New indices of adequate and excess speculation and their relationship with volatility in the crude oil futures market

by

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Abstract

I develop new indices of adequate and excess speculation in futures markets, defining adequate speculation as speculation which equals unbalanced hedging, while excess speculation is speculation in excess of this amount. The indices explicitly account for balancing hedging and balancing speculative contracts. I demonstrate that these indices accurately estimate Working's (1960) *conceptual definition* for his speculative index as the ratio of speculation to unbalanced hedging in all situations, while Working's *formula* for his speculative index *T* does not. I compare these indices to Working's formula for 21 futures contracts, including commodity, financial, cash-settled and physical delivery contracts. I apply these indices to investigate the relationship between speculation and volatility of the NYMEX's West Texas Intermediate (WTI) crude oil futures contract, over the period 1986 through 2012, while controlling for market fundamental risk. The results suggest that volatility in the crude oil futures market increases with adequate and excess speculation.

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1. Introduction

I build on previous research by Working (1960) to develop two new indices: 1) an index of adequate speculation, which measures the degree of speculation which is just sufficient to meet unbalanced hedging, and, 2) an index of excess speculation, which measures the degree of speculation in excess of adequate speculation. In these definitions, I explicitly recognize that not *all* of long hedging may balance short hedging, since short and long hedgers may differ on the duration, size and timing of their hedging positions. Keynes (1923) notes that commodity producers initiate short futures hedges much before production is completed, while users hold long futures hedges for shorter periods. Hirshleifer (1990) notes that commodity producers tend to be large enterprises which use large hedges, while users tend to be small enterprises which use small hedges. Peck (1979-80) notes that short and long hedgers differ on seasonal needs, timing and duration of hedging. In comparison, Ward's (1974) speculative index is defined as long speculation divided by the excess of short hedging over long hedging.

Consider the case in which short hedging exceeds or equals long hedging. Then unbalanced hedging equals short hedging minus that portion of long hedging which balances short hedging. Actual long speculation equals the sum of: 1) a portion which equals unbalanced hedging; and 2) a portion which balances short speculation. Dividing both sides of the above identity by short hedging, I obtain the actual linear relationship between the speculative ratio (ratio of long speculation to short hedging), and the hedging ratio (ratio of long hedging to short hedging). The slope of this relationship is the negative of the ratio of balancing hedging contracts to long hedging, and the intercept is 1 plus the ratio of balancing speculative contracts to short hedging. I define the index of adequate speculation as the ratio of unbalanced hedging to short hedging, and the index of excess speculation as the ratio of balancing speculative contracts to short hedging. The index of adequate speculation captures the presence of speculators who take on the risk transferred by hedgers, and is therefore, a measure of hedging pressure. The index of excess speculation captures the presence of speculators who trade with other speculators.

These indices offer an alternative to Working's *formula* for his speculative index *T*, which is used extensively, as in Sanders et al (2010), Du et al (2011) and Büyükşahin and Harris (2011). Working (1960, page 209, second paragraph, lines 2-4) provides a *conceptual definition* for his speculative index as the ratio of long speculation to unbalanced short hedging, in stating, "The excess of long speculation … over unbalanced short hedging… is an excess that should be measured by the speculative index, according to our definition of that index…". He notes that in a futures market with no long hedging, the speculative index is the ratio of long speculation to short hedging. He then adds that "If there is a purely logical reason for deducing how to write the formula for a speculative index for markets *with* long hedging, it escapes me". For a futures market with short and long hedging, he arrives at a *formula* for his speculative index as 1 plus the ratio of short speculation to the sum of short and long hedging, by assuming a particular relationship between the speculative ratio and the hedging ratio. I show that Working's *conceptual definition* equals 1 plus the ratio of the index of excess speculation to the index of adequate speculation, for markets with both short and long hedging. These indices share the intuition behind Working's *concept* of measuring speculation relative to unbalanced hedging. However, Working's *formula* for his speculative index is difficult to explain for markets *with* long hedging, does not explicitly incorporate balancing hedging, accurately measures his conceptual definition only for a market with no long hedging, and implies that excess speculation exists in markets in which it is absent. I illustrate these results with numerical examples.

I use data provided by the Commodity Futures Trading Commission (CFTC) in its Commitments of Traders (COT) reports to compare the indices of adequate and excess speculation, and Working's speculative index, for 21 futures contracts in 7 groups, energy, grains and oilseeds, livestock, metals, equity indexes, interest rates, and foreign exchange, over the period 31 January 1986 or the date of contract initiation till 31 December 2012. Estimation of the indices of adequate and excess speculation needs estimates of balancing hedging and balancing speculative contracts, for which no data are directly available. I estimate these unobservable quantities by applying a Kalman (1960) filter approach with inequality constraints imposed on the state variables, which are the time-varying intercept and slope of the actual linear relationship between the speculative and hedging ratio for each contract. The estimation is more complex than that used to calculate Working's *formula*, which is a ratio of observables.

I contribute to the debate on the role of market fundamentals and speculation upon the volatility of crude oil prices. I investigate the relationship between volatility in the WTI crude oil futures market and the indices of adequate and excess speculation, while accounting for the risk contributed by market fundamentals. Keynes (1930) notes that speculators must be induced to take long positions to meet net short hedging demand by a risk premium which reduces the current futures price below the expected future spot price. Cootner (1960) adds that hedgers may be net long as well, which could cause the risk premium to increase the current futures price. These, and other papers on hedging pressure (Hirshleifer (1990)), imply that there should be a positive relationship between volatility in the crude oil futures market and the index of adequate speculation. Previous research offers conflicting implications for the relationship between volatility in the crude oil futures market and the index of excess speculation. Friedman (1953) argues that rational arbitrageurs in currency markets stabilize prices. DeLong et al (1990a) note that noise traders could move an asset's price away from its fundamental value, while De Long et al (1990b) note that even rational speculators in a market with positive feedback traders could do likewise. Thus, an asset's price risk is the sum of the risk contributed by market fundamentals and that contributed by speculation. I estimate the volatility of the crude oil futures market by the stochastic variance of the log return on the futures contract. I estimate the risk contributed by market fundamentals by the stochastic variance of the growth in the log demand for crude oil in the U. S., building on research by Chatrath et al (2009), who model the price of crude oil as a function of the demand for crude oil in the U. S. and other variables.

Section 2 describes the indices of adequate and excess speculation, compares them with Working's speculative index, and provide results on these indices for the 21 different futures contracts. Section 3 describes the research on the relationship between volatility in the crude oil futures market, the risk contributed by market fundamentals and the indices of adequate and excess speculation, and provides results. Section 4 provides conclusions.

2. Indices of adequate and excess speculation

The indices of adequate and excess speculation are based on comparing the amount of speculation that is just sufficient to meet unbalanced hedging, with the actual amount of speculation in a market.

2.1. Situation in which short hedging exceeds or equals long hedging

2.1.1. Required long speculation and excess long speculation

Let *HS*=open futures positions of short hedgers, *HL*=open futures positions of long hedgers, *SS*=open futures positions of short speculators and *SL*=open futures positions of long speculators. Let *HB* represent balancing hedging contracts, which Working (1960, page 197, footnote 15) describes as "the amount of "balancing" long hedging, that serves to carry, or "balance", an equal amount of short hedging". Let *SB* represent balancing speculative contracts, which is the amount of balancing long speculation that serves to carry, or balance, an equal amount of short speculation. When $HS \geq HL$, unbalanced hedging equals HS-HB, and the amount of long speculation SL_R which is required to meet or carry this unbalanced hedging is:

$$SL_R = HS - HB \tag{1}$$

However, the actual amount of long speculation SL_A is the sum of the required amount of long speculation which equals unbalanced hedging and the amount of long speculation which balances short speculation *SB*. Thus:

$$SL_A = HS - HB \quad + \quad SB \tag{2}$$

Figure 1 illustrates the above analysis for the case when $HS \geq HL$. The first rectangle represents short hedging contracts, the second represents long hedging contracts, the third represents long speculative contracts and the fourth represents short speculative contracts. As the figure indicates, short hedging *HS* equals the sum of balancing hedging *HB* and unbalanced hedging HS-HB. Actual long speculation SL_A equals the sum of the long speculative contracts required to meet unbalanced hedging $SL_R = HS$-HB, and balancing speculative contracts *SB*. Excess long speculation, which exceeds that required to meet unbalanced hedging, equals *SB*.

2.1.2. Actual relationship between the speculative ratio and the hedging ratio

Define HL/HS as the hedging ratio and SL/HS as the speculative ratio, as Working does. HB/HL is the proportion of long hedging contracts which are balancing hedging contracts. If long and short hedgers enter the market at the same time, and all long hedging contracts *HL* equal balancing hedging contracts *HB*, then HB/HL=1. If long and short hedgers enter the market at completely different times, then no part of long hedging contracts offset short hedging contracts, HB=0 and HB/HL=0. If some long hedgers enter the market at the same time as some short hedgers, some portion of long hedging offsets short hedging, so that $0 \le HB/HL \le 1$. Equation (1), for the required amount of long speculation, may be written using *HB/HL* as:

$$SL_R = HS - \left(\frac{HB}{HL}\right).HL \tag{3}$$

Dividing both sides of equation (3) by *HS*, the relationship between the required speculative ratio and the hedging ratio when speculation exactly equals unbalanced hedging is:

$$\frac{SL_R}{HS} = 1 - \left(\frac{HB}{HL}\right).\frac{HL}{HS} \qquad if\ HS \ge HL \tag{4}$$

Similarly, equation (2), for the actual amount of long speculation, may be written as:

$$SL_A = HS - \left(\frac{HB}{HL}\right).HL + SB \tag{5}$$

Dividing both sides of equation (5) by *HS*, the actual relationship between the speculative ratio and the hedging ratio is:

$$\frac{SL_A}{HS} = 1 + \frac{SB}{HS} - \left(\frac{HB}{HL}\right).\frac{HL}{HS} \tag{6}$$

The intercept $1+\frac{SB}{HS}$ of equation (6) depends on the ratio of balancing speculative contracts *SB* to short hedging *HS*, while the slope – *HB/HL* depends on the ratio of balancing hedging contracts *HB* to long hedging *HL*. In a futures market with no long hedging, *HL*=0, *HB*=0, *HB/HL* is undefined, and the relationship between the actual speculative ratio and the hedging ratio is represented by a single point, with coordinates *HL*/*HS*=0 and *SL*/*HS*=*1+SB/HS.*

2.1.3. Index of adequate speculation

I define adequate speculation as the amount of long speculation which is just sufficient to equal unbalanced hedging. In this case, equation (4) provides the required speculative ratio, which I define as the index of adequate speculation *INDADSP,* so that:

$$INDADSP = 1 - \left(\frac{HB}{HL}\right).\frac{HL}{HS} \qquad if\ HS \geq HL \tag{7}$$

As *HB* increases, *HB/HL* increases and *INDADSP* decreases.

