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COMMODITY PRICE CHANGES ARE CONCENTRATED AT THE END OF THE CYCLE

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DISCUSSION PAPER 14.20

Commodity Price Changes are Concentrated at the End of the Cycle

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Abstract

This paper introduces a new approach to the analysis of the cyclical behaviour of world commodity prices. Within booms and slumps, the behaviour of commodity prices seems to be quite similar, surprisingly even amongst different types of commodities (soft and hard), which are influenced by different shocks. The key result is that during commodity price booms, the faster growth occurs towards the end of the boom. Likewise, most of the collapse of prices occurs towards the end of slumps. This paper first establishes this behaviour as a new empirical regularity of commodity prices. Secondly, this paper introduces a novel way to conceptualise shocks to commodity prices as a cyclical occurrence, and on the basis of this newly established empirical regularity, the size of these cyclical shocks act as leading indicators of impending turnings points.

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1 Introduction

This paper distinguishes cycles of commodity prices into two categories; natural cycles which refer to generally rising and falling prices, and growth cycles which reflect periods of rapidly increasing and decreasing prices.

Natural cycles are the less frequent of the two as they reflect natural long run movements in commodity prices. Periods of generally rising prices are referred to as the boom phase; booms are typically brought upon by long periods of increasing demand and exacerbated by sluggish supply responses. Slumps are defined as periods of generally falling prices, which are typically caused by the accumulation of excess reserves and technological advancements making the extraction and production process more efficient as well as the substitution away from primary commodities easier (Wright and Williams, 1982; Gilbert, 1996).

The key features of booms and slumps are their duration (how long they persist for), their amplitude (the net growth), and cumulative amplitude (trajectory). Utilising these concepts we apply an adaptation of Sichel's (1993) test for cyclical asymmetry, to determine where, during booms and slumps, the growth is concentrated. We establish as an empirical regularity that on average, and across a wide range of different commodities, a significant proportion of the positive growth during booms and the negative growth during slumps are concentrated at the end of each respective phase. A corollary of this result is that, on average, during booms prices increase at an increasing rate until the peak, and during slumps, prices decrease at an increasing rate until the trough.

Commodity prices are frequently influenced by shocks emanating from real factors including; adverse weather conditions, geopolitical conflict, recovering supply stocks, sudden demand shocks, as well as nominal factors such as the effect of an appreciating and depreciating USD¹. This paper provides a novel method to identify these rapid movements and conceptualise them as a short run cyclical phenomenon. Specifically, a Hamiltonian Markov-Switching (MS) state space model is developed and applied to isolate periods of rapidly rising prices (growth spurts) and periods of rapidly falling prices (growth plunges). The purpose for identifying these growth phases is that we can analyse their amplitude and determine what the relative size of their amplitude indicates about the likelihood of an impending turning point. Complementing this newly established regularity that most of the gain (fall) in prices occurs towards the end of the booms (slumps), we find that the largest shocks, in terms of their amplitude, does provide an indication that the peaks (troughs) are nearby. This paper explains how to distinguish between these extreme growth spurts and plunges and those of less considerable sizes. Interestingly, extreme growth spurts seem to be of a similar magnitude across different and unrelated commodities, whereas the magnitude of extreme growth plunges varies significantly across different and unrelated commodities.

¹As these commodities are denominated in USD, changes in the exchange value of the dollar have inverse effects on the dollar prices of commodities. When the dollar appreciates (depreciates) vis-à-vis other major trading currencies, commodity prices are then reduced (raised) (Dornbusch, 1976).

2 Data

In total, 28 commodities were selected, consisting of 19 renewable commodities (primarily agricultural products and a few industrial raw commodities) and 9 non-renewable commodities (base metals, oil and fertiliser inputs). The data extends from 1957 to 2013 in quarterly intervals. All data is obtained from the International Monetary Fund’s International Financial Statistics database, and their details are displayed in Section A of the Appendix in Table A.1.

In forming real prices, the nominal prices are deflated by the 1990 base weighted manufacturing unit value index² (MUV), also supplied by the IMF.

3 Natural Cycles

Booms and slumps are the natural phases of commodity price cycles. A definition of a boom (slump) in commodity prices which is consistent with the business cycle literature, in particular the pioneering work of Burns and Mitchell (1946), would simply be a period of generally rising (falling) commodity prices. This definition is appealing because its flexibility allows enough time for longer durations and hence better reflect natural, long run up and down movements in commodity prices (Cashin et al., 2002). The point at which the slump (boom) transitions into the boom (slump) is named the cyclical trough (peak). A natural cycle is formed by combining a slump with a boom, a trough-peak-trough cycle; or by combining a boom with a slump, otherwise known as a peak-trough-peak cycle.

Despite the intellectual appeal of these boom and slump definitions, the ambiguity surrounding what exactly classifies as ‘generally rising’ and ‘generally falling’ leads to substantial debate over which models are best at locating the turning points as to separate periods of generally rising prices from generally falling prices. Structural time series (STS) models, developed by Harvey (1993) and favoured by Labys et al. (2000) and Jacks (2012), in the context of analysing commodity price cycles, provide a parametric approach for capturing the cyclical components of time series data. However, STS models are designed to replicate the cyclical process of an underlining process, and it is this conflict between model design and discovery which has prompted other researchers, notably Cashin et al. (2002) and Clements et al. (2012) to shift away from applying these parametric STS models and towards non-parametric algorithms, specifically the celebrated Bry and Boschan (1971) algorithm which is designed to isolate turning points based on a set of rules. The BBQ³ algorithm provides a more appealing method to capture periods of generally increasing and decreasing prices

²One potential drawback of the MUV index is that it may be overstated due to improvements in the quality of manufactured goods which dampens its ability to represent market prices (Prebisch, 1950). Grilli and Yang (1988) concur that the MUV index may not have been the best index to use during the 1970s, where large monetary and supply shocks in conjunction with exchange rate turmoil dominated the macroeconomic landscape. Caveats aside, every index contains imperfections, and for all intents and purposes the MUV index will suffice.

³BBQ is an acronym for Bry and Boschan Quarterly, details on how this algorithm works are disclosed in Section B of the Appendix.

because it incorporates minimum phase and cycle restrictions. This feature of the model is most appealing because it allows researchers to incorporate reasonable judgments, based on priori information, regarding the expected length of each boom and slump. Early insights into explaining why commodity prices cycle suggest that the cyclical behaviour is driven by the outcome of the independent production decision (which occurs several months prior to harvest) which over compensates for short-term imbalances between supply and demand, which inevitably leads to cyclical variations in quantity and therefore prices Kaldor (1934), on the basis of this theory, it is reasonable to impose a minimum phase length of 4 quarters, and the minimum cycle length to 8 quarters, for renewable commodities. In theory the longer the lag between the investment decision of producers, and the actual increase in output, the longer the cycle in prices. Clearly, non-renewable commodities exhibit longer supply lags, however, non-renewable commodities tend to peak and trough more abruptly, therefore to capture the more definitive peaks and troughs we reduce the minimum phase length to 2 quarters and cycle length to 5 quarters.

