08	0.08	0.10	0.14	0.19	0.11	0.46	36.5
Lead	0.11	0.13	0.15	0.19	0.21	0.26	0.18	0.62	27.2
Nickel	0.13	0.13	0.12	0.10	0.10	0.10	0.11	0.48	34.8
Copper	0.13	0.15	0.15	0.16	0.15	0.14	0.15	0.51	11.9
Zinc	0.09	0.10	0.11	0.12	0.13	0.15	0.12	0.50	18.6
Tin	0.19	0.22	0.25	0.27	0.28	0.27	0.25	0.78	12.8
Oil	0.06	0.05	0.05	0.06	0.06	0.06	0.06	0.33	29.1
Platinum	0.59	0.57	0.60	0.63	0.60	0.58	0.60	0.95	28.3
Palladium	0.41	0.36	0.35	0.36	0.33	0.33	0.36	0.89	28.1
Soybeans	0.29	0.28	0.26	0.25	0.24	0.24	0.26	0.81	21.1
Wheat	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.50	17.2
Corn	0.21	0.22	0.21	0.21	0.22	0.19	0.21	0.68	23.7
Coffee	0.09	0.12	0.16	0.15	0.16	0.18	0.14	0.54	9.9
Cotton	0.13	0.12	0.14	0.15	0.18	0.16	0.15	0.60	22.7
Cocoa	0.19	0.21	0.20	0.19	0.18	0.17	0.19	0.66	2.46
Sugar	0.07	0.08	0.08	0.09	0.09	0.10	0.09	0.44	15.2
Orange juice	0.42	0.41	0.43	0.44	0.41	0.43	0.43	0.94	20.4
Palm oil	0.33	0.34	0.35	0.35	0.36	0.36	0.35	0.86	3.1
Rubber	0.20	0.19	0.20	0.20	0.19	0.19	0.20	0.69	2.7
Canola	0.23	0.23	0.24	0.24	0.23	0.22	0.23	0.78	22.9
Rough rice	0.18	0.17	0.15	0.15	0.15	0.15	0.16	0.61	14.8
Soy oil	0.19	0.17	0.16	0.16	0.16	0.17	0.17	0.62	20.7

Table 2: Herfindahl index, market share of top three producers, and their area in millions of squared kilometres, based on yearly national output between 1995 and 2012.

	Raw returns				Excess returns			
	Mean	Std. Dev.	Kurt.	Rank	Mean	Std. Dev.	Kurt.	Rank
Aluminum	0.0001	0.013	2.505	5	-0.0001	0.010	1.824	2
Lead	0.0004	0.020	3.549	13	0.0002	0.016	3.650	15
Nickel	0.0003	0.022	3.701	14	0.0001	0.019	3.622	14
Copper	0.0003	0.017	4.127	15	0.0001	0.014	3.443	11
Zinc	0.0002	0.018	3.444	11	0.0001	0.014	3.447	12
Tin	0.0004	0.016	7.749	21	0.0002	0.013	7.145	20
Oil Brent	0.0006	0.021	3.067	9	0.0004	0.019	2.711	8
Platinum	0.0003	0.013	7.198	20	0.0001	0.011	8.463	21
Palladium	0.0005	0.021	6.231	19	0.0003	0.018	7.000	19
Soybeans	0.0004	0.015	2.744	8	0.0002	0.012	2.458	6
Wheat	-0.0001	0.019	2.215	1	-0.0003	0.016	1.879	3
Corn	0.0001	0.016	2.456	3	-0.0001	0.014	2.357	5
Coffee	0.0001	0.023	6.126	18	-0.0001	0.021	6.113	18
Cotton	-0.0002	0.017	2.717	7	-0.0004	0.016	3.055	10
Cocoa	0.0001	0.019	2.487	4	-0.0001	0.018	2.066	4
Sugar	0.0002	0.021	3.374	10	0.0000	0.019	3.523	13
Orange juice	0.0001	0.020	11.97	22	0.0000	0.019	10.68	22
Palm oil	0.0002	0.016	4.760	16	0.0000	0.016	3.971	16
Rubber	0.0000	0.021	3.470	12	-0.0002	0.020	2.841	9
Canola	0.0000	0.012	5.174	17	-0.0003	0.013	4.650	17
Rough rice	0.0001	0.015	2.434	2	-0.0001	0.014	2.471	7
Soy oil	0.0001	0.014	2.569	6	-0.0001	0.011	1.584	1

Table 3: Commodity return statistics (mean, standard deviation, excess kurtosis), based on daily data between 1995 and 2012. Raw returns computed using price changes in the nearest future. Excess return computed as raw return minus the average cross sectional return for the same day. Ranking of commodities according to kurtosis is also shown.

Maximum likelihood estimates of GARCH(1,1) models for daily raw returns

$$r_t = \mu + \epsilon_t$$

$$Var(\epsilon_t) = \sigma_t^2 = \gamma_0 + \alpha_{1,1}\epsilon_{t-1}^2 + \alpha_{2,1}\sigma_{t-1}^2$$

where the innovation follows a Gaussian distribution or a Student's t distribution with freely estimated ν degrees of freedom. Models estimated over daily returns between January 1st, 1995 and December 31st, 2012. By *, ** and *** I indicate statistical significance at the 10%, 5% and 1% levels.

	Student's t GARCH				Gaussian GARCH		
	$\alpha_{1,1}$	$\alpha_{2,1}$	ν	$t-$ Kurt.	$\alpha_{1,1}$	$\alpha_{2,1}$	Kurt.
Aluminum	0.045 **	0.946 **	7.3 (6.1, 8.9)	1.79	0.038 **	0.955 **	0.88
Lead	0.036 **	0.963 **	5.6 (4.8, 6.7)	3.77	0.033 **	0.963 **	1.28
Nickel	0.042 **	0.951 **	5.5 (4.7, 6.5)	4.00	0.044 **	0.943 **	0.52
Copper	0.040 **	0.953 **	5.4 (4.6, 6.3)	4.37	0.038 **	0.953 **	0.66
Zinc	0.030 **	0.97 **	5.9 (5.0, 7.1)	3.12	0.035 **	0.963 **	11.9
Tin	0.084 **	0.922 **	3.7 (3.3, 4.2)	NA	0.050 **	0.949 **	NA
Oil Brent	0.042 **	0.952 **	6.5 (5.4, 8.0)	2.36	0.046 **	0.945 **	0.94
Platinum	0.206 **	0.821 **	3.8 (3.4, 4.4)	NA	0.068 **	0.924 **	4.14
Palladium	0.174 **	0.809 **	4.2 (3.7, 4.8)	39.9	0.105 **	0.879 **	6.82
Soybeans	0.061 **	0.928 **	6.4 (5.2, 7.9)	2.54	0.062 **	0.924 **	1.31
Wheat	0.043 **	0.947 **	9.5 (7.4, 12.4)	1.08	0.046 **	0.946 **	1.35
Corn	0.079 **	0.916 **	6.3 (5.3, 7.6)	2.58	0.068 **	0.922 **	3.20
Coffee	0.051 **	0.92 **	4.4 (3.8, 5.2)	14.2	0.062 **	0.892 **	0.29
Cotton	0.052 **	0.945 **	5.7 (4.8, 6.8)	3.55	0.047 **	0.947 **	2.17
Cocoa	0.021 **	0.975 **	5.5 (4.7, 6.6)	3.92	0.025 **	0.971 **	0.62
Sugar	0.041 **	0.957 **	5.2 (4.4, 6.2)	5.08	0.037 **	0.958 **	1.21
Orange juice	0.107 **	0.833 **	3.1 (2.8, 3.5)	NA	0.092 **	0.808 **	0.30
Palm oil	0.089 **	0.912 **	4.8 (4.2, 5.6)	7.69	0.083 **	0.904 **	3.83
Rubber	0.084 **	0.901 **	4.7 (4.0, 5.6)	8.82	0.077 **	0.894 **	0.83
Canola	0.076 **	0.905 **	5.2 (4.4, 6.2)	5.12	0.068 **	0.914 **	1.16
Rough rice	0.070 **	0.919 **	5.9 (5.0, 7.2)	3.07	0.056 **	0.929 **	0.81
Soy oil	0.049 **	0.939 **	6.6 (5.5, 8.1)	2.28	0.045 **	0.941 **	0.53
Corr. with sample kurt.				0.74			0.04
Mean kurt.				6.29			2.13