Figure 2 graphs the relationship between the required speculative ratio and the hedging ratio of equation (4), when speculation is just sufficient to equal unbalanced hedging, for three different values of *HB/HL*. Line AB represents the situation in which *HB/HL*=0, and none of the long hedging contracts balance short hedging, line AC represents the situation in which *HB/HL*=0.5 and 50% of the long hedging contracts balance short hedging, while line AD represents the situation in which *HB/HL* =1 and 100% of the long hedging contracts balance short hedging. Consider a futures market which is characterized by *HB/HL* =0.5, so that 50% of the long hedging contracts balance short hedging contracts. Line A'C', which is parallel to line AC, represents the actual relationship between the speculative ratio and the hedging ratio for this market. Comparing equations (4) and (6), we note that the vertical distance between line AC and A'C' is always *SB/HS*. Point E, with actual values of the hedging ratio of 0.6 and speculative ratio of 0.9, represents the characteristics of this market at the same time. Then the index of adequate speculation *INDADSP* is the speculative ratio corresponding to point F, which lies on line AC and has the same hedging ratio as point E. We note that this equals (1-0.5x0.6) = 0.7.

If *HL*=0, the relationship between the required speculative ratio and the hedging ratio are represented by point A, with a value for the hedging ratio of 0 and a value for the speculative ratio of 1. The index of adequate speculation *INDADSP* in this case is then equal to 1.

2.1.4. Index of excess speculation

Comparing equations (6) and (7), I define the index of excess speculation *INDEXSP* as:

$$INDEXSP = \frac{SB}{HS} \qquad if\ HS \geq HL \tag{8}$$

Note that *INDEXSP* equals the intercept of the actual linear relationship between the speculative ratio and the hedging ratio minus 1. Comparing equation (8) with equation (6), we note that:

$$INDEXSP = \frac{SL_A}{HS} - INDADSP \qquad if \ HS \geq HL \tag{9}$$

While equation (9) provides the relationship between the two indices, note that *INDADSP* depends on balancing hedging contracts *HB*, while *INDEXSP* depends on balancing speculative contracts *SB*. *HB* and *SB* need not depend on each other. *SB* could increase while *HB* is unchanged, if short speculation increases, and, *HB* could increase without increasing *SB*.

Consider Figure 2 and line AC, which represents the relationship between the required speculative ratio and the hedging ratio for a market in which 50% of the long hedging contracts offset short hedging contracts. Point E, with coordinates (0.6, 0.9), represents the actual characteristics of the market at the same time, and lies on line A'C', which represents the actual relationship between the speculative ratio and hedging ratio for this market. Point F, which lies on line AC, shares the same hedging ratio of 0.6 as point E. The index of excess speculation *INDEXSP* is given by the vertical distance between point E and point F, which equals (0.9-0.7) = 0.2. *INDEXSP* also equals the intercept of line A'C' minus 1, which equals 0.2. In this situation, speculation is 20% in excess of that required to meet unbalanced hedging.

2.2. Situation in which long hedging equals or exceeds short hedging

When $HS \leq HL$, the speculative ratio is SS/HL and the hedging ratio is HS/HL. Using an analysis similar to that of subsections *2.1.1-2.1.4*, the required amount of short speculation SS_R needed to meet unbalanced long hedging $HL-HB$, the actual amount of short speculation SS_A, which is the sum of the required amount of short speculation and balancing speculative contracts *SB*, the actual relationship between the speculative ratio and the hedging ratio, the index of adequate speculation, and, the index of excess speculation, are specified by applying equations

(1), (2), (6), (7) and (8), respectively, with the following substitutions: *SS* for *SL*, *HS* for *HL*, *HL* for *HS,* and, *HB/HS* for *HB/HL*. The analysis of Figure 2 and the graphical representation of the indices of adequate and excess speculation as described in sub-sections *2.1.3-2.1.4*, also hold with the appropriate substitutions for the speculative ratio and the hedging ratio.

2.3. Summary of the indices of adequate and excess speculation

Table 1, Panel A, summarizes the equations for the indices of adequate and excess speculation and the actual relationship between the speculative ratio and the hedging ratio. Summing up, the index of adequate speculation is a measure of speculation which bears the risk transferred from hedgers. It is thus a more accurate measure of hedging pressure, since it explicitly considers balancing hedging contracts, than net short hedging, which assumes that all long hedging contracts are balancing hedging contracts. The index of excess speculation measures pure speculation which aims to benefit from a judgment or forecast of future prices.

2.4. Comparison of the indices of adequate and excess speculation with Working's index

2.4.1. Congruence with Working's conceptual definition for the speculative index

Let us represent the actual level of short speculation by *SL* from this point onwards. Working's conceptual definition for the speculative index as "The excess of long speculation… over unbalanced short hedging" may be represented as:

$$Working's\ conceptual\ speculative\ index = \frac{SL}{HS - HB} \qquad HS \geq HL \tag{10}$$

This index may be written in terms of balancing hedging and balancing speculative contracts as:

$$\frac{SL}{HS-HB} = \frac{SL-SB+SB}{HS-HB} = \frac{HS-HB+SB}{HS-HB} = 1 + \frac{SB}{HS-HB} = 1 + \frac{SB}{SL-SB} \qquad HS \geq HL \tag{11}$$

Writing the index in this form compares balancing speculative contracts with unbalanced short hedging, or, compares balancing speculative contracts with that portion of long speculation which equals unbalanced short hedging. Equation (11) may also be written in terms of the indices of adequate and excess speculation as follows:

$$\frac{SL}{HS-HB}=1+\frac{SB}{HS-HB}=1+\frac{SB/HS}{\left(HS-HB\right)/HS}=1+\frac{INDEXSP}{INDADSP} \qquad HS\geq HL \qquad (12)$$

Hence there is congruence between what Working intends that his speculative index should measure and the indices of adequate and excess speculation. Table 1, Panel B, row 1, shows the equations for Working's conceptual speculative index, its value in terms of balancing hedging and speculative contracts, and in terms of the indices of adequate and excess speculation. Equations (10), (11) and (12) share the same intuition, by comparing the amount of speculation which exceeds unbalanced hedging with the amount of speculation equal to unbalanced hedging.

2.4.2. Working's formula for the speculative index

Working (page 199, second full paragraph, line 6) derives a formula for the speculative index, by assuming a particular relationship between the speculative ratio and hedging ratio. This formula may be represented by[1]:

$$T=1+\frac{SS}{HS+HL} \qquad HS\geq HL \qquad (13)$$

Table 1, Panel B, row 2, provides Working's formula for the speculative index *T*. Note that it does not explicitly include terms for balancing hedging and balancing speculative contracts. Providing an intuitive explanation for equation (13) is difficult, especially for a market with long hedging. This may be why previous authors, such as Sanders et al. (2010), used the special case of a market with no long hedging, to explain the formula for *T*. If long hedging is absent, *HL*=0, $T=1+SS/HS=SL/HS$. This equals Working's conceptual speculative index of equations (10)

[1] When long hedging exceeds or equals short hedging, Working's formula for the speculative index is:

$$T=1+\frac{SL}{HS+HL} \qquad HL\geq HS \qquad (13)'$$

through (12), since *HB*=0, and *SS*=*SB*. In a market with long hedging, *T* will overestimate, accurately estimate, or underestimate, Working's conceptual definition of the speculative index, according as *SS/(HS+HL)* is greater than, equal to or less than *SB/(SL-SB)*, or, as *SB* is less than, equal to, or greater than, *(SS.SL)/(HS+HL+SS)*. In a market with no excess speculation, *SB=0*, *INDEXSP*=0, and Working's conceptual speculative index equals 1, according to equations (10) through (12). However, the *T* index of equation (13) will exceed 1, as long as short speculation *SS* exceeds zero, implying that excess speculation exists, when it is absent. The *T* index will equal 1 only if short speculation is zero. This result of the formula for *T* implies that if long speculation equals unbalanced short hedging, there will be no short speculators in the market, in which case, the futures price would then "be so low that no speculator thought the price would go lower", which Working judges is "too low". This leads Working to conclude that more speculation is "economically necessary" than required to meet unbalanced hedging. But this conclusion arises only because of the formula for *T*. Long speculation could equal unbalanced short hedging and short speculation would still exist. However, it would equal unbalanced long hedging.

2.4.3 . Working's assumed relationship between the speculative ratio and the hedging ratio

Table 1, Panel B, row 3, shows Working's assumed relationship between the speculative ratio *SL/HS* and the hedging ratio *HL/HS*. Working (1960, page 196) examines a chart of the relationship for 11 futures markets, and concludes that it may be represented as:

$$SL = (1+\alpha).HS - (1-\alpha).HL \qquad HS \geq HL \tag{14}$$

where α represents the speculative characteristic of a market. This implies that:

$$\frac{SL}{HS} = (1+\alpha) - (1-\alpha).\frac{HL}{HS} \qquad HS \geq HL \tag{15}$$

Using the identity, *HS*+*SS* = *HL*+*SL*, he obtains an equation for α as:

$$\alpha = \frac{SS}{HS + HL} \tag{16}$$

Working's assumed relationship may be represented as:

$$\frac{SL}{HS} = \left(1 + \frac{SS}{HS + HL}\right) - \left(1 - \frac{SS}{HS + HL}\right) . \frac{HL}{HS} \qquad HS \geq HL \tag{17}$$

The intercept of equation (17) is *T*. In contrast, the relationship between the actual speculative ratio and the hedging ratio when *HS*≥ *HL* is given by equation (6), with an intercept of *1+SB/HS* and a slope of -*HB/HL*. There need not be any relationship between the intercept and the slope, since the former depends on *SB*, while the latter depends on *HB*. Comparing equations (17) and (6), we conclude that *T* will overestimate, correctly estimate or underestimate the intercept of the actual relationship, if *1+SS/(HS+HL)* is greater than, equal to or less than *1+SB/HS*, or if *SB* is less than, equal to or greater than *(HS.SS)/(HS+HL)*. *T* cannot simultaneously measure Working's conceptual definition for the speculative index, as well as the intercept of the actual relationship, unless balancing hedging and speculative contracts both equal zero. The slopes of the actual and assumed relationships also differ.

2.4.4. Illustration of the congruence and differences

Appendix A compares the indices of adequate and excess speculation and the *T* index in estimating Working's conceptual speculative index, as well as the actual and Working's assumed relationship between the speculative and hedging ratio, for different situations, with numerical examples and graphs. The results confirm that the indices of adequate and excess speculation together correctly estimate Working's conceptual speculative index in all situations, while the *T* index does not. Further, Working's assumed relationship between the speculative and hedging ratio coincides with the true relationship only when long hedging is absent.