3.1 The dynamics of prices within booms and slumps

Figure 1 shows the booms and slumps of four commonly encountered commodities, and the most striking and perhaps obvious feature of these cycles, as well as cycles of other commodities, is the fact that their booms and slumps are not symmetric. Sichel (1993) argued that asymmetric cycle phases can take two forms, a cycle can either be characterised as being 'steep' or 'deep'. Steep phases describe the situation where prices rapidly increase (decrease) at the beginning of the boom (slump), and then tend to plateau until the peak (trough). By contrast, deep phases describe phases where the growth is concentrated at the end of the boom (slump) and hence prices tend to meander at the beginning of the phase and then increase (decrease) rapidly until the peak (trough).

The question here is whether or not either form of asymmetry is systematic across a wide variety of different commodities. If commodities systematically exhibit either steep or deep cycle phases then this information is best used to help aid our understanding of how commodity prices move and hence may lead to a model than can explain commodity price behaviour, or for the purposes discussed in this paper, the forecastability of future movements.

To detect the presence of cycle phase asymmetry Sichel (1993), and to a certain extent Neftci (1984), computes the average growth rate for each phase and then tests for steepness or deepness as evidence against cycle symmetry, however, detecting asymmetry is not necessarily sufficient, because given the broad range of commodities, it is more useful to know whether or not the extent to which cycles phases are asymmetric is consistent across different commodities. If this were the case then the turning points of some prices may be easier to predict than others. Harding and Pagan (2002) provide a more transparent and intuitive method for calculating the exact form and size of phase asymmetry. They begin by conceptualising each of the n_1 booms and n_0 slumps as a right-angled triangle and then comparing the actual trajectory to a stylised trajectory representing the case where each price increase (decrease) was proportional to the amount of time spent in each boom (slump). Figure 2 illustrates how each boom and slump phase is conceptualised as a right-angled triangle. Here the price

Figure 1: Booms and Slumps of Commonly Encountered Commodities, as Dated by the BBQ Algorithm

Notes: slumps are represented by the shaded regions and booms are left unshaded. The log of the real price is indicated along the y-axis.

of tea from 1957Q1 to 2012Q4 is segregated into its 10 slumps and 9 booms. Furthermore, panel (a) and (b) shows how the right-angle triangle is applied to represent slumps and booms, respectively.

Figure 2: Dissecting the Cycle

(a) Representative slump phase

(b) Representative boom phase

Notes: the BBQ algorithm has detected 10 slumps (shaded regions) and 9 booms for tea from 1957Q1 to 2012Q4, hence $n_0 = 10$ and $n_1 = 9$. The superscript indexes the phase number ($i = 1, \dots, n_j$), and the subscript, takes the value of a 0 or a 1 to index a slump and boom, respectively. For example T_0^2 refers to the second slump and T_1^2 refers to the second boom.

Each right-angle triangle provides information regarding the time spent in each phase, the growth, and the cumulative growth. Formally, these components are defined respectively as:

1. Duration

The duration is the length of time spent in each phase. As the base of the triangle

runs parallel to the time axis, the length of which (in quarters) measures the duration of each phase. Duration, for each phase, is denoted by T_j^i where $i = 1, \dots, n_j$ and $j = 0, 1$ ⁴. The average duration is given by:

$$\bar{T}_j = \frac{1}{n_j} \sum_{i=1}^{n_j} T_j^i \quad i = 1, \dots, n_j \quad j = 0, 1. \quad (1)$$

2. Amplitude

The amplitude of each phase is represented by the height of the adjacent side of the triangle. Point p_{Bj}^i is the log real price at the end of the i^{th} phase and point p_{Aj}^i is the log real price at the beginning of the i^{th} phase. The difference between the two provides an approximation of the percentage growth over the course of each phase⁵ which henceforth will be referred to as the amplitude. Specifically, we define the amplitude of the i^{th} phase as:

$$A_j^i = (p_{Bj}^i - p_{Aj}^i) \times 100 \quad i = 1, \dots, n_j \quad j = 0, 1. \quad (2)$$

hence the average amplitude of each phase simply becomes:

$$\bar{A}_j = \frac{1}{n_j} \sum_{i=1}^{n_j} A_j^i \quad i = 1, \dots, n_j \quad j = 0, 1. \quad (3)$$

3. Cumulative amplitude

The cumulative amplitude is the cumulative vertical distance between p_{Aj}^i and each subsequent price point until p_{Bj}^i *i.e.* the total area above the base, and below the price trajectory. Harding and Pagan (2002) devise a method to calculate this area by adding together the area of rectangles of unit length and height equal to $(p_{tj}^i - p_{Aj}^i)$ ⁶. This approximation, however, is too large because each rectangle will overstate or understate the actual area by approximately half the amplitude. In order to correct for this, half of the amplitude is subtracted from the height of these rectangles. Mathematically:

$$\begin{aligned} F_j^i &= \sum_{t=1}^{T_j^i} (p_{tj}^i - p_{Aj}^i) - \frac{(p_{tj}^i - p_{t-1j}^i)}{2} \\ &= \left(\sum_{t=1}^{T_j^i} (p_{tj}^i - p_{Aj}^i) \right) - \frac{A_j^i}{2} \quad i = 1, \dots, n_j \quad j = 0, 1. \end{aligned} \quad (4)$$

likewise the average cumulative amplitude is given by:

$$\bar{F}_j = \frac{1}{n_j} \sum_{i=1}^{n_j} F_j^i \quad i = 1, \dots, n_j \quad j = 0, 1. \quad (5)$$

⁴Refer to Figure 2 for details regarding the notation.

⁵The amplitude is the sum of the growth rates from trough to peak for booms and peak to trough for slumps, which is approximated by (2).

⁶ $p_{Aj}^i \leq p_{tj}^i \leq p_{Bj}^i$ such that $p_{1j}^i = p_{Aj}^i$.