Table 4: Estimated parameters for GARCH models with Student's t and Gaussian innovations. The kurtosis associated to each model is also reported as well the cross sample correlation between model kurtosis and sample kurtosis.

	Raw returns				Excess returns			
Commodity	Left Thr.	Left Shape	Right Thr.	Right Shape	Left Thr.	Left Shape	Right Thr.	Right Shape
Aluminum	0.018	0.148 **	0.019	-0.124	0.015	0.055	0.015	0.001
Lead	0.028	0.001	0.028	0.071	0.023	0.109	0.024	0.065
Nickel	0.031	0.108	0.033	0.097	0.026	0.191 **	0.028	0.073
Copper	0.024	0.164 **	0.025	0.119	0.019	0.112	0.020	0.095
Zinc	0.025	0.061	0.026	-0.096	0.020	0.048	0.021	0.016
Tin	0.021	-0.032	0.022	0.190 **	0.019	0.154 **	0.019	0.103
Oil Brent	0.031	0.059	0.031	0.111	0.028	0.005	0.028	0.071
Platinum	0.018	0.065	0.018	0.191 **	0.015	0.075	0.016	0.261 **
Palladium	0.028	0.052	0.030	0.224 **	0.024	0.105	0.026	0.222 **
Soybeans	0.021	-0.011	0.022	-0.045	0.017	0.093	0.018	0.005
Wheat	0.026	0.125	0.028	0.039	0.023	0.110	0.024	0.003
Corn	0.024	0.017	0.024	-0.090	0.020	0.026	0.021	0.016
Coffee	0.032	0.181 **	0.033	0.129 **	0.029	0.100 **	0.030	0.144 **
Cotton	0.026	-0.042	0.026	0.051	0.022	0.031	0.024	0.058
Cocoa	0.027	0.050	0.027	0.007	0.025	0.033	0.026	-0.021
Sugar	0.029	0.154 **	0.031	-0.134	0.027	0.106	0.028	-0.053
Orange juice	0.027	0.017	0.026	0.253 **	0.027	0.042	0.027	0.239 **
Palm oil	0.023	0.102	0.023	0.127	0.022	0.081	0.023	0.136 **
Rubber	0.032	0.130 **	0.030	0.148 **	0.030	0.058	0.029	0.083
Canola	0.017	0.246 **	0.017	0.153 **	0.019	0.253 **	0.018	0.072
Rough rice	0.022	0.060	0.024	0.094	0.021	0.100	0.021	0.082
Soy oil	0.020	0.033	0.022	0.043	0.017	-0.077	0.017	0.039
Correlation shape/kurtosis		-0.07		0.70		0.24		0.84

Table 5: Threshold and point estimates for the shape parameters estimated from daily commodity returns, with ** for statistical significance at the 5% level. Maximum likelihood estimates using maximal and minimal fluctuations, on a 20 day block partition of 1995-2012, for raw and excess returns. The cross sample correlation between shape parameter and corresponding return kurtosis is reported at the bottom.

GLS random effects robust estimation of

$$Kurtosis_{k,t} = \alpha + \beta_1 ProdConcentration_{k,t} + \beta_2 FutsSlope_{k,t} + \beta_3 FutTurn_{k,t} + \beta_4 Area_{k,t} + year_t + \epsilon_{k,t}$$

on a panel of 22 commodities and six triennial periods between January 1st, 1995 and December 31st, 2012. Kurtosis is computed on daily raw returns over a triennium. Commodities are also ranked by the magnitude of their kurtosis and this ranking used as dependent variable. Producer concentration for each triennium is the average Herfindahl index or market share of the top three producers based on national shares of global output. Futures slope is the ratio of the 6-month and nearest future contracts, minus 1, averaged over a triennium. Liquidity is futures turnover in number of contracts. The area of the top three producers is in millions of square kilometres. Triennial time dummies are included. By *, ** and *** I indicate statistical significance at the 10%, 5% and 1% levels.

	Kurt. Raw	Kurt. Raw	Rank Kurt. Raw	Rank Kurt. Raw
Herfindahl	10.3***		18.3***	
	(3.7)		(5.0)	
Share top 3		7.08**		11.8**
		(3.17)		(4.6)
Slope futures	-5.26	-5.41	-17.6	-15.6
	(8.11)	(8.27)	(14.8)	(15.3)
Turnover lots	-4.2e-05	3.8e-05	-9.5e-05	-1.0e-05
	(3.3e-05)	(4.9e-05)	(1.1e-04)	(1.2e-04)
Area top 3	0.014	0.033	-0.006	0.030
	(0.018)	(0.019)	(0.058)	(0.059)
years95-97	1.94**	1.96**	0.24	0.26
	(0.79)	(0.81)	(1.79)	(1.80)
years98-00	3.41**	3.36**	0.66	0.51
	(1.57)	(1.57)	(1.94)	(1.95)
years01-03	1.33**	1.27**	0.50	0.35
	(0.56)	(0.56)	(1.82)	(1.79)
years04-06	1.22***	1.14***	0.16	0.02
	(0.39)	(0.38)	(1.78)	(1.77)
years07-09	0.46	0.41	0.45	0.30
	(0.35)	(0.35)	(1.32)	(1.33)
Const	-0.17	-2.96	8.26***	3.81
	(1.04)	(2.50)	(2.13)	(3.81)
Sample size	132	132	132	132
R-squared	0.24	0.22	0.20	0.17

Table 6: Panel data analysis of the impact of producer concentration on raw return kurtosis.