2.5. Methodology used to estimate the indices of adequate and excess speculation

The CFTC provides a breakdown of the open interest for reporting commercial and noncommercial traders and for non-reporting traders in its Commitment of Traders (COT) reports, for different futures contracts, on a bi-weekly basis prior to September 1992, and weekly thereafter. Historically, the CFTC (2006) notes, commercial open interest represented hedging positions, while noncommercial open interest represented speculative[2] positions. As in Du et al (2011), and Irwin et al (2009), I treat commercial positions as hedging and noncommercial positions as speculative. I allocate non-reporting traders' open interest into commercial and noncommercial categories by assuming that the ratio of commercial to noncommercial positions for non-reporting traders is the same as that for the reporting traders, as in Sanders et al (2010), Irwin et al (2009), and Peck (1979-80). I estimate the open interest of short (long) hedgers *HS* (*HL*) as the sum of the short open interest of reporting commercials and allocated non-reporting commercials, and the open interest of short (long) speculators *SS* (*SL*) as the sum of the short (long) open interest of reporting and allocated non-reporting noncommercials and the spread positions of noncommercials. I do this for 21 futures contracts in seven groups, energy, grains and oilseeds, livestock, metals, equity indexes, interest rates, and foreign exchange, for the period 15 January 1986 or the date of contract initiation to 31 December 2012.

Estimation of the index of adequate speculation using equation (7) needs an estimate of balancing hedging contracts *HB*, while estimation of the index of excess speculation using

[2] The COT data has some limitations. Speculative position limits for noncommercial traders may provide incentives for traders to self-identify themselves to the CFTC as commercials (Sanders et al (2004)). Ederington and Lee (2002) note that while noncommercials may accurately be classified as speculators, some firms in the heating oil futures markets which are classified as commercials do not appear to possess energy assets. However, the CFTC employs a rigorous process to verify this self-identification. Index trading in futures markets and the CFTC's regulatory response resulted in inclusion of swap dealers' open interest in the commercial category and index traders such as managed funds and pension funds in the noncommercial category. This classification is defensible on the grounds that swap dealers generally take positions in commodity futures contracts to hedge their exposures to commodity index swaps with index funds, while managed and pension funds are not hedging such an exposure.

equation (8), needs an estimate of balancing speculative contracts *SB*. There are no data available from the CFTC or another source on balancing hedging and balancing speculative contracts, which therefore must be estimated. Consider equation (6) which relates the actual speculative ratio *SL/HS* to the hedging ratio *HL/HS*. This may be rewritten as follows:

$$\frac{SL}{HS} - 1 = \frac{SB}{HS} + \frac{HB}{HL}\left(-\frac{HL}{HS}\right) \tag{18}$$

The slope of equation (18) equals *HB/HL*, and the intercept equals *SB/HS*. Since balancing hedging and speculative contracts should vary over time, the slope and intercept of equation (18) should also vary over time. Time series of balancing hedging and speculative contracts may be estimated by the following time-varying regression:

$$\frac{SL_t}{HS_t} - 1 = a_{0,t} + a_{1,t}\left(-\frac{HL_t}{HS_t}\right) + \varepsilon_t \tag{19}$$

HL_t, HS_t, SL_t and SS_t represent the open interest of long hedgers, short hedgers, long speculators and short speculators, respectively, $\frac{SL_t}{HS_t}$ is the speculative ratio and $\frac{HL_t}{HS_t}$ is the hedging ratio, for time *t*. $a_{0,t}$ is the time varying intercept which equals $\frac{SB_t}{HS_t}$, where SB_t represents balancing speculative contracts at time *t*. $a_{1,t}$ is the time varying slope which equals $\frac{HB_t}{HL_t}$, where HB_t represents balancing hedging contracts at time t. ε_t is the error term in the regression. In accordance with equation (6), the constraints are: $a_{0,t} \geq 0$, and $a_{1,t} \geq 0$.

The estimate of the above time varying regression may be conducted by applying a Kalman (1960) filter analysis with inequality constraints on the state variables, following an approach suggested by Gupta and Hauser (2007). In equation (19), which represents the observation equation of the state-space representation, $\frac{SL_t}{HS_t} - 1$, is the dependent observable variable, $-\frac{HL_t}{HS_t}$, is the exogenous observable variable, and $a_{0,t}$ and $a_{1,t}$ are state variables which represent the true state of the underlying system at time t. In the state-space representation, a state equation describes how the system transitions from the state at time $t-1$ to the state at time t. Appendix B provides a detailed explanation of the application of the Kalman filter analysis with inequality constraints on the state variables. Once $a_{1,t}$ and $a_{0,t}$ are estimated[3], corresponding values of HB_t and SB_t and the indices of adequate and excess speculation are estimated. Estimation of corresponding values of Working's T are conducted by applying equations (13) and (13)'.

2.6. Results of the estimation of the indices of adequate and excess speculation

Figures 3a through 3e illustrate the input and the results of the estimation for the crude oil futures contract[4] over the dates 31 January 1986 through 31 December 2012. Figure 3a shows how the hedging ratio and the speculative ratio vary over time. The hedging ratio is relatively stable in the overall period, ranging between 0.70 and 1.25. The speculative ratio assumes lower values in the earlier period up to December 2001, and higher values thereafter. Figure 3b shows the estimates of the slope $a_{1,t}$ and indicates that as constrained by the estimation process $a_{1,t} \geq 0$. Up to June 2002, the ratio of balancing hedging contracts to long hedging contracts was 70% or higher, but this ratio decreased thereafter. Figure 3b also shows that the corresponding estimates of the index of adequate speculation are less than 40% up to June 2002, but increase thereafter. Figure 3c shows the estimates of the intercept $a_{0,t}$ and the corresponding estimates of the index

[3] The speculative ratio and the hedging ratio may be associated with measurement error due to the reasons cited in Footnote 2. The error in the speculative ratio is accounted for by the error in the observation equation in the Kalman filter analysis. However, the error in the hedging ratio would give rise to an errors-in-variables problem. Kim (2008) provides an approach for dealing with this problem in a time-varying regression. However, to apply this approach, we need an instrumental variable which is uncorrelated with the errors in the speculative ratio while being correlated with the hedging ratio, which, to the best of my knowledge, is unavailable.

[4] Similar figures for the other futures contracts are available from the author on request.

of excess speculation, which coincide for most of the observations. The figure indicates that as constrained by the estimation process, $a_{0,t} \geq 0$. It also indicates that excess speculation was less than 5% prior to June 2005 but increases above this value thereafter.

Figure 3d compares two estimates of Working's conceptual speculative index: *1+INDEXSP/INDADSP* and *T*. The results indicate that *T* is sometimes higher and sometimes lower than *1+INDEXSP/INDADSP*. Figure 3e compares the two estimates of the intercept of the relationship between the actual speculative ratio and the hedging ratio: *1+INDEXSP* and *T*. The results indicate that *T* is higher than *1+INDEXSP* in the overall period. These results are consistent with the analysis of subsection 2.4.2

Table 2 provides information on the futures exchange, method of settlement, the number of observations used, and summary statistics on the indices of adequate and excess speculation, the estimate of Working's conceptual speculative index by *1+INDEXSP/INDADSP* and Working's *T,* for each of the 21 futures contracts. The ending date is December 31, 2012 for all contracts. The results indicate that, on average, the *T* index exceeds *1+INDEXSP/INDADSP* for 18 of the 21 futures contracts. The minimum value of the index of excessive speculation is 0, and the corresponding minimum value of *1+INDEXSP/INDADSP* is 1 for all contracts. However, the minimum value of Working's *T* is 1 only for natural gas and copper.

Table 3 shows that the correlation between *INDADSP* and *INDEXSP* is highest for the natural gas futures contract and lowest for the soybeans futures contract, the correlation between *1+INDEXSP/INDADSP* and the *T* index is highest for the DJIA futures contract and lowest for the Eurodollar futures contract, while the correlation between 1+*INDEXSP* and the *T* index is highest for the natural gas futures contract and lowest for the live cattle futures contract. On average, for all contracts, the lowest correlation (0.4438) is between *INDADSP* and *INDEXSP* while the highest correlation (0.8126) is between 1+*INDEXSP/INDADSP* and the *T* index.

3. Crude oil futures price risk, market fundamentals and speculation

3.1 Hypotheses

De Long et al. (1990a) establish that in a risky asset market with sophisticated investors and noise traders, the asset price risk is the sum of the risk contributed by market fundamentals and by noise traders. Accordingly, the first hypothesis is:

H1: The futures price risk is positively related to the risk contributed by market fundamentals.

According to Keynes (1930) and Cootner (1960), the risk premium that speculators require to meet net hedging demand would decrease or increase the futures price, when net hedging demand is short or long, respectively. Thus, the futures price risk increases with unbalanced hedging and hence with the index of adequate speculation. The second hypothesis is:

H2: The futures price risk is positively related to the index of adequate speculation.

Friedman (1953) argues that rational speculators stabilize prices by buying the asset when its price is too low, and selling it when it is too high, relative to fundamental value. Hart and Kreps (1986) note that rational speculators may buy a commodity and store it, on receiving a signal that the next period's demand will be high. If the signal is accurate, their sale of the commodity in the next period would stabilize prices, but, if not, it would destabilize them. According to De Long et al (1990a, 1990b), both noise traders and rational speculators could destabilize prices. The above research implies that the futures price risk could decrease or increase with pure speculation, as measured by the index of excess speculation. The third hypothesis is:

H3: The futures price risk is negatively (positively) related to the index of excess speculation if speculation is stabilizing (destabilizing).

3.2. Data

3.2.1. Crude oil futures price data

I obtain a continuous time series of daily futures prices for the NYMEX WTI crude oil futures contract from March 30, 1983 to December 31, 2012 from Datastream. The prices are for the closest to maturity futures contract until the first business day of the contract month is reached, at which point the prices are for the next closest to maturity contract.

3.2.2. Data used to estimate the demand for crude oil

I obtain a time series of daily data on the crude oil and petroleum products product supplied in the United States in thousand barrels per day from January 1, 1986 through December 31, 2012 from Datastream, as provided by the Energy Information Administration (EIA). The EIA notes on its website that this variable is computed as "field production, plus refinery production, plus imports, plus unaccounted-for crude oil (plus net receipts when calculated on a PAD District basis) minus stock change, minus crude oil losses, minus refinery inputs, and minus exports" . I use this variable as an estimate of the daily demand for crude oil in the United States, following Chatrath et al (2009), who estimate the monthly demand for crude oil as U. S. production plus net imports minus the change in the stock of crude oil.