Figure 3: Stylised Movements of Prices During Booms and Slumps

Notes: panel (a) depicts a price movement that is increasing at a decreasing rate until the peak, the alternative movement during booms is shown in Panel (b) which depicts a price movement that is increasing at an increasing rate until the peak. Likewise during slumps, Panel (c) depicts a price movement that is decreasing at a decreasing rate until the trough and Panel (d) depicts a price movement that is decreasing at an increasing rate until the trough.

Consider the case where a particular phase could not be characterised as being either steep or deep, in these unrealistic circumstances, the increase (decrease) in price is directly propor-

tional to the phase's duration, and hence the price would follow the hypotenuse perfectly, therefore, the cumulative amplitude, defined by (4) would be equal to the area of the right-angled triangle. As the area of each right-angled triangle is given by:

$$AREA_j^i = \frac{T_j^i \times A_j^i}{2} \quad (6)$$

the difference between (4) and (6) would equal 0. If the difference between (4) and (6) is positive then the price trajectory must overshoot the the hypotenuse, as depicted in Figure 3, panels (a) and (c); and if this difference were negative, then the price trajectory must undershoot the hypotenuse, as depicted in Figure 3, panels (b) and (d)⁷.

This positive, neutral or negative difference is defined as the excess area, the excess area of each phase is then divided by its respective duration to form the excess index⁸:

$$E_j^i = \frac{F_j^i - AREA_j^i}{T_j^i} \quad i = 1, \dots, n_j \quad j = 0, 1. \quad (7)$$

and the average excess index is given by:

$$\bar{E}_j = \frac{1}{n_j} \sum_{i=1}^{n_j} E_j^i \quad i = 1, \dots, n_j \quad j = 0, 1. \quad (8)$$

The type of phase asymmetry is then determined by the coefficient of the average excess index, which is calculated for each commodity's boom and slump phase and the results are displayed in Figure 4.

Over two-thirds of the commodities have a negative excess index for both booms and slumps. This overwhelmingly suggests that panels (b) and (d) from Figure 3 best characterises the general behaviour of prices during booms and slumps, respectively. Moreover, whilst there is no obvious pattern regarding the size of the average excess index amongst the commodities⁹, these results sympathise with Deaton and Laroque's (1992) conjecture that prices often spend long periods in the 'doldrums' before being punctuated by severe spikes, and when a high price is established, the possibility remains, that prices will remain high, particularly when inventories are low.

The next focus of this paper is to use this newly established regularity to provide a theoretical foundation to support the belief that large price changes can be used as leading indicators of impending turning points. Owing to the definition of booms (slumps), which stipulates the prices during booms (slumps) are generally rising (falling) there is substantial scope for falling (rising) prices to interrupt booms (slumps). Referring to Figure 1 for guidance, it is rather obvious that nested within both booms and slumps are short periods of rapidly

⁷This is only true for booms *i.e.* when $j = 1$ as the cumulative amplitude will always be positive, however, the same conclusion is reached if the absolute value of the cumulative amplitude is used when $j = 0$.

⁸If $E_j^i = 0$, then it may be the case that the price has either undershot and then overshot (or vice versa) the hypotenuse by the exact proportion, these events are extremely unlikely therefore this possibility can be ignored.

⁹For example, zinc and jute share a similar average excess index value for their boom phases, and they are two completely unrelated commodities.

increasing and decreasing prices. These rapid movements emanate from reoccurring shocks that commodities are frequently subject to, usually as a result of USD movements, geopolitical turmoil, sudden shortages and recovering supply World Bank (2009), and it is expected that the largest positive (negative) shocks to impact commodity prices end at, or relatively close to the cyclical peak (trough).

Figure 4: The Average Excess Index for Booms and Slumps

Notes: commodities are ranked from the smallest to the largest $\bar{E}_j$.

The next focus of this paper is to identify these shocks, which is achieved by developing and applying a parametric model to detect periods of high and low growth, or positive and negative shocks.

4 Growth Cycles

Here we define a positive shock as a growth spurt and a negative shock as a growth plunge, as a growth plunge must always occur after a growth spurt, together they form a short term cycle which will be referred to as a growth cycle.

Growth cycle phases can be identified by isolating periods of high and low growth based on the probability that the commodity is experiencing either one. The most popular model used to achieve this is the Markov-Switching (MS) model introduced by Goldfeld and Quandt (1973) and redesigned by Hamilton (1989) so that the MS model can be used to characterise changes in the parameters of an autoregressive (non-linear) process.

Shumway and Stoffer (2010) show that Hamilton's MS model can be transformed into a state space model; the most appealing aspect of the state space model adaption is the ability to use the Kalman filter which provides time dependent estimates of the conditional probability that the commodity price, at any particular time, is in either the high or low growth state. The benefits of time varying conditional probability estimates are that the duration of the growth phases become dependent on the amount of time that the particular growth phase has been in that state (Durland and McCurdy, 1994). Growth phases may exhibit duration dependence because of the potential influence of weather patterns, the price of production inputs, and the state of the economy, have on the persistence of individual shocks.

The model stipulates that commodity prices y_t are generated by:

$$y_t = z_t + n_t \quad (9)$$

such that

$$z_t = \phi_1 z_{t-1} + \phi_2 z_{t-2} + w_t \quad Var(w_t) = \sigma_w^2 \quad (10a)$$

$$n_t = n_{t-1} + \alpha_0 + \alpha_1 S_t \quad (10b)$$

Here (10a) is an AR(2)¹⁰ process that governs the movement of commodity prices throughout time. The crux of the regime switching model comes from equation (10b), here n_t is a random walk with a drift component, where the drift component switches value from α_0 during a growth plunge to $\alpha_0 + \alpha_1$ during a growth spurt. This is because S_t switches between a value of 0 or 1 corresponding to plunges and spurts, respectively.

The unobserved parameters in (9) forms the basis of the first component of the state space model, the state vector, $\mathbf{x}_t$:

$$\mathbf{x}_t = (z_t, z_{t-1}, \alpha_0, \alpha_1)'$$

The generation of the state vector $\mathbf{x}_t$ from the past state $\mathbf{x}_{t-1}$, for all time periods $t = 1, \dots, n$, is given by the state space model, which in its simplest form, employs a first-order

¹⁰Unlike Hamilton's (1989) model, Shumway and Stoffer (2010) follow Lam (1990) by not restricting one of the autoregressive parameters to unity.

vector auto-regression¹¹:

$$\mathbf{x}_t = \Phi \mathbf{x}_{t-1} + \mathbf{w}_t \quad Var(\mathbf{w}_t) = \mathbf{Q} \quad (11)$$

$$\begin{bmatrix} z_t \\ z_{t-1} \\ \alpha_0 \\ \alpha_1 \end{bmatrix} = \begin{bmatrix} \phi_1 & \phi_2 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} z_{t-1} \\ z_{t-0} \\ \alpha_0 \\ \alpha_1 \end{bmatrix} + \begin{bmatrix} w_{1t} \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

As the state vector is not directly observed it needs to be estimated by the second component of the state space model, the observation equation¹²:

$$\Delta y_t = \mathbf{A}_t \mathbf{x}_t + \mathbf{v}_t \quad Var(\mathbf{v}_t) = \mathbf{R} \quad (12)$$

The observation equation is controlled by the observation matrix, $\mathbf{A}_t$, which can take two forms corresponding to the two different states. As shown in Figure 5 below, $\mathbf{A}_t$ takes the form of $\mathbf{M}_0$ during plunges and $\mathbf{M}_1$ during spurts and the observation equation is shown to adjust accordingly.