GLS random effects robust estimation of

$$Kurtosis_{k,t} = \alpha + \beta_1 ProdConcentration_{k,t} + \beta_2 FutsSlope_{k,t} + \beta_3 FutTurn_{k,t} + \beta_4 Area_{k,t} + year_t + \epsilon_{k,t}$$

on a panel of 22 commodities and six triennial periods between January 1st, 1995 and December 31st, 2012. Kurtosis is computed on daily excess returns over a triennium. Commodities are also ranked by the magnitude of their kurtosis and this ranking used as dependent variable. Producer concentration for each triennium is the average Herfindahl index or market share of the top three producers based on national shares of global output. Futures slope is the ratio of the 6-month and nearest future contracts, minus 1, averaged over a triennium. Liquidity is futures turnover in number of contracts. The area of the top three producers is in millions of square kilometres. Triennial time dummies are included. By *, ** and *** I indicate statistical significance at the 10%, 5% and 1% levels.

	Kurt. Exc.	Kurt. Exc.	Rank Kurt. Exc.	Rank Kurt. Exc.
Herfindahl	9.80***		17.16***	
	(3.1)		(5.06)	
Share top 3		6.29**		10.07**
		(3.06)		(4.63)
Slope futures	-6.39	-6.80	-14.8	-13.1
	(7.82)	(7.99)	(14.9)	(15.4)
Turnover lots	-4.2e-05	-4.4e-05	-1.4e-04	-1.5e-04
	(3.1e-05)	(4.4e-05)	(1.1e-04)	(1.2e-04)
Area top 3	0.025	0.043**	0.034	0.068
	(0.019)	(0.020)	(0.072)	(0.070)
years95-97	1.88**	1.88**	0.23	0.22
	(0.84)	(0.85)	(1.72)	(1.72)
years98-00	3.11*	3.06*	0.58	0.43
	(1.63)	(1.63)	(1.87)	(1.86)
years01-03	1.28**	1.23**	0.43	0.29
	(0.59)	(0.59)	(1.61)	(1.58)
years04-06	0.84**	0.77**	0.14	0.02
	(0.38)	(0.38)	(1.83)	(1.83)
years07-09	0.33	0.28	0.38	0.25
	(0.34)	(0.34)	(1.20)	(1.19)
Const	-0.42	-2.76	7.98***	4.54
	(0.88)	(2.38)	(1.86)	(3.53)
Sample size	132	132	132	132
R-squared	0.22	0.19	0.21	0.17

Table 7: Panel data analysis of the impact of producer concentration on excess return kurtosis.

Heteroscedasticity robust OLS estimation of

$$ShapeParameter_k = \alpha + \beta_1 ProdConcentration_k + \beta_2 FutsSlope_k + \beta_3 Area_k + \epsilon_k$$

The shape parameter for each commodity is taken from Table 5. Producer concentration is the Herfindahl index or the market share of the top three producers. These measures are based on national shares of global output between 1995 and 2012. Futures slope is the ratio of the 6-month and nearest future contracts, minus 1, averaged over 1995-2012. The area of the top three producers is in millions of square kilometres. By *, ** and *** I indicate statistical significance at the 10%, 5% and 1% levels.

	Raw Right Tail	Raw Right Tail	Exc. Right Tail	Exc. Right Tail
Herfindahl	0.50**		0.53***	
	(0.17)		(0.08)	
Share top 3		0.36**		0.33***
		(0.16)		(0.11)
Slope futures	-0.03	-0.05	-0.24	-0.12
	(0.77)	(0.85)	(0.52)	(0.63)
Area top 3	-0.0013	-4.0e-04	8.0e-04	0.0016
	(0.0022)	(0.0021)	(0.0012)	(0.0015)
Const	-0.007	-0.151	-0.050	-0.168*
	(0.057)	(0.121)	(0.035)	(0.087)
Sample size	22	22	22	22
R-squared	0.32	0.30	0.61	0.45

	Raw Left Tail	Raw Left Tail	Exc. Left Tail	Exc. Left Tail
Herfindahl	-0.04		0.10	
	(0.10)		(0.11)	
Share top 3		-0.08		0.13
		(0.11)		(0.10)
Slope futures	-0.71	-0.57	-0.64	-0.81
	(0.47)	(0.58)	(0.47)	(0.52)
Area top 3	-6.2e-04	-8.8e-04	7.5e-04	0.0012
	(0.0014)	(0.0015)	(0.0013)	(0.0012)
Const	0.094***	0.141	0.045	-0.025
	(0.030)	(0.082)	(0.027)	(0.070)
Sample size	22	22	22	22
R-squared	0.12	0.14	0.08	0.12

Table 8: Impact of producer concentration on the shape parameter of the distributions of maximum (right tail) raw and excess returns, and minimum (left tail) raw and excess returns.

Option prices and implied statistics under a jump-diffusion process

$$\frac{dF}{F} = \sigma dW + (Z_\tau - 1)\mathbb{1}_\tau$$

where the diffusive volatility is σ, the jump times τ follow a Poisson process with arrival rate λ and the logarithm of $Z\tau$ is normally distributed with mean 0 and standard deviation γ. Simulation based on daily steps and 100,000 paths. I present call option prices for four models that coincide in their ATM option prices yet differ significantly in the presence of jumps in their dynamics. Jump sizes and frequencies are chosen to reproduce the kurtosis observed empirically in commodity futures.

Model	A	B	C	D	
Diffusive volatility σ	0.250	0.248	0.245	0.240	
Jump rate λ	0.0	0.1	0.25	0.5	
Jump volatility γ	0.0	0.1	0.1	0.1	
Return kurtosis	0.0	2.0	5.1	10.2	
Strike	Call price	Call price	Call price	Call price	price ratio D/A
100	4.986	4.945	4.966	4.971	0.99
105	2.994	2.948	2.975	2.978	0.99
110	1.682	1.648	1.669	1.674	0.99
115	0.887	0.867	0.882	0.889	1.00
120	0.441	0.432	0.441	0.451	1.02
125	0.207	0.204	0.210	0.221	1.06
130	0.092	0.093	0.096	0.106	1.14
Prob. of daily return larger than 10% in 3 month period	0	0.008	0.020	0.041	

Table 9: Impact of jumps in kurtosis, option prices and probability of extreme events.