3.2.3. Data used to estimate the indices of adequate and excess speculation

Data are obtained from the CFTC's COT reports on the open interest of reporting and nonreporting traders from January 15, 1986 through December 31, 2012, for the NYMEX's WTI crude oil futures contract. The data are provided bi-weekly from January 1986 to September 1992, as of the 15^{th} and the last day of the month, in general, and weekly as of each Tuesday, following September 1992. These data are used to estimate the open interest of short hedgers, long hedgers, short speculators and long speculators, and the indices of adequate and excess speculation, for each “as of date”, extending from January 15, 1986 through December 31, 2012. Sub-section *2.5* provides details of the estimation. The differing periodicity of the data does not affect the estimation which depends only on the speculative and hedging ratios.

3.2.4. Matching data on the crude oil futures price, demand for crude oil, and indices of adequate and excess speculation

Four time series, of the crude oil futures price, demand for crude oil and the indices of adequate and excess speculation, for each as of date of the COT data are created, extending from January 15, 1986 through December 31, 2012. The crude oil futures price is the price from the continuous series of daily futures prices on the as of date. For January 15, 1986, the demand for crude oil is computed as the average of the daily demand from January 1, 1986 through January 15, 1986. Following this, for each specific as of date, the corresponding demand is the average of the daily demands for the dates which follow the previous as of date and end at the current as of date. The averaging is done so that the data on the demand for crude oil are comparable across time, since the time between the as of dates is approximately 15 days prior to October 1992 and 5 days after September 1992.

3.3.Estimation of the futures price risk and the risk due to market fundamentals

I estimate the crude oil futures price risk by the stochastic variance of the log return on the futures contract. I estimate the risk due to market fundamentals as the stochastic variance of the growth in the log demand for crude oil in the U. S., building on research by Chatrath et al (2009) who model the price of crude oil as a function of its demand and other economic indicators. I apply a stochastic volatility model authored by Harvey, Ruiz and Shepherd (1994) to estimate the futures price risk and the risk due to market fundamentals. The model is represented by:

$$y_t = \varepsilon_t \sqrt{h_t}, \qquad \varepsilon_t \sim N(0,1) \tag{20}$$

$$\log h_t = \gamma + \varphi \log h_{t-1} + \omega_t, \qquad \omega_t \sim N\left(0, \sigma^2\right) \tag{21}$$

y_t is the log return for the crude oil futures contract at time *t*, when estimating the futures price risk, and is the growth in log demand for crude oil at time *t*, when estimating the risk due to market fundamentals. h_t is the stochastic variance of y_t, which is the stochastic variance of the futures' log return $SVFR_t$ when estimating the futures price risk, and the stochastic variance of the growth in log demand $SVDM_t$ when estimating the risk contributed by market fundamentals. ε_t and ω_t are the error terms. γ, φ, and σ are parameters which are to be estimated. Following Harvey et al, I estimate the model parameters using a quasi-maximum likelihood approach and use Kalman smoothing to obtain estimates of volatility for the sample. I conduct the estimation using RATS, and the procedure DLM.

Table 4 shows the estimated values of the parameters φ, σ^2 and $\gamma(1-\varphi)$, along with their *t* statistics and significance level. Since γ and φ are highly correlated when φ is close to 1, it is difficult to estimate γ and φ separately, hence $\gamma(1-\varphi)$ is estimated instead. We note that φ equals 0.9523 when estimating the stochastic variance of the log return on the futures contract and equals 0.1408 when estimating the stochastic variance of the growth in log demand for crude oil. All of the parameters are significantly different from 0 for both estimations.

Figure 4a, which shows the variation of the WTI crude oil futures price and the stochastic variance $SVFR_t$ of the log return on the futures contract over time, indicates that there are several peaks in $SVFR_t$ in the overall period, with the second highest peak on 13 January 2009. Figure 4b which shows the variation of the demand for crude oil and the stochastic variance $SVDM_t$ of the growth in log demand for crude oil over time indicates that $SVDM_t$ has several peaks, with the highest being on January 31, 1990, and the third highest occurring on 21 October 2008.

3.4. Relationship between the futures price risk, and the risk contributed by market fundamentals and speculation

3.4.1. Summary statistics on variables used in the analysis and tests of stationarity

Table 5, Panel A, shows the summary statistics on the variables used in the analysis of the relationship between the futures price risk, *SVFR*, the risk contributed by market fundamentals, *SVDM*, and the indices of adequate and excess speculation, for the crude oil futures contract. The variances *SVFR* and *SVDM* are scaled up by multiplying by 10,000 and are expressed in terms of %%. Table 5, Panel B, shows the correlation between the different variables.

I test for stationarity of *SVFR, SVDM, INDADSP* and *INDEXSP* using the Augmented-Dickey Fuller (ADF) test. This tests if the series of interest is non-stationary or "has a unit root", versus the alternative of being trend-stationary, in that it is stationary after adjusting for an intercept, a linear time trend or both. The time trend variable for each as of date is the length of time from January 1, 1986 expressed in years and fractions of years. Table 5, Panel C, shows the results. The null hypothesis of the existence of a unit root is rejected for *SVFR* (0.05 level) and *SVDM* (0.01 level), but is not rejected for *INDADSP* and *INDEXSP*. Visual inspection of Figures 3b and 3c which graph *INDADSP* and *INDEXSP*, suggest the existence of a structural break in these series. As Perron (2006) notes, "…most tests that attempt to distinguish between a unit root and a (trend) stationary process will favor the unit root model when the true process is subject to structural changes but is otherwise (trend) stationary within regimes specified by the break dates". Therefore, I apply the Zivot and Andrews (1992) test to *INDADSP* and *INDEXSP* using the Akaike Information Criterion and a trimming fraction of 10%. This tests the null hypothesis of non-stationarity in each series of interest, while allowing for a break at an unknown point in time in the intercept, the trend or both. The results indicate that after taking the structural break in the intercept and trend into account, the null hypothesis of nonstationarity is rejected at the 0.01 level for *INDADSP* and *INDEXSP.* Table 5, Panel C, also shows the estimated break date for each index, which is May 15, 2001 for *INDADSP* and November 30, 2004 for *INDEXSP*. Each of the series *INDADSP* and *INDEXSP* is expressed in percentage terms by multiplying by 100, and regressed in turn on an intercept and the time trend, while accounting for the break in the intercept and trend at the specific break dates. The residuals from each regression, which are confirmed to be stationary by applying the ADF test, are then used in place of the specific index in the subsequent analyses.

3.4.2. Contemporaneous relationship between the futures price risk, and the risk contributed by market fundamentals and speculation

I examine the contemporaneous relationship between the futures price risk and the risk contributed by market fundamentals and by speculation by conducting the following multiple regression analysis.

$$SVFR_t = b_0 + b_1 * SVDM_t + b_2 * IND_t + \varepsilon_t \tag{22}$$

SVFR is the estimate of the futures price risk. *SVDM* is the estimate of the risk contributed by market fundamentals. The risk contributed by speculation is proportional to the measure of speculation *IND*. *IND* is in turn the stationary series of residuals obtained by regressing each of *INDADSP* and *INDEXSP* on an intercept and a time trend, while taking into account the specific break date for these values. The coefficient b_1 is an estimate of the relationship between the futures price risk and the risk due to market fundamentals. The coefficient b_2 is an estimate of the relationship between the futures price risk and the risk contributed by the specific measure of speculation. Table 6 shows the results. The t statistics are calculated after applying White's correction for heteroscedasticity to the standard errors of the coefficients. The results indicate the lack of a statistically significant relationship between the futures price risk and the risk contributed by market fundamentals in both equations. However, the positive and statistically significant (at the 0.01 level) coefficients of the measure of speculation in both equations indicates that both adequate speculation and excess speculation are destabilizing. These results are consistent with hypotheses H2 and H3 respectively.

3.4.3. Causality analysis of the relationship between the futures price risk and the risk contributed by market fundamentals and by speculation

I test if the futures price risk is Granger-caused by the risk due to market fundamentals and by each of the measures of speculation, by conducting the following regression:

$$SVFR_t = c_0 + \sum_{i=1}^{L} c_{1i} SVFR_{t-i} + \sum_{i=1}^{L} c_{2i} SVDM_{t-i} + \sum_{i=1}^{L} c_{3i} IND_{t-i} + \varepsilon_t \tag{23}$$

Equation (23) is used to test if the risk contributed by market fundamentals, and by speculation, add additional explanatory power to forecasting the futures price risk, over that contributed by past values of the futures price risk. As before, *IND* is in turn, the stationary series of residuals obtained by regressing each of *INDADSP* and *INDEXSP* on an intercept and a time trend, while taking into account the specific break date in these values. *L* represents the number of lags used in the analysis, c_0, c_{11} through c_{1L}, c_{21} through c_{2L} ,and c_{31} through c_{3L}, are the coefficients and ε_t is the error term. The optimal number of lags *L* is chosen by minimizing the Schwarz information criterion, for lags varying from 1 to a maximum of 8. The sign of the sum of the coefficients $\sum_{i=1}^{L} c_{2i}$ and $\sum_{i=1}^{L} c_{3i}$ indicates the direction of the cumulative effect of the risk contributed by market fundamentals and by speculation, respectively. Wald's test is used to test the null hypothesis that the coefficients c_{21} through c_{2L} are jointly equal to zero. If the null hypothesis is rejected, then the conclusion is that the risk contributed by market fundamentals

Granger-causes the futures price risk. Wald's test is also applied to test the null hypothesis that the coefficients c_{31} through c_{3L}, are jointly equal to zero. If the null hypothesis is rejected, this implies that the risk contributed by speculation Granger-causes the futures price risk.

Table 7 presents the results. The optimal number of lags L equals 1, and 4, for the regressions with *INDADSP* and *INDEXSP*, respectively, as the measure of speculation. The F statistic resulting from Wald's test indicates that the null hypothesis that the coefficients c_{31} through c_{3L} are jointly equal to zero is rejected only when *INDEXSP* is the measure of speculation, however, even this is only at the 0.10 level of significance. The results weakly support the conclusion that excess speculation as measured by *INDEXSP* Granger-causes the futures price risk. There is no evidence that adequate speculation, as measured by *INDADSP*, Granger-causes the futures price risk. The statistically insignificant F statistics associated with the null hypothesis that the coefficients c_{21} through c_{2L} equal zero, indicate a lack of a causal link between the risk contributed by market fundamentals and the futures price risk.

4. Conclusion

Building on Working (1960), I develop two new indices of speculation in futures markets, an index of adequate speculation, which is the amount of speculation which equals unbalanced hedging, and an index of excess speculation, which is speculation in excess of that required to meet unbalanced hedging. I demonstrate that the indices together accurately estimate Working's *conceptual speculative index* (ratio of speculation to unbalanced hedging), for all situations, while Working's *formula* for T does not. A major implication of the correct estimation of Working's conceptual index is that it is not necessary that speculation should exceed the amount required to meet unbalanced hedging for a well-functioning futures market. Long speculation could equal unbalanced short hedging and short speculation could equal unbalanced long hedging, and both long and short speculators would still be present in the market.