Figure 5: The Switching Process

Notes: the difference between being in a high growth state and a low growth state is evident in equation (10b). When the commodity price is in a plunge, α_1 drops out of (10b) and therefore (12), in order for this to occur $\mathbf{A}_t$ must switch from $\mathbf{M}_1$ to $\mathbf{M}_0$. As seen above, the only difference between $\mathbf{M}_1$ and $\mathbf{M}_0$ is the fourth element (S_t), for example, when the commodity price is experiencing a plunge, $\mathbf{A}_t = \mathbf{M}_0 = [1 \ -1 \ 1 \ 0]$, and hence (12) becomes $y_t = \mathbf{M}_0 \mathbf{x}_t + \mathbf{v}_t = \phi_1 z_{t-1} + \phi_2 z_{t-2} + \alpha_0 + w_t$.

The parameters of the observation equation, which are specified below, are estimated by maximum likelihood estimation, and the estimated values as well as their standard errors are reported in Section C of the Appendix in Table A.2.

$$\{\Theta\} : \{\phi_1, \phi_2, \sigma_w^2, \alpha_0, \alpha_1\}$$

¹¹It is assumed that w_{1t} is normally distributed, with variance $\mathbf{Q}$.

¹²The observation noise $\mathbf{v}_t$ is assumed to be Gaussian white noise and uncorrelated with $\mathbf{w}_t$.

Prior to estimation, each commodity's price observations are passed through a Kalman filter, the role of which is to calculate the individual densities of $\mathbf{y}_t$, given the past $\mathbf{y}_1, \dots, \mathbf{y}_{t-1}$, which is necessary for maximum likelihood estimation (Kalman, 1960; Kalman and Bucy, 1961). These densities are denoted by $(f_t(t|t-1))^{13}$ in the log-likelihood function¹⁴:

$$\ln L_y \Theta = \sum_{t=1}^n \left(\sum_{j=0}^m \pi_j(t) f_j(t|t-1) \right) \quad j = 0, 1 \quad m = 2 \quad (13)$$

Here $\pi_j(t)$ is the unconditional time-varying probability that $\mathbf{A}_t$ takes the form of $\mathbf{M}_j$, specifically:

$$\pi_j(t) = P(\mathbf{A}_t = \mathbf{M}_j)$$

as the conditional probability is equal to the product of the unconditional time-varying probability and the individual densities of $\mathbf{y}_t$, given the past $\mathbf{y}_{t-1}, \dots, \mathbf{y}_1$, the term within the brackets of (13) is the sum of the conditional probabilities that $\mathbf{A}_t$ takes the form of $\mathbf{M}_j$, specifically:

$$\pi_j(t|t) = P(\mathbf{A}_t = \mathbf{M}_j | \mathbf{Y}_t)$$

For filtering purposes the conditional transition probabilities are equal to:

$$\pi_j(t|t) = \frac{\pi_j(t) f_j(t|t-1)}{\sum_{k=0}^m \pi_k(t) f_k(t|t-1)} \quad k = 0, 1 \quad j = 0, 1 \quad m = 2 \quad (14)$$

the reason for this is because the conditional transitional probabilities must sum to unity to satisfy the Markov property. Hamilton (1989) uses these conditional transition probabilities to distinguish between high and low growth states on the basis that the series will only change state if the conditional transition probability is greater than 50%. Following this rule, any commodity is said to be experiencing a growth plunge when the filtered conditional probability that $\mathbf{A}_t$ takes the form of $\mathbf{M}_0$ is greater than 50%, and when this is the case, S_t takes the value of 0 and therefore, referring to Figure 5, $\mathbf{A}_t$ takes the form of $\mathbf{M}_0$.

$$S_t = \begin{cases} 0 & \text{if } \pi_0(t|t) = 1 - P(\mathbf{A}_t = \mathbf{M}_1 | \mathbf{Y}_t) > 0.5 \\ 1 & \text{otherwise} \end{cases}$$

A corollary of (14) when Hamilton's rule is adhered to is that S_t will equal 0 and hence the commodity will be experiencing a growth plunge if the conditional probability of this event occurring is greater than the conditional probability that the commodity is experiencing a growth spurt,

$$\pi_0(t) f_0(t|t-1) > \pi_1(t) f_1(t|t-1)$$

As an example, Figure 6 shows the prices of the same four commodities depicted in Figure 1, segregated into growth spurts and plunges, where the growth plunges are indicated by the shaded regions, therefore when ever these shaded region are observed, the above corollary holds true.

¹³Shumway and Stoffer (1991) approximate the densities using a normal distribution.

¹⁴Optimisation of (13) was achieved by using a Broyden-Fletcher-Goldfarb-Shanno (BFGS) type algorithm.

Figure 6: Growth Spurts and Plunges of Commonly Encountered Commodities, as Dated by the Hamiltonian MS State Space Model

Notes: growth plunges are represented by the shaded regions and growth spurts are left unshaded. The log of the real price is indicated along the y-axis.

Figure 7 compares the two types of cycles, using the price of wheat as an example, here the price of wheat is plotted twice on a single time axis, so that it can be seen exactly where during booms and slumps prices are experiencing either the high or low growth state, and the extent to which growth spurts and plunges interrupt slumps and booms, respectively.

Figure 7: Growth Cycles are Nested within Natural Cycles.

Notes: the log of the real price is indicated along the y-axis.