ONLINE APPENDIX

Country	Area	95-97	98-00	01-03	04-06	07-09	10-12	Avg 95 - 12
China	9,600	1.85	2.56	4.33	7.94	12.90	18.20	7.96
Russia	17,098	2.83	3.13	3.38	3.65	3.99	3.90	3.48
United States	9,832	3.52	3.72	2.68	2.43	2.31	1.93	2.76
Canada	9,985	1.85	2.38	2.69	2.85	3.08	2.91	2.63
Australia	7,741	1.39	1.70	1.83	1.91	1.96	1.91	1.78
Brazil	8,515	1.20	1.25	1.28	1.52	1.62	1.47	1.39
Norway	324	0.88	1.01	1.12	1.34	1.36	1.12	1.14
India	3,287	0.52	0.60	0.70	0.97	1.34	1.66	0.96
UAE	84	0.30	0.42	0.53	0.76	0.95	1.67	0.77
South Africa	1,219	0.49	0.68	0.70	0.87	0.84	0.76	0.72
Bahrain	1	0.47	0.50	0.52	0.72	0.86	0.87	0.66
Germany	357	0.57	0.63	0.66	0.61	0.48	0.41	0.56
Venezuela	912	0.63	0.58	0.59	0.62	0.59	0.31	0.55
World		20.73	23.50	26.13	31.90	38.30	43.83	30.73
Herfindahl		0.077	0.079	0.078	0.100	0.144	0.194	0.112
Share top 3		0.410	0.401	0.398	0.452	0.521	0.570	0.459

Table A.1: Aluminium. In the upper panel: country area in thousands of square kilometres and production statistics in millions of metric tons. In the bottom panel: measures of market concentration.

Country	Area	95-97	98-00	01-03	04-06	07-09	10-12	Avg 95 - 12
China	9,600	0.625	0.596	0.757	1.156	1.503	2.267	1.151
Australia	7,741	0.501	0.680	0.699	0.709	0.617	0.625	0.639
United States	9,832	0.430	0.493	0.454	0.437	0.420	0.352	0.431
Peru	1,285	0.250	0.267	0.301	0.313	0.326	0.242	0.283
Mexico	1,964	0.171	0.143	0.139	0.124	0.122	0.219	0.153
Canada	9,985	0.218	0.167	0.111	0.080	0.081	0.059	0.119
Sweden	450	0.102	0.112	0.060	0.064	0.064	0.063	0.078
Poland	313	0.057	0.058	0.073	0.078	0.082	0.061	0.068
South Africa	1,219	0.087	0.080	0.047	0.043	0.046	0.052	0.059
Morocco	447	0.072	0.080	0.059	0.043	0.042	0.039	0.057
India	3,287	0.034	0.033	0.037	0.060	0.086	0.110	0.060
Ireland	84	0.053	0.046	0.042	0.064	0.049	0.047	0.050
Russia	17,098	0.021	0.013	0.018	0.032	0.060	0.086	0.038
Kazakhstan	2,725	0.035	0.035	0.038	0.037	0.040	0.035	0.037
North Korea	121	0.078	0.063	0.013	0.011	0.013	0.020	0.034
Bolivia	1,099	0.019	0.011	0.009	0.011	0.063	0.094	0.035
Macedonia	26	0.027	0.056	0.005	0.005	0.034	0.040	0.027
Iran	1,745	0.017	0.012	0.019	0.023	0.024	0.035	0.021
Turkey	784	0.011	0.015	0.017	0.016	0.028	0.027	0.019
Bulgaria	111	0.029	0.017	0.019	0.014	0.014	0.012	0.018
Greece	132	0.016	0.017	0.020	0.004	0.016	0.018	0.015
Brazil	8,515	0.011	0.009	0.010	0.018	0.022	0.020	0.015
Argentina	2,780	0.012	0.015	0.012	0.011	0.023	0.024	0.015
World		3.007	3.097	3.040	3.417	3.820	4.687	3.511
Herfindahl		0.112	0.128	0.154	0.187	0.205	0.264	0.175
Share top 3		0.516	0.571	0.628	0.674	0.625	0.692	0.618

Table A.2: Lead. In the upper panel: country area in thousands of square kilometres and production statistics in millions of metric tons. In the bottom panel: measures of market concentration.

Country	Area	95-97	98-00	01-03	04-06	07-09	10-12	Avg 95 - 12
Russia	17,098	254	302	296	274	269	269	277
Canada	9,985	188	195	182	207	217	199	198
Australia	7,741	112	143	194	187	183	205	171
Indonesia	1,905	82	87	130	143	208	282	155
New Caledonia	19	126	121	110	111	107	134	118
Philippines	300	16	21	24	36	108	278	80
Cuba	110	50	66	73	73	98	88	75
China	9,600	44	50	55	77	73	87	64
Colombia	1,142	28	43	61	86	83	77	63
Brazil	8,515	29	41	45	67	55	120	60
South Africa	1,219	32	36	39	41	34	41	37
Dominican Republic	49	47	40	41	49	39	23	41
Botswana	582	21	33	31	37	28	27	30
Greece	132	20	18	22	22	17	19	20
World		1,080	1,213	1,343	1,467	1,600	1,923	1,438
Herfindahl		0.125	0.128	0.116	0.101	0.099	0.101	0.112
Share top 3		0.526	0.528	0.501	0.456	0.441	0.431	0.480

Table A.3: Nickel. In the upper panel: country area in thousands of square kilometres and production statistics in thousands of metric tons. In the bottom panel: measures of market concentration.

Country	Area	95-97	98-00	01-03	04-06	07-09	10-12	Avg 95 - 12
Chile	756	3.00	4.23	4.74	5.36	5.42	5.35	4.68
United States	9,832	1.90	1.63	1.20	1.17	1.22	1.12	1.37
Peru	1,285	0.47	0.52	0.81	1.03	1.24	1.24	0.89
China	9,600	0.47	0.55	0.60	0.81	1.04	1.34	0.80
Indonesia	1,905	0.49	0.85	1.09	0.91	0.81	0.62	0.79
Australia	7,741	0.50	0.73	0.86	0.88	0.87	0.93	0.79
Russia	17,098	0.52	0.53	0.66	0.70	0.72	0.71	0.64
Canada	9,985	0.69	0.65	0.60	0.59	0.56	0.54	0.61
Poland	313	0.41	0.45	0.49	0.51	0.44	0.43	0.46
Zambia	753	0.33	0.28	0.34	0.44	0.58	0.67	0.44
Kazakhstan	2,725	0.26	0.38	0.48	0.44	0.45	0.42	0.41
Mexico	1,964	0.35	0.38	0.35	0.39	0.29	0.28	0.34
Congo	2,345	0.04	0.03	0.04	0.11	0.24	0.51	0.16
World		10.83	12.73	13.70	14.93	15.57	16.37	14.02
Herfindahl		0.126	0.146	0.151	0.158	0.152	0.136	0.145
Share top 3		0.516	0.527	0.513	0.508	0.507	0.485	0.509

Table A.4: Copper. In the upper panel: country area in thousands of square kilometres and production statistics in millions of metric tons. In the bottom panel: measures of market concentration.