The first index is related to the slope of the actual relationship between the speculative ratio and the hedging ratio in a futures market, while the second index is related to the intercept. Using data from the CFTC's COT reports, I apply a Kalman (1960) filter analysis with nonlinear constraints on the state variables, which are the time-varying intercept and slope, to estimate the indices and compare their performance to Working's *T*, for 21 different futures contracts, including commodity and financial, physical delivery and cash-settled, contracts. On average, Working's *T* overestimates his conceptual speculative index for all markets. I investigate the relationship between the crude oil futures price risk, the risk due to market fundamentals and the risk contributed by speculation, over 1986-2012. The results indicate a strong positive contemporaneous relationship between the futures price risk and the indices of adequate and excess speculation, and a weaker positive causal link between the index of excess speculation and the futures price risk. The indices may be applied to future research of use to policy makers, on the effect of regulations, such as the Dodd-Frank Act of 2010, and the Commodity Futures Modernization Act of 2000, as well as of changes imposed by the futures exchanges, such as on margin requirements, price limits and position limits, upon speculation.

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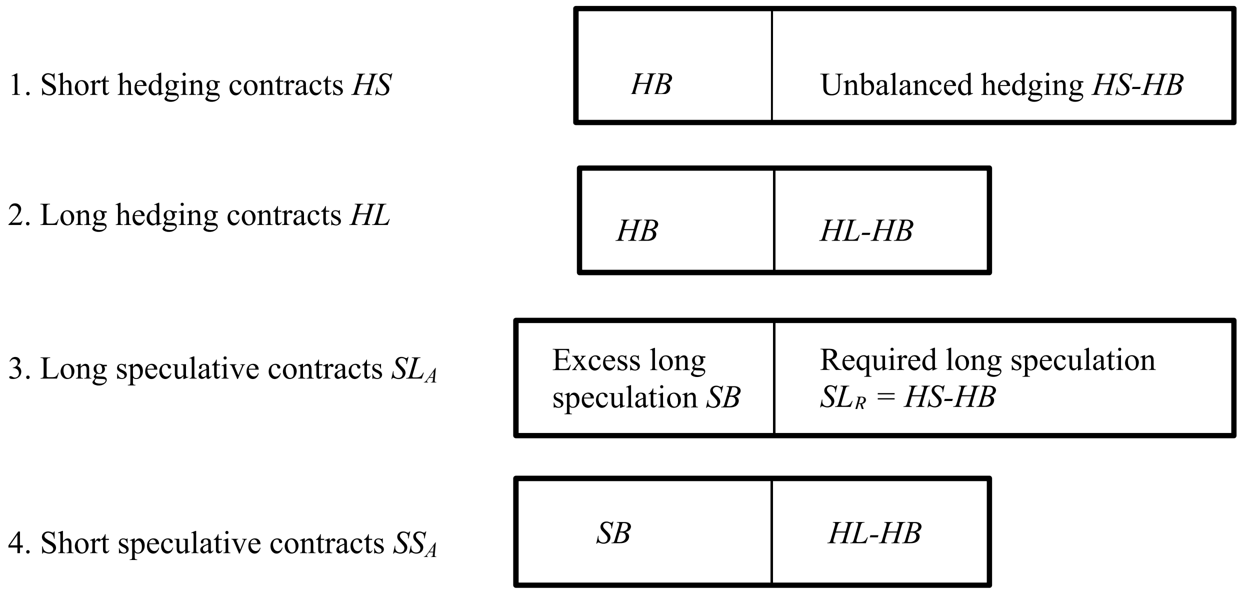

Figure 1. Unbalanced hedging, required long speculation and excess long speculation
***HB* represents balancing hedging contracts and *SB* represents balancing speculative contracts**

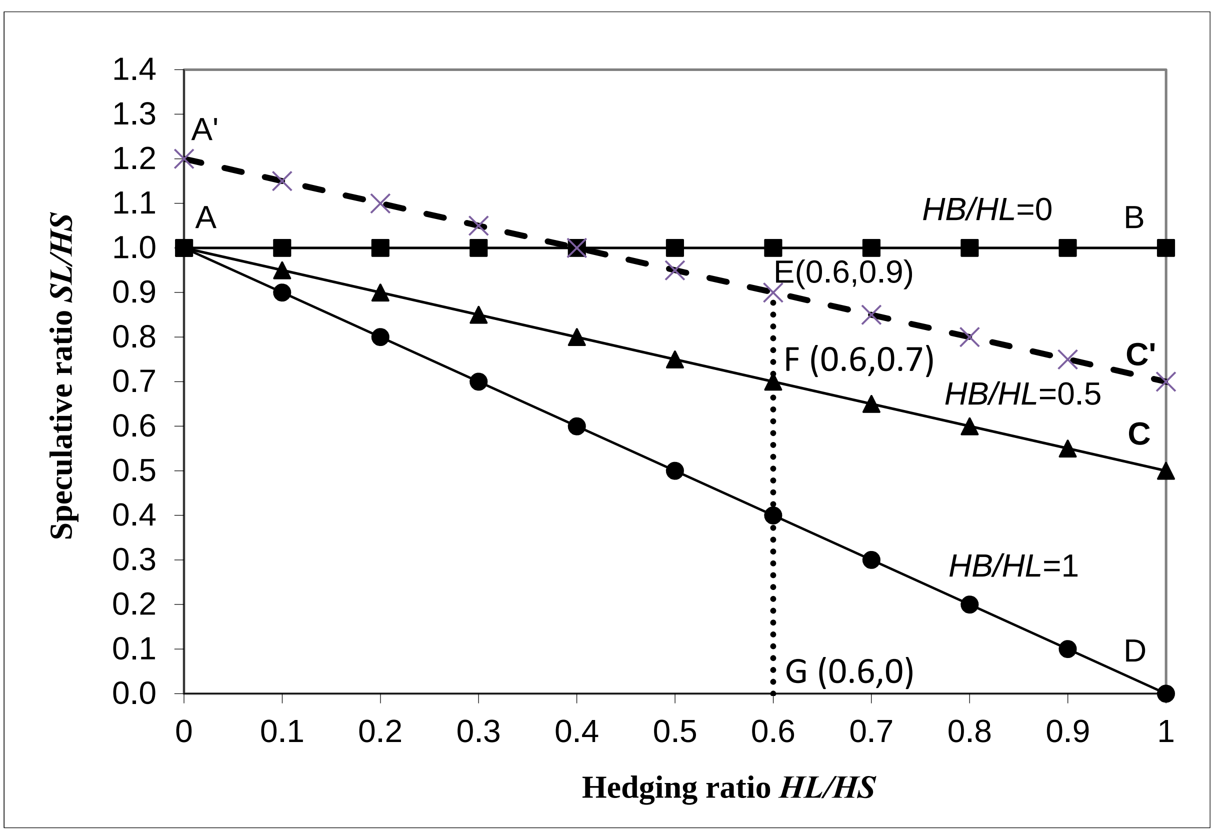

Figure 2. Relationship between the speculative ratio and the hedging ratio for different values of *HB/HL*. Lines AB, AC and AD represent the required relationship between the speculative ratio and the hedging ratio, for *HB/HL*=0, *HB/HL*=0.5 and *HB/HL*=1, respectively, when speculation equals unbalanced hedging. Line A'C' represents the actual relationship between the speculative ratio and the hedging ratio for *HB/HL*=0.5, when speculation exceeds unbalanced hedging.

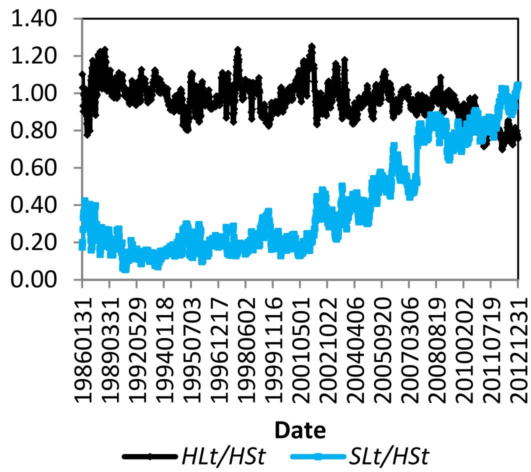

Figure 3a. Hedging ratio and speculative ratio for the crude oil futures contract

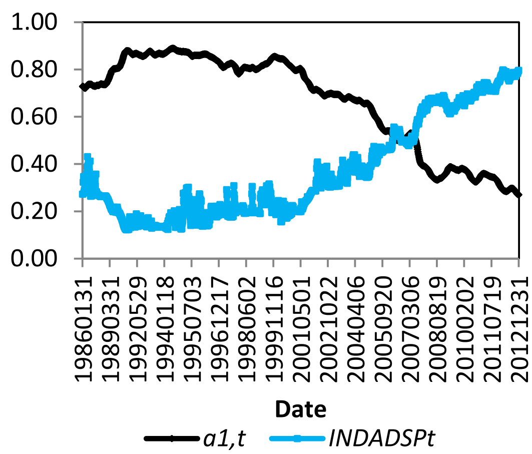

Figure 3b. Estimates of $a_{1,t}$ and $INDADSP_t$ for the crude oil futures contract

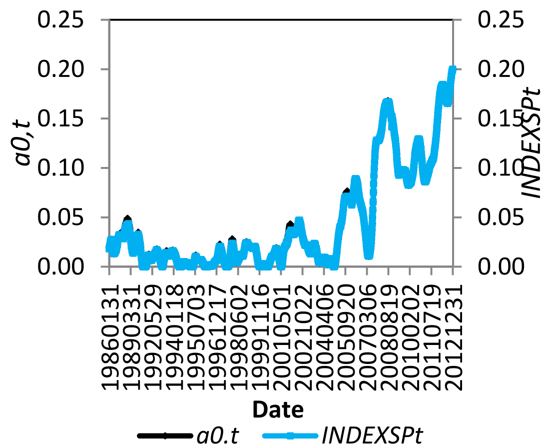

Figure 3c. Estimates of $a_{0,t}$ and $INDEXSP_t$ for the crude oil futures contract