Consider the periods from 1957Q1 to 1961Q3 and 1992Q1 to 1995Q3 as an example of when the price of wheat remained relatively stable. During these periods, the model seems to capture strictly increasing and falling prices of very short duration and low amplitude. What is important here is how the model identifies growth spurts and plunges during more definitive periods of increasing and decreasing prices, as the success of the model rests on its ability to capture, long periods of rapidly increasing and decreasing prices. For example, consider the period from 1970Q1 to 1980Q1, here the model does not declare that the growth spurt or plunge is over simply because prices change direction briefly. The fact that the model ignores these very minor corrections is an attractive feature, emanating from its ability to incorporate duration dependence. Furthermore, since the model is able to capture these large, but not necessarily strictly, increasing and decreasing prices, we have a better understanding of what constitutes as an extreme growth spurt and plunge as well as where they occur.

5 Are extreme shocks good leading indicators of impending turning points?

As the booms and slumps of commodity prices reflect long run up and down movements in commodity prices, it is inevitable that most will be interrupted by movements occurring in the opposite direction, hence a boom may comprise of two or more growth spurts and a slump may consist of two or more growth plunges. This was certainly the case for commodity price booms and slumps during the 1970s where prices rose to unprecedented heights as a direct result of a combination of factors including OPEC's control over the oil supply and the exchange rate turmoil brought upon by the collapse of the Bretton Woods system (World Bank, 2009). During any lengthy boom (slump) period, there is potential for supply and demand factors to cause prices to decrease (increase) and hence interrupt these phases, as were the case during these years.

Figure 8: The larger the Amplitude, the Smaller the Distance from the Turning Point

(a) Growth spurts nested within trough-peak-trough cycles.

(b) Growth plunges nested within peak-trough-peak cycles.

Notes: the log of the real price is indicated along the y-axis.

To illustrate how these factors affected the price of wheat, as an example, Figure 8 panel (a) magnifies one of wheat's numerous natural cycles; the top half of panel (a) shows the beginning of this cycle with a trough at 1970Q1, the cyclical peak occurring at 1973Q3, and another trough at 1977Q2 to complete the cycle. Directly below this cycle is shown the same price path for wheat over this period, however, the emphasis is now on the growth

cycles that wheat exhibits during this period, and it is clear that given the minor growth plunge, this boom comprises of two growth spurts. Likewise, panel (b) also magnifies one of wheat's natural cycles, here the top half shows the beginning of the cycle in 1974Q1, the cyclical trough at 1977Q2, and a peak to conclude the cycle at 1980Q1. During this slump, which many observers attribute to falling oil prices, other factors including the depreciating USD, caused several price increases (World Bank, 2009). These reverse movements were successfully captured by the Hamiltonian MS state space model, in particular panels (a) and (b) makes it clear that wheat prices experienced two minor growth spurts and hence the subsequent slump comprised of three growth plunges.

What is important is the fact that the largest growth spurt began at 1972Q1 and ended at the cyclical peak in 1973Q3, complementing the conjecture that prices increase at an increasing rate during booms. Likewise, it is clear that the largest growth plunge began at 1975Q2 and finished at the cyclical trough in 1977Q2, again supporting the conjecture that prices decrease at an increasing rate during slumps. To be able to infer that the largest growth spurts end at, or relatively close to the peak for all other cases, it needs to be emphasised that the amplitude of the growth spurts that end considerably prior to, or even interrupt the subsequent slump are not of a considerable size; and likewise with growth plunge amplitudes and the distance from the trough. Hence, the focus here is relating the distance between the end of the growth spurt from the peak of the boom/slump cycle, panel (a), to its corresponding amplitude; and relating the distance between the end of the growth plunge from the cyclical trough of the slump/boom cycle, panel (b), to its corresponding amplitude.

Figure 9 displays a number of items. The top tier, on the LHS plots the observed amplitudes that correspond to the growth spurt amplitudes detected within all the trough-peak-trough cycles, and on the RHS, the growth plunge amplitudes that occur within all the peak-trough-peak cycles; both against the distance between the end of each growth phase and the cyclical turning point. The middle tier is a frequency histogram of this distance, designed to give the reader a more precise idea on how many observations appear in the top tier. The third tier is a density histogram of this distance fitted with a Kernel density estimator and a normal Q-Q plot. The evidence is compelling that the majority of growth spurts end at the peak, and the majority of growth plunges end at the trough. The average distance from the peak is 0.2 years for growth spurts and the average distance from the trough is -0.2 years for plunges, or roughly 10 weeks prior to the peak and past the trough respectively. The large density around the mean confirms that these means are well defined. Furthermore, given that some natural phases can persist for up to 10 years¹⁵; these results indicate that the relative amplitude size of these growth spurts and plunges have substantial predictive power as to when the peaks and troughs will occur. Whilst these results provide support on the aggregate level, it is more important to shift this focus to the individual level, so that the size of each extreme growth spurt and plunge can be compared on the basis of their magnitude

¹⁵The average duration of booms and slumps, as defined by equation (1) are disclosed under Column 1 in Tables 1 and 2 respectively.

Figure 9: Relationship between the Amplitude of Growth Spurts and Plunges and their Distance from the Cyclical Turning Point

and how well they help predict turning points, across different types of commodities.

The idea is to find the minimum size of an extreme growth spurt and plunge for each commodity, and to examine as to whether or not periods of increasing (decreasing) prices of at least this magnitude can help predict future turning points. So that the question becomes if one observes a consistent¹⁶ price increase (decrease) of this magnitude, how close is the cyclical peak (trough)? Here, an extreme growth spurt and plunge is defined in accordance with the empirical regularity that commodity prices increase (decrease) at an increasing rate during booms (slumps). As each natural cycle typically exhibits more than one growth spurt and plunge, only the extreme ones are informative as these are more likely to be situated relatively close to the turning point, which in turn implies that if a commodity experiences n_1 trough-peak-trough cycles (hence n_1 peaks) and n_0 peak-trough-peak (hence n_0 troughs) then that particular commodity should experience n_1 extreme growth spurts and n_0 growth plunges. On this basis, an extreme positive shock can be defined as an increase in price greater than the amplitude of the n_1^{th} largest growth spurt; and an extreme negative shock is defined as a decrease in price greater than the absolute value of the n_0^{th} largest growth plunge.

For example, oil experienced 25 growth spurts and 10 peaks (see Table 1, Column 3), the size of the 10th largest growth spurt is 0.28 (28%). Therefore, if the price of oil increases by at least 28%, over 2.5 quarters, then it is plausible to argue that the price of oil is in the vicinity of a cyclical peak. Figure 10 maps the completion dates of all of oil's 25 growth spurts, and 7 out of oil's 10 extreme growth spurts end at a peak, as indicated by a solid point.

Figure 10: Extreme Growth Spurts End Relatively Close to the Peak: The Case for Oil

Notes: the horizontal dashed line indicates the cut of for an extreme growth spurt (0.28). Only 7 growth spurts end at the peak (as indicated by the dot), and all are considered extreme.