Country	Area	95-97	98-00	01-03	04-06	07-09	10-12	Avg 95 - 12
China	9,600	1.11	1.51	1.76	2.59	3.24	4.12	2.39
Australia	7,741	1.01	1.21	1.49	1.35	1.44	1.49	1.33
Peru	1,285	0.77	0.89	1.22	1.20	1.52	1.33	1.16
Canada	9,985	1.14	1.01	0.91	0.70	0.69	0.63	0.85
United States	9,832	0.66	0.82	0.80	0.74	0.77	0.76	0.76
Mexico	1,964	0.37	0.38	0.43	0.45	0.40	0.59	0.44
India	3,287	0.15	0.14	0.23	0.44	0.62	0.70	0.38
Kazakhstan	2,725	0.22	0.28	0.38	0.39	0.45	0.46	0.36
Ireland	84	0.18	0.22	0.30	0.43	0.39	0.34	0.31
Bolivia	1,099	0.15	0.15	0.14	0.16	0.34	0.42	0.23
Sweden	450	0.16	0.17	0.16	0.21	0.20	0.13	0.17
Russia	17,098	0.12	0.13	0.14	0.18	0.20	0.18	0.16
Brazil	8,515	0.15	0.10	0.13	0.17	0.18	0.14	0.15
Poland	313	0.16	0.16	0.15	0.13	0.13	0.05	0.13
World		7.43	8.10	9.11	9.97	11.47	12.67	9.79
Herfindahl		0.091	0.102	0.107	0.120	0.130	0.146	0.116
Share top 3		0.439	0.460	0.490	0.517	0.540	0.548	0.499

Table A.5: Zinc. In the upper panel: country area in thousands of square kilometres and production statistics in millions of metric tons. In the bottom panel: measures of market concentration.

Country	Area	95-97	98-00	01-03	04-06	07-09	10-12	Avg 95 - 12
China	9,600	66.3	83.2	86.3	123.3	123.7	111.7	99.1
Indonesia	1,905	51.2	51.1	73.9	75.0	55.1	42.1	58.1
Peru	1,285	25.8	59.9	39.1	49.4	38.5	30.6	40.5
Bolivia	1,099	14.0	12.1	14.8	18.1	17.6	20.2	16.1
Brazil	8,515	18.7	13.9	12.4	11.2	11.7	11.0	13.1
Australia	7,741	9.2	9.8	6.8	1.8	3.2	6.4	6.2
Vietnam	331	4.6	4.2	1.8	4.1	5.4	5.4	4.3
Malaysia	331	5.5	6.5	4.2	2.7	2.4	3.1	4.1
Congo	2,345	0.0	0.0	0.6	4.4	8.7	5.1	3.1
Russia	17,098	8.3	3.2	1.8	2.8	1.7	0.2	3.0
Portugal	92	4.0	2.2	0.7	0.2	0.0	0.0	1.2
Thailand	513	1.4	2.1	1.3	0.3	0.2	0.8	1.0
Nigeria	924	0.1	2.1	1.8	1.2	0.2	0.2	1.0
Rwanda	26	0.3	0.2	0.5	0.2	0.8	2.1	0.7
World		212.7	251.7	247.3	297.0	270.0	240.3	253.2
Herfindahl		0.187	0.216	0.250	0.273	0.279	0.274	0.246
Share top 3		0.673	0.770	0.805	0.834	0.803	0.766	0.775

Table A.6: Tin. In the upper panel: country area in thousands of square kilometres and production statistics in thousands of metric tons. In the bottom panel: measures of market concentration.

Country	Area	95-97	98-00	01-03	04-06	07-09	10-12	Avg 95 - 12
Saudi Arabia	2,150	445	444	451	510	485	516	475
Russia	17,098	307	312	387	475	497	519	416
US	9,832	382	356	340	313	310	358	343
Iran	1,745	186	187	189	208	210	197	196
China	9,600	156	161	167	180	189	204	176
Mexico	1,964	161	170	181	186	159	145	167
Venezuela	912	165	167	154	170	162	142	160
Canada	9,985	116	124	133	146	154	171	141
Norway	324	150	153	158	139	114	93	135
UAE	84	117	123	119	137	136	146	130
Kuwait	18	105	107	107	129	129	138	119
Nigeria	924	105	104	107	119	107	119	110
Iraq	435	37	120	98	96	115	137	101
United Kingdom	243	129	132	113	85	72	53	97
Brazil	8,515	42	60	77	88	100	113	80
Algeria	2,382	59	64	72	85	83	74	73
Libya	1,760	69	69	67	81	83	57	71
Indonesia	1,905	76	72	63	53	49	47	60
Angola	1,247	34	37	41	64	88	87	59
World		3,385	3,552	3,652	3,937	3,944	4,038	3,752
Herfindahl		0.058	0.054	0.054	0.056	0.055	0.058	0.056
Share top 3		0.335	0.313	0.322	0.330	0.328	0.345	0.329

Table A.7: Oil. In the upper panel: country area in thousands of square kilometres and production statistics in millions of metric tons. In the bottom panel: measures of market concentration.

Country	Area	95-97	98-00	01-03	04-06	07-09	10-12	Avg 95 - 12
South Africa	1,219	108	117	137	162	149	143	136
Russia	17,098	27	32	27	29	26	25	28
Canada	9,985	5	6	8	5	7	6	6
Zimbabwe	753	0	1	2	5	6	10	4
United States	9,832	2	3	4	4	4	4	3
Japan	378	1	1	1	1	1	2	1
Colombia	1,142	1	0	1	1	1	1	1
Finland	338	0	0	0	1	0	0	0
Botswana	582	0	0	0	0	1	0	0
Australia	7,741	0	0	0	0	0	0	0
World		144	161	182	208	195	192	180
Herfindahl		0.593	0.571	0.596	0.628	0.604	0.578	0.595
Share top 3		0.972	0.962	0.950	0.947	0.935	0.930	0.949

Table A.8: Platinum. In the upper panel: country area in thousands of square kilometres and production statistics in metric tonnes. In the bottom panel: measures of market concentration.

Country	Area	95-97	98-00	01-03	04-06	07-09	10-12	Avg 95 - 12
Russia	17,098	78.3	69.3	96.3	97.6	89.2	83.7	85.8
South Africa	1,219	53.1	56.9	65.8	81.9	78.1	79.7	69.2
United States	9,832	6.6	10.2	14.5	13.8	12.5	12.1	11.6
Canada	9,985	8.3	9.3	12.4	11.0	11.9	10.9	10.6
Japan	378	2.1	4.7	5.3	5.4	6.9	6.9	5.2
Zimbabwe	753	0.1	0.9	1.9	3.8	4.7	8.1	3.3
Botswana	582	0.0	0.0	1.5	2.1	3.9	2.7	1.7
Australia	7,741	0.4	0.8	0.8	0.7	0.7	0.5	0.7
Finland	338	0.2	0.1	0.0	0.0	0.3	1.2	0.3
Serbia	102	0.1	0.0	0.0	0.0	0.0	0.0	0.0
World		149.0	152.3	199.7	216.3	208.3	205.7	188.6
Herfindahl		0.410	0.356	0.352	0.355	0.333	0.325	0.355
Share top 3		0.940	0.896	0.885	0.893	0.870	0.856	0.890

Table A.9: Palladium. In the upper panel: country area in thousands of square kilometres and production statistics in metric tonnes. In the bottom panel: measures of market concentration.