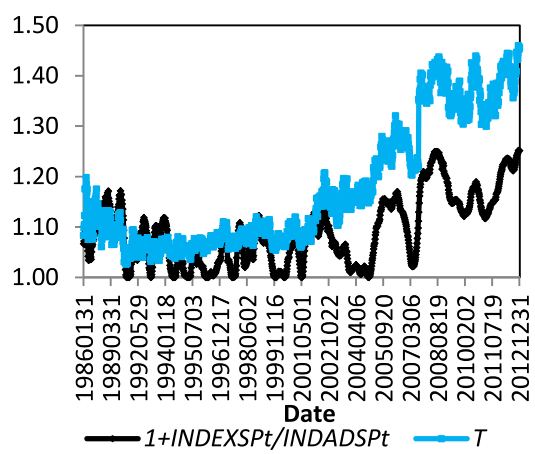

Figure 3d. Estimates of $1{+}INDEXSP_t/INDADSP_t$ and T_t for the crude oil futures contract

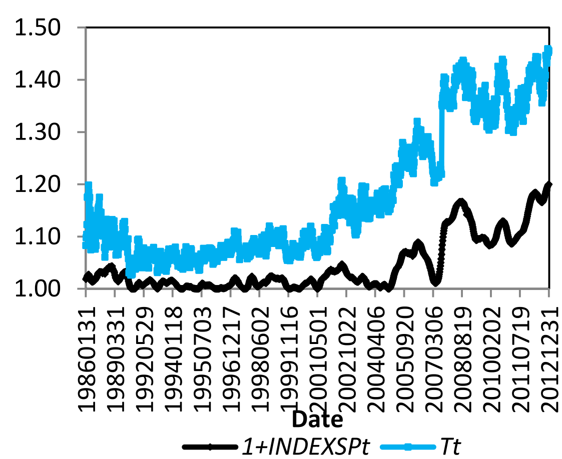

Figure 3e. Estimates of $1{+}INDEXSP_t$ and T_t for the crude oil futures contract

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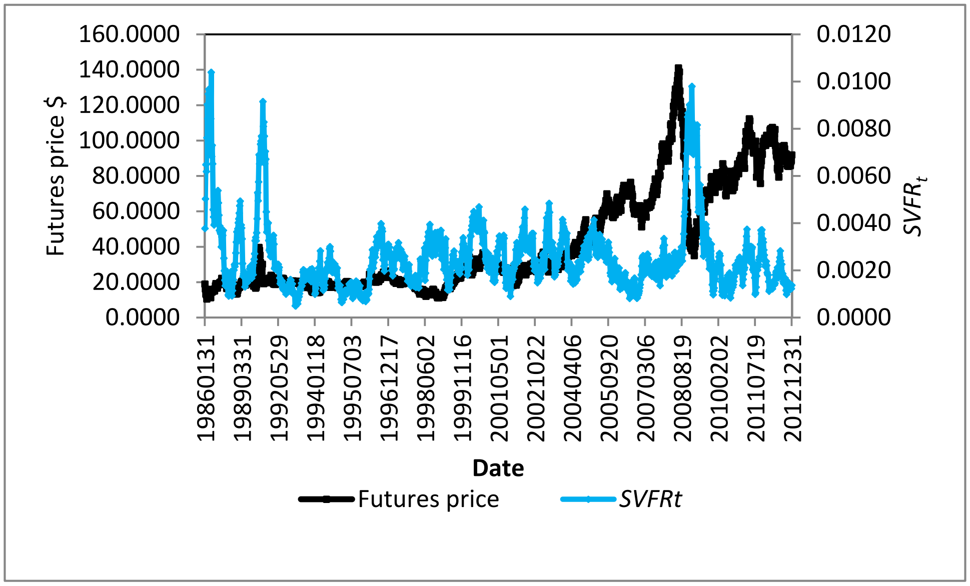

Figure 4a. Futures price and stochastic variance of the futures return *$SVFR_t$* for the crude oil futures contract

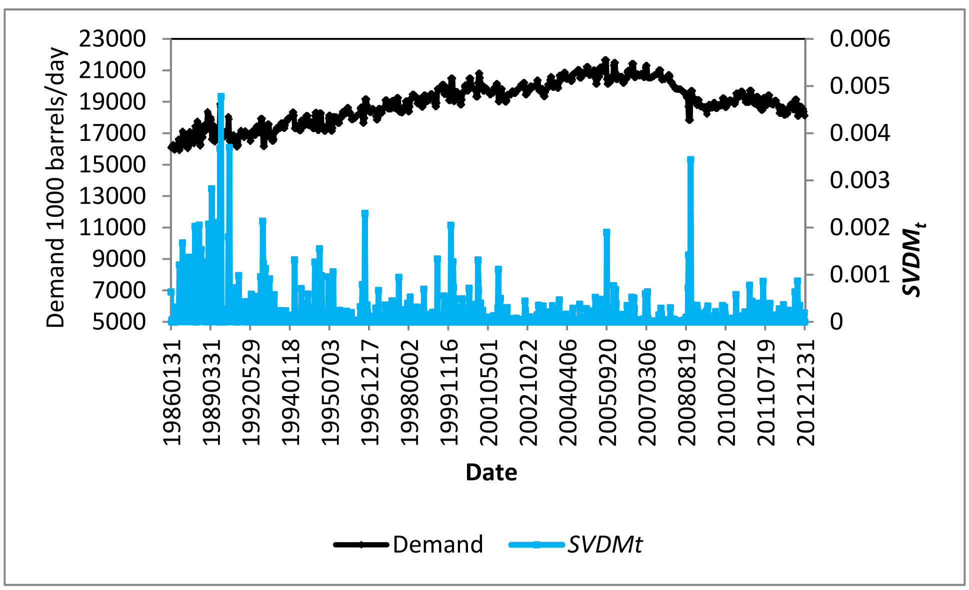

Figure 4b. The demand for crude oil in the U. S. and stochastic variance of the growth in log demand *$SVDM_t$*

Table 1. Summary of equations resulting from my work and that of Working

Variable	Equations: $HS \geq HL$	Equations: $HS \leq HL$
Panel A. Indices of adequate and excess speculation and the actual relationship between the speculative ratio and the hedging ratio		
INDADSP=index of adequate speculation	$(HS-HB)/HS=1-(HB/HL).HL/HS$	$(HL-HB)/HL=1-(HB/HS).HS/HL$
INDEXSP=index of excess speculation	SB/HS	SB/HL
Actual relationship between speculative ratio and hedging ratio	$\frac{SL}{HS}=1+\frac{SB}{HS}-\left(\frac{HB}{HL}\right).\left(\frac{HL}{HS}\right)$	$\frac{SS}{HL}=1+\frac{SB}{HL}-\left(\frac{HB}{HS}\right).\left(\frac{HS}{HL}\right)$
Panel B. Working's conceptual definition for the speculative index, formula for the speculative index *T* and assumed relationship between the speculative ratio and the hedging ratio		
Conceptual definition of speculative index	$\frac{SL}{HS-HB}=1+\frac{SB}{HS-HB}=1+\frac{SB}{SL-SB}=1+\frac{INDEXSP}{INDADSP}$	$\frac{SS}{HL-HB}=1+\frac{SB}{HL-HB}=1+\frac{SB}{SS-SB}=1+\frac{INDEXSP}{INDADSP}$
Working's formula for the speculative index *T*	$1+SS/(HS+HL)$	$1+SL/(HS+HL)$
Assumed relationship between speculative ratio and hedging ratio	$\frac{SL}{HS}=1+\frac{SS}{HS+HL}-\left(1-\frac{SS}{HS+HL}\right)\left(\frac{HL}{HS}\right)$	$\frac{SS}{HL}=1+\frac{SL}{HS+HL}-\left(1-\frac{SL}{HS+HL}\right)\left(\frac{HS}{HL}\right)$

Note. *HS* represents short hedging contracts, *HL* represents long hedging contracts, *HB* represents balancing hedging contracts, *SS* represents short speculative contracts, *SL* represents long speculative contracts, and *SB* represents balancing speculative contracts.

Table 2. Summary statistics of the indices of adequate and excess speculation and Working's *T* for 21 different futures contracts

Futures contract	Exchange	Sett.	No. of Obs.	*INDADSP*		*INDEXSP*		*1+INDEXSP/INDADSP*			*T*		
				Mean	**Std. Dev.**	**Mean**	**Std. Dev.**	**Min.**	**Mean**	**Std. Dev.**	**Min.**	**Mean**	**Std. Dev.**
Crude oil	NYMEX	Physical	1217	0.3678	0.2078	0.0442	0.0517	1.0000	1.0920	0.0684	1.0262	1.1753	0.1247
Heating oil	NYMEX	Physical	1217	0.2701	0.1006	0.0285	0.0300	1.0000	1.0950	0.0827	1.0191	1.1128	0.0585
Natural gas	NYMEX	Physical	1115	0.3987	0.3092	0.2602	0.2975	1.0000	1.4270	0.3898	1.0000	1.2959	0.3004
Corn	CBOT	Physical	1219	0.4904	0.1364	0.0195	0.0189	1.0000	1.0403	0.0376	1.0441	1.1890	0.0711
Soybeans	CBOT	Physical	1219	0.6111	0.0939	0.0290	0.0256	1.0000	1.0485	0.0448	1.0296	1.2352	0.0605
Wheat	CBOT	Physical	1219	0.6736	0.1112	0.0344	0.0324	1.0000	1.0511	0.0500	1.0822	1.2927	0.0888
Live cattle	CME	Physical	1219	0.6801	0.1386	0.0522	0.0480	1.0000	1.0773	0.0693	1.1047	1.3112	0.0893
Lean hogs	CME	Cash	869	0.8071	0.1094	0.1102	0.1965	1.0000	1.1356	0.2338	1.1564	1.4008	0.1637
Feeder	CME	Cash	1219	0.7678	0.1440	0.4259	0.2714	1.0000	1.5371	0.3124	1.0681	1.5621	0.2195
Gold	COMEX	Physical	1218	0.6592	0.1879	0.0369	0.0540	1.0000	1.0465	0.0592	1.0596	1.2047	0.0864
Silver	COMEX	Physical	1218	0.7379	0.1680	0.0448	0.0574	1.0000	1.0569	0.0637	1.0578	1.2332	0.1224
Copper	COMEX	Physical	1133	0.5243	0.1464	0.0438	0.0570	1.0000	1.0765	0.0898	1.0000	1.1989	0.1074
S&P 500	IMM	Cash	1219	0.1434	0.0391	0.0170	0.0155	1.0000	1.1142	0.0947	1.0100	1.0530	0.0208
DJIA	CBOT	Cash	681	0.5288	0.1749	0.0398	0.0592	1.0000	1.0588	0.0680	1.0293	1.2043	0.1364
NASDAQ	IMM	Cash	838	0.3222	0.0993	0.0287	0.0340	1.0000	1.0822	0.0832	1.0003	1.1167	0.0676
U.S.Tbond	CBOT	Physical	1040	0.2623	0.0576	0.0172	0.0139	1.0000	1.0633	0.0457	1.0366	1.1084	0.0342
10 year	CBOT	Physical	1041	0.2513	0.1040	0.0154	0.0177	1.0000	1.0585	0.0510	1.0071	1.1005	0.0540
Eurodollar	CME	Cash	1219	0.2436	0.1198	0.0267	0.0205	1.0000	1.1245	0.0961	1.0114	1.1012	0.0563
EUR/USD	CME	Physical	730	0.6003	0.1860	0.0237	0.0347	1.0000	1.0368	0.0468	1.0144	1.1841	0.1187
Japanese	CME	Physical	1219	0.5604	0.1253	0.0064	0.0099	1.0000	1.0111	0.0160	1.0186	1.1400	0.0789
British	CME	Physical	1218	0.5602	0.1709	0.0137	0.0206	1.0000	1.0230	0.0323	1.0113	1.1403	0.1001

Note. The beginning date is 15 January 1986 or the date of contract initiation, the ending date is 31 December 2012.