¹⁶A consistent increase and decrease in price is determined by the average duration of growth spurts and plunges, see Column 2 of Tables 1 and 2.

Furthermore, oil experiences 10 peak-trough-peak cycles and hence 10 troughs (see Table 2, Column 3). The absolute value of the amplitude of oil's 10th largest growth plunge is 0.20 (20%). Therefore, if the price of oil plummets by at least 20%, over 5.3 quarters, then the cyclical trough could be nearby. Figure 11, plots the completion dates of all of oil's 26 growth plunges against their corresponding amplitude; of the 10 growth plunges with amplitudes greater than 20%, 5 end at a cyclical trough.¹⁷

What is clear from both Figure 10 and Figure 11, is that even though most of the extreme growth shocks end at a cyclical turning point, some do not, although most end within a relatively close distance from the cyclical turning point. The reason as to why this occurs is inherent within the dating procedure of the BBQ algorithm. As the BBQ algorithm allows minimum cycle and phase duration restrictions, it is inevitable that some booms and slumps may persist for several years longer than normal. An example of such an occurrence was the slump following the early 1970s peak which was one of the most prolonged slumps in commodity price history owing to the impact of falling production input (oil) prices in conjunction with extensive technology improvements making substitution away from primary commodities easier and greater extraction more viable (World Bank, 2009). The length of this slump, during this period, differed considerably across different commodities. Referring back to Figure 3, it is clear that soybean's price slumped for longer than wheat's, copper's and oil's. During this slump the Hamiltonian MS switching state space model concurs that soybean prices experienced a few extreme growth plunges (Figure 6), and hence if a slump contains more than one extreme growth plunge (or a boom contains more than one extreme growth spurt) then this reduces the power of these extreme growth phases to predict future turning points.

Figure 11: Extreme Growth Plunges end Relatively Close to the Trough: The Case for Oil

Notes: the horizontal dashed line indicates the cut of for an extreme growth plunge. Only 6 growth plunges end at the trough (as indicated by the dot), and 5 are considered extreme.

¹⁷The number of times that an extreme growth spurt (plunge) ends at the peak (trough) is, under Column 4 of Tables 1 and 2 respectively, referred to as the 'number of hits'.

However, in the majority of cases each boom and slump contains only one extreme growth spurt and plunge, similar to the scenarios depicted in Figure 8, panels (a) and (b).

Despite the fact that slumps typically persist longer than booms (see Figure A.1), extreme growth plunges provide as sufficient indication that a trough is approaching as extreme growth spurts predict peaks. Figure 12 plots the average distance¹⁸ between the end of each extreme growth spurt and plunge from the closest cyclical peak and trough for each commodity, in panels (a) and (b) respectively. If these extreme price movements were able to predict exactly when the cyclical turning points occur, then this distance would be equal to 0. It is more informative and useful if these extreme price movements acted as a leading indicators, instead of exact predictors, owing to the fact that many stake holders (such as those entities who would be vulnerable to depreciating prices) would benefit from prior warning in order to consider their hedging options. This is particularly important for Governments of commodity exporting countries, as their spending patterns tend to increase pro-cyclically with commodity price booms (IMF, 2012) and developing countries who still derive approximately 60% of their export revenue from non-fuel primary commodities (World Bank, 2009).

Figure 12: At What Stage of the Cycle do Extreme Price Movements End?

(a) The average distance between the end of an extreme growth spurt and the cyclical peak.

(b) The average distance between the end of an extreme growth plunge and the cyclical trough.

Notes: in both panels, the prominent line indicates a distance of 0 between the end of a growth phase and the cyclical turning point, and the two dashed lines represent ± 1 years.

It is clear that, for most commodities, extreme price movements end in the lead up to a

¹⁸If this distance is positive then the growth phase ended prior to the cyclical turning point, and if this distance is negative then the growth phase was completed after the cyclical turning point.

cyclical turning point. For some commodities such as tin and coconut oil there is almost no warning, where as for others including coffee and hides, extreme price movements are not helpful at indicating the arrival of turning points.¹⁹

The distance that these extreme price movements end from the closest cyclical turning point is the most important aspect, and beneficial to our stakeholders. However, another interesting result is how the size of these extreme price movements differ across commodities. Referring to Figure 10, it is clear that oil experienced some of the largest growth spurts across all the commodities, yet an extreme growth spurt, in oil's case, is only considered to be 28%, where as, the average minimum value is only 26%. Furthermore, as shown in Figure 13, panel (a), approximately two-thirds of the commodities have minimum growth spurt values that fall within ± 2 standard deviations of the mean (18% and 3%). By contrast, there is significantly more discrepancy amongst what constitutes as an extreme growth plunge, as the mean minimum value defining an extreme growth plunge is 26%, as shown in panel (b), while most values fall within ± 2 standard deviations, this region is significantly wider (13% to 39%). These results provide evidence that prices rises during booms are relatively more uniform across commodities, than the fall in prices during the subsequent slump.

Figure 13: How the Minimum Value of an Extreme Price Movement Differs Across Different Types of Commodities

(a) The minimum value of an extreme growth spurt.

(b) The minimum value of an extreme growth plunge.

Minimum value for an extreme growth spurt

Minimum value for an extreme growth plunge

Notes: in both panels, the prominent line indicates the mean value and the two dashed lines represent ± 2 standard deviations.

¹⁹This should not be surprising as these commodities are exceptions in a sense that their growth is not concentrated at the end of their booms and slumps, see Figure 4.

Table 1: Summary Information Regarding the Predictive Power of Extreme Growth spurts