Country	Area	95-97	98-00	01-03	04-06	07-09	10-12	Avg 95 - 12
United States	9,832	65.7	74.0	73.5	85.2	81.7	85.6	77.6
Brazil	8,515	28.0	35.2	48.8	56.3	62.6	74.6	50.9
Argentina	2,780	14.4	23.0	32.8	42.8	44.2	46.2	33.9
China	9,600	13.8	14.9	15.8	16.3	14.6	14.1	14.9
India	3,287	4.6	5.5	5.4	6.8	9.4	10.8	7.1
Paraguay	407	2.7	3.1	4.0	4.4	5.7	6.8	4.5
Canada	9,985	2.4	2.7	2.1	3.2	3.2	4.6	3.0
Bolivia	1,099	1.0	1.1	1.6	1.9	1.4	2.4	1.6
Indonesia	1,905	1.4	1.2	0.8	0.8	0.8	0.6	0.9
Uruguay	176	0.0	0.0	0.2	0.7	1.3	2.5	0.8
EU15/27	3,367/4,329	1.2	1.5	1.2	1.3	0.8	1.1	1.2
Ukraine	604	0.0	0.0	0.1	0.6	0.9	2.1	0.6
Russia	17,098	0.3	0.3	0.4	0.7	0.8	1.6	0.7
Nigeria	130	0.3	0.3	0.4	0.4	0.5	0.5	0.4
South Africa	1,219	0.1	0.2	0.2	0.3	0.5	0.7	0.3
World		138.2	165.3	189.4	224.1	230.8	256.9	200.8
Herfindahl		0.291	0.276	0.257	0.251	0.244	0.235	0.259
Share top 3		0.789	0.799	0.819	0.822	0.816	0.803	0.808

Table A.10: Soybean. In the upper panel: country area in thousands of square kilometres and production statistics in millions of metric tons. In the bottom panel: measures of market concentration. European Union was EU-15

Country	Area	95-97	98-00	01-03	04-06	07-09	10-12	Avg 95 - 12
EU15/27	3,367/4,329	93	120	123	135	137	136	124
China	9,600	112	108	90	99	112	118	107
India	3,287	66	71	69	70	78	88	74
United States	9,832	63	64	54	55	61	59	59
Russia	17,098	36	31	44	46	58	45	43
Canada	9,985	26	26	20	25	25	25	25
Australia	7,741	20	23	20	19	19	26	21
Pakistan	796	17	19	19	21	23	24	20
Turkey	784	16	18	16	18	17	17	17
Ukraine	604	16	13	15	17	20	18	17
Argentina	2,780	13	15	15	16	14	14	15
Iran	1,745	10	10	12	15	12	14	12
Kazakhstan	2,725	8	8	12	12	15	14	12
World		576	587	570	614	660	668	613
Herfindahl		0.100	0.113	0.109	0.109	0.110	0.110	0.108
Share top 3		0.470	0.510	0.496	0.497	0.497	0.511	0.497

Table A.11: Wheat. In the upper panel: country area in thousands of square kilometres and production statistics in millions of metric tons. In the bottom panel: measures of market concentration.

Country	Area	95-97	98-00	01-03	04-06	07-09	10-12	Avg 95 - 12
United States	9,832	219	246	242	283	324	301	269
China	9,600	115	122	117	140	161	192	141
EU15/27	3,367/4,329	34	49	57	62	58	62	54
Brazil	8,515	33	35	41	43	55	70	46
Mexico	1,964	18	18	20	21	23	20	20
Argentina	2,780	15	15	15	20	20	24	18
India	3,287	10	11	13	15	18	22	15
South Africa	1,219	9	9	10	9	13	12	10
Canada	9,985	7	8	9	9	11	12	9
Ukraine	604	4	3	5	7	10	19	8
Indonesia	1,905	6	6	6	7	8	8	7
Nigeria	130	5	5	5	7	8	9	6
World		561	602	611	710	805	859	691
Herfindahl		0.205	0.223	0.210	0.213	0.215	0.189	0.209
Share top 3		0.657	0.694	0.681	0.685	0.677	0.656	0.675

Table A.12: Corn. In the upper panel: Country area in thousands of square kilometres and production statistics in millions of metric tons. In the bottom panel: measures of market concentration.

Country	Area	95-97	98-00	01-03	04-06	07-09	10-12	Avg 95 - 12
Brazil	8,515	22.8	33.5	40.6	42.1	45.7	53.3	39.7
Vietnam	331	5.6	11.3	13.0	16.8	17.8	23.5	14.6
Colombia	1,142	11.9	10.3	11.6	11.9	9.8	8.4	10.6
Indonesia	1,905	6.9	6.7	6.7	8.5	9.5	9.4	7.9
Ethiopia	1,104	3.8	3.4	3.8	4.5	5.5	6.3	4.5
India	3,287	3.6	4.8	4.7	4.7	4.5	5.2	4.6
Mexico	1,964	5.2	5.3	4.3	4.2	4.4	4.2	4.6
Guatemala	109	4.1	4.4	3.7	3.9	4.0	4.2	4.0
Honduras	112	2.5	2.8	2.9	3.1	3.5	4.7	3.2
Peru	1,285	1.7	2.5	2.7	3.5	3.4	4.5	3.0
Cote d'Ivoire	322	4.1	4.3	2.7	2.1	2.1	1.7	2.8
Costa Rica	51	2.5	2.5	2.2	1.8	1.6	1.7	2.1
El Salvador	21	2.3	2.0	1.4	1.4	1.5	1.4	1.7
Ecuador	256	1.6	1.2	0.8	0.8	0.7	0.6	1.0
World		96.8	113.4	116.5	124.3	129.6	145.0	120.9
Herfindahl		0.092	0.120	0.156	0.154	0.162	0.177	0.144
Share top 3		0.428	0.485	0.558	0.569	0.575	0.594	0.535

Table A.13: Coffee. In the upper panel: country area in thousands of square kilometres and production statistics in millions of 60-kg bags. In the bottom panel: measures of market concentration.