Table 3. Correlation between the different measures of speculation

		Correlations between		
Futures contract	**Observations**	***INDADSP&INDEXSP***	***1+INDEXSP/INDADSP&T***	***1+INDEXSP&T***
Crude oil	1217	0.9000	0.8126	0.9388
Heating oil	1217	0.5825	0.7078	0.8432
Natural gas	1115	0.9438	0.8398	0.9836
Corn	1219	0.2282	0.4427	0.6648
Soybeans	1219	0.0546	0.4454	0.5524
Wheat	1219	0.1845	0.3576	0.4745
Live cattle	1219	0.1288	0.2782	0.3900
Lean hogs	869	0.1173	0.7128	0.7751
Feeder cattle	1219	0.5254	0.7432	0.8581
Gold	1218	0.6105	0.7596	0.7745
Silver	1218	0.4194	0.7523	0.8060
Copper	1133	0.3971	0.6430	0.6883
S&P 500	1219	0.4777	0.4915	0.6061
DJIA	681	0.8161	0.8560	0.8949
NASDAQ 100	838	0.4623	0.6199	0.7324
U.S.Tbond	1040	0.5229	0.5342	0.6562
10 year Tnote	1041	0.5436	0.3832	0.7465
Eurodollar	1219	0.3863	0.0019	0.6991
EUR/USD	730	0.3783	0.5795	0.6640
Japanese yen	1219	0.2729	0.4352	0.5052
British pound	1218	0.3670	0.5134	0.6293
Average		0.4438	0.8126	0.7087

Table 4. Results of the estimation of the crude oil futures price risk and the risk contributed by market fundamentals using a stochastic volatility model

	Estimate/t statistic for Stochastic variance of	
Parameter	**Futures log return *SVFR***	**Growth in log demand for crude oil in the U. S. *SVDM***
φ	0.9523	0.1408
	47.5352***	4.7690***
σ^2	0.0538	18.4444
	2.2156**	19.4885***
$\gamma(1-\varphi)$	-6.0920	-13.2208
	-46.8896***	-206.0327***
Number of observations	1,217	1,217
Log Likelihood	-2726.9286	-3644.4393

Note. ***Statistically significant at the 0.01 level, ** Statistically significant at the 0.05 level

Table 5. Summary statistics on variables used in the analysis of the relationship between the crude oil futures price risk, risk due to market fundamentals and speculation, and results of tests of stationarity

Panel A. Summary statistics

Variable	**Period**	**Number of observations**	**Minimum**	**Maximum**	**Mean**	**Std. dev.**
SVFR %%	1986/01/31-2012/12/31	1217	4.9300	103.8900	25.6186	14.7771
SVDM %%	1986/01/31-2012/12/31	1217	0.0000	47.7600	1.2802	3.6793
INDADSP	1986/01/31-2012/12/31	1217	0.1217	0.7977	0.3678	0.2078
INDEXSP	1986/01/31-2012/12/31	1217	0.0000	0.1999	0.0442	0.0517

Panel B. Correlation between the variables used in the analysis

	SVFR	*SVDM*	*INDADSP*	*INDEXSP*
SVFR	1.0000	0.0513	0.0257	0.0230
SVDM		1.0000	-0.1045	-0.0574
INDADSP			1.0000	0.9000
INDEXSP				1.0000

Panel C. Tests of stationarity

				ADF test	**Zivot and Andrews test**	
Variable	**Period**	**Number of observations**	**Deterministic components**	**Test statistic**	**Date of break**	**Test statistic**
SVFR	1986/01/31-2012/12/31	1217	No intercept or trend	-2.5221**		
SVDM	1986/01/31-2012/12/31	1217	No intercept or trend	-31.2556***		
INDADSP	1986/01/31-2012/12/31	1217	Intercept and trend	-3.2298	2001/05/15	-6.1056***
INDEXSP	1986/01/31-2012/12/31	1217	Intercept and trend	0.8627	2004/11/30	-6.0089***

Note. ***statistically significant at the 0.01 level, **statistically significant at the 0.05 level

Table 6. Contemporaneous relationship between the futures price risk, the risk due to market fundamentals and the risk due to speculation

Measure of speculation	Period	Coefficient/t statistic of Intercept	*SVDM*	*IND*	Adj. R^2
INDADSP	1986/01/31 to 2012/12/31	25.4024	0.1689	0.6253	0.0407
		57.3836***	1.1861	4.8679***	
INDEXSP	1986/01/31 to 2012/12/31	25.3853	0.1823	0.7555	0.0151
		56.7884***	1.306	3.8697***	

Note. ***statistically significant at the 0.01 level, **statistically significant at the 0.05 level

Table 7 Results of the Granger-causality tests of whether the risk contributed by market fundamentals and by the measure of speculation Granger-cause the crude oil futures price risk

Measure of speculation	Dependent variable	Optimal number of lags *L*	Independent variable	Null hypothesis	Sum of coefficients of lagged values of the independent variable	Granger causality F statistic
1. *INDADSP*	$SVFR_t$	*1*	*INDADSP*	*INDADSP* does not Granger- cause *SVFR*	0.0223	0.7817
			SVDM	*SVDM* does not Granger-cause *SVFR*	-0.0115	0.1360
2. *INDEXSP*	$SVFR_t$	4	*INDEXSP*	*INDEXSP* does not Granger-cause *SVFR*	0.1264	2.0368*
			SVDM	*SVDM* does not Granger-cause *SVFR*	-0.0006	0.6712

Note. *Statistically significant at the 0.10 confidence level

Appendix A. Performance of the indices of adequate and excess speculation and Working's formula for *T* in estimating Working's conceptual speculative index

Table A.1 provides numerical comparisons for six cases. Cases 1 and 2 consider a futures market with no long hedging, so that HL=0, while Cases 3 through 6 consider futures markets with HL>0. In Cases 1, 3 and 4, balancing speculative contracts SB=0. For Cases 2, 5 and 6, SB>0. In Cases 1 through 3, balancing hedging contracts HB=0. In Cases 4 and 5, HL exceeds HB which is greater than zero. In Case 6, $HL=HB$. Panel A.1.1 of Table A.1 provides the assumed values for HS, HL, SB, HB, the resulting values of SL (equal to HS-HB+SB) and SS (equal to HL+SL-HS), as well as ($SS.SL$)/(HS+SS+HL) and $(HS.SS)/(HS+HL)$. Panel A.1.2.1 shows Working's conceptual speculative index, calculated using equation (11). Panel A.1.2.2 shows Working's conceptual speculative index as estimated by using the indices of adequate and excess speculation, by applying equation (13). The two estimates are identical for all cases. Panel A.1.2.3 shows the value of T, calculated using equation (14). The T index accurately estimates Working's conceptual speculative index only in Cases 1 and 2, markets with no long hedging. For both Cases 3 and 4, in which long speculation exactly equals unbalanced hedging, the T index overestimates Working's conceptual speculative index and implies that there is excess speculation in the market, when this is not so. The actual value for Working's conceptual speculative index is 1, while the T index is greater than 1. In Cases 5 and 6, with long hedging, and with balancing hedging and speculative contracts, the T index overestimates Working's conceptual speculative index in Case 5 and underestimates it in Case 6. The results also confirm that the T index overestimates, correctly estimates or underestimates Working's conceptual speculative index, if SB is less than, equal to or greater than ($SS.SL$)/(HS+SS+HL), respectively.

Panel A.1.3 of Table A.1 provides a numerical comparison of the actual relationship between the speculative ratio and the hedging ratio and the relationship assumed by Working. Figures A.1 through A.6 illustrate the comparisons. Figures A.1 and A.2 indicate that in Cases 1 and 2, with no long hedging, the actual relationship is represented by one point on the graph with coordinates (0,1) in Case 1, and with coordinates (0,1.2) in Case 2. While Working's assumed relationship is a straight line with intercepts of 1 and 1.2, and with slopes of -1 and -0.8, in Cases 1 and 2 respectively, when long hedging is absent, the actual relationship and Working's assumed relationship coincide on the graphs. Figures A.3 and A.4 provide a graphical comparison for Cases 3 and 4, respectively. While excess speculation is zero in both cases and is correctly described as such by the intercept (1.0) of the actual relationship between the speculative and hedging ratio, the intercept in Working's assumed relationship exceeds 1, implying the presence of excess speculation. The absolute value of the slope of Working's assumed relationship is higher than that of the actual relationship in both cases, as both the results in Table A.1, Panel A.1.3, and Figures A.3 and A.4 show. Figures A.5 and A.6 provide a graphical comparison for Cases 5 and 6, respectively. The results of Table A.1 and the figures show that Working's assumed relationship overestimates the intercept in Case 5, and underestimates it in Case 6. Working's assumed relationship overestimates the absolute value of the slope in Case 5 and underestimates it in Case 6. The intercept in Working's assumed relationship is equal to (Cases 1 and 2), greater than (Cases 3, 4, and 5) or less than (Case 6) the intercept of the actual relationship, according as *SB* is equal to, less than or greater than, *(HS.SS)/(HS+HL),* respectively.

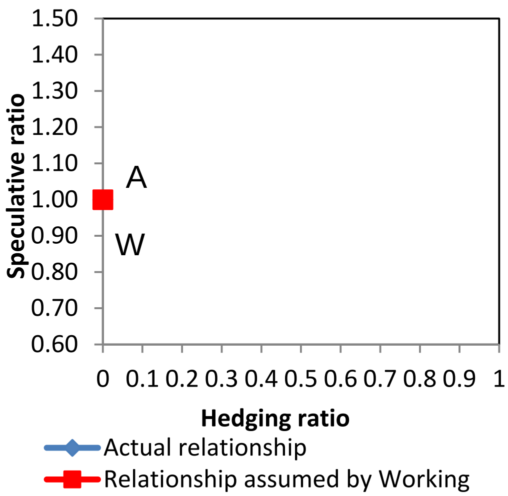

Figure A.1. ***HL* = 0, *SB* = 0**

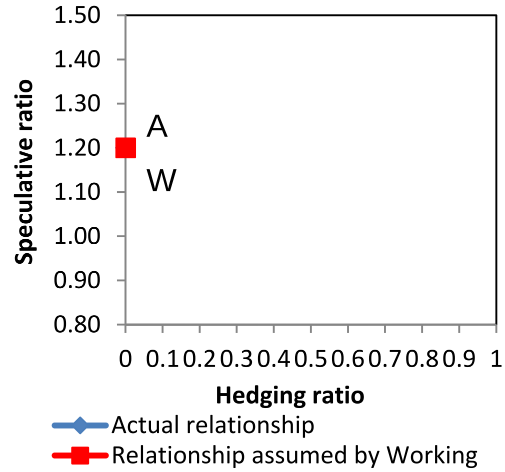

Figure A.2. ***HL*=0, *SB*>0**

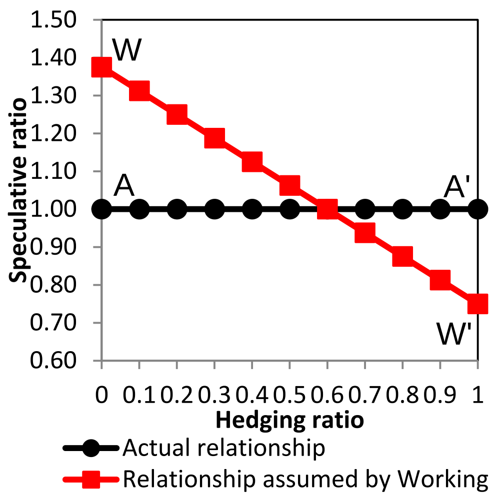

Figure A.3. ***HL>0, HB=0,SB=0***

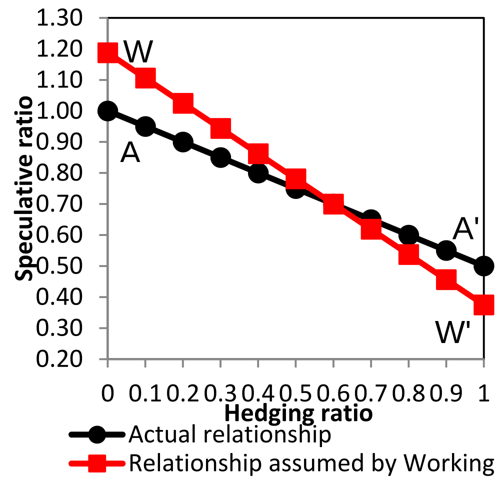

Figure A.4. ***HL*>0,*HB*>0,*SB*=0**

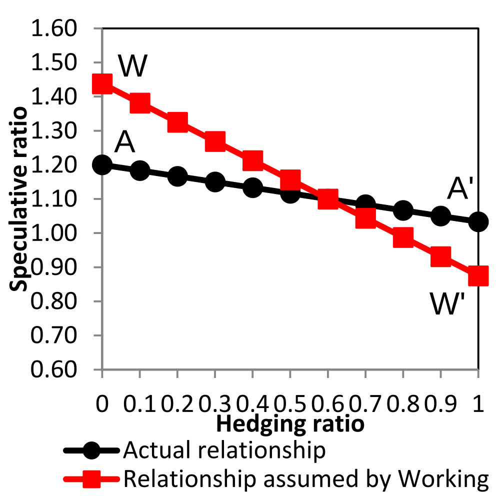

Figure A.5. ***HL*>0,*HB*>0,*HB*<*HL*,*SB*>0**

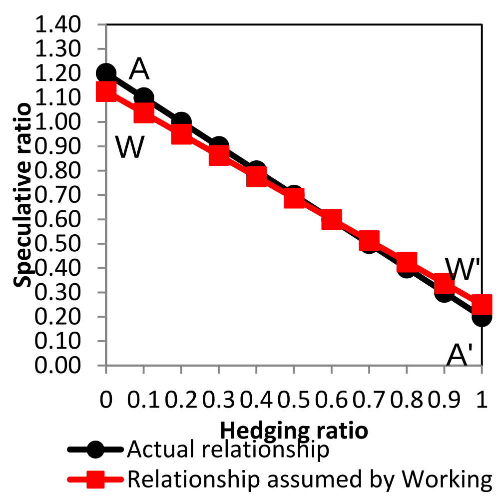

Figure A.6. ***HL*>0,*HB*>0,*HB*=*HL*,*SB*>0**

Figures A.1 through A.6. Comparison of the actual relationship between the speculative and hedging ratio with Working's assumed relationship

Table A.1. Performance of the indices of adequate and excess speculation and Working's formula for *T* in estimating Working's conceptual speculative index, and comparison of the actual relationship between the speculative ratio and hedging ratio and Working's assumed relationship

	No long hedging *HL=0*		With long hedging *HL>0*			
	No balancing speculative contracts	With balancing speculative contracts	Long speculation = Unbalanced hedging No balancing speculative contracts		Long speculation > Unbalanced hedging With balancing speculative contracts	
	SB=0	*SB>0*	*SB=0*	*SB=0*	*SB>0*	*SB>0*
	HB=0	*HB=0*	*HB=0*	*HB>0, HB<HL*	*HB>0, HB<HL*	*HB>0, HB=HL*
Case	**1**	**2**	**3**	**4**	**5**	**6**
Panel A1.1. Input						
HS	100	100	100	100	100	100
HL	0	0	60	60	60	60
SB	0	20	0	0	20	20
HB	0	0	0	30	10	60
SL = HS-HB+SB	100	120	100	70	110	60
SS = HL+SL-HS	0	20	60	30	70	20
SS.SL/(HS+SS+SL)	0.00	20.00	27.27	11.05	33.48	6.67
HS.SS/(HS+HL)	0.00	20.00	37.50	18.75	43.75	12.50
Panel A.1.2 Comparison with Working's conceptual speculative index						
Panel A.1.2.1. Working's conceptual speculative index						
SL/(HS-HB)	1.00	1.20	1.00	1.00	1.22	1.50
Panel A.1.2.2. Estimate of Working's conceptual speculative index by indices of adequate and excess speculation						
INDADSP	1.00	1.00	1.00	0.70	0.90	0.40
INDEXSP	0.00	0.20	0.00	0.00	0.20	0.20
1+INDEXSP/INDADSP	1.00	1.20	1.00	1.00	1.22	1.50
Panel A.1.2.3. Estimate of Working's conceptual speculative index by Working's formula for *T*						
T	1.00	1.20	1.38	1.19	1.44	1.13
Panel A.1.3. Comparison of the actual relationship between the speculative ratio and hedging ratio with Working's assumed relationship						
Actual relationship						
Intercept	1.00	1.20	1.00	1.00	1.20	1.20
Slope	Undefined	Undefined	0.00	-0.50	-0.17	-1.00
Working's assumed relationship						
Intercept	1.00	1.20	1.38	1.19	1.44	1.13
Slope	-1.00	-0.80	-0.63	-0.81	-0.56	-0.88

Note. *HS* represents short hedging contracts, *HL* represents long hedging contracts, *HB* represents balancing hedging contracts, *SS* represents short speculative contracts, *SL* represents long speculative contracts, and *SB* represents balancing speculative contracts.

Appendix B. Estimation of the time-varying regression of the speculative ratio on the hedging ratio

The time- varying regression that is to be estimated is equation (19) in the text:

$$\frac{SL_t}{HS_t} - 1 = a_{0,t} + a_{1,t}\left(-\frac{HL_t}{HS_t}\right) + \varepsilon_t \tag{19}$$

Referring to Durbin and Koopman (2012), pages 42, 60, and 164, the above can be represented as the following state space model:

$$y_t = X_t \alpha_t + \varepsilon_t, \qquad \varepsilon_t \sim N(0, H_t) \tag{B.1}$$

$$\alpha_{t+1} = \alpha_t + \eta_t, \qquad \eta_t \sim N(0, Q_t) \tag{B.2}$$

for $t=1,\ldots,n$, where n is the number of observations on the speculative ratio and the hedging ratio, $y_t = \left[\frac{SL_t}{HS_t} - 1\right]$ is the vector of observations on the speculative ratio called the observation vector, $\alpha_t = \begin{bmatrix} a_{0,t} \\ a_{1,t} \end{bmatrix}$ is the unobserved vector of regression coefficients called the state vector, and $X_t = \begin{bmatrix} 1 & -\frac{HL_t}{HS_t} \end{bmatrix}$ is the regressor vector. Equation (B.1) is the observation equation, while equation (B.2) is the state equation. The error terms ε_t and η_t are assumed to be serially independent and independent of each other. The above unconstrained state space model can be estimated by Kalman (1960) filtering or smoothing. This estimates the state variables through a recursive process, under which the state equation is used to provide an *a priori* prediction of the state at step *t+1*, given all information at step *t*. These estimates are combined with the information on the dependent variable to provide an *a posteriori* estimate of the state variables. The objective is to minimize the mean square state estimate error.

However, note the restrictions on the time varying coefficients of equation (19), which are: $a_{0,t} \geq 0$; and $a_{1,t} \geq 0$. Gupta and Hauser (2007) offer an approach to constrained state space estimation, which restricts the state estimates to lie in the constrained space by choosing an "active set" or "subset of the constraints" to treat as equality constraints. I use this approach in the estimation. I first apply Kalman smoothing to the unconstrained model to estimate the state variables, using the software package RATS and the procedure DLM (Dynamic Linear Model). I then check whether the estimates of the state variables satisfy the inequality constraints. If any state variable estimates do not, I constrain the worst offender to lie on the boundary given by the inequality constraint and re-estimate the Kalman smoother with the constraint added. As noted by Durbin and Koopman (2012), page 164, this adds the set of time-varying linear restrictions:

$$R_t^* \alpha_t = r_t^*, \qquad t = 1, \ldots, n, \tag{B.3}$$

The number of rows in R_t^* can vary with t. For example, if the state estimate of $a_{0,t}$ for t=230 is to be constrained to equal 0, while the state estimate of $a_{1,t}$ for t=230 is unconstrained, then $R_{230}^* = \begin{bmatrix} 1 & 0 \end{bmatrix}$ and $r_{230}^* = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$. The observation equation is augmented as:

$$\begin{pmatrix} y_t \\ r_t^* \end{pmatrix} = \begin{bmatrix} X_t \\ R_t^* \end{bmatrix} \alpha_t + \begin{pmatrix} \varepsilon_t \\ 0 \end{pmatrix}, \qquad t = 1, \ldots, n, \tag{B.4}$$

The augmented model is re-estimated using Kalman smoothing. This process is repeated until all state variable estimates satisfy the inequality constraints and the Lagrangian multipliers associated with those state variable estimates which form the active set are all greater than or equal to zero.