Commodity	Average duration of booms (years)	Average duration of growth spurts	Number of peaks	Number of hits	Minimum value of an extreme growth spurt	Average distance from the peak (years)	Standard deviation
Aluminium	1.7	2.7	12	9	12	0.25	1.03
Beef*	2.8	2.6	9	9	24	1.75	2.28
Coconut oil	2.1	3.7	12	10	39	0.42	0.81
Coffee	2.4	4.3	6	4	35	-2.38	4.34
Copper*	1.9	3.3	14	13	27	0.41	0.64
Fishmeal	2.0	2.7	13	13	17	0.38	0.70
Groundnut oil	3.0	2.8	10	10	32	1.35	3.00
Groundnuts	3.9	3.9	12	8	26	-0.40	0.87
Hard logs	3.5	3.6	8	5	35	0.59	0.98
Hides*	2.4	3.2	11	9	30	1.27	2.40
Jute	4.1	2.7	8	7	32	-0.59	1.29
Lamb*	2.0	2.1	9	8	18	-0.58	2.40
Lead	1.9	2.4	13	13	26	0.77	1.08
Linseed oil	2.1	3.2	12	11	27	0.60	0.91
Nickel*	2.5	2.7	8	8	28	1.03	1.37
Oil	2.2	2.5	10	7	28	0.60	1.21
Phosphate rock*	2.5	2.4	9	6	14	1.33	1.32
Potash*	3.0	5.7	10	6	20	0.25	1.55
Rubber	2.8	2.4	7	7	21	-0.50	1.32
Soybean meal	3.3	2.5	9	8	33	1.58	2.54
Soybean oil	1.9	2.6	11	10	30	-0.16	0.90
Soybeans	2.4	2.3	8	7	31	-0.97	1.94
Sugar	2.2	2.2	11	11	39	0.84	1.94
Tea	2.1	2.3	9	5	19	0.36	1.06
Tin	2.0	2.9	11	10	16	0.20	1.34
Wheat	2.2	3.1	11	9	19	0.05	0.88
Wool	2.0	3.1	11	9	17	-0.80	1.19
Zinc	1.8	2.3	14	14	24	0.59	1.09

Notes: commodities which are indexed by an asterisk are those commodities whose prices decrease at a decreasing rate and hence their growth is not concentrated at the end of the boom.

Table 2: Summary Information Regarding the Predictive Power of Extreme Growth Plunges

Commodity	Average duration of slumps (years)	Average duration of growth plunges	Number of troughs	Number of hits	Minimum value of an extreme growth plunge	Average distance from the trough (years)	Standard deviation
Aluminium	2.5	2.7	13	11	11	0.94	1.09
Beef*	2.8	2.3	9	8	20	0.92	1.98
Coconut oil	1.9	3.1	13	6	22	0.10	0.72
Coffee*	5.6	4.7	6	5	77	4.75	6.06
Copper	1.9	2.4	13	11	23	0.85	1.38
Fishmeal	2.3	2.5	12	9	18	0.56	1.09
Groundnut oil	2.2	3.4	10	6	26	-0.68	2.21
Groundnuts	2.3	3.4	11	5	23	0.41	1.13
Hard logs	2.1	3.9	9	9	30	0.42	1.29
Hides*	2.0	3.5	11	9	24	-1.11	3.23
Jute	2.7	2.7	7	7	42	0.75	1.07
Lamb	3.1	2.7	9	8	20	1.31	2.79
Lead	2.1	2.8	12	11	19	0.75	1.25
Linseed oil	2.3	3.5	12	8	23	0.35	0.58
Nickel*	3.1	2.8	9	9	26	1.08	1.78
Oil	2.7	5.3	10	6	20	0.93	1.37
Phosphate rock	3.4	4.6	10	9	15	0.38	0.49
Potash*	2.2	3.1	9	5	9	-0.69	1.53
Rubber	3.9	2.1	7	7	38	1.39	4.52
Soybean meal	2.5	3.0	9	8	28	0.42	1.90
Soybean oil	2.8	2.9	10	9	36	1.00	1.76
Soybeans*	3.9	3.3	8	6	32	3.09	3.00
Sugar	2.4	2.5	11	11	43	1.18	1.80
Tea	2.9	2.2	8	6	33	1.91	1.79
Tin*	2.3	2.8	12	10	15	0.13	0.85
Wheat	2.5	3.1	10	5	27	1.23	1.35
Wool*	2.8	2.8	11	9	20	0.75	1.21
Zinc	2.1	2.5	13	11	17	0.63	0.90

Notes: commodities which are indexed by an asterisk are those commodities whose prices decrease at a decreasing rate and hence their growth is not concentrated at the end of the slump.

6 Conclusion

The research undertaken in this paper compliments the emerging trend in commodity price research. Over the past decade, the focus has shifted away from examining how stakeholders can benefit from appropriate intervention (if any), towards understanding patterns in world commodity prices and then creating inference about future movements.

Owing to the time between investment, production and eventual supply, commodity prices exhibit lengthy periods of generally rising prices (booms) and generally falling prices (slumps). By characterising these natural cycle phases in the form of a right-angled triangle and employing the excess index, we established as an empirical regularity, that for the vast majority of commodities, their growth is concentrated at the end of their booms and slumps.

Within these booms and slumps, commodities frequently experience periods rapidly rising and falling prices, these shocks are typically caused by sudden shifts in demand, supply side influences, or geopolitical events. By developing and utilising a Hamiltonian (MS) state space model we are able to capture and identify these shocks and conceptualise them as a cyclical phenomenon. Consistent with our findings that commodity prices increase at an increasing rate during booms and decrease at an increasing rate during slumps, we find that the largest of these shocks are situated at the end of the booms and slumps.

The benefit from isolating these shocks is that we can measure their size in terms of amplitude (net growth) and assign a minimum value for them to be considered extreme. Furthermore, by measuring the distance between the end of these extreme growth spurts (plunges) and the corresponding peak (trough), and concluding that this distance is small relative to the average amount of time that booms and slumps persist for, we determined, with a reasonable amount of accuracy, that movements in commodity prices greater and/or equal to this minimum value defining an extreme price movements, signal that the end of the booms and slumps are fast approaching; usually within a year. This is a welcoming result because considering that many booms and slumps can persist for many years, many stakeholders could benefit from knowing how long the boom or slump has to go. Interestingly, the size of extreme price increases is relatively consistent amongst different commodities, compared to extreme price decreases.

Appendices

A. Data

Table A.1: Commodities and their Units

A. Renewables	
Coconut oil	\$/Mt
Coffee (World)	Cents/lb
Fishmeal	\$/Mt
Groundnut oil	\$/Mt
Groundnuts	\$/Mt
Hard logs	\$/Mt
Hides	Cents/lb
Jute	Cents/lb
Lamb	Cents/lb
Linseed oil	\$/Mt
Rubber	Cents/lb
Soybeans	\$/Mt
Soybean meal	\$/Mt
Soybean oil	\$/Mt
Sugar (World)	Cents/lb
Tea	Cents/Kg
Wheat	\$/Mt
Wool	Cents/Kg
B. Non-renewables	
Aluminium	\$/Mt
Copper	\$/Mt
Lead	\$/Mt
Nickel	\$/Mt
Oil (World)	\$/bbl
Phosphate rock	\$/Mt
Potash	\$/Mt
Tin	Cents/lb
Zinc	\$/Mt

Notes: all currency values are
expressed in USD at current
exchange rates.