Country	Area	95-97	98-00	01-03	04-06	07-09	10-12	Avg 95 - 12
China	9,600	20.8	19.5	24.5	31.4	35.2	33.2	27.4
India	3,287	13.2	12.0	12.3	20.0	23.5	26.8	17.9
United States	9,832	18.5	16.0	18.6	22.9	14.7	17.0	18.0
Pakistan	796	7.6	8.0	8.0	10.2	8.8	9.5	8.7
Brazil	8,515	1.7	3.3	4.5	5.9	6.1	7.8	4.9
Uzbekistan	447	5.3	4.7	4.5	5.4	4.6	4.3	4.8
Turkey	784	3.7	3.7	4.1	3.8	2.3	2.7	3.4
Australia	7,741	2.6	3.5	2.2	2.4	1.3	4.8	2.8
Greece	132	1.8	1.9	1.8	1.8	1.2	1.2	1.6
Syria	185	1.3	1.6	1.4	1.3	1.1	0.8	1.2
Turkmenistan	488	0.9	0.9	0.8	1.1	1.5	1.6	1.1
Egypt	1,002	1.4	1.0	1.2	1.1	0.6	0.6	1.0
Argentina	2,780	1.7	0.8	0.4	0.7	0.8	1.0	0.9
Mali	1,240	0.9	0.8	1.0	0.9	0.4	0.7	0.8
Burkina	274	0.4	0.5	0.8	1.3	0.7	0.9	0.8
Mexico	1,973	1.0	0.7	0.3	0.6	0.6	1.0	0.7
Benin	113	0.7	0.7	0.7	0.5	0.4	0.4	0.6
Cote d'Ivoire	322	0.5	0.7	0.6	0.5	0.3	0.5	0.5
World		92.1	87.7	95.5	120.0	109.7	120.8	104.3
Herfindahl		0.127	0.120	0.136	0.147	0.181	0.159	0.145
Share top 3		0.570	0.542	0.580	0.619	0.670	0.637	0.603

Table A.14: Cotton. In the upper panel: country area in thousands of square kilometres and production statistics in millions of 480 pound bales. In the bottom panel: measures of market concentration.

Country	Area	95-97	98-00	01-03	04-06	07-09	10-12	Avg 95 - 12
Cote d'Ivoire	322	1,158	1,255	1,276	1,367	1,279	1,430	1,286
Indonesia	1,905	320	415	617	737	784	778	599
Ghana	239	376	427	409	737	669	666	540
Nigeria	924	281	311	362	446	364	400	358
Brazil	8,515	277	228	177	206	207	242	222
Cameroon	475	129	121	134	157	226	268	167
Ecuador	256	88	77	84	90	100	178	98
Malaysia	331	119	81	47	31	27	17	56
Dominican Republic	49	63	44	46	42	48	56	49
Colombia	1,142	52	46	37	37	43	42	43
Papua New Guinea	463	35	37	41	46	53	41	42
Togo	57	9	9	8	49	98	101	42
Mexico	1,964	45	38	48	39	27	21	37
Peru	1,285	22	23	24	28	34	52	29
World		3,084	3,220	3,414	4,138	4,100	4,450	3,692
Herfindahl		0.189	0.205	0.204	0.190	0.176	0.174	0.191
Share top 3		0.603	0.651	0.676	0.687	0.666	0.646	0.655

Table A.15: Cocoa. In the upper panel: country area in thousands of square kilometres and production statistics in thousands of metric tons. In the bottom panel: measures of market concentration.

Country	Area	95-97	98-00	01-03	04-06	07-09	10-12	Avg 95 - 12
Brazil	8,515	14.7	18.5	23.5	28.8	33.3	37.7	26.1
India	3,287	15.8	19.4	19.3	22.0	21.7	27.5	21.0
EU15/27	3,367/4,329	18.3	18.6	17.3	20.3	15.4	16.5	17.7
China	9,600	7.7	7.6	10.1	10.7	13.5	12.5	10.4
United States	9,832	6.8	7.9	7.6	7.2	7.2	7.7	7.4
Thailand	784	5.5	5.4	6.9	5.6	7.3	9.9	6.8
Mexico	1,964	5.0	5.1	5.2	5.8	5.4	5.8	5.4
Australia	7,741	5.4	4.9	5.1	5.3	4.8	3.9	4.9
Pakistan	796	3.4	3.0	3.8	3.0	3.7	4.4	3.6
Russia	17,098	1.6	1.5	1.7	2.6	3.4	4.5	2.5
South Africa	1,219	2.2	2.7	2.7	2.4	2.3	2.0	2.4
Cuba	110	3.9	3.8	2.8	1.3	1.3	1.4	2.4
Colombia	1,142	2.1	2.3	2.6	2.5	2.3	2.3	2.3
Turkey	784	1.9	2.7	2.0	2.1	2.1	2.2	2.2
Philippines	300	1.8	1.7	2.1	2.2	2.1	2.5	2.1
Ukraine	604	2.9	1.8	1.6	2.3	1.7	2.0	2.1
Guatemala	109	1.5	1.6	1.8	2.1	2.3	2.4	2.0
Argentina	2,780	1.6	1.7	1.7	2.1	2.3	2.2	1.9
World		124.5	132.4	141.8	149.8	153.7	169.5	145.3
Herfindahl		0.069	0.076	0.078	0.093	0.095	0.101	0.085
Share top 3		0.391	0.426	0.424	0.474	0.458	0.483	0.443

Table A.16: Sugar. In the upper panel: country area in thousands of square kilometres and production statistics in millions of metric tons. In the bottom panel: measures of market concentration.

Country	Area	95-97	98-00	01-03	04-06	07-09	10-12	Avg 95 - 12
Brazil	8,515	1,253	1,178	1,329	1,402	1,244	1,283	1,282
United States	9,832	1,011	976	985	677	731	655	839
Mexico	1,964	54	42	21	67	98	82	61
EU15/27	3,367/4,329	97	100	101	128	119	96	107
South Africa	1,219	16	20	24	21	28	27	23
Israel	21	17	44	16	13	4	3	16
Australia	7,741	19	18	18	14	10	9	15
Turkey	784	8	10	13	10	9	9	10
China	9,600	0	0	2	5	16	33	9
South Korea	100	0	0	0	0	0	0	0
Morocco	447	3	2	7	9	9	7	6
World		2,485	2,400	2,516	2,346	2,272	2,208	2,371
Herfindahl		0.423	0.413	0.434	0.445	0.410	0.428	0.425
Share top 3		0.950	0.940	0.960	0.940	0.923	0.919	0.939

Table A.17: Orange juice. In the upper panel: country area in thousands of square kilometres and production statistics in thousands of metric tons. In the bottom panel: measures of market concentration.

Country	Area	95-97	98-00	01-03	04-06	07-09	10-12	Avg 95 - 12
Malaysia	331	8,422	9,905	12,356	14,940	17,041	18,230	13,482
Indonesia	1,905	4,921	6,305	9,487	13,348	18,176	21,627	12,311
Nigeria	924	815	880	962	1,184	1,291	947	1,013
Thailand	513	407	541	762	924	1,327	1,473	906
Colombia	1,142	413	483	534	671	787	887	629
Papua New Guinea	463	248	306	324	340	442	530	365
Cote d'Ivoire	322	271	271	233	272	312	383	290
Ecuador	256	204	217	237	281	308	290	256
China	9,600	209	210	220	230	225	223	220
Cameroon	475	140	136	151	192	226	334	197
Honduras	112	76	93	138	222	274	330	189
Congo	2,345	183	168	171	175	183	192	179
Costa Rica	51	97	118	137	178	198	241	162
Brazil	1,247	78	96	119	157	213	277	157
Guatemala	109	35	55	80	101	165	247	114
Ghana	239	93	110	108	117	127	121	113
Philippines	300	52	50	57	63	82	92	66
Venezuela	912	46	58	50	64	81	63	60
Guinea	246	53	50	50	50	50	50	51
World		17,075	20,393	26,550	33,918	41,998	47,113	31,174
Herfindahl		0.331	0.335	0.347	0.354	0.355	0.363	0.347
Share top 3		0.829	0.837	0.859	0.868	0.872	0.877	0.857

Table A.18: Palm oil. In the upper panel: country area in thousands of square kilometres and production statistics in thousands of metric tons. In the bottom panel: measures of market concentration.

Country	Area	95-97	98-00	01-03	04-06	07-09	10-12	Avg 95 - 12
Thailand	513	2,117	2,213	2,672	3,019	3,094	3,200	2,691
Indonesia	1,905	1,552	1,557	1,677	2,325	2,649	2,912	2,065
Malaysia	331	1,047	861	919	1,193	1,043	948	1,005
India	3,287	510	619	664	802	840	877	709
China	9,600	426	478	523	542	585	721	536
Vietnam	331	151	244	325	485	659	771	420
Cote d'Ivoire	322	87	116	129	162	200	237	150
Nigeria	924	125	113	121	148	133	144	130
Sri Lanka	66	108	93	90	103	128	156	110
Philippines	300	66	72	89	108	133	135	98
Brazil	1,247	52	75	93	103	120	149	96
Liberia	111	37	93	108	106	88	63	84
Burma	677	26	26	37	51	84	131	55
Guatemala	109	32	39	49	54	75	94	55
Cameroon	475	56	56	50	58	51	55	55
Cambodia	181	38	43	35	23	29	41	34
Mexico	1,964	20	24	25	25	30	35	26
World		6,502	6,778	7,666	9,382	10,038	10,779	8,391
Herfindahl		0.201	0.192	0.199	0.196	0.192	0.187	0.195
Share top 3		0.726	0.683	0.687	0.697	0.676	0.655	0.689

Table A.19: Rubber. In the upper panel: country area in thousands of square kilometres and production statistics in thousands of metric tons. In the bottom panel: measures of market concentration.

Country	Area	95-97	98-00	01-03	04-06	07-09	10-12	Avg 95 - 12
EU15/27	3,367/4,329	8,079	11,768	11,533	15,711	19,697	19,742	14,422
China	9,600	9,518	9,938	11,101	12,400	12,110	13,509	11,429
Canada	9,985	5,963	7,882	5,436	8,719	11,718	13,755	8,912
India	3,287	5,959	4,578	5,117	6,433	6,183	6,700	5,828
Australia	7,741	679	1,975	1,443	1,178	1,655	3,127	1,676
United States	9,832	275	746	764	655	658	975	679
Ukraine	604	36	116	82	347	1,931	1,370	647
Russia	17,098	102	136	149	367	683	918	393
Pakistan	796	278	268	231	238	215	303	256
Bangladesh	148	245	252	230	212	218	228	231
Belarus	208	22	61	70	136	455	486	205
Chile	756	39	62	14	44	63	114	56
World		31,282	37,856	36,262	46,630	55,832	61,560	44,904
Herfindahl		0.234	0.228	0.242	0.240	0.232	0.217	0.232
Share top 3		0.773	0.781	0.776	0.790	0.780	0.764	0.777

Table A.20: Canola. In the upper panel: country area in thousands of square kilometres and production statistics in thousands of metric tons. In the bottom panel: measures of market concentration.

Country	Area	95-97	98-00	01-03	04-06	07-09	10-12	Avg 95 - 12
China	9,600	194	195	171	180	191	200	189
India	3,287	121	130	127	134	143	151	134
Indonesia	1,905	50	51	51	54	61	67	56
Bangladesh	148	28	34	37	39	46	45	38
Vietnam	331	26	31	34	36	38	42	34
Thailand	513	23	24	28	29	32	36	29
Burma	677	17	20	22	28	32	32	25
Philippines	300	11	11	13	15	16	17	14
Brazil	1,247	9	10	10	13	12	12	11
Japan	378	13	12	11	11	10	8	11
United States	9,832	8	9	9	10	9	9	9
Pakistan	796	6	7	7	8	10	9	8
South Korea	100	7	7	7	7	7	6	7
Egypt	1,002	5	5	6	6	7	6	6
Cambodia	181	3	4	4	5	7	9	5
Nepal	147	4	4	4	4	4	5	4
World		564	596	586	628	677	714	628
Herfindahl		0.180	0.173	0.153	0.149	0.147	0.147	0.158
Share top 3		0.645	0.631	0.595	0.587	0.583	0.587	0.605

Table A.21: Rough rice. In the upper panel: country area in thousands of square kilometres and production statistics in millions of metric tons. In the bottom panel: measures of market concentration.

Country	Area	95-97	98-00	01-03	04-06	07-09	10-12	Avg 95 - 12
United States	9,832	7,429	8,214	8,227	9,108	8,912	8,837	8,454
China	9,600	1,245	2,590	4,280	5,993	7,699	10,793	5,433
Brazil	1,247	3,848	4,079	5,155	5,677	6,250	6,977	5,331
Argentina	2,780	2,048	3,151	4,333	5,850	6,339	6,793	4,752
EU15/27	3,367/4,329	2,619	2,784	2,931	2,602	2,453	2,266	2,609
India	3,287	743	850	815	1,069	1,368	1,705	1,092
Mexico	1,964	495	722	766	670	649	653	659
Japan	378	675	678	706	578	507	391	589
Taiwan	36	398	351	358	364	366	380	370
Canada	9,985	250	294	301	278	245	262	272
Thailand	513	117	220	284	263	271	320	246
Bolivia	1,099	95	128	257	323	250	355	235
Paraguay	407	119	146	223	226	278	346	223
South Korea	100	220	207	204	168	164	155	186
Russia	17,098	32	55	73	120	267	419	161
World		21,071	25,281	29,936	34,609	37,474	42,221	31,765
Herfindahl		0.190	0.174	0.159	0.163	0.162	0.168	0.169
Share top 3		0.660	0.612	0.595	0.610	0.614	0.632	0.621

Table A.22: Soy oil. In the upper panel: country area in thousands of square kilometres and production statistics in thousands of metric tons. In the bottom panel: measures of market concentration.