B .Bry and Boschan Type Algorithm

The Bry and Boschan (1971) algorithm (BBQ)²⁰ is essentially a non-parametric pattern recognition procedure that identifies where the turning points of natural cycles occur. Below is a brief description on how the algorithm works:

1. Identify the turning point.

The lower bound of the boom phase is the trough and the upper bound is the peak. For slumps, the lower bound is the peak, and the upper bound is the trough. The BBQ algorithm uses the following rule to identify peaks and troughs.

$$\text{Peak : } \Delta_t = 1(\Delta p_t > 0, \Delta p_{t-1} > 0, \Delta p_{t+1} < 0, \Delta p_{t+2} < 0)$$

$$\text{Trough : } \nabla_t = 1(\Delta p_t < 0, \Delta p_{t-1} < 0, \Delta p_{t+1} > 0, \Delta p_{t+2} > 0)$$

2. Impose strict conditions on the turning points.

The second step ensures that peaks and troughs must alternate. The Bry and Boschan algorithm ensures that once a peak is observed, the next turning point must be a trough. This is to ensure the existence of a slump. Likewise, for booms to exist, once a trough is observed, the next turning point must be a peak.

3. Restrict the number of phases.

This step sets the minimum duration of each phase. The idea is that in order to capture natural movements that depict generally rising or falling commodity prices we require phases to persist for a considerable amount of time before one can be confident that the commodity has entered a new phase.

²⁰Versions of the BBQ program exist in GAUSS and MATLAB written by James Engel and are available from the NCER web page at <http://www.ncer.edu.au/data>. Based on the GAUSS code Sam Ouliaris (soularis@imf.org) of the IMF Institute has produced a version of BBQ that is a macro for EXCEL, and this is what is used in this paper.

C. Hamiltonian Markov Switching State Space Model Parameter Estimates

Table A.2: Maximum likelihood estimates for the observation equation using a BFGS type algorithm

Commodity	ϕ_1	SE(ϕ_1)	ϕ_2	SE(ϕ_2)	σ_w^2	SE(σ_w^2)	α_0	SE(α_0)	β_0	SE(β_0)
Beef	1.03	(0.07)	-0.07	(0.07)	0.08	(0)	-1.1	(0.32)	-0.64	(0.95)
Coconut oil	1.37	(0.06)	-0.48	(0.06)	0.12	(0.01)	-0.79	(1.2)	-0.44	(1.03)
Coffee	1.25	(0.07)	-0.29	(0.07)	0.11	(0.01)	0.97	(0.45)	0.54	(0.93)
Fishmeal	1.38	(0.06)	-0.41	(0.06)	0.09	(0)	0.69	(0.52)	0.32	(1.04)
Groundnut oil	1.23	(0.07)	-0.32	(0.07)	0.1	(0.01)	-0.22	(1.77)	-0.08	(1.44)
Groundnuts	1.15	(0.07)	-0.14	(0.07)	0.13	(0.01)	1.05	(0.51)	0.65	(0.93)
Hard logs	1.12	(0.06)	-0.28	(0.06)	-0.1	(0)	1.1	(0.33)	0.62	(0.94)
Hides	0.98	(0.09)	-0.2	(0.07)	0.12	(0.01)	0.84	(0.38)	0.19	(1.14)
Jute	1.24	(0.07)	-0.34	(0.07)	0.12	(0.01)	0.86	(0.43)	0.36	(1.01)
Lamb	1.09	(0.07)	-0.16	(0.07)	0.07	(0)	-0.35	(0.78)	-1.85	(0.72)
Linseed oil	1.2	(0.07)	-0.27	(0.07)	0.12	(0.01)	-0.19	(1.91)	-0.07	(1.51)
Rubber	1.21	(0.07)	-0.24	(0.07)	0.1	(0.01)	-0.07	(2.43)	-0.02	(1.81)
Soybean	1.06	(0.07)	-0.16	(0.07)	0.1	(0.01)	-1.08	(0.47)	-0.63	(0.94)
Soybean Meal	1.11	(0.07)	-0.26	(0.07)	0.11	(0.01)	-1.03	(0.61)	-0.61	(0.94)
Soybean Oil	1.11	(0.07)	-0.2	(0.07)	0.11	(0.01)	1	(0.69)	0.62	(0.94)
Sugar*	1.21	(0.07)	-0.29	(0.07)	-0.17	(0.01)	0.51	(0.92)	0.21	(1.13)
Tea	0.92	(0.07)	-0.02	(0.07)	0.11	(0.01)	-0.4	(0.86)	-0.04	(1.23)
Wheat	1.09	(0.07)	-0.17	(0.07)	0.1	(0)	1.08	(0.35)	0.62	(0.95)
Wool	1.33	(0.06)	-0.36	(0.07)	0.08	(0)	0.98	(0.38)	0.49	(0.97)
Aluminium	1.19	(0.06)	-0.3	(0.06)	0.07	(0)	1.15	(0.35)	0.63	(0.95)
Copper	1.2	(0.07)	-0.22	(0.07)	0.11	(0.01)	0.99	(0.55)	0.57	(0.96)
Lead	1.26	(0.07)	-0.28	(0.07)	0.1	(0.01)	-1.12	(0.42)	-0.62	(0.93)
Nickel	1.24	(0.06)	-0.31	(0.06)	-0.11	(0.01)	1.05	(0.53)	0.59	(0.94)
Oil	1.02	(0.07)	-0.05	(0.07)	0.14	(0.01)	0.08	(3.62)	0.05	(2.52)
Phosphate Rock	1.23	(0.07)	-0.28	(0.07)	0.13	(0.01)	-1	(0.61)	-0.57	(0.94)
Potash	1.26	(0.07)	-0.31	(0.07)	0.1	(0)	-1.09	(0.31)	-0.59	(0.94)
Tin	1.31	(0.07)	-0.31	(0.07)	0.09	(0)	1.11	(0.33)	0.6	(0.95)
Zinc	1.3	(0.06)	-0.4	(0.06)	0.1	(0)	1.07	(0.38)	0.57	(0.98)

Notes: here $\beta_0 = \alpha_0 + \alpha_1$.

D. Duration of Natural and Growth Cycle Phases

Figure A.1: Natural Phase Durations

Notes: commodities are listed in order from longest to shortest slump. Numerical values for average boom duration are from Table 1, Column 1 and for average slump durations, from Table 2, Column 1.

Figure A.2: Growth Phase Durations

Notes: commodities are listed in order from longest to shortest plunge. Numerical values for average growth spurt duration are from Table 1, Column 2 and for average growth plunge durations, from Table 2, Column 2.